Dec. 27, 1938. C. E. BROWN 2,141,853

GRINDING MACHINE

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FIG. 1.

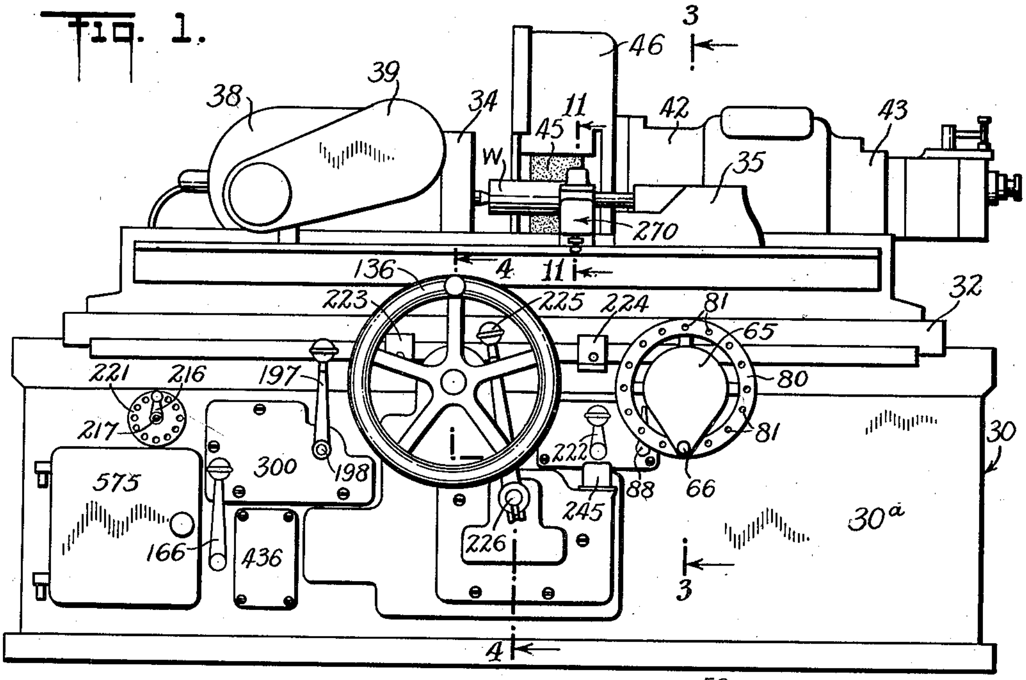
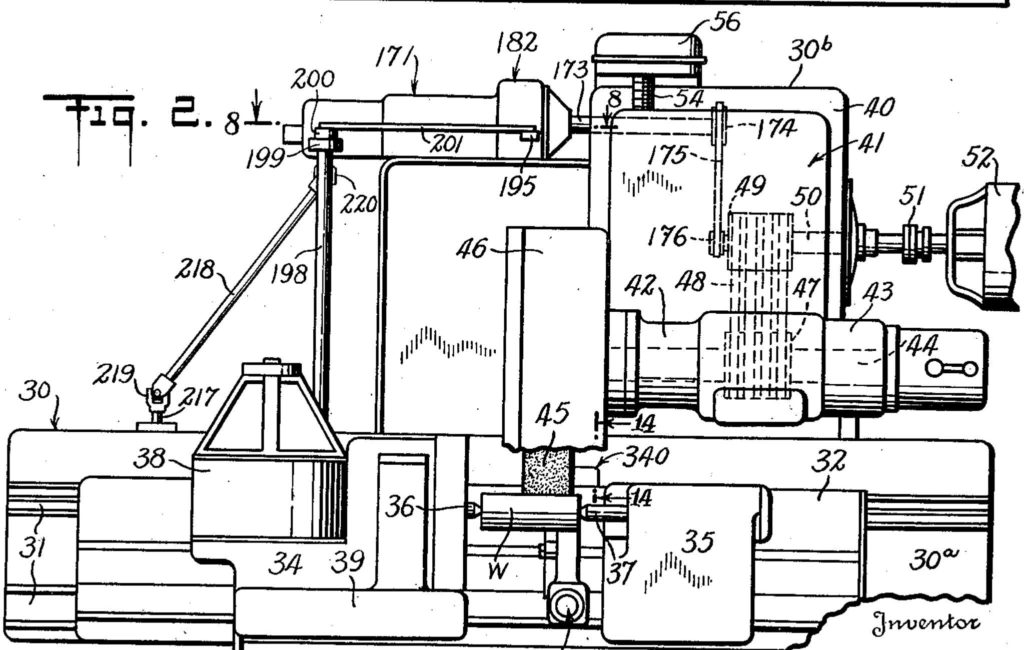


FIG. 2.



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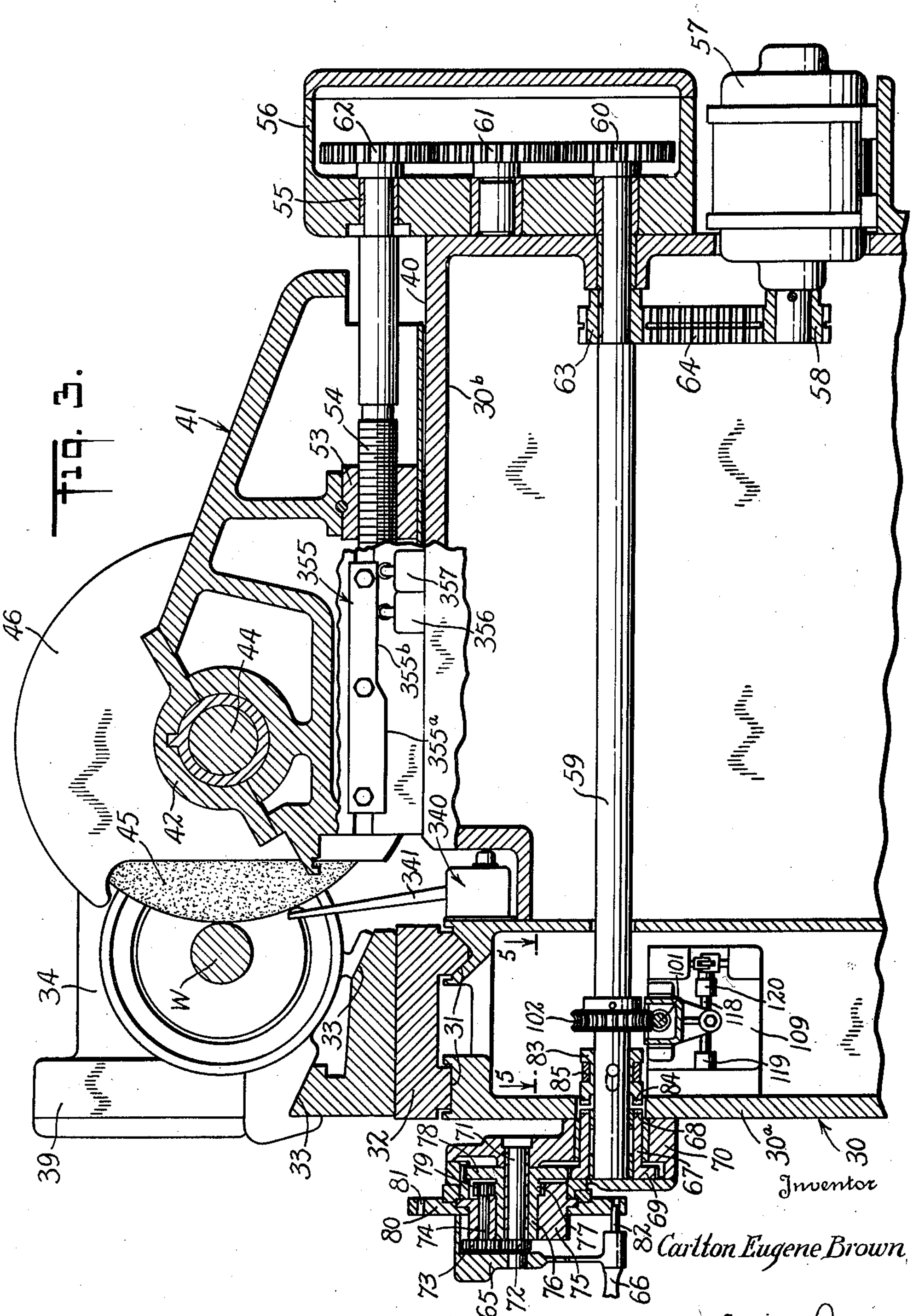

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Fig. 4.

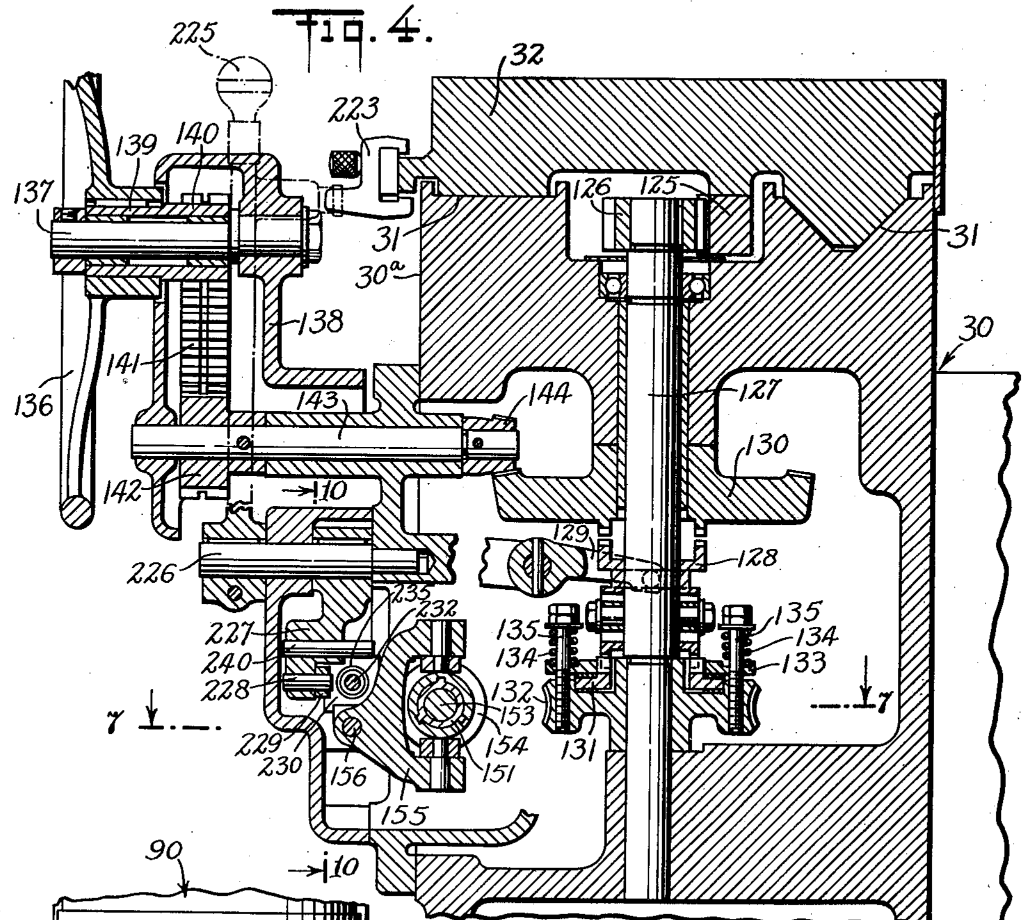
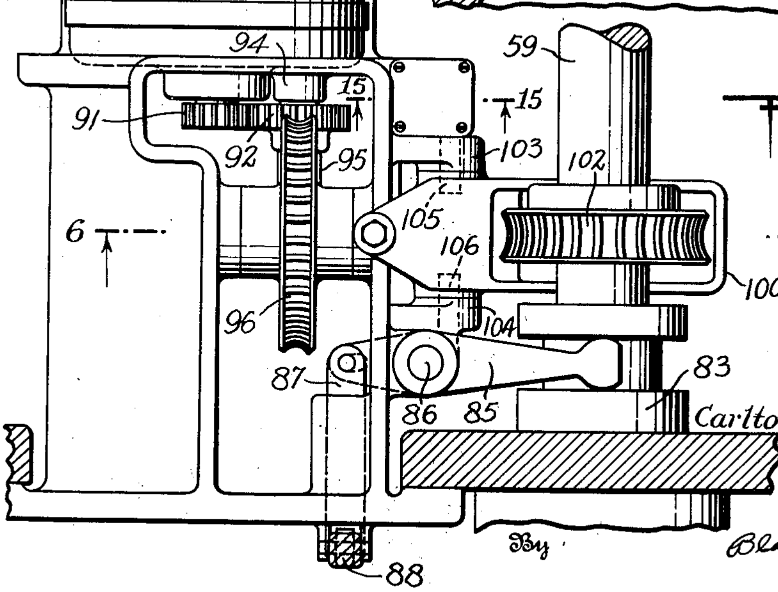


Fig. 5.



