Dec. 10, 1935. H. L. BLOOD 2,023,662

SIZE DETERMINING MECHANISM FOR AUTOMATIC MACHINES

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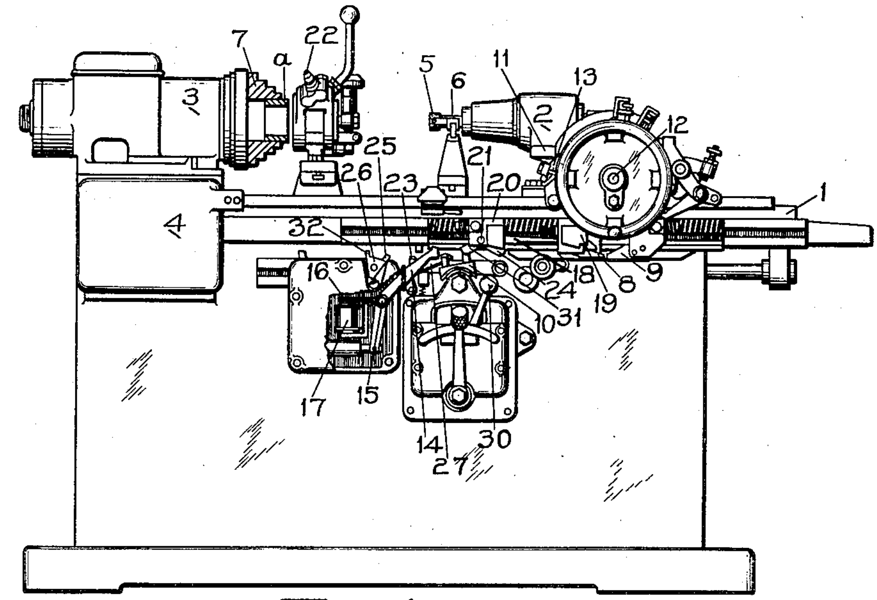

Fig. 1

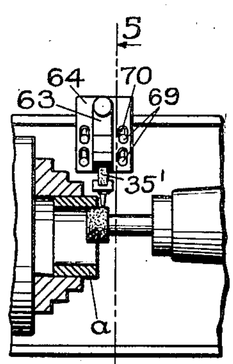

Fig. 4

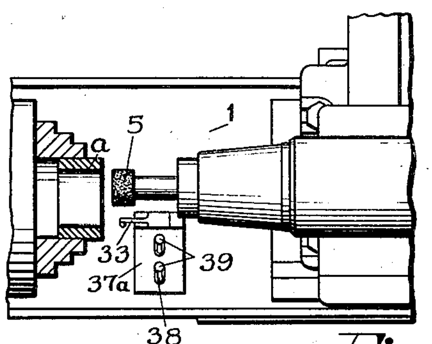

Fig. 2

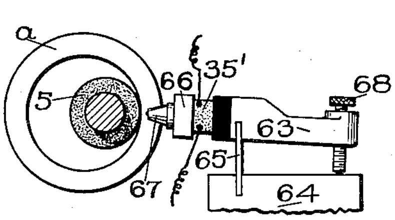

Fig. 5

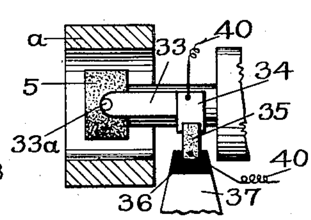

Fig. 3

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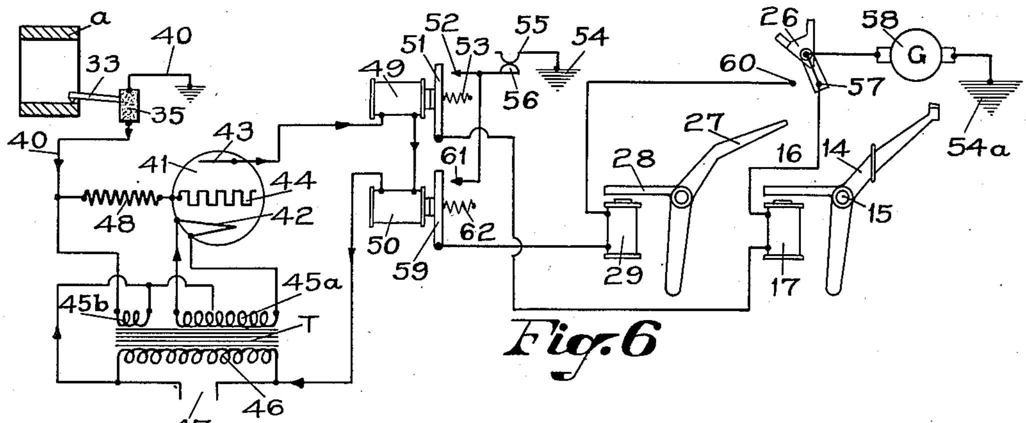