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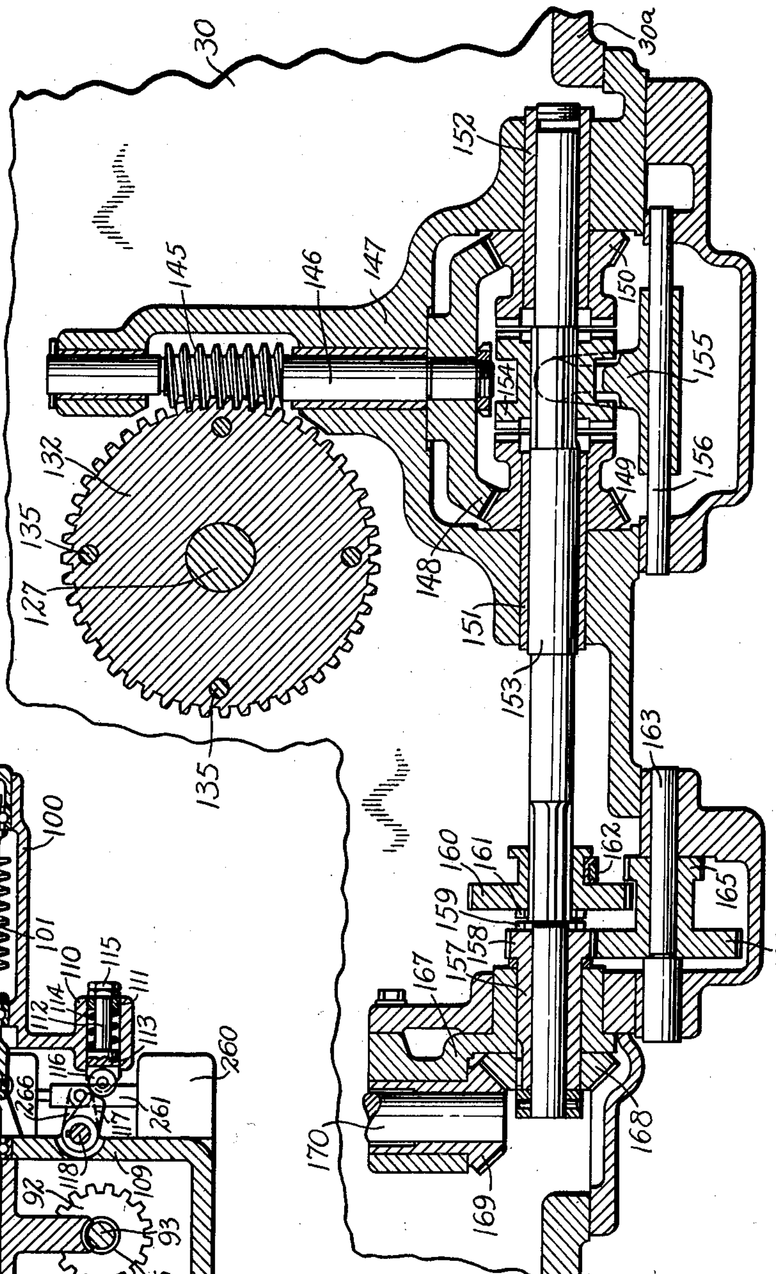

Fig. 7.

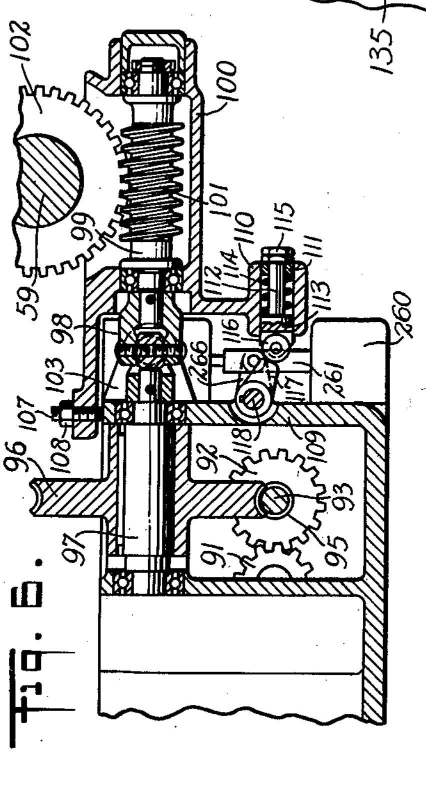

Fig. 6.

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FIG. 8.

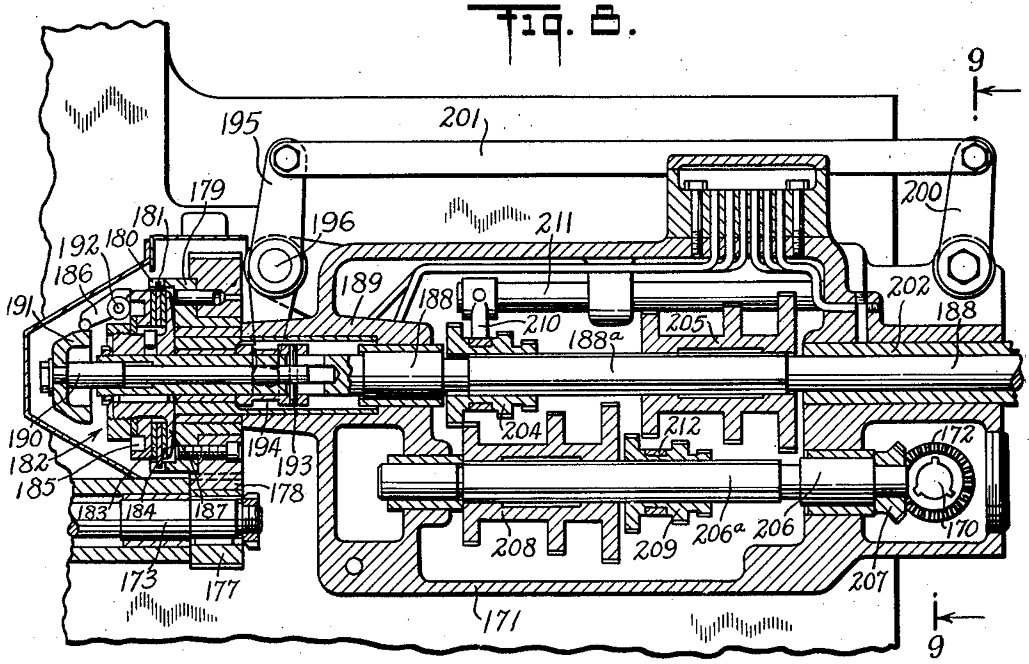

FIG. 9.

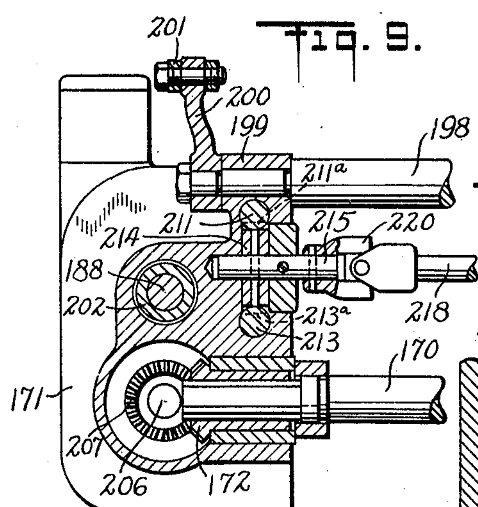

FIG. 15.

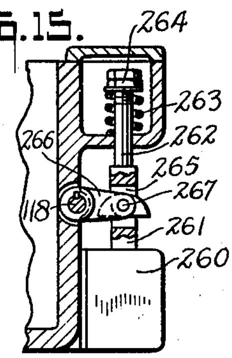

FIG. 13.

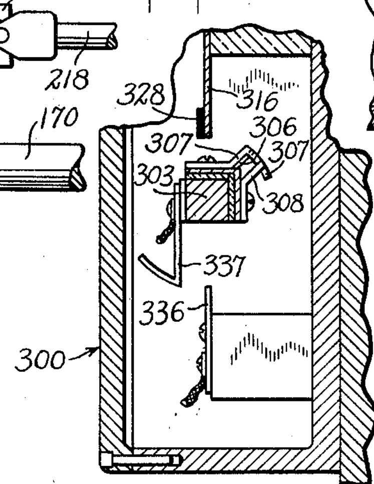

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FIG. 10.

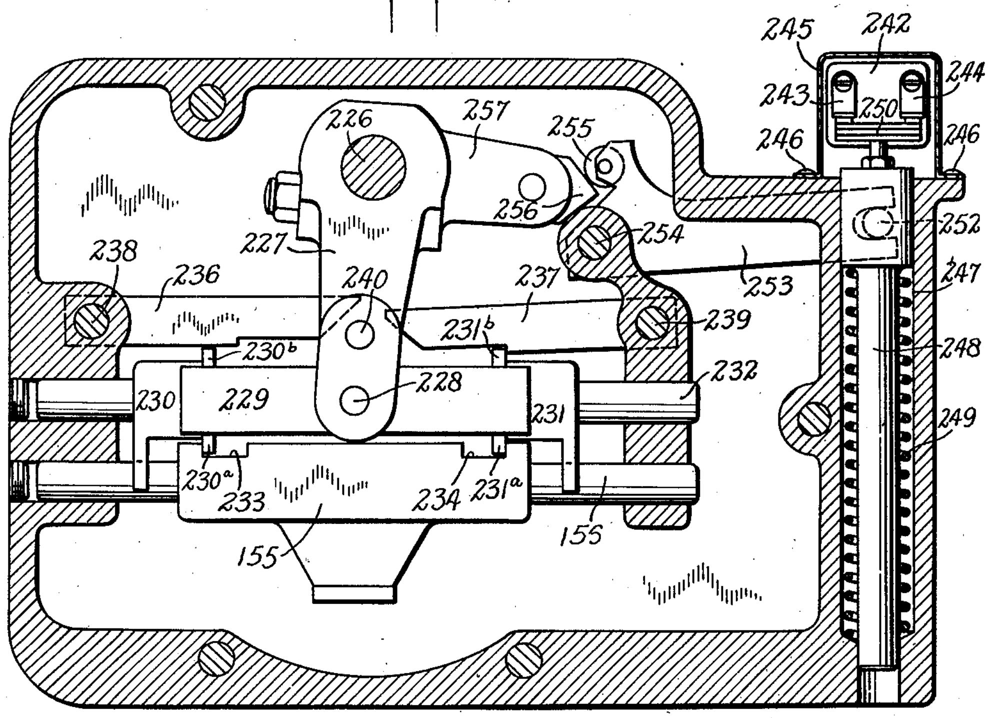

FIG. 11.

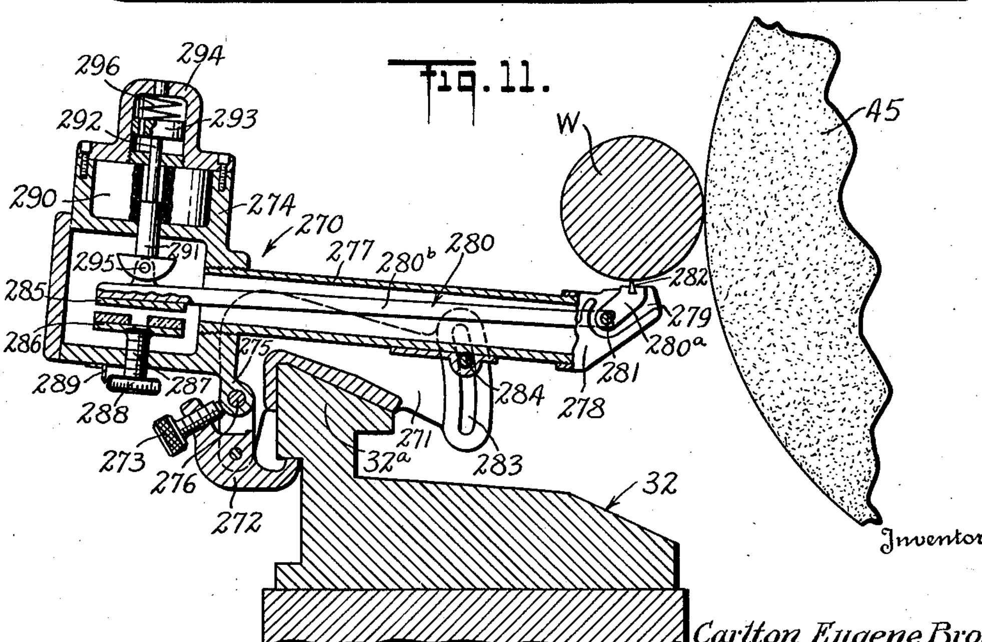

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FIG. 12.

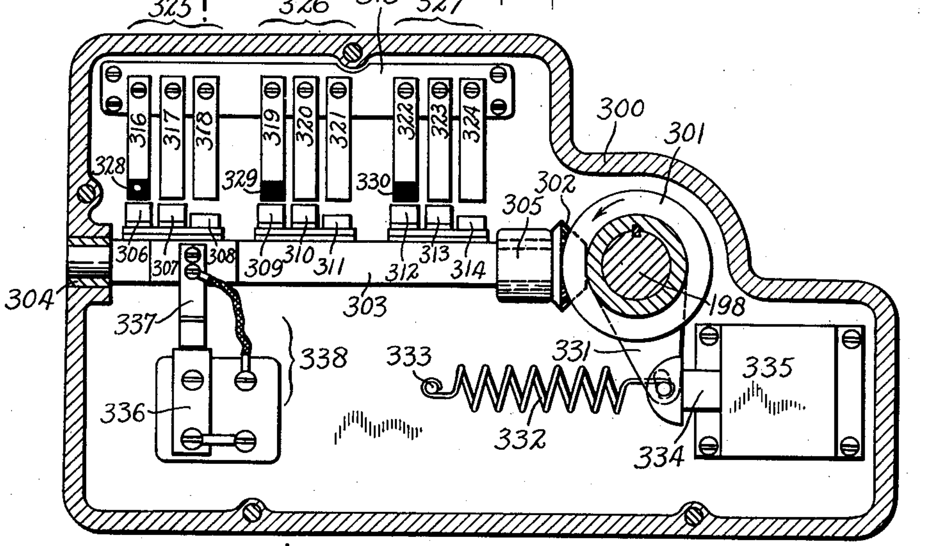


FIG. 14.

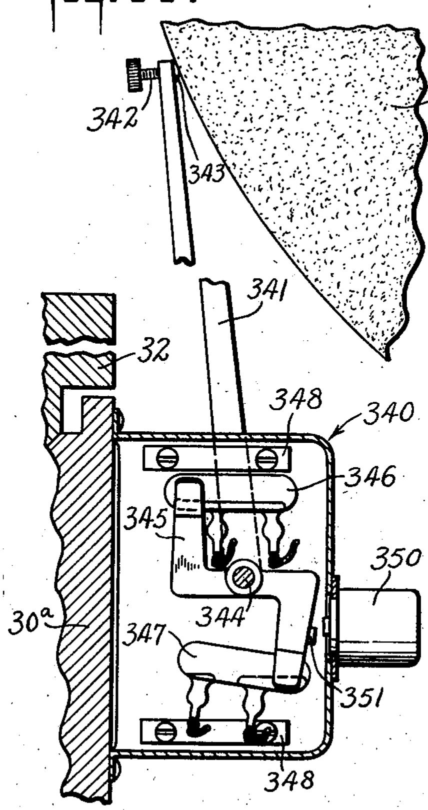
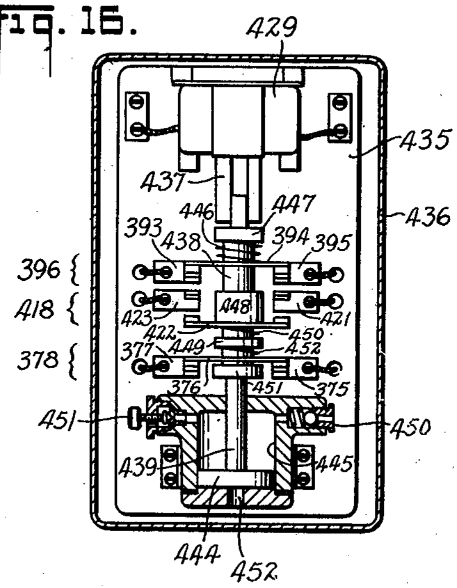


FIG. 16.



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GRINDING MACHINE

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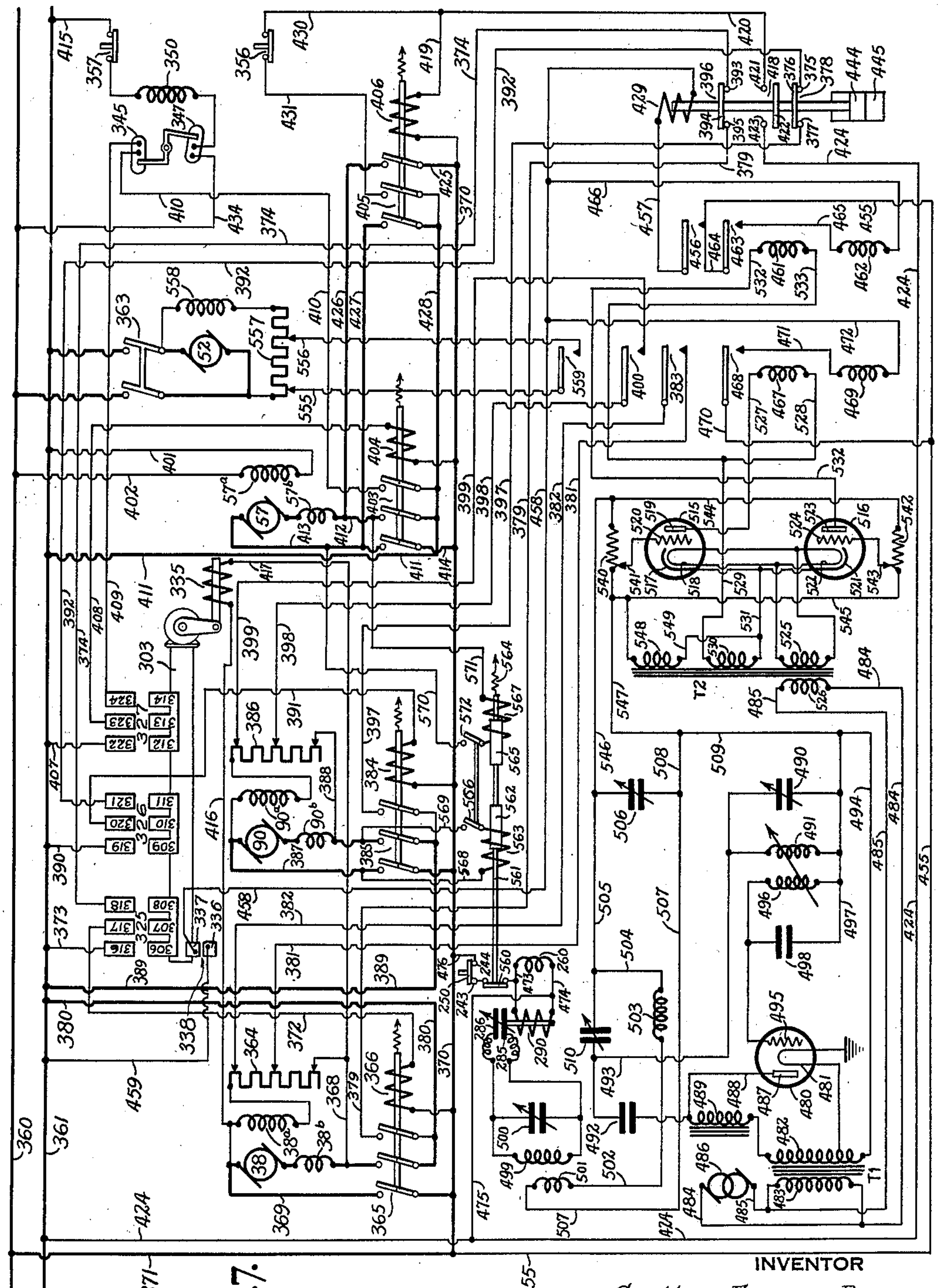

Fig. 17.

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UNITED STATES PATENT OFFICE

2,141,853

GRINDING MACHINE

Carlton Eugene Brown, Cincinnati, Ohio, assignor to Cincinnati Grinders Incorporated, a corporation of Ohio

Application January 18, 1936, Serial No. 59,711

47 Claims. (Cl. 51—95)

This invention relates to grinding machines.

One of the objects of this invention is to provide a dependable, compact, and efficient apparatus for grinding, particularly for grinding metal parts of round cross-section, in which high speed of grinding production with minimum manual tension or manipulation may be effectively carried on. Another object is to provide a grinding apparatus that will be well suited for producing, particularly at high rates of production, ground work pieces or parts that will be of high and uniform precision. Another object is to provide a grinding machine of the so-called "center" type that will be capable of a high rate of grinding production without impairment of quality, precision, or uniformity of grinding results. Another object is to provide a grinding machine of the center type capable of achieving substantial savings in time of grinding production. Another object is to provide a grinding apparatus of the above-mentioned character in which numerous heretofore necessary manual operations or manipulations on the part of the operator, with attendant time consumption and risk of spoilage of work pieces, may be dependably and inexpensively eliminated. Another object is to provide a grinding apparatus in which the numerous difficulties and disadvantages attendant upon hand or manual gaging of the work being operated upon will be dispensed with in a thoroughly practical, dependable and inexpensive manner. Another object is to provide a grinding apparatus for precision grinding in which high efficiency of grinding operation may be dependably achieved and in which, more particularly, the conditions under which the grinding operation is carried on may then be automatically varied as the final grinding step, to bring the work piece to the final or required size or dimension, is approached or reached. Another object is to provide a grinding apparatus of the above-mentioned character in which such factors or conditions under which the grinding operation is carried on as the depth of cut of the grinding element, rate of relative traverse between the work piece and the grinding element, rate of rotation of the work piece, and the like, may be efficiently varied in accordance with and suited to the progressive stages or steps of the grinding operation.