Fig. 6

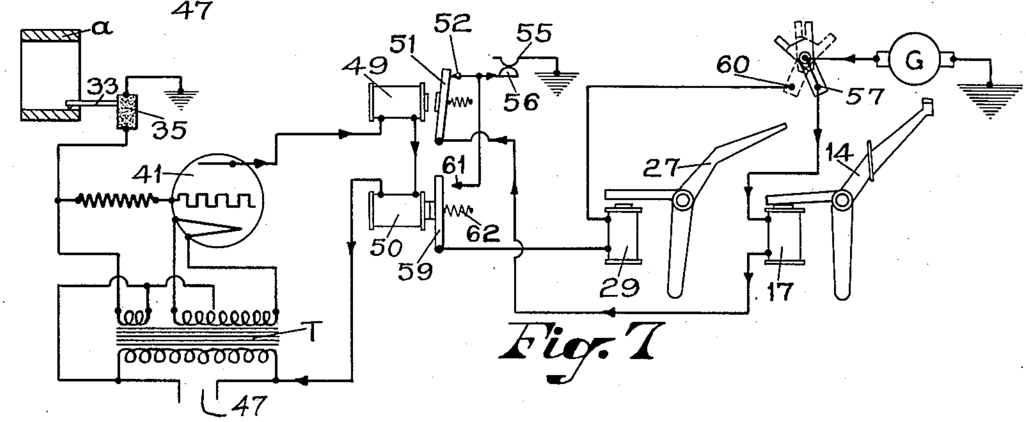

Fig. 7

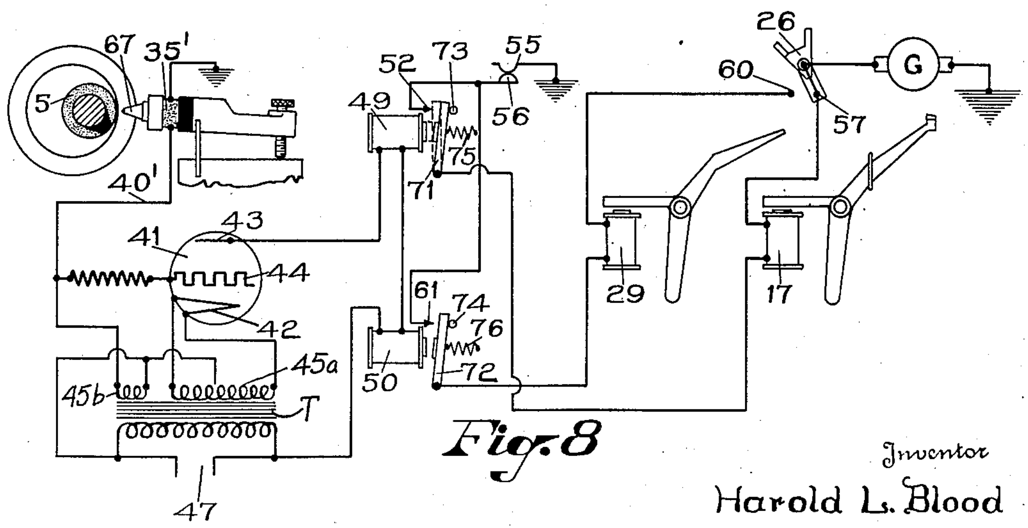

Fig. 8

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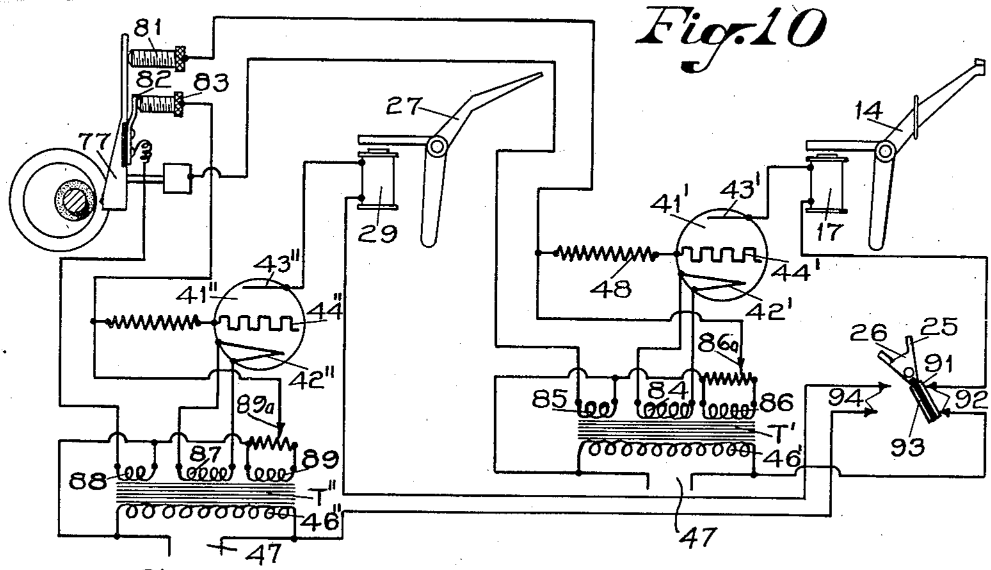
Fig. 10



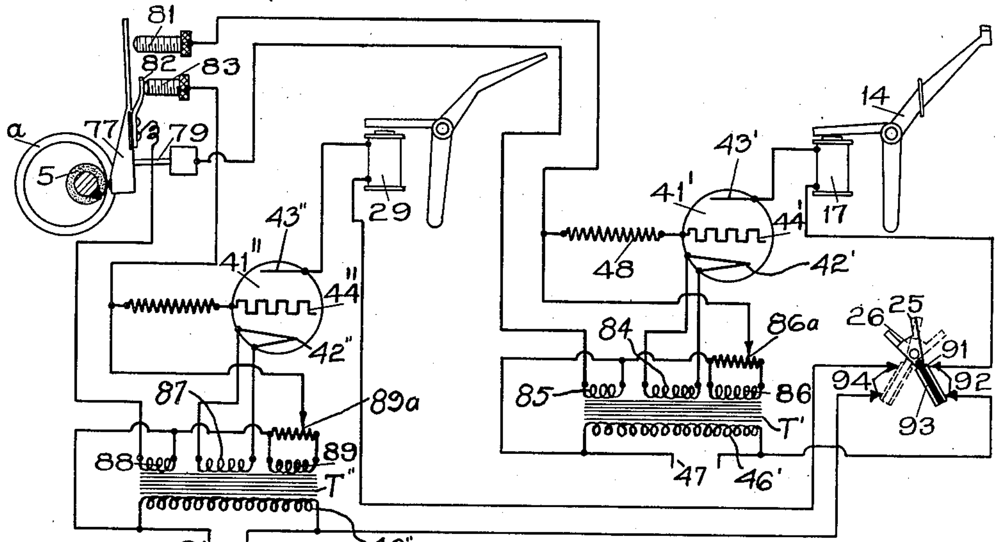


Fig. 11

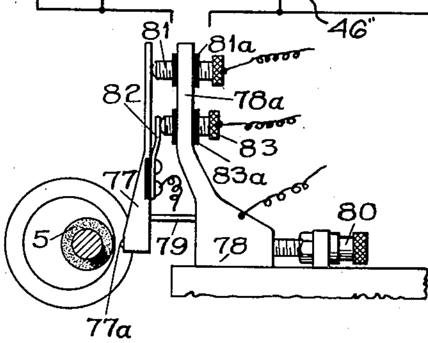


Fig. 9

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UNITED STATES PATENT OFFICE

2,023,662

SIZE DETERMINING MECHANISM FOR AUTOMATIC MACHINES

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Application February 23, 1933, Serial No. 658,028

19 Claims. (Cl. 51—165)

The present invention relates to automatic machines for the reduction of workpieces to a predetermined size, and although in certain of its aspects it is applicable to various types of automatic machines, its particular utility, as will hereinafter appear, is in connection with machines for treating, as by a cutting operation, the internal surfaces of sleeves, gears, bushings and like articles.

In prior constructions of automatic machines of this character, the size of the workpiece being operated upon is determined either by a gage mechanism of the type shown in the McDonough Reissue Patent No. 16,141, issued August 11, 1925, a later construction of the same type being shown in the Kempton & Gallimore Patent No. 1,731,719, issued October 15, 1929, or by the movement of the crossfeed mechanism which causes the cutting tool to cut progressively deeper and deeper into the surface of the workpiece, as shown in the Guild Patent No. 1,682,672, granted August 28, 1928.

In the McDonough and Kempton & Gallimore grinding machine constructions, the gage member is reciprocated relative to the workpiece, and the grinding operation is interrupted when the workpiece is ground to such a size that the gage may enter the bore therein. While a gaging mechanism of the above indicated character is entirely satisfactory in operation, it has been found that the continued hammering action of a gage against the end of successive workpieces before a given workpiece reaches the predetermined size, in addition to the wear on a gage as it enters within the bore of the workpiece, will impair the accuracy of the gage, necessitating inspection and replacement thereof in order to procure successive workpieces which are reduced consistently to a predetermined size.

In a grinding machine construction of the type disclosed in the Guild patent, the size of the workpieces is controlled by the movement of the crossfeed mechanism which operates to terminate the grinding operation when the cutting surface of the grinding wheel reaches a predetermined vertical plane during the crossfeed movement. The location of this plane is determined by a dressing tool which operates during each grinding operation to maintain the surface of the grinding wheel smooth and in the desired position relative to said plane, said dressing operation resulting in a reduction in diameter of the grinding wheel, which is compensated for by a transverse compensatory movement of the grinding wheel relative to the workholding member to cause said wheel, during successive grinding operations, to move into the above noted predetermined vertical plane before the grinding operation is terminated. Although machines of this construction are also entirely satisfactory in operation, the inequalities inherent in grinding wheels and the necessarily involved construction and operation of the machine are such that frequent inspections and adjustments must be made in order that successive workpieces shall all be reduced to the same desired size.

The principal object of the present invention is to provide a novel arrangement for determining the size of a workpiece, which incorporates the advantages of the above described constructions, without incorporating any of the disadvantages thereof. According to the present invention, the size of the workpiece is automatically determined by utilizing variations in the potential of an electrical circuit to control the grinding operations, such variations of potential resulting from either removal of material from the workpiece, or the approach of a grinding wheel to a predetermined plane. In carrying out the invention, the use of sizing gages that fit the workpiece, or the utilization of the actual flow of current through the workpiece is avoided, the invention utilizing instead small variations of voltage in an electroresponsive device resulting from contact with either the workpiece or the grinding wheel, all as will hereinafter appear from the following detailed description taken in connection with the accompanying drawings, in which:—

Fig. 1 is a view in front elevation of an internal grinding machine embodying the invention.

Fig. 2 is a fragmentary plan view of a portion of the parts of Fig. 1, on an enlarged scale.

Fig. 3 is a view in front elevation, showing a portion of the parts of Fig. 2 in a different position.

Fig. 4 is a plan view similar to Fig. 2, showing a modification of the invention.

Fig. 5 is an enlarged transverse sectional view along the line 5—5 of Fig. 4, looking in the direction of the arrows.

Fig. 6 is a wiring diagram illustrating automatic control of the machine through variations of potential obtained from the apparatus of Fig. 2.

Fig. 7 is a wiring diagram similar to Fig. 6, illustrating the parts in different positions.

Fig. 8 is a wiring diagram illustrating automatic control of the machine through variations of potential obtained from the apparatus of Fig. 4.

Fig. 9 is a fragmentary view, similar to Fig. 5, showing a further modification of the invention.

Fig. 10 is a wiring diagram illustrating automatic control of the machine through variations of potential obtained from the apparatus of Fig. 9.

Fig. 11 is a wiring diagram, similar to Fig. 10, illustrating the parts in different positions.

Like reference characters refer to like parts in the different figures.

Referring first to Fig. 1, the machine provides the usual reciprocatory table 1 provided in an internal grinding machine; either the grinding wheel or the work to be ground may be carried on said table, the reciprocations of the latter operating in either case to produce a relative movement between said grinding wheel and workpiece. In the construction shown, the table 1 supports and carries a wheelhead 2, and the work to be operated upon is held in a workhead 3, the latter being carried by a bridge 4 which spans the slideways, not shown, provided by the machine frame, for the back and forth movement of the table 1. A grinding wheel 5 is mounted on a spindle 6 journaled in the wheelhead 2 and a workpiece *a* is mounted in a suitable workholding chuck or other clamping device 7 journaled in the workhead.

The back and forth movement of the table 1 to cause the wheel 5 to make the required traverse of the workpiece *a* may be procured in any well known manner, as by the use of the fluid pressure controlling and reversing mechanism, forming the subject matter of the Heald & Guild Patent No. 1,582,468, granted April 27, 1926. Such mechanism forms no part of the present invention; it is sufficient to note that the driving means employed procures the reversal of the table at each end of its normal grinding stroke by the use of spaced adjustable dogs 8 and 9 carried by the table 1 and adapted alternately to engage and to move a reversing member 10. The latter during the grinding operation, when the grinding wheel 5 is moving back and forth within the workpiece *a* is situated between said dogs 8 and 9 in position to be alternately struck by said dogs and, by its consequent movement, effects the reversals of the table 1. The grinding wheel 5 is rotated at a high speed in any suitable manner and the workholding member 7 is also rotated at a somewhat slower speed by a belt drive, as will hereinafter appear.

The wheel head 2 of the machine is mounted on a cross-slide 11 which is arranged to have a transverse movement on suitable ways, not shown, on the reciprocatory table, movement of said cross-slide being procured by rotation of a threaded crossfeed shaft 12, the latter engaging an internally threaded member, not shown, which is secured in any suitable way to the cross-slide. The crossfeed shaft 12 is rotated in a step-by-step movement by mechanism of the type disclosed in the above noted Guild Patent No. 1,682,672 to procure a feeding movement of the grinding wheel 5 to cause said wheel to cut progressively deeper and deeper into the workpiece *a*; for the purpose of the present invention, it is sufficient to note that a ratchet wheel, not shown, is engaged by a pawl 13 which is actuated in response to the reciprocations of the carriage 1, thereby procuring rotation of said crossfeed shaft 12 carrying the grinding wheel transversely against the surface of the workpiece.

In the previous operation of grinding machines of the type shown and described in the aforesaid Patent No. 1,682,672, the grinding operation is interrupted before the workpiece reaches predetermined finished size, the interruption occurring in response to the movement of the crossfeed mechanism to procure separation of the grinding wheel from the workpiece, in order that a dressing operation may be performed on the wheel. After the dressing operation has been performed on the wheel, the grinding operation is resumed until the workpiece is ground to a predetermined finished size, whereupon the grinding operation is brought to a close by a second separation of the grinding wheel from the work in response to the crossfeed mechanism. And since the present invention also contemplates both an initial separation of the grinding wheel from the workpiece for truing, followed by resumption of the grinding to complete the work, there is shown in Fig. 1 as an illustrative embodiment of the invention, certain of the same wheel controlling mechanism described in the aforesaid Patent No. 1,682,672, to which mechanism automatic control through variations of electrical potential has been applied.

As previously pointed out, in normal operation of the machine, back and forth movement is imparted to the table 1 by the cooperation of the spaced dogs 8 and 9 with the reversing member 10, and for the purpose of automatically interrupting the grinding operation on the workpiece and separating the wheel for the dressing operation, the machine provides a lever 14 pivotally mounted on a shaft 15, as shown in the broken away portion of Fig. 1. The lever 14 has integral therewith a magnetic armature 16 disposed in operative relation with respect to the core of an electromagnet 17, the unbalanced weight of the lever 14 tending to maintain the armature 16 spaced from the end of the electromagnet core as long as the electromagnet 17 remains in a deenergized condition. Upon energization of the electromagnet 17 in a manner hereinafter described, attraction of the armature 16 imparts upward movement to the lever 14 and causes the latter to lift a latch 18, assuming that the grinding wheelhead 2 is then in its left hand position with the grinding wheel 5 within the workpiece *a*.