Another object is to provide an efficient and thoroughly dependable control of the grinding operation particularly with respect to achieving the desired size, or dimension of any one work piece or uniformity of size or dimension of a succession of work pieces, and to carry out such control in such a practical form as will lend itself quickly and readily to manipulation or supervision by any ordinary skilled grinding machine operator. Another object is to provide, in a grinding apparatus of the above-mentioned character, an electromechanical control system and mechanism coacting with the grinding element or elements and the work piece or work pieces, for varying or changing the grinding conditions, in accordance with the progress of the work piece or pieces toward completion, or to halt the grinding operation, or both, that will be thoroughly dependable, easily set, manipulated or controlled by the average skilled operator and, moreover, that will be capable of continued dependable operation under the peculiar working or operating conditions under which grinding operations generally have to be carried on. Another object is to carry out such objects as those pointed out above by way of apparatus and mechanism that will be well adapted to meet the varying conditions of hard practical use. Other objects will be in part obvious or in part pointed out hereinafter.

The invention accordingly consists in the features of construction, combinations of elements, and arrangements of parts as will be exemplified in the structure to be hereinafter described and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings in which are shown several of the various possible embodiments of certain features of my invention,

Figure 1 is a front elevation of the complete grinding machine or apparatus;

Figure 2 is a plan view thereof as seen from the top in Figure 1;

Figure 3 is a vertical sectional view on an enlarged scale, as seen along the line 3—3 of Figure 1;

Figure 4 is a vertical sectional view on an enlarged scale through a portion of the machine of Figure 1, being more particularly a section along the line 4—4 of Figure 1, through certain of the table control mechanism;

Figure 5 is a detached plan view on an enlarged scale as seen along the line 5—5 of Figure 3, showing part of the wheel-carriage moving or control mechanism;

Figure 6 is a transverse sectional view as seen along the line 6—6 of Figure 5;

Figure 7 is a detached and fragmentary view through the table drive and reversing mechanism as seen along the line 7—7 of Figure 4;

Figure 8 is a sectional view taken along a vertical plane through the starting mechanism and gear box of the machine and more particularly is such a sectional view on an enlarged scale as seen along the line 8—8 of Figure 2;

Figure 9 is a vertical sectional view as seen along the line 9—9 of Figure 8;

Figure 10 is a sectional view on an enlarged scale as seen along the line 10—10 of Figure 4, showing certain parts of the reversing control mechanism;

Figure 11 is a transverse sectional view on an enlarged scale as seen along the line 11—11 of Figure 1, showing certain of the mechanical and electrical features of a work-dimension gaging mechanism.

Figure 12 is a vertical sectional view on an enlarged scale through a casing at the front of the machine of Figure 1, showing a main switching structure and part of the actuating mechanism therefor;

Figure 13 is a transverse vertical sectional view as seen along the line 13—13 of Figure 12;

Figure 14 is a vertical sectional view on an enlarged scale showing certain switching mechanism and certain of the actuating or control mechanism therefor, in relation to the grinding wheel;

Figure 15 is a vertical sectional view, as seen along the line 15—15 of Figure 5, showing certain of the actuating means for the power connection in the feed drive of the grinding wheel carriage;

Figure 16 is a vertical sectional view on an enlarged scale through a casing or housing at the front of the machine, as seen in Figure 1, showing certain switching apparatus partly in elevation and partly in section;

Figure 17 is a diagrammatic showing of the electrical circuit arrangements and of certain of the mechanisms and apparatus interrelated therewith.

Similar reference characters refer to similar parts throughout the several views in the drawings.

Referring first to Figures 1, 2 and 3, I provide a main frame or bed generally indicated at 30, preferably constructed to be hollow and provided along its forward portion 30^a with longitudinally extending ways 31 (see also Figure 3) which support for longitudinal sliding movement a table 32. The table 32 is in turn provided with suitable ways 33 (Figure 3) upon which are supported the headstock 34 and tailstock 35 (Figures 1 and 2), the headstock and tailstock being thereby adjustably positionable lengthwise of the ways 33, suitable means (not shown) being provided for anchoring or clamping the two stocks in adjusted position. The headstock 34 and tailstock 35 are provided with suitable means for supporting and rotating a work piece W (Figures 1 and 2) and these means may take any suitable form, illustratively a live center 36 rotatably carried by the headstock 34 and a dead center 37 carried by the tailstock 35; between these centers the work piece W may be mounted for rotation and any suitable means (not shown) may be provided to cause the work W to be rotated or driven, as by a suitable device connecting it to the rotatable center 36. The headstock 34 carries an electric motor 38 connected by suitable driving connections (not shown), enclosed in the casing-like portions 39 of the headstock 34, to the live center 36 to rotate the latter and to drive the work piece W at a suitable rate of speed.

As is better shown in Figures 2 and 3 the bed 30 is extended rearwardly as at 30^b at substantially right angles to the direction along which the ways 31 extend and is provided with suitable guiding ways 40 on which is slidably mounted a carriage 41, the slidable movement of which along the ways 40 is therefore in a direction toward or away from the ways 31 and hence the table 32. The carriage 41 is provided with suitable bearings 42, 43 (Figures 1, 2 and 3) in which is rotatably mounted a shaft 44 at the left-hand end of which, as viewed in Figures 1 and 2, is mounted a grinding wheel 45, the latter somewhat overhanging the carriage 41 and the rearward extension 30^b of the bed 30. A suitable casing or guard 46 carried by the carriage 41 encloses the grinding wheel 45.

Intermediate of the bearings 42, 43 (Figures 1 and 2) the shaft 44 has secured thereto a suitable pulley 47 about which passes a belt 48 of any suitable character, the carriage 41 and the upper part of the bed extension 30^b being suitably recessed or apertured to allow the belt 48 to extend downwardly into the hollow bed extension 30^b where it passes over a pulley 49 mounted on a main drive shaft 50 that is carried in suitable bearings (not shown) provided in the bed of the machine. The drive shaft 50 extends to the right (Figure 2) through the side of the bed 30 where it is coupled as by coupling 51 to a suitable source of driving power, such as an electric motor 52.

By such a driving arrangement as that just described, the grinding wheel 45 may be driven at a suitable and preferably high grinding speed and since the carriage 41 is slidably mounted on the ways 40, there is provided any suitable means, such as an idler pulley (not shown) for maintaining the driving belt 48 suitably taut to insure the driving of the grinding wheel 45 throughout the range of movement of the carriage 41.

Referring to Figure 3, it will be seen that the grinding wheel carriage 41 has secured thereto and interiorly thereof a nut 53 with which a feed screw 54 is in threaded engagement. The feed screw 54 extends rearwardly of the machine, as viewed in Figure 2, and to the right, as viewed in Figure 3, and is rotatably mounted in a bearing 55 provided in an auxiliary casing or housing 56 mounted at the rear of the bed extension 30^b, suitable means being provided to hold the feed screw against axial movement. By rotation of the feed screw, therefore, the grinding wheel carriage 41 is moved along its ways in a direction depending upon the direction of the rotation of the feed screw 54.

For purposes, some of which are outlined in detail later hereinafter, I provide various and different means for rotating the feed screw 54. Among these means is a source of driving power such as a motor 57 (Figure 3) preferably positioned underneath the casing 56 and suitably supported by or on the rear wall of the bed extension 30^b and preferably in such a way that its shaft extends inwardly of the bed, where it is provided with a sprocket 58.

Mounted in suitable bearings substantially as shown and extending through the bed 30 from front to rear is a shaft 59 (Figure 3) and its rear or right-hand end extends into the gear casing 56 and has mounted upon it a gear 60 which is in driving relation, through an idler gear

61, to a gear 62 on the rear end of the feed screw 54, these gears being enclosed within the casing 56. To transmit the drive of the motor 57 to the feed screw 54 through this gearing and by way of the shaft 59, the latter has mounted upon it a sprocket 63 which is in driving connection with the motor sprocket 58 by way of a driving chain 64.

At the front or left-hand end of the shaft 59 (Figure 3) the latter is arranged to have certain other driving connections made thereto. For example, it is desirable that the grinding wheel carriage 41 be shiftable manually. Accordingly, I provide, at the front of the machine a hand crank 65 provided with a handle 66 so selectively geared up or connected to the main cross-shaft 59 as to achieve rotation of the latter and hence movement of the grinding wheel carriage at different rates. The connections or mechanisms may comprise a sleeve 67 (Figure 3) suitably mounted to rotate coaxially with the cross-shaft 59 and provided with clutch teeth 68 at its inner end and a gear 69 at its outer end. Suitable bearing means therefor are provided in the lower end of a housing 70 secured at the front of the bed portion 30^a.

An upward extension of the housing 70 rotatably supports a shaft 71 that extends forwardly of the apparatus (to the left in Figure 3), and it is to the outer end of shaft 71 that the hand crank 65 is secured; adjacent the hand crank 65 there is mounted on the shaft 71 a gear 72 which meshes with a gear 73 mounted on the outer end of a shaft 74 that is rotatably mounted in a sleeve or hub 75; the hub 75 is rotatably carried by the sleeve or hub 76 which is in turn rotatably carried by the shaft 71 and has two gears 77 and 78 at its inner end. Gear 78 meshes with gear 69 while gear 77 meshes with a pinion or gear 79 fixed to the inner or right-hand end of the shaft 74. The hub or sleeve 75 has secured thereto a disk-like member 80 provided with a series of circularly arranged holes 81 (see also Figure 1).

The handle 66 (Figure 3) movably supports at its inner end a pin 82 which may be projected into any selected hole 81 in the disk 80, thereby linking the disk 80 and the crank arm 65 together to turn as a unit.

When it is desired to give the grinding wheel carriage 41 a rapid manual movement or a coarse adjustment, the pin 82 is seated into an opening 81 in the disk 80 and the crank arm 65 rotated; the parts described above are thereby caused to rotate as a unit and the gear 69 of the clutch sleeve 67 is rotated by the crank 65 through the gear 78, the cross-shaft 59 being placed in driving connection with the clutch sleeve 67 by a companion clutch member 83 later described in detail.

When, however, it is desired to give the grinding wheel carriage 41 a slow manual movement and hence a fine adjustment, the pin 82 (Figure 3) is disengaged from the disk member 80, and the handle 66 and hence shaft 71 with pinion 72 are rotated; but this rotation is not transmitted directly to the gear 78 but indirectly thereto through the reduction gearing 72—73 and 79—77, the gear 78 being as a result much more slowly rotated and thus the amount of rotation of the feed screw 54 per rotation of the crank 65 becomes and is much less than was the case where a rapid movement or coarse adjustment of the grinding wheel carriage is effected.

The companion clutch member 83 (Figure 3) is slidably mounted on the cross-shaft 59 but is splined to rotate therewith, as is indicated in Figure 3, and it is provided with clutch teeth 84 which engage the clutch teeth 68 when the clutch member 83 is moved toward the left, as viewed in Figure 3. This clutch member is shown on a larger scale in Figure 5 of the drawings and it is engaged and shiftable by a forked lever 85 pivoted as at 86 and connected at its other end to a link 87 which extends forwardly through the front wall of the machine bed where the link is connected to an operating lever 88 (Figure 1) at the front of the machine. Accordingly, when the above described manual adjustment or movement of the grinding wheel carriage is desired to be made effective, the lever 88 is operated in a direction to cause the clutch member 83 to be moved into engagement with the clutch sleeve 67, thus completing the drive of the hand crank through the above described selective gearing to the main cross-shaft 59.