The latch 18 extends between a block 19 carrying the left hand table dog 8, which block 19 is capable of free sliding movement on the table 1, and a stationary block 20 on which the latch 18 is pivotally mounted at 21. Under normal conditions, the block 19 is held in spaced relation to the stationary block 20 by the latch 18, but when the lever 14 is elevated as described above, the latch 18 releases the block 19 and subsequent right hand travel of the table 1 involves relative sliding movement between the table and the block 19, owing to the obstruction which the reversing member 10 imposes against the left hand table dog 8. Continued travel of the table 1 finally brings the stationary block 20 up against the then slidable block 19, whereupon the dog 8 becomes immovably supported for shifting the reversing member 10 to procure reversal of the table. The above described sliding movement of the block 19 on the table 1, when released by the latch 18, results in an amplified right hand stroke of the table to withdraw the wheel 5 from the workpiece *a* and the disposal in the temporarily amplified path of movement of the wheel 5 of a dressing device 22, in the manner fully described in the above noted Patent No. 1,682,672.

On the left hand movement of the table following the amplified dressing stroke, the reversing dog 8 is restored to its normal position by a resiliently supported lug 23 which engages the block 19, and as the table moves to the left, offers enough resistance to movement of the block 19 with the table to detain the block until the latch 18 is restored to its normal position in which it positively holds the block 19 separated from the block 20. On the above noted amplified right hand dressing stroke of the table 1, in order to prevent a repetition of the dressing stroke, an arm 24 mounted on the latch pivot 21 strikes a lug 25 of a switch member 26 pivotally mounted above the lever 14, thereby turning the switch member 26 into the position shown to break the circuit through the electromagnet 17 and release the lever 14, as will be hereinafter more fully described.

Upon the resumption of the grinding operation after dressing of the wheel as described above, the normal back and forth movement of the table continues until the work is reduced to a predetermined finished size, whereupon the grinding operation is brought to a close by a second separation of the grinding wheel from the work in response to the electric potential control of the present invention. For the purpose of obtaining a final run out of the table 1 into the position shown in Fig. 1, there is provided a second lever 27 mounted on the same shaft 15 as the lever 14, the lever 27 having integral therewith an armature 28 responsive to an electromagnet 29, as shown in Fig. 6. Normally, the unbalanced weight of the lever 27 maintains the armature 28 away from the core of the electromagnet 29 while the latter is in a deenergized condition, and such is the condition of affairs during the grinding operation. Upon energization of the electromagnet 29 in the manner hereinafter described, the lever 27 is raised to move its upper end into the path of the left hand table dog 8, while the table is in its left hand position. Since the table dog 8 is pivotally mounted on its block 19, right hand movement of the table after elevation of the lever 27 results in lifting of the dog 8 so that it is carried clear of the reversing member 10. Therefore, the table 1 is not reversed, but continues its movement to the right carrying the grinding wheel 5 out of the workpiece *a*, the table being brought to a full stop by any suitable means, such as is shown in the aforesaid Heald & Guild Patent No. 1,582,468.

The return of the table 1 to the working position from the fully withdrawn position of Fig. 1 is effected by the shifting of a hand lever 30 operatively connected to the reversing member 10, and on the left hand movement of the table an arm 31 also mounted on the pivot 21 strikes a second lug 32 on the movable switch member 26, thereby turning the switch member in a position to disconnect the electromagnet 29 from its source. This turning movement of the switch member 26 upon the initiation of another grinding cycle restores the switch member to the position shown in Fig. 6 in readiness for the energization, at the proper time in the grinding of the next workpiece, of the electromagnet 17 controlling the wheel dressing operation.

The above described mechanism for mechanically controlling the movements of the table 1 carrying the grinding wheel is more fully described in the above mentioned Guild Patent No. 1,682,672, and therefore forms no part of the present invention per se; the present invention, as previously pointed out, involving the attainment in connection with the above described or similar grinding machine instrumentalities, of automatic size determining mechanism primarily responsive to variations in the potential of an electrical circuit resulting from either removal of material from the workpiece, or the approach of the grinding wheel to a predetermined plane. In other words, the table controlling mechanism described above with reference to Fig. 1 is merely an illustrative embodiment of the manner in which any one of the several forms of potential control, next to be described, can be applied to a grinding machine of the character shown.

As best shown in Figs. 2 and 3, one form of the potential control contemplated by the present invention embodies the use of a gaging finger 33, one end of which provides a head 34 mounted on a block 35 of piezo-electric material of such character that an electro-motive force will be generated therein, in response to twisting of the block. A Rochelle salt crystal is a well known example of such material of which the block 35 may be composed, the base of the block 35 being insulated at 36 from a bracket 37 carried by and movable with the lower portion of the table 1.

As indicated in Fig. 2, the base 37*a* of the bracket 37 is laterally adjustable on the table through the provision of slots 38 receiving the table bolts 39, so that the free end of the gaging finger 33 may be set so as to cause an inset 33*a*, preferably a diamond or other hard material, to engage the periphery of the unreduced workpiece substantially coincidentally with the engagement of the grinding wheel 5 at the initiation of the grinding operation. As the finger 33 enters the workpiece *a*, its initial engagement with the inner periphery thereof will result in a turning moment being exerted on the finger in a clockwise direction about the axis of the crystal block 35. This turning moment will result in actual twisting of the crystal block 35 with the generation of an electro-motive force across leads 40 extending from the base of the block and the head 34, respectively. Obviously, removal of material from the workpiece *a* by the grinding wheel 5 from successive working strokes of the wheel will result in a decrease of the turning moment exerted on the gaging finger 33 as the internal diameter of the workpiece increases. Therefore, the potential generated within the crystal block 35 will vary with each cut of the wheel, and the invention contemplates the utilization of such variations of the crystal block potential to automatically control the grinding operation, as will next be described.

Since the electro-motive force impressed across the leads 40 by twisting of the crystal 35 is relatively small and the range of variation of potential is limited, the invention provides means for amplifying the effect of potential variations of the crystal block so as to better control the energization of the electromagnets 17 and 29 respectively. One means of readily amplifying the potential of the crystal block is through the use of a grid glow tube designated by the reference character 41 in Fig. 6. The glow tube 41 comprises a filament 42, plate 43 and grid 44, with the filament 42 energized from a portion 45*a* of the secondary winding of a transformer T, the primary winding 46 of which is connected across a suitable source of alternating current indicated at 47. One terminal of another portion 45*b* of the transformer secondary is connected to the grid 44 through a resistor 48 so as to give the grid 44 a negative bias with respect to the anode or filament 42 of the tube. The plate 43 is connected in series with the energizing coils 49 and 50 of relays that are adapted to control energization of the electromagnets 17 and 29 respectively, in a manner hereinafter described, with one terminal of coil **50** connected to one side of the primary winding **46**. Therefore, with the connections shown, the coils **49** and **50** will be energized when the glow tube **41** passes sufficient current, as determined by the characteristics of the coils.