Thus, the grinding wheel carriage may be manually moved, set, or adjusted, and as already set forth above, it may be moved under power by the motor 57 (Figure 3) which is in direct driving connection with the main cross-shaft 59 and which, due to the gearing or driving ratios employed, may and does effect a relatively rapid movement or traverse of the carriage along the ways 40. There are, however, also provided means for effecting a power-actuation of the grinding wheel carriage 41 at a relatively slow rate, for purposes later described in detail.

Such means preferably include a suitable source of driving energy or power preferably in the form of an electric motor 90 (Figure 5) suitably mounted or related to the bed 30 of the machine and illustratively positioned to the rear of the rear wall of the front bed portion 30^a, having its shaft projecting through that wall where it carries a driving pinion 91 (Figures 5 and 6) which meshes with and drives a pinion 92 secured to a shaft 93 suitably mounted by or having bearings in an appropriate bracket 94, or the like (Figure 5), formed in the machine bed. Pinion 92 has coaxially mounted with respect thereto and drives a worm 95 (Figures 5 and 6). Worm 95 meshes with and drives a worm wheel 96 that is keyed to a shaft 97 (Figure 6) provided with suitable bearings carried in suitable spaced webs integrally formed with the machine bed, substantially as shown in Figure 6; the shaft 97 extends through the right-hand web and is coupled, as by a flexible coupling 98, to a shaft 99 rotatably supported in spaced bearings mounted in a movably mounted housing 100, the shaft 99 having formed thereon or mounted thereon a worm 101 which meshes with a worm wheel 102 keyed or secured to the cross-shaft 59 (see also Figures 5 and 3).

As just noted, the housing 100 is movably mounted and, moreover, is so mounted to bring the worm 101 into or out of driving mesh with the worm wheel 102. A preferred arrangement for effecting this mounting may comprise a pair of spaced brackets or ears 103—104 (Figure 5) integrally formed with the web of the bed through which the shaft 97 (Figure 6) extends, the housing 100 being received between the two ears 103—104 (see Figure 5), the latter and the respectively adjacent side or vertical walls of the housing 100 having studs 105 and 106, respectively, passed therethrough; the ears 103—104 with their respective studs or pins 105—106 thereby form in effect trunnions by or between which the housing 100 is thereby pivotally supported to swing about an axis or position (see Figure 6) that a swinging of the housing 100 in clockwise direction moves the worm 101 out of engagement with the worm wheel 102 and a swinging thereof in reverse direction and into the position shown in Figure 6 meshes the worm 101 with the worm wheel 102.

Swinging movement of the housing 100 in the last-mentioned direction, that is to mesh the worm and worm wheel, is limited by appropriate stop means which, referring to Figure 6, may comprise an adjustable stop in the form of a set screw 107, provided with a lock nut 108, the screw 107 being threaded through an upper horizontal wall extension of the housing 100 to bring it into overlapping relation with respect to the right-hand web 109 of the machine bed and through which the shaft 97 (Figure 6) extends.

As is better shown in Figure 6, the housing 100 has a downward extension whose lower end is formed into a sleeve 110; the right-hand end of the sleeve 110 is closed by a head 111 through which slidably extends a rod 112 whose left-hand end is enlarged as at 113 to slidably fit the interior of the sleeve 110. Between the part 113 and the head 111 is an expansible helical spring 114, tending always to move the part 112 to the left to an extent limited by the nuts 115 on the outer end of the part 112.

The left-hand portion of the part 113 is slotted or bifurcated and has mounted therein a roller 116 which is to function as a cam follower with respect to a cam 117 keyed to a shaft 118 rotatably mounted in spaced bearings or brackets 119 and 120 (see Figure 3), shaft 118 thereby extending alongside of the web 109.

If, therefore, shaft 118 is swung to bring the cam 117 into engagement with the roller 116 (Figure 6), the latter with its plunger arrangement 113 is made to move toward the right to an extent substantially that indicated in Figure 6, and through the compressible spring 114 movement of the plunger arrangement 113 is transmitted to the worm-housing 100 to swing the latter in counter-clockwise direction to effect interengagement of worm 101 with the worm wheel 102. The spring 114 insures such yieldability of movement of the worm toward the worm wheel and provides, when needed, a delayed time interval to achieve and maintain ultimate driving interengagement where, as may be the case at times, the initial upward swinging movement of the worm housing 100 does not find the teeth of the worm in exact position to at once mesh with the teeth of the worm wheel 102. The adjustable stop means 107 of course limits the extent of upward swinging of the housing 100 under the action of the cam 117 and spring 114.

With worm 101 and worm wheel 102 thus brought into engagement, the cross-shaft 59 may thus be driven from and by the motor 90 (Figure 5) but at a relatively low speed as compared with the speed of rotation given the cross-shaft 59 by the motor 57 (Figure 3) when the latter is made effective, it being noted that the successive pairs of worms and worm wheels 95—96 and 101—102, are in effect a speed reduction gearing. Accordingly, the feed screw 54 (Figure 3) is rotated very slowly and correspondingly the movement or adjustment of the grinding wheel carriage 41 along its ways 40 is relatively very slow.

Movement of the cam 117 out of the position shown in Figure 6 permits the worm housing 100 to drop downwardly and disengage the worm from the worm wheel, thus interrupting the drive of the cross-shaft 59 from the motor 90.

The control of the power drive of the grinding wheel carriage 41 from the motor 90 is described in detail later herein.

As earlier above indicated, the work W (Figures 1 and 2) can be moved in an axial direction while the grinding wheel 45 acts thereon and this movement is thereby effected by appropriately moving or shifting the table 32 along its ways 31. Such movement of the table 32 and work W is, in accordance with certain features of the invention, related, as later described in detail, to the movement of the grinding wheel carriage 41 with the grinding wheel 45 along its ways 40.

For effecting movement of the table 32, the latter, as is better shown in Figure 4, is provided on its under side with a rack 125 extending centrally thereof and intermediate of the ways 31—31.

With the rack 125 meshes a pinion 126 keyed to the upper end of a vertically extending shaft 127 which is rotatably supported in suitable bearings in the front portion 30^a of the bed 30, substantially as shown in Figure 4. Accordingly, rotation of shaft 127 in one direction or the other effects, through the pinion 126 and rack 125, a correspondingly directional movement of the table 32 and of the work W carried thereby.

Splined to the shaft 127 (Figure 4) is a double-ended clutch member 128 whose position along the shaft 127 is controllable by a clutch fork 129 whose arms engage into the annular groove of the clutch member 128. If the clutch member 128 is moved upwardly, its dogs or teeth are brought into interengagement with corresponding dogs or teeth on the under face of a bevel gear 130 which is suitably mounted for rotation about the axis of the shaft 127 and in a position upwardly of the clutch member 128. Accordingly, the table 32 may be moved in response to a driving of the bevel gear 130.

If the clutch member 128 is moved downwardly, and hence into the position shown in Figure 4, its clutch dogs or teeth at its lower end interengage with corresponding dogs or teeth provided in a friction clutch disk 131 which is gripped between the hub of a worm wheel 132 and an annular plate 133, the latter being pressed toward the worm wheel hub by springs 134 interposed between it and the heads of suitable bolts or screws 135 threaded into and peripherally distributed about the hub of the worm wheel 132. Suitable ring-like parts of appropriate material may be interposed between the clutch disk 131 and the parts 133 and 132 between which it is gripped, all as is indicated in Figure 4.

Accordingly, if the worm wheel 132 is driven, the just described interengagement of the clutch member 128 when in its lowermost position brings about a driving of the shaft 127 and hence a shifting of the table 32, but through the friction clutch arrangement just described, the latter being so adjusted, as by appropriately tensioning or loading the springs 134, as to yield if opposition to movement of the table 32 exceeds a certain value.

By way of the bevel gear 130, driving connection is made to a suitable form of manually operable mechanism in order that the table 32 may be moved or adjusted manually. This mechanism may and illustratively does comprise a handwheel 136 at the front of the machine (see Figures 4 and 1), mounted to be rotatable about the axis of a stud shaft 137 mounted in a housing 138 (Figure 4) secured to the front of the machine bed portion 30^a. Handwheel 136 is keyed to a sleeve 139 which extends into the housing 138 or it is formed into or carries a sprocket 140, the driving chain 141 of which extends downwardly over a sprocket 142 pinned to a horizontal shaft 143 that extends into the interior of the front bed portion 30^a where it carries a small bevel gear 144 that meshes with the bevel gear 130 above described.

Accordingly, the latter may be manually rotated by the handwheel 136 and the just described chain of driving mechanism and the table 32 and parts carried thereby moved or shifted along the ways 31 as desired, the clutch member 128 being, of course, in upper position.

Considering now the drive of the worm wheel 132 of Figure 4, reference should now be made to Figure 7 in which the coaxial relation of the worm wheel 132 and the vertical shaft 127 appears, the worm wheel 132 meshing with a worm 145 mounted upon or integrally formed with a horizontally extending shaft 146 that is rotatably supported in suitably spaced bearings in an interior housing 147, the latter extending toward and being suitably secured to the front of the bed portion 30^a. At its front end the shaft 146 has secured thereto a bevel gear 148 with which constantly mesh bevel gears 149 and 150 which are rotatably mounted upon sleeves 151 and 152, respectively.

The latter are secured in the housing 147 and they form also bearings for a horizontally extending shaft 153, driven in a manner later described.

Splined upon the shaft 153 and intermediate of the bevel gears 149 and 150 is a clutch member 154 provided with clutch dogs or teeth at its right-hand and left-hand ends, as viewed in Figure 7, engageable, respectively, according to the position of the clutch member 154, with corresponding clutch dogs or teeth formed in the ends of the hubs of the bevel gears 150 and 149.

Assuming that the shaft 153 is constantly driven, therefore, shaft 146 (Figure 7) and hence worm wheel 132 and vertical shaft 127 (Figure 4) is driven in one direction or the other according to whether the clutch member 154 is moved out of its neutral position (as shown in Figure 7), and is in driving engagement with bevel gear 149 or bevel gear 150; likewise and as a result, the direction of traverse of the table 32 along its ways 31 is controllable and reversible according to the position of the clutch member 154.

The latter is provided with an annular external recess (Figure 7) into which engages the clutch-shifting fork 155 (see also Figure 4) whose hub is slidably mounted on a shaft 156 secured in the front portion of the bed 30^a. The shifting of the fork 155 takes place in a manner later described in detail.

Further considering the power drive of the table 32 and again referring to Figure 7, the shaft 153 will be seen to extend toward the left inside of the machine bed portion 30^a, terminating in abutting relation to a sleeve-like shaft 157 which is driven as later described and which is arranged to be placed in driving connection with the shaft 153 selectively according to what speed change may be desired. For this latter purpose, the driven shaft 157 has at its right-hand end a spur gear 158 and also clutch teeth or dogs 159. Splined onto the left-hand end of shaft 153 is a gear 160 provided with clutch teeth 161 which, if the gear 160 is moved to the left by the shifting fork 162, mesh with the clutch teeth 159 so that the shaft 153 is directly driven from the driving member 157.

Forwardly of the gear 158 (Figure 7) is rotatably mounted, on a shaft 163, a gear cone having a gear 164 that is always in mesh with gear 158 and having to the right thereof a smaller gear 165 with which gear 160 may be meshed if moved to the right out of its neutral or disconnected position, as now shown in Figure 7, by the shifting fork 162. In such case, shaft 153 is driven at a lower speed inasmuch as the drive is now from the driving member 157 by way of pinion 158, larger gear 164, and then smaller gear 165 and larger gear 160.

The gear shifting fork 162 is manually shiftable by way of a handle or lever 166 at the front of the machine (see Figure 1), the latter having suitable connections (not shown) with the shifting fork 162.

Still referring to Figure 7, the left-hand end of the driving shaft 157, which is rotatably mounted in a bracket or housing 167, mounted interiorly of the machine bed, has keyed thereto a bevel gear 168 which meshes with a bevel gear 169 secured to a horizontally but rearwardly extending shaft 170. Shaft 170 extends rearwardly and crosswise of the machine bed and substantially parallel to the main cross-shaft 59 (Figure 3) and has a bearing at its front end in the bracket or housing 167 (Figure 7) and at its rear end in a lower end portion of a housing 171 (Figures 8 and 2) where it terminates in a bevel gear 172 (Figures 8 and 9).

By means of a clutch and speed-change mechanism about to be described, shaft 170 is driven from a shaft 173 (Figures 8 and 2) that is mounted in suitable bearings at one end in the housing 171 and extends into the interior of the rearward bed extension 30^b (see Figure 2) where it is supported in suitable bearings (not shown) and where it is provided with a pulley 174 that is driven by belt 175 from a pulley 176 on the main shaft 50 (Figure 2) through which motor 52 drives the grinding wheel 45 as earlier above described. It is thus seen that, by the arrangement just outlined, the power supplied by the motor 52 (Figure 2) is made available to move the work-carrying table 32 along its ways.

The clutch and speed-change mechanism abovementioned as being included in this driving train may take the form better shown in Figure 8 in which it will be seen that the shaft 173, driven as above-mentioned from the grinding wheel driving motor 52, is provided at its end with a pinion 177 that meshes with a gear 178 to which is pinned or otherwise secured a clutch member 179 having connections as at 180 with a friction disk 181 of a multiple disk or plate clutch generally indicated at 182.

Friction disks 183 and 184 are provided for contacting the clutch disk 181 on opposite faces of the latter while the outermost friction disk 183 has bearing against it a clamping plate 185 which is movable along the axis of the gear 178, through the agency of a crank 186, to clamp the three clutch disks between itself and a clutch disk 187 which is keyed and secured to a specially formed or constructed shaft 188 mounted in suitable spaced bearings carried by the housing part 189.

The left-hand portion of the shaft 188 is hollow or tube-like in order slidably to receive a clutch controlling rod 190 at whose left-hand end is secured a peripherally extending cam member 191 engageable with the left-hand end of the clamping lever or crank 186 (the latter being pivoted as at 192 to the hub of the clutch plate 187).

The right-hand end of the clutch rod 190 is pinned, by pin 193, to a shifter spool 194 that is slidable along the reduced portion of the shaft 188, the latter being slotted to receive the pin 193 and thereby form a splined connection between the shifter spool 194 and the shaft 188. The outer annular groove of the shifter spool 194 is engaged by the lower forked end of a lever 195, pivoted at 196 (Figure 8) exteriorly of the housing 171, the latter and the housing portion 189 being suitably cut away to bring and maintain the forked arm of lever 195 in proper coacting relation with the shifter spool 194 and accordingly, the shifter spool 194 may be shifted into the position shown in Figure 8, in which the clutch disks are pressed together and the clutch is in power-transmitting condition so as to effect a power-driven movement of the table 32, or the shifter spool 194 may be shifted to the right from the position shown in Figure 8 in which case the cam member 191 is likewise moved and held to the right, the pressing together of the clutch disks being thereby terminated and the power drive of the table 32 interrupted.

The shifter spool lever 195 (Figure 8) is preferably arranged to be controlled from the front of the machine and for that purpose I provide a control lever 197 (see Figure 1) at the front of the machine and to the left of the handwheel 136. This control lever may be swung in clockwise or counter-clockwise direction, as viewed in Figure 1 and has connected to it a shaft 198 (Figure 2) which extends through the front portion 30ª of the bed 30 to an end portion of the clutch and speed-change casing 171 (Figure 2) where it is provided with a suitable bearing or support 199 and where, also, it has secured to it an upstanding lever 200 (Figures 2 and 8) which is connected by a link 201 (Figures 8 and 2) to the upper end of the spool-shifting lever 195. The clutch 182 (Figure 8) may therefore be conveniently operated from the front of the machine by way of handlever 197.

The shaft 188, driven through the clutch 182 from the driving shaft 173, as above described, extends to the right-hand end of the casing or housing 171 (Figure 8) where it is provided with a suitable bearing 202 an intervening portion of the shaft 188 having a splined portion 188ª on which is slidably but non-rotatably mounted a gear cone 204 and to which is keyed a gear cone 205.

Rotatably mounted in suitable bearings in the lower part of the housing 171 and substantially underneath but parallel to the shaft 188 is another shaft 206 whose right-hand end carries a bevel gear 207 which meshes with the bevel gear 172 of the above-described shaft 170 (Figures 8, 9 and 7). Shaft 206 has an intermediate splined portion 206ª upon which is secured a gear cone 208 for coaction with the slidable gear cone 204, and upon which is slidably but non-rotatably mounted a gear cone 209 for coaction selectively with the gear cone 205 on shaft 188.

Illustratively, these gear cones each comprises three steps of gears, as shown in Figure 8, and the various gears are so proportioned as to give a corresponding range of speed changes in appropriate steps.

Gear cone 204 is engaged by a shifting fork 210 carried by a slidably mounted rod 211 whereby the gear cone 204 may be shifted with respect to the lower and fixed gear cone 208 and their gears selectively paired to give one range of speed-change of drive from shaft 188 to shaft 206.

The lower shiftable gear cone 209 is engaged by a shifting fork 212 secured to a slidably mounted rod 213 (Figure 9) and thereby gear cone 209 may be shifted with respect to gear cone 205 to selectively pair their gears for another range of speed-change in transmission.

The shift rods 211 and 213 are slidably carried by suitably formed portions of the housing 171, extend parallel to each other (see Figure 9), and at their adjacent and spaced ends are toothed as at 211ª and 213ª (Figure 9) for alternate engagement by a gear sector 214 whose gear teeth extend throughout such an arc (approximately 180° or less) that the gear sector 214 (which is fixed to a shaft 215 and thereby can be rotated), engages and slides only one shift rod at a time. Thereby the desired speed ratio of transmission may be conveniently and easily manually selected.

The movement or setting of the gear sector 214 (Figure 9) may be controlled from any suitable point or position on the machine and preferably from the front of the machine. Accordingly, there is provided (see now Figure 1) at the left-hand front portion of the machine a rotatably mounted hand lever 216 connected at the outer end of a shaft 217 (Figures 1 and 2) which extends transversely through and to the rear of the front bed extension 30ª, where it is connected by a shaft 218 and flexible couplings 219 and 220 (Figures 2 and 9) to the shaft 215 of the gear sector 214.

Preferably the hand lever 216 (Figure 1) is provided with a suitable spring-pressed plunger (not shown) adapted to coact with an index plate 221 for thereby accurately determining the setting of the hand lever 216 and of the above-described shiftable gear cones.

Accordingly, to initiate the power driving of the table 32, after motor 52 (Figure 2) has been set into operation, lever 197 (Figure 1) is actuated to bring about an actuation of the clutch 182 (Figure 8), appropriate selection of speed ratios in the speed-change gearing of Figure 8, by way of lever 216 (Figure 1), having theretofore been made; the drive of the pinion 126 (Figure 4) which meshes with the table rack 125 being completed by way of the shaft 170 (Figure 7) through the gearing or driving train better shown in Figure 7, to the shaft 127 itself. Of course the clutch member 128 (Figure 4) is, for effecting this power drive of the table 32, in its lowermost position, as shown in that figure, clutch shifting fork 129 being manually controlled or set by a lever or handle 222 (Figure 1) mounted at the front of the machine bed portion 30ª. The drive also, it will be noted, takes place through the reversing gearing shown in Figure 7 and controllable by the shifting fork 155 which determines the position of the clutch member 154. The latter is to be periodically shifted in order to effect reciprocation of the table 32.

Accordingly, any suitable mechanism for operating these reverse gears and for actuating the clutch shifter 155 in response to movements of the table 32 itself may be employed and illustratively that mechanism includes two dogs 223 and 224 (see Figure 1 and also Figure 4) adjustably positionable along a suitably formed or shaped portion of the table 32; these dogs are spaced about according to the length of the stroke desired to be given the table 32 and each is positioned (see now Figure 1) to one side of a lever 225 pivoted at the front of the machine bed and having a rearward extension (see Figure 4) that projects into the path of movement of the dogs 223—224.

Lever 225 is secured to a shaft 226 (Figures 1 and 4) which is rotatably mounted in bearings formed in a suitable housing at the front of the machine bed, substantially as shown in Figure 4, and has keyed to it a lever arm 227 (see now Figure 10) which extends downwardly. Between lever 227 and the clutch shifter 155 there is interposed a suitable mechanical connection or mechanism, of the so-called "load and fire" type, for causing the clutch to be shifted out of driving connection with one bevel gear (149 or 150 of Figure 7) and into driving connection with the other bevel gear (150 or 149), at an appropriate point in the swing of the lever 227 in one direction or the other depending upon the direction in which the handle 225 (Figures 4 and 1) is shifted by the table dogs 223—224 (Figure 1). Such "load and fire" mechanisms are well known and hence the mechanism in question need not be illustrated or described in full detail herein.

It will therefore be sufficient to point out, turning now to Figure 10, that the lower end of lever arm 227 is pivotally connected, as by the pin 228 (see also Figure 4) to a member 229 which is connected through suitable springs 235 (Figure 4) to two members 230, 231 (Figure 10) slidably mounted upon a rod 232 suitably supported above and in substantial parallelism with the rod 156 (Figures 4 and 10) on which the clutch shifter 155 is slidably supported. Springs 235 preferably surround and are supported by the rod 232. The clutch shifter is provided with recesses 233 and 234 (Figure 10) of greater length than the dimension of lugs 230ª and 231ª, projecting respectively thereinto, of the slidable members 230 and 231, respectively.

For the members 230, 231, there are provided pivotally mounted latches 236 and 237, respectively, pivotally supported as by the pins or studs 238 and 239. These latches are shaped as shown in Figure 10 to be engageable with lugs 230ᵇ and 231ᵇ of the slidable members 230, 231, respectively. When interengaged with their respective lugs, as is the latch 237 engaged with the lugs 231ᵇ in Figure 10, the latch 236 holds the slidable member 230 against movement toward the left and latch 237 holds the member 231 against sliding movement toward the right.

The latches 236, 237 tend to swing downwardly into latching position under the action of their own weight, but lever 227 carries an inwardly directed pin 240 (Figures 10 and 4) which, as the lever arm 227 is oscillated or swung, moves into engagement with the end of one latch or the other to lift it out of latching position. For example, in Figure 10, if the arm 227 is now swung in counter-clockwise direction, the spring interposed between the member 229 and the sliding member 231 becomes tensioned throughout such a movement of the lever arm 227 as is terminated by the lifting of latch member 237 by engagement therewith of the pin 240; the slide member 231 is thereby released and is snapped toward the right, moving clutch shifter 155 with it and thereby, referring now to Figure 7, effects a rapid disengagement of the clutch 154 from the bevel gear 149 and an engagement thereof with the bevel gear 150, thereby effecting a reversal of the direction of drive of the shaft 146 (Figure 7) with resultant reversal of the traverse of the table 32 (Figures 4 and 1) along its ways 31.