With the connections shown in Fig. 6, in the absence of any potential across the crystal block **35**, that is to say with the crystal in an untwisted condition, the negative bias of the grid **44** by the winding portion **45b** is such as to effectively prevent the passage of current by the tube **41**. However, when the crystal block **35** is twisted, as a result of the engagement of the finger **33** with the workpiece *a*, the lead **40** from the crystal block **35** to the grid **44** gives the grid **44** a positive bias sufficient to overcome the basic negative bias and cause the glow tube **41** to pass enough current to energize the relay coils **49** and **50**. Obviously, the amount of current passed by the tube will depend upon the degree of positive bias by the crystal block **35**, which in turn will be dependent upon the degree of engagement of the finger **33** with the workpiece to twist the crystal block. The amount of twisting is at a maximum at the beginning of the grinding operation and decreases progressively as the material is removed, and the manner in which the resulting variations in the degree of energization of the relay coils **49** and **50** to first cause withdrawal of the wheel from the workpiece, for truing, and then the final run out of the wheel when the workpiece is reduced to finished size will now be described.

To this end, one terminal of the electromagnet **17** is connected to the movable contact **51** under the control of the relay coil **49**, the contact **51** being biased in the direction of a stationary contact **52** by a spring **53**. This stationary contact **52** is adapted to be connected to ground, as indicated at **54** by relatively movable contacts **55** and **56**, the contact **55** being mounted on the table so as to engage the stationary contact **56** just as the finger **33** carried by the crystal block **35** enters or leaves the workpiece *a*. The other terminal of electromagnet **17** is connected to a stationary contact **57** engaged by the movable switch member **26** in the position shown in Fig. 6, the switch member **26** being in turn connected to the supply generator **58** shown as being grounded at **54***a*. With the circuit connections just described, it is obvious that the electromagnet **17** will remain in a deenergized condition as long as the glow tube **41** passes enough current to hold the movable contact **51** out of engagement with the stationary contact **52** at the time when the finger **33** is engaging the workpiece, and the table controlled contacts **55** and **56** are in engagement, as shown in Fig. 6.

The terminals of electromagnet **29** are similarly connected to the movable contact **59** under the control of relay coil **50** and to a stationary contact **60** adapted to be engaged by the pivoted switch member **26**, when the latter is moved into the position shown in dotted lines in Fig. 7. The movable relay contact **59** is normally biased in the direction of a stationary contact **61** by a spring **62**, so that the circuit of the electromagnet **29** is adapted to be completed through the table controlled contacts **55** and **56** only when the current passed by the glow tube **41** is reduced to a value in which the relay coil **50** no longer maintains its movable contact **59** out of engagement with the stationary contact **61**.

As previously pointed out, each left hand movement of the grinding wheel **5** into contact with the workpiece *a* is accompanied by entrance of the finger **33** into the workpiece, and at the beginning of the grinding operation with the diameter of the workpiece substantially unreduced as indicated in Fig. 6, the twisting of the crystal block **35** is at a maximum. Thereafter during the early stages of the grinding operation, the crystal block **35** is twisted each time the finger **33** enters the workpiece to such an extent that the potential across its leads **40** is more than sufficient to overcome the basic negative grid bias and cause the glow tube **41** to pass enough current to fully energize the relay coils **49** and **50** and hold the movable contacts **51** and **59** out of engagement with the corresponding stationary contacts **52** and **61**, as shown in Fig. 6. Therefore, the engagement of the contacts **55** and **56**, during this phase of the grinding operation has no effect upon the electromagnets **17** and **29**.

As the grinding operation proceeds and the diameter of the workpiece *a* increases, the amount of twisting of the crystal block **35** gradually decreases, with a corresponding decrease in the amount of current passed by the glow tube **41**. Therefore, after a number of reciprocations of the grinding wheel **5**, sufficient to reduce the workpiece *a* to roughing size, the amount of twisting of the crystal block **35** will be reduced to such an extent that not enough current will be passed by the tube **41** to energize the relay coil **49** and hold the movable contact **51** away from stationary contact **52** as the finger **33** is about to leave the workpiece on the right hand stroke of the wheelhead. Therefore, the movable contact **51** will engage the stationary contact **52** at this moment, and since as previously pointed out, the table contact **55** is then in engagement with the stationary contact **56**, the electromagnet **17** will be energized as indicated in Fig. 7, thereby raising the lever **14**. Since the lever is raised by energization of the electromagnet **17** after the grinding wheel **5** has started on its right hand movement, the resulting lifting of the latch **18** releases the block **19** and renders the table dog **8** ineffective to turn the reversing member **10** until after the table has run out far enough to withdraw the grinding wheel **5** from the work for truing by the dressing tool **22**, as previously described. The circuit of the electromagnet **17** is broken as the grinding wheel **5** is withdrawn, due to the engagement of the lug **25** on the movable switch member **26** by the arm **24**, thereby disconnecting contact **57** from the generator **58**, see Fig. 1.

With the switch member **26** in engagement with the contact **60** leading to the electromagnet **29**, as indicated in dotted lines in Fig. 7, the circuit of the electromagnet **29** is then in condition to be completed upon engagement of the movable contact **59** with the stationary contact **61**, as will next be described. Upon resumption of the grinding operation following truing of the wheel **5** as just described, the re-entry of the finger **33** into the workpiece *a*, then reduced to roughing size, is accompanied by just enough twisting of the crystal block **35** to cause the tube **41** to pass sufficient current to energize the relay coil **50**, although not enough to energize coil **49** as previously described. Therefore, the relay coil **50** still holds its movable contact **59** out of engagement with stationary contact **61** as the wheel enters the workpiece for the final cut, or cuts. The finger **33** carried by the crystal block **35** is so set that removal of additional material sufficient to bring the workpiece to its predetermined finished diameter finally results in substantially no contact between the finger 33 and the workpiece, so that there is no appreciable twisting of the crystal 35. When this point is reached, obviously the passage of current by the glow tube 41 is substantially reduced to zero by the basic negative grid bias and the relay coil 50 no longer holds the movable contact 59 out of engagement with contact 61 against the pull of spring 62. The resulting engagement of the movable contact 59 with stationary contact 61 thereupon energizes the electromagnet 29, thereby raising the lever 27 into the path of movement of the left hand table dog 8. Consequently, on the succeeding right hand movement of the table, the dog 8 clears the reversing member 10 and the right hand movement of the table continues to the extreme run-out position shown in Fig. 1, following which the completed workpiece is removed. Upon initiation of the grinding operation upon a new workpiece, the left hand movement of the table from the run-out position causes the arm 31 to engage the lug 32 on the movable switch member 26, thereby breaking the circuit through the electromagnet 29, when the switch member moves from the dotted to the full line position of Fig. 7 to reengage the contact 57. This partially restores the circuit of the electromagnet 17, and the gaging finger 33 associated with the crystal block 35 resumes control of the grinding cycle in the manner previously described, so as to automatically cause the tool to be withdrawn for truing when the work reaches predetermined roughing size and to cause the tool to be finally run out from the work when the predetermined finished size is reached.

In the automatic control of the grinding cycle just described, variations of voltage indirectly resulting from removal of material from the workpiece have been utilized, but as previously pointed out, the invention also contemplates utilization of the actual approach of the periphery of the grinding wheel to a predetermined plane by the cross feed movement to obtain the desired variations of voltage values. In Figs. 4 and 5, a crystal block 35′ is shown carried by a holder 63 that is mounted on a bracket 64 by a resilient member 65. The resilient member 65 is shown as a leaf spring, with one end received in the bracket 64, so that the member 65 tends to maintain the holder 63 in a substantially horizontal position. The crystal block 35′ extends in the direction of the grinding wheel 5 and terminates in a head 66 carrying a feeler 67 of wear-resistant material adapted to be engaged by the periphery of the grinding wheel when the latter has been fed a predetermined amount with respect to the workpiece *a*. The end of the holder 63 opposite to the head 67 carries a stud 68 that is adapted to limit movement of the right hand end of the holder 63 in response to a horizontal thrust exerted on the opposite end by reason of engagement of the feeler 67 by the periphery of the grinding wheel 5. The exact position of the feeler 67 with respect to the wheel 5 is adjustable through the provision of bolts 69 cooperating with slots 70 provided in the bracket 64, as shown in Fig. 4.

At the beginning of a cycle of grinding operations on a workpiece *a*, it is obvious from Fig. 5 that the holder 63 extends substantially horizontally with the end of the feeler 67 spaced an appreciable distance from the periphery of the grinding wheel 5. As the grinding proceeds, each operation of the cross feed mechanism brings the periphery of the grinding wheel nearer the feeler 67, and the bracket 64 is so set that when the workpiece has been reduced to roughing size, the next succeeding cross feed of the wheel head will cause the periphery of the wheel 5 to engage the feeler 67. When this occurs, a substantially horizontal thrust is exerted on the holder such as to tend to move the head 66 away from the wheel 5, but the setting of the stud 68 is such that any shifting of the holder 63 is prevented, and there results an axial compression of the crystal block 35′ sufficient to generate an electromotive force therein. Obviously, the voltage generated within the crystal block 35′ will vary with the pressure exerted by the wheel 5, and the manner in which such voltage variations may be employed to control energization of the electromagnets 17 and 29 will next be described.

Referring to Fig. 8, a lead 40′ from the crystal block 35′ is shown as connected to the grid 44 of a glow tube 41 that is adapted to be energized from a source 47 in exactly the same manner as described with reference to Fig. 6. Furthermore, the relay coils 49 and 50 are connected in series with the plate 43, as shown in Fig. 6, so that the flow of current through these coils is directly controlled by the output of the tube 41.

The electromagnets 17 and 29 are connected to the stationary contacts 57 and 60 under the control of the movable switch member 26 in the manner previously described with reference to Fig. 6, while the other terminals of the electromagnets are connected to movable contacts 71 and 72 under the control of the relay coils 49 and 50, respectively. With the coils 49 and 50 in a deenergized condition as shown in Fig. 8, the movable contacts 71 and 72 are held against stops 73 and 74 by springs 75 and 76 respectively. Consequently, the movable contacts 71 and 72 are adapted to engage their stationary contacts 52 and 61 respectively, leading to the table controlled contacts 55 and 56, only upon energization of the corresponding relay coils 49 and 50.

At the beginning of a grinding cycle the parts occupy the position of Fig. 8, at which time the grinding wheel is operating with its periphery at an appreciable distance from the end of the feeler 67. Consequently, there being no voltage generated in the crystal block 35′, the basic negative grid bias prevents the passage of current by the tube 41, and the coils 49 and 50 remain completely deenergized. During this stage of the grinding cycle engagement between the table controlled contacts 55 and 56 has no effect on the circuits of the electromagnets 17 and 29, in view of the fact that the movable contacts 71 and 72 are maintained out of engagement with the corresponding stationary contacts 52 and 61, as shown in Fig. 8.

As the grinding proceeds and the diameter of the workpiece increases, the wheel 5 comes closer and closer to the feeler 67, and the bracket 64 is so set that when the workpiece has been reduced to roughing size, the feeler 67 is engaged by the wheel 5 and the crystal block 35′ axially compressed. The resulting voltage generated in the block 35′ imparts a positive bias to the grid 44 sufficient to overcome the negative bias and cause the tube 41 to pass enough current to energize the coil 49, the coil 49 being designed to pull up its armature carrying the movable contact member 71 on considerably less current than is required for the coil 50 to pull up its armature. When the movable relay contact 71 engages its stationary contact 52, the resulting energization of the electromagnet 17 raises the lever

14 and automatically causes separation of the grinding wheel from the workpiece, for truing, in the manner previously described with reference to Fig. 7.

Upon return of the grinding wheel to the workpiece for completion of the grinding operation, it is evident that the feeler 67 will be engaged by the grinding wheel with a greater pressure than before, so that sufficient voltage will be generated in the crystal block 35′ to cause the tube to pass enough current to energize the coil 50. That is to say, the coil 50 is so designed that when the periphery of the grinding wheel reaches a vertical plane corresponding to the position it occupies when the workpiece has been reduced to predetermined finished size, compression of the crystal block 35′ is such as to cause energization of the coil 50. The resulting engagement of the movable contact 72 with the stationary contact 61 serves to energize the electromagnet 29 and lift the lever 27. When this occurs, the succeeding right hand movement of the table is continued until the tool reaches the full run-out position shown in Fig. 1, following which the completed workpiece is removed. Upon initiation of the grinding operation upon a new workpiece, the circuit through the electromagnet 29 is broken by the switch member 26, as previously described, thereby partially restoring the circuit of the electromagnet 17, whereupon the feeler 67 associated with the crystal block 35′ resumes control of the grinding cycle.

Referring now to Figs. 9 and 10, there is illustrated a further modification of the invention, whereby variations in the voltage impressed on the grid of a glow tube may be obtained in a manner different from that previously described with reference to Figs. 6 and 8, for the purpose of automatically controlling the grinding cycle. In Fig. 9, an arm 77 is shown as being yieldingly supported on a bracket 78 by a resilient member 79, the arm 77 normally extending in a substantially vertical direction. The bracket 78 is adjustably mounted on a portion of the machine base, a screw 80 serving to shift the bracket 78 and its arm 77 with respect to the axis of the grinding wheel 5. The lower end of the arm 77 carries an inset 77*a* of wear resistant material, and feeding movement of the grinding wheel 5 with respect to the workpiece *a* will cause the periphery of the wheel to engage the inset 77*a* and to shift the arm 77 on its flexible support 79 in such a direction as to swing the upper end of the arm away from an upward extension 78*a* of the bracket 78.