The above described swinging of lever arm 227 (Figure 10) is effected by the table dog 224 (Figure 1) in engaging the lever 225 to swing it in counter-clockwise direction. A similar series of steps or operations takes place at the end of the following reversed stroke of movement of the table 32 when the dog 223 (Figure 1) is brought into engagement with the lever 225 to swing it in clockwise direction and thus to swing arm 227 (Figure 10) in clockwise direction to tension the spring and subsequently lift latch 236 to release slide member 230 for movement to the left under the action of the tension spring and thereby move clutch shifter 155 to the left (Figures 10 and 7) to disengage the clutch 154 from bevel gear 150 and engage it with bevel gear 149, thereby initiating the succeeding stroke of the table but in reversed direction.

At the right-hand portion (Figure 10) of the housing that contains the above described load and fire reverse operating mechanism, and preferably exteriorly thereof, there is provided a switch, whose purposes are later described in detail, and arranged to be actuated in a certain synchronous manner with the actuation of the reversing mechanism. This switch comprises a suitable insulating base or panel 242 carrying two switch contacts 243 and 244 provided with suitable terminal connectors to which certain conductors, as later described, may be connected. This panel, preferably mounted on or covered by a detachable casing 245, secured to the housing detachably, as by screw 246, so that access thereto may be gained when needed, is positioned over or in alinement with a cylindrical bore 247 in the housing itself.

In this bore 247 is slidably mounted a plunger 248 pressed upwardly by a spring 249 also accommodated in the bore. At its upper end the plunger 248 carries a switch member 250 which may bridge and contact the contacts 243—244 to close the circuit of the latter, being held in that bridging relation by the spring 249; movement downwardly of the latter removes the switch member 250 out of bridging relation to the contacts 243, 244 and thus effects an interruption of the circuit of the latter.

Adjacent its upper end the plunger 248 is provided with a pin 252 which extends through a suitable opening or slot (not shown) in the wall of the bore 247 to hold the latter and hence switch member 250 against rotation and to be engaged in the slot or fork of a bell crank lever 253 (Figure 10) pivotally supported by a pin 254 in a web or bracket of the housing. Lever 253 is in effect a bell crank lever whose other effective arm carries a roller 255 positioned in the path of oscillation of a V-shaped cam 256 secured to a lever arm 257 integrally formed with the lever arm 227 through which the reverse gearing is controlled, as was above described.

With the spring 249 (Figure 10) always urging and holding the plunger 248 in uppermost position, as shown, the lever cam 256 occupies a position either above or below the roller 255 during the movement of the table 32 (Figure 1) along the machine bed, depending upon the direction of the stroke of movement of the table. In Figure 10 the lever cam **256** is shown in position underneath the roller **255**.

Accordingly, as the lever arm **227** is swung at the end of the table stroke, as was above described, lever arm **257** causes the lever cam **256** to be shifted throughout a corresponding arc and thereby, in either direction of swing of the lever cam **156**, causes the bell crank lever **253** to be swung in clockwise direction, as viewed in Figure 10, and the downward movement of plunger **248** against the action of spring **249**, thereby to open the switch **242**. The plunger **248** is in its downmost position at the midpoint of the stroke of swing of the lever cam **256**, and during the remaining half of that stroke of swing, the lever cam **256** permits the spring **249** to return the parts to the position shown in Figure 10, in which the switch is again closed and in which the lever cam **256** and roller **255** are again interrelated for a repetition of the above described action when the next swing of the lever arm **257** (now in the opposite direction) is brought about at the end of the reversed stroke of movement of the table **32**.

The actuation of the switch, therefore, will be seen to occupy but a relatively short interval of time and by the above described mechanism that time interval is substantially coincident with the time interval during which actual reversal of the table movement is brought about.

Thus the table **32** (Figure 1) may be reciprocated throughout a range of movement commensurate with the length of the work W, thereby to traverse the latter with respect to the operative surface of the grinding wheel **45**, but in order to effect an appropriate increment of feed of the grinding wheel carriage **41** (Figure 3) and hence of the grinding wheel **45** toward the work at the end of each stroke of reciprocation of the work W, in order that the grinding wheel effect appropriate and successive removals of metal from the work W, certain other mechanisms are brought into play. Among these is the actuation of the pivotally mounted housing **100** (Figures 6 and 5) at appropriate intervals, to bring the worm **101** (Figure 6) driven by the motor **90** (Figure 5) into driving engagement with the worm **102** in order thereby and through the driving train above described, to feed the grinding wheel carriage toward the work.

This actuation of the worm **101** (Figure 6) into engagement with the worm **102** is preferably achieved by way of an electromagnetic means preferably taking the form of a solenoid **260** (Figures 6 and 15). The solenoid **260** is provided with a core **261** and is mounted in any suitable manner exteriorly of the right-hand web **109** (Figure 6) with the axis of the core **261** extending vertically. The core **261** has an upwardly directed extension **262** (Figure 15) that is slidably guided in a suitable web or lug of the housing or bed and is urged or held in uppermost position by a coiled spring **263**, the action or tension of which may be adjusted as by the nuts **264**. The core extension is provided with a slot **265** (Figure 15) into which extends a lever arm **266** that is keyed to the shaft **118** at its left-hand end, and is pivotally connected to the core extension as by pin **267**. Shaft **118**, through the lever arm **117** (Figure 6), controls the position of the worm **101** in or out of engagement with the worm wheel **102**, as was described above in detail.

Spring **263** (Figure 15) is thus opposed by the solenoid **260** and the latter when energized overcomes the pull of the spring **263**, compresses the latter beyond the position shown in Figure 15, and holds the shaft **118** in such a position that the cam arm **117** (Figure 6) is so positioned that pivoted housing **100** and hence worm **101** are in lowermost position, the worm being disengaged and held disengaged from the worm **102**. As is later set forth in detail, the circuit of the solenoid **260** includes the switch **242** of Figure 10 and bearing in mind the actuation of the latter as above described, the solenoid **260** remains energized throughout any moving stroke of the table **32** as effected through the reverse gearing of Figure 7, and accordingly worm **101** is held disengaged from the worm wheel **102** during the same steps in the operation of the apparatus; however, at the end of any stroke of the carriage **32**, the table-reversing control mechanism opens the switch **242** (Figure 10), as was above described, and thus effects deenergization of solenoid **260** during a corresponding time interval. During that interval, therefore, the spring **263** (Figure 15) moves the solenoid core **261** upwardly to swing the shaft **118** and hence cam arm **117** (Figure 6) in counterclockwise direction and into the position shown in Figure 6, thus effecting, in the manner already above described, engagement of the worm **101** with the worm wheel **102**, whereby the grinding wheel carriage **41** (Figure 3) is moved toward the left.

However, the above-described mechanisms and features coact with certain other mechanisms and circuits. For example, while the actual table-reversing operation takes place, as was above described in connection with Figures 10 and 7, the work piece W is gaged as to its dimension as resulting from the previous operation thereon of the grinding wheel. This gaging mechanism is mounted, preferably detachably, at the front of the table **32** (Figures 1 and 2) and is generally indicated by the reference character **270** and is shown in transverse enlarged section in Figure 11, to which reference may now be made. In Figure 11 the multiple table structure of the table **32**, well known and usual, is indicated, and will be seen to be provided with a longitudinally extending way-like rib **32**[a] at any suitable point along which, preferably as determined by the position of the work W on the table **32**, is detachably secured the gaging or sizing device **270**. The latter comprises a base **271** shaped to interfit with the rib **32**[a] (Figure 11) and a pivoted clamp member **272**, actuated by the screw **273** and engaging underneath the rib **32**[a] for clamping the rib **32** between itself and the base **271**, thereby rigidly to secure the base and the parts carried by it to the table.

The frame or base **271** carries a housing or casing **274** provided with an ear **275** by which a pin **276** pivots the housing **274** to the frame **271**; the housing **274** has an extension toward the right in the form of a tube **277**, the latter being conveniently threaded in a suitable opening in the housing **274**. At its right-hand end the tubular housing extension **277** has secured to it a head **278**, the latter being open at its upper portion as at **279** through which is exposed in an upward direction the arm **280**[a] of a lever **280**, pivoted in the head **278** by a shaft **281** and whose other arm **280**[b] is a long one that extends through the tubular housing extension **277** and into the housing **274**. The short arm **280**[a] has mounted in it a contact point **282**, made of a suitable wear-resisting material such as a diamond, and this contact point **282** is to contact with and engages the work

W at the under side thereof substantially as shown in Figure 11.

To effect an appropriate initial setting of the gaging device and particularly of the contact point 282 with respect to the work W to give the gaging device its intended range of action and control, as later described in detail, the right-hand end of the frame or base 271 is provided with an arcuate slot 283 whose center of curvature is at the axis of the pin 276 and the housing extension 277 is provided with a clamping screw 284 engageable in the slot 283. Thereby the gaging device as a whole may be initially set with respect to the initial dimension or diameter of the work W to insure the desired contact between the latter and the contact point 822. For example, where the diameter of the work W is smaller than that indicated in Figure 11, the clamping screw 284 is loosened and the housing 274—277 is swung upwardly about the pin 276 to set the contact point 282 for engagement, in a manner later described, with the work W (and subsequent work pieces of the same lot) to insure the subsequent range of action of the gaging device as the dimension or diameter of the work W is reduced. For larger diameter of work W, the housing structure may be swung in clockwise direction and thereby lower the contact point 282 with respect to the axis of the work W, in like manner and for like purposes.

Moreover, the parts are so proportioned and positioned that, as is better shown in Figure 11, the contact point 282 engages the work W at the end of that radius of the latter that is most nearly in line with the slightly curved path of movement of the contact point 282 as determined by the length of its lever arm with respect to the axis of the shaft or pin 281. Thereby more faithful response in the movement of contact point 282 and hence in the swinging or positioning of the lever 280 to changes in diameter of the work W is assured.

The lever arm of contact point 282 is relatively small or short as compared to the length of the lever arm 280^b at whose outer and left-hand end is carried a conducting element in the form of a plate-like electrode 285 of appropriate or suitable area; the plate member 285 may, if desired, be substantially circular and is preferably insulatingly secured to the lever arm 280^b in any suitable way.

With the above described difference in lengths of the lever arms represented by the arm 280^a that carries the contact point 282 and the arm 280^b which carries the plate member 285, an amplification or multiplication takes place in that for a relatively small change in position of the contact point 282 a relatively large change in position or displacement of the plate member 285 results, the latter being moved in a general up and down direction, as viewed in Figure 11. Juxtaposed to the plate member 285 is a companion electrode or plate 286, preferably of the same shape and area as the movable plate 285 and forming with the latter an electrical condenser the electrostatic capacity of which varies or changes with change in the spacing between the two plates, all for a purpose as later described in detail.

The bottom plate member 286 is supported within the housing 274 in any suitable way and preferably adjustably so; also, it is preferably insulated from the housing in any suitable way (not shown). A preferred adjustable mounting for the plate 286 may comprise a screw 287 (Figure 11) threaded through a substantial opening in the bottom of the housing part 274 and having the plate member 286 suitably secured thereto at its upper end; its lower end is preferably provided with a disk-like head 288 which is preferably peripherally graduated, as indicated in Figure 11, a suitable fixed pointer or datum 289 being secured to the bottom of the housing 274 adjacent the graduated head 288, whereby suitable precision of setting of the condenser plate 286 may be achieved.

Preferably the contact point 282 (Figure 11) is arranged so that it is not continuously in contact with the work W but is periodically brought into engagement with the work. Accordingly, there is provided suitable means for holding the lever 280 and hence the contact point 282 in such a position that the latter is out of engagement with the work but may, under controlling means as later described, be released for movement to contact with and gage the work. A preferred arrangement comprises a solenoid winding 290 (Figure 11) housed in a suitable upper portion of the housing 274, the upper and lower walls of which housing portion being shaped also to slidably guide the core 291 of the solenoid winding 290 and an upward piston rod like extension 292 of the latter which carries a piston 293 slidably fitted into a cylinder 294 formed at the upper part of the housing 274.

At its lower end the core 291 is linked to the left-hand end of lever arm 280^b, as at 295, while a spring 296 in the upper end of the cylinder 294 acts to urge the core 291 downwardly.

The winding 290, which is in circuit with the switch 250 (Figure 10 and Figure 17), may, therefore, when energized, overcome the action of spring 296 and swing and hold lever arm 280^b in its uppermost position, thereby swinging and holding the contact point 282 downwardly away from and out of contact with the work W (Figure 11); but if deenergized, it might be noted that deenergization takes place when switch 250 opens at the end of each stroke of reciprocation of the work table 32 and work W (Figure 1), spring 296 is freed to move the lever arm 280^b downwardly to an extent permitted by the engagement of the contact point 282 with the work W, an extent which is dependent upon the dimension or radius of the work W.

Correspondingly, the capacitance of the condenser 285—286 assumes a value corresponding to the spacing between the plates 285 and 286 as that spacing is determined by the range of movement of the contact point 282 as limited by the dimension of the work W. The manner and means whereby this change in capacitance of the condenser 285—286 coacts with other elements and achieves certain controls is dealt with in greater detail later.

The piston 293 (Figure 11) and the cylinder 292 are preferably so constructed and interrelated or are made to operate with any suitable fluid medium, such as air or oil, as to give the action of a dashpot and thereby to damp the movements of the gaging lever 280 in response to energization or deenergization of the solenoid 290. For example, when the latter is deenergized, the dashpot action causes the descent of the piston 293 under the action of spring 296 and the resultant counter-clockwise swinging of gaging lever 280 to take place with sufficient retardation as will always bring the contact point 282 neatly into engagement with the work W and without danger of marring the surface of the latter or of injuring the contact point itself.

As earlier above indicated, there is a number of mechanisms, means or devices coacting with various of the parts of the machine above described; aside from such devices as the above described gaging device of Figure 11, there is a main control related switch mechanism associated with the main control lever 197 (Figure 1) and by which lever, as above already described, shaft 198 (Figure 2) is swung to actuate the clutch 182 (Figure 8) to set into action the power reciprocation of the work table 32. This shaft 198 passes through a housing 300 (Figure 1) secured to the front wall of the front bed portion 30a of the bed 30 and in Figure 12 the housing 300 is shown in longitudinal vertical cross-section; in Figure 12 the shaft 198 appears in transverse section and is seen to have secured thereon a bevel gear 301 which meshes with a bevel gear 302 on a shaft or rod 303 slidably mounted in bearings 304—305 suitably formed or provided in the housing 300.

Shaft 303, as better appears in Figure 13, is square in cross-section and has mounted upon it and insulated therefrom a number of switch contacts, certain of which are preferably arranged in sets.

Three of these sets of contacts appear in elevation in Figure 12. Going along the shaft 303 from left to right the first set of contacts comprises contacts 306, 307 and 308, the second set comprises contacts 309, 310 and 311; and the third set comprises contacts 312, 313 and 314.

The contacts of these three sets of contacts coact respectively with contacts of three sets of stationary or relatively fixed contact members which are mounted in alinement and in depending relation from a suitable block 315 of insulating material suitably mounted in the upper portion of the housing 300 (Figure 12). Again considering the showing of Figure 12 in a direction from the left to the right, the first companion set of contacts comprises contacts 316, 317 and 318 for coaction, respectively, with the contacts 306, 307 and 308, in a manner later described, these two sets of contacting contacts forming a switch which, for convenience in later description, will be generally designated and indicated as switch 325.

The second companion set of contacts comprises contact members 319, 320 and 321 for coaction, respectively, with movable contacts 309, 310 and 311; these two sets of coacting contacts thus form a switch which, for convenience, will be designated as switch 326.

The third set of companion contacts are contacts 322, 323 and 324 for coaction, respectively, with movable contacts 312, 313 and 314 on the rotatable shaft 303, and together they form a switch which will be referred to as switch 327.

Fixed contacts 316, 319 and 322 have secured at their lower and forward ends, as viewed in Figure 12, blocks 328, 329 and 330, respectively, of insulating material; see Figure 13 in which the insulating block 328 of spring contact 316 appears in side elevation. These blocks of insulating material are provided in order that circuit-closing action between contacts 306—316, 309—319, and 312—322 occurs only when the contact-carrying shaft 303 rotates in one direction relative to the fixed contacts and not when its rotation is subsequently reversed, all for purposes later described.

Furthermore, the contacts of the three sets carried by the shaft 303 are shaped or staggered so that they engage their respective fixed contacts in certain sequences when the shaft 303 is rotated in counter-clockwise direction, as viewed in Figure 13, that being the direction of rotation that takes place upon starting the entire apparatus in consequence of a counter-clockwise swinging (to the left) of the starting lever 197, as the latter is viewed in Figure 1. This shaping or positioning of the contacts is sufficiently indicated in Figure 13.

In Figure 13 contacts 306 and 308 will be seen to be angularly spaced from each other while the intermediate contact 307 is shaped like a brush to maintain a longer period of contact with its fixed contact member.

Accordingly, when switch shaft 303 is swung in counter-clockwise direction (Figure 13) and hence to bring the three sets of contacts thereon, as viewed in Figure 12, over toward the observer, contacts 306 and 307 engage fixed spring contacts 316 and 317, respectively, thereby closing a circuit later described, but as the swinging of the shaft 303 continues, contact 306 moves out of engagement with fixed contact 316, and intermediate contact 307, due to its arcuate shape, maintains contact with fixed spring contact 317, during the engagement of contact 308 with fixed spring contact 318; the circuit thus first established by contacts 306—307 is interrupted and thereafter a different circuit is closed but now by contacts 307—308.

Swinging the switch shaft 303 in clockwise direction (Figure 13), as occurs when the apparatus is to be stopped as later described, reverses the above-described sequence of events excepting that insulating block 328 on fixed spring contact 316 prevents moving contact 306 on the shaft from engagement with the contact 316 and hence from effecting a closure of the above-mentioned initially closed circuit.

Moving contacts 309, 310 and 311 of switch 326 (Figure 12) and moving contacts 312, 313 and 314 of switch 327 are shaped respectively like contacts 306, 307 and 308 just described and coact with their respective fixed spring contacts 319, 320 and 321, and 322, 323 and 324, to effect sequential circuit controls just as was above described with respect to switch 325.

Still referring to Figure 12 that portion of the shaft 198 that extends through the housing 300 has secured or keyed to it a downwardly directed arm 331 to the lower end of which is connected a spring 332 anchored to a pin 333. The spring 332 acts to oppose movement of the main control or starting lever 197 (Figure 1) in a direction toward the left and acts, as will later be pointed out, to restore the lever 197 and the switches that respond to movement of switch shaft 303 to their normal positions (see Figure 13); also connected to the lower end of the arm 331 is the core 334 (Figure 12) of a solenoid whose winding is shown at 335. Winding 335, when energized, may therefore hold the starting lever 197, switch shaft 303, and related parts, in their operated position against the action of spring 332, the latter becoming effective when the winding 335 is deenergized, all as later described.

Also within the housing 300 (Figure 12) is a switch generally indicated by the reference character 338 and it comprises a fixed contact 336 and a movable contact 337, the latter being insulatingly mounted upon the switch shaft 303 while the former is insulatingly mounted in the housing 300; suitable leads are provided for connecting the switch 338 into a circuit as later described. The switch contact 337 (see Figure 13) is arcuate or brush-like in shape so that it maintains contact with the contact 336 throughout a suitable range of swinging movement of the switch shaft 303.

As will later appear more clearly, switch 325 (Figure 12) controls motor 38 (Figure 2) that effects rotation of the work W by way of the headstock 34, switch 326 controls motor 90 (Figure 5) which drives the grinding wheel carriage feed train of gearing, and switch 327 controls motor 57 (Figure 3) which as earlier described is connected up to the grinding wheel carriage 41 to move the latter at a high rate of speed, these switches, however, acting in coaction with certain other mechanisms and apparatus.

Among the latter is a switch mechanism generally indicated in Figures 3 and 14 by the reference character 340 provided with a suitable arrangement for actuating the switch in one direction in response to a certain position of the grinding wheel 45, and illustratively such a means may comprise a lever 341 which, with the casing of switch 340 mounted as shown in Figures 3 and 14 at the rear of the front bed extension 30^a but at the forward end of the rear bed extension 30^b, projects upwardly into the path of leftward movement of the grinding wheel 45 as its carriage is traversed toward the left along ways 40. Lever 341 (Figure 14) carries, preferably adjustably as by way of a suitably lockable thumb screw 342, a wheel-contacting member 343 of any suitable material or construction adapted to be substantially unaffected by the grinding wheel; it may, for example, be a roller, of suitably hardened material, which is thus brought into rolling contact with the rotating grinding wheel 45 and thus resists grinding action thereon.

Within the switch casing a shaft 344 (Figure 14) to which the lever 341 is secured is suitably pivotally mounted and has secured thereto a carrier or bracket 345 in the upper arm of which is mounted a mercury switch 346 and in the lower arm of which is mounted a mercury switch 347, the two electrodes of which are provided with suitable flexible lead wires leading to suitably insulatingly mounted connectors, as is indicated at 348, whereby the two mercury switches may be connected into appropriate circuits as is later described.

The two mercury switches (Figure 14) are so constructed or mounted, for example by arranging them out of parallelism, as indicated in Figure 14, that when one of them is in circuit-closing condition the other is in circuit-opening condition.

For example, switch 346 is shown in Figure 14 as having its electrodes bridged by the mercury therein while switch 347 is in such a tilted position that the mercury does not bridge its electrodes. As the grinding wheel moves toward the left (Figures 3 and 14) it comes into engagement with the part 343 of the operating lever 341 and swings the carrier 345 in counter-clockwise direction, thus to tilt switch 346 out of horizontal and cause its mercury to flow out of electrode-bridging position and to move switch 347 into a substantially horizontal position to cause its mercury content to bridge its electrodes. As will later be set forth in greater detail, the circuit-interrupting action thus brought about in switch 346 is made effective to stop motor 57 (Figure 3) and hence to stop the movement toward the left of the grinding wheel carriage.

The circuit-closing action brought about in switch 347, as is later explained further, is made effective to energize a magnet or coil 350 (Figure 14) suitably mounted in the switch casing and positioned so that an armature 351 carried by the switch carrier 345 and brought into coaction with the coil 350 becomes held by the latter, thus holding the switch mechanism 340 in the position in which it has been moved by the grinding wheel, as just above described.

Preferably winding 350 is made sufficiently powerful and the remaining parts so constructed that, once the grinding wheel 45 (Figure 14) has moved the switch carrier to cause mercury switch 346 to break its circuit and mercury switch 347 to close its circuit (thereby energizing winding 350), the coil 350 when thus energized can effect a slight additional counter-clockwise rotation of the carrier 345 to bring it into a secure holding position but particularly also and thereby to move the wheel-contacting member 343 slightly away (to the left) from the grinding wheel 45 and thus hold it out of engagement therewith while the grinding operations continue, it being borne in mind that, as above described, the periodic deenergization of switch 250 (Figure 10) in timed relation to the reversals in the strokes of reciprocation of the work carriage 32 is effective to couple the motor 90, through worm 101 and worm wheel 102 (Figure 6) to the grinding wheel carriage drive and thus feed the grinding wheel 45 further to the left.

This switch mechanism 340 is so arranged or balanced that, were the grinding wheel 45 to be sufficiently withdrawn toward the right (Figures 14 and 3) and were the holding coil 350 to be deenergized, the carrier 345 with the operating lever 341 tilt or swing in clockwise direction against a suitable stop (not shown), thereby to restore mercury switch 346 to circuit-closing condition and mercury switch 347 to circuit-opening