With the grinding wheel 5 spaced from the lower end of the arm 77, as at the beginning of the grinding cycle, the upper end of the arm 77 is in engagement with a contact 81 adjustable within an insulating bushing 81*a* on the bracket extension 78*a* (while a flexible contact finger 82 also carried by the arm 77 but insulated therefrom is in engagement with a contact 83 carried by the bracket extension 78*a* and insulated therefrom, as by a bushing 83*a*. With the parts in the position shown in Fig. 9, the contact finger 82 is under a slight initial compression, so that when the grinding wheel 5, due to its feeding movement, engages the arm 77 as shown in Fig. 11, the end of the arm 77 will be disengaged from the upper contact 81, while the contact finger 82 remains in engagement with the contact 83. The contact 83 is so adjusted with respect to the finger 82 that a very slight further movement of the arm 77 from the position shown in Fig. 11 will cause the finger 82 to leave the contact 83. With the above described arrangement, it is apparent then that the arm 77 will leave the contact 81, when the periphery of the grinding wheel 5 reaches a predetermined plane, and that the contact finger 82 will leave the contact 83 when the periphery of the wheel 5 reaches another plane parallel to but slightly removed from the first plane.

Referring now to Fig. 10, the plate 43′ of a grid glow tube 41′ is connected directly to one terminal of the electromagnet 17, the other terminal of the electromagnet 17 being connected to one side of the primary winding 46′ of a transformer T′, so that the electromagnet 17 will be energized when the tube 41′ passes sufficient current. The filament 42′ of the tube 41′ is energized from a portion 84 of the secondary of transformer T′, and with the parts in the position of Fig. 10, a negative bias is maintained on the grid 44′ by a secondary winding portion 85 having one terminal thereof connected through the engaged arm 77 and contact 81 to one end of the grid 44′ through the usual resistor 48. The secondary winding of transformer T′ also provides a third portion 86, the function of which is to place a positive bias on the grid 44′ through an adjustable potentiometer connection at 86*a*, so set that normally the negative bias from winding 85, through the contact 81, is more than sufficient to overcome the positive bias and prevent the tube 41′ from passing any appreciable current. This condition of affairs is maintained during the first part of the grinding cycle and as long as the arm 77 engages contact 81.

The electromagnet 29 controlling the lever 27 has one terminal thereof connected to a plate 43″ of a second grid glow tube 41″, the other terminal of the electromagnet being connected to one side of the primary winding 46″ of a second transformer T″. The filament 42″ of this tube 41″ is energized from a secondary winding portion 87 in substantially the same manner as is the filament 42′ of tube 41′ energized from winding 84. With the parts in the position of Fig. 10, the tube 41″ is prevented from passing any appreciable current by reason of the fact that a negative bias is placed on the grid 44″ by means of a secondary winding portion 88 connected to one end of the grid 44″ through the then closed contact finger 82 and contact 83. It is to be noted that one terminal of the negative bias winding 88 is connected directly to the contact finger 82, and that the latter is insulated from the arm 77, so that the circuits for controlling the negative bias of grids 44′ and 44″ are maintained independently of each other. A positive bias is adapted to be placed on the grid 44″ from a secondary winding portion 89 through an adjustable potentiometer connection at 89*a*, so set that the positive bias is less than the negative bias, and the tube 41″ therefore passes no current at the beginning of the grinding cycle. With the parts arranged as described with reference to Fig. 10, it is apparent that while the electromagnets 17 and 29 are directly under the control of the glow tubes 41′ and 41″, these tubes are both maintained in such a condition that they will not pass sufficient current to energize either the electromagnet 17 or the electromagnet 29 during the first part of the grinding cycle.

Referring now to Fig. 11, it is evident that when the grinding cycle proceeds to the point that the workpiece *a* has been reduced to roughing diameter, the wheel 5 will engage the lower end of the arm 77, whereupon shifting of the arm 77 on its resilient supporting member 79 will cause the upper end thereof to leave the stationary contact 81, as indicated. When this occurs, the basic negative bias on the grid 44' is immediately removed, so that the positive bias from the secondary winding portion 86 immediately becomes effective on the grid 44'. The tube 41' thereupon passes sufficient current to energize the electromagnet 17, the resulting lifting of the lever 14, as shown, automatically causing separation of the wheel 5 from the workpiece *a* for truing. The circuit of the electromagnet 17 is broken as the grinding wheel is withdrawn, due to the engagement of the lug 25 on the movable switch member 26 by the arm 24, see Fig. 1, thereby disengaging a bridging contact 91 on the switch member 23 from the spaced stationary contacts 92 in the circuit of the electromagnet, as indicated in dotted lines in Fig. 11. Upon resumption of the grinding operation after truing, it is evident that further removal of material from the workpiece to bring it to predetermined finished diameter will cause the wheel 5 to further shift the arm 77 from the position of Fig. 11, so as to separate the flexible contact finger 82 from the contact 83. When this occurs, removal of the negative bias from winding portion 88 on the grid 44'' immediately causes the tube 41'' to pass current, due to the positive bias impressed on the grid 44'' by the secondary winding portion 89. This passage of current by the tube 41'' is sufficient to energize the electromagnet 29 and cause the grinding wheel 5 to be moved to the final run-out position of Fig. 1. At this time the circuit from the electromagnet 29 is maintained by a bridging contact 93 on switch member 26, which bridging contact 93 is in engagement with stationary contacts 94 when the switch member 26 is in the dotted line position. Upon the initiation of the grinding operation upon a new workpiece, obviously the above described cycle of operations will be repeated.

From the foregoing, it is apparent that by the present invention there is provided a size determining mechanism of the above indicated type, characterized by the automatic control of the entire grinding cycle through variations of electrical potential resulting from either removal of material from the workpiece, or the approach of the grinding wheel to a predetermined plane. In other words, the control of the grinding cycle is obtained without the use of sizing gages that fit within the workpiece, or without utilization of the actual flow of current through the workpiece or the grinding wheel.

I claim:

1. In a mechanism of the class described, the combination with a cutting tool, means for holding a workpiece, means to procure a cutting operation between said tool and workpiece by feeding movement of the tool relative to the workpiece, and an electromagnet adapted to bring about the separation of said tool from said workpiece, of a glow tube for controlling the energization of said electromagnet, and means dependent upon variations in the internal condition of an electro-responsive material for automatically subjecting the grid of said tube to a voltage such as to cause it to pass enough current to energize said magnet and cause separation of the tool from the workpiece when said workpiece reaches a predetermined diameter.

2. In mechanism of the class described, the combination with a cutting tool, means for holding a workpiece, means to procure a cutting operation between said tool and workpiece by feeding movement of the tool relative to the workpiece, and an electromagnet adapted to bring about the separation of said tool from said workpiece, of a glow tube for energizing said electromagnet, said tube having a basic negative grid bias to restrict its passage of current, and means dependent upon variations in the internal condition of an electro-responsive material resulting from the removal of material from said workpiece for creating a voltage sufficient to overcome the negative grid bias and cause said tube to pass sufficient current to energize said electromagnet.

3. In mechanism of the class described, the combination with a cutting tool, means for holding a workpiece, means to procure a cutting operation between said tool and workpiece by feeding movement of the tool relative to the workpiece, and an electromagnet adapted to bring about the separation of said tool from said workpiece, of a glow tube for energizing said electromagnet, said glow tube having a basic negative grid bias to restrict its passage of current, and means dependent upon variations in the internal condition of an electro-responsive material resulting from the approach of said tool to a predetermined plane for overcoming said negative grid bias and causing said tube to pass sufficient current to energize said electromagnet.

4. In a mechanism for performing a cutting operation on a workpiece by a cutting tool, involving feeding movement of the tool relative to the workpiece, an electrical circuit, piezoelectric material in said circuit and means for automatically controlling the progress of the cutting operation in accordance with variations of the voltage generated in said electrical circuit by said piezoelectric material, as a result of such feeding movement between tool and workpiece.

5. In a mechanism for performing a cutting operation on a workpiece by reciprocatory movement between the workpiece and a cutting tool, accompanied by feeding of the tool relative to the workpiece, an electrical circuit, piezoelectric material in said circuit and means for automatically controlling the progress of the cutting operation in accordance with variations of the voltage generated in said electrical circuit by said piezoelectric material when subjected to variations of its internal condition resulting directly from such reciprocatory movement.

6. In a mechanism for performing a cutting operation on a workpiece by reciprocatory movement between the workpiece and a cutting tool, accompanied by feeding of the tool relative to the workpiece, an electrical circuit, piezoelectric material in said circuit and means for automatically controlling the progress of the cutting operation in accordance with variations of the voltage generated in said electrical circuit by said piezoelectric material as a result of the application of force tending to deform the material due to reciprocatory movement of the cutting tool.

7. In a mechanism for performing a cutting operation on a workpiece by reciprocatory movement between the workpiece and a cutting tool, accompanied by feeding of the tool relative to the workpiece, an electrical circuit, a piezoelectric crystal in said circuit and means for automatically controlling the progress of the cutting operation in accordance with variations of the voltage generated in said electrical circuit by the deformation of said piezo-electric crystal result-

ing from direct engagement of said crystal with the workpiece.

8. In a machine of the class described, the combination with a cutting tool, means for holding a workpiece, and means to procure the removal of material from the workpiece by a cutting operation resulting from relative feeding movement between said tool and workpiece, of an electrical circuit, piezoelectric material in said circuit and means for automatically controlling the cutting operation of the machine in response to variations in the voltage of said electrical circuit, with said piezoelectric material being subject to variations of its internal condition resulting from the removal of material from said workpiece.

9. In a machine of the class described, the combination with a cutting tool, means for holding a workpiece, and means to procure the removal of material from the workpiece by a cutting operation resulting from relative feeding movement between said tool and workpiece, of an electrical circuit, piezo electric material in said circuit and means for automatically interrupting the cutting operation when the workpiece reaches a predetermined size in response to a voltage generated in said electrical control circuit with said piezo electric material being subject to variations in its internal condition resulting from the removal of material from said workpiece.

10. In a machine of the class described, the combination with a cutting tool, means for holding a workpiece, and means to procure the removal of material from the workpiece by a cutting operation resulting from relative feeding movement between said tool and workpiece, of an electric circuit, piezo electric material in said circuit and means for automatically interrupting the cutting operation in response to the generation of a voltage in said electrical control circuit, with said piezo electric material being subject to variations in its internal condition by the approach of the cutting tool to a predetermined plane due to its feeding movement toward said workpiece.

11. In a machine of the class described, the combination with a cutting tool, means for holding a workpiece, and means to procure the removal of material from the workpiece by a cutting operation resulting from relative feeding movement between said tool and workpiece, of an electric circuit, piezo electric material in said circuit and means for automatically interrupting the cutting operation in response to the generation of a voltage in said electrical control circuit, with said piezo electric material being subject to variations in its internal condition due to reduction in the size of the workpiece.

12. In a machine of the class described, the combination with a cutting tool, means for holding a workpiece, and means to procure the removal of material from the workpiece by a cutting operation resulting from relative feeding movement between said tool and workpiece, of a control circuit for said machine, and an electroresponsive material in said circuit adapted to generate a voltage in said circuit due to deformation of the material by engagement with the cutting tool as the latter approaches a predetermined plane in its feeding movement with respect to the workpiece.

13. In a machine of the class described, the combination with a cutting tool, means for holding a workpiece, and means to procure the removal of material from the workpiece by a cutting operation resulting from relative feeding movement between said tool and workpiece, of a control circuit for said machine and an electroresponsive material in said circuit adapted to generate a voltage in the circuit as a result of deformation of the material due to its engagement with the workpiece.

14. In a machine of the class described, the combination with a cutting tool, means for holding a workpiece, and means to procure the removal of material from the workpiece by a cutting operation resulting from relative feeding movement between said tool and workpiece, of a gaging member supported by a block of piezoelectric crystal and an electrical circuit for controlling the operation of the machine, said circuit including said crystal and being responsive to voltages generated through the deformation of said crystal as a result of the relative feeding movement between said tool and workpiece.

15. In a machine of the class described, the combination with a cutting tool, means for holding a workpiece and means to procure the removal of material from the workpiece by a cutting operation resulting from relative feeding movement between said tool and workpiece, of an electrical control circuit, piezo electric material in said circuit subject to variations in its internal condition due to relative feeding movement between said tool and workpiece, which variations are reflected in said control circuit, and means under the supervision of said circuit for automatically interrupting the cutting operation when the workpiece reaches a predetermined size.

16. In a machine of the class described, the combination with a cutting tool, means for holding a workpiece and means to procure the removal of material from the workpiece by a cutting operation resulting from relative feeding movement between said tool and workpiece, of an electrical control circuit, piezo electric material in said circuit subject to variations in its internal condition by the approach of the cutting tool to a predetermined plane due to its feeding movement toward said workpiece, which variations are reflected in said control circuit, and means under the supervision of said circuit for automatically interrupting the cutting operation when the workpiece reaches a predetermined size.

17. In a machine of the class described, the combination with a cutting tool, means for holding a workpiece and means to procure the removal of material from the workpiece by a cutting operation resulting from relative feeding movement between said tool and workpiece, of an electrical control circuit, piezo electric material in said circuit subject to variations in its internal condition due to reducton in size of the workpiece, which variations are reflected in said control circuit, and means under the supervision of said circuit for automatically interrupting the cutting operation when the workpiece reaches a predetermined size.

18. In a grinding machine, the combination with a workholder, a grinding wheel, and means to procure a grinding cycle on a workpiece carried by said holder, of an electric circuit, piezo electric material in said circuit subject to variations in its internal condition due to relative feeding movement between the workpiece and the grinding wheel, and means under the influence of said circuit to automatically control the progress of the grinding cycle, said cycle being characterized by temporary separation of the wheel from the

workpiece for truing, when the workpiece is reduced to roughing size, and final separation of the wheel from the workpiece when the latter reaches a predetermined finished size.

19. In a grinding machine, the combination with a workholder, a grinding wheel, and means to procure a grinding cycle on a workpiece carried by said holder, of an electric circuit, piezo electric material in said circuit subject to deformation due to relative feeding movement between the workpiece and the grinding wheel, and means responsive to variations in the voltage of said circuit resulting from deformation of said piezo electric material to automatically control the progress of the grinding cycle, one voltage value causing temporary separation of the wheel from the workpiece for truing, when the workpiece is reduced to roughing size, and a second voltage value causing final separation of the wheel from the workpiece when the latter is reduced to predetermined finished size.

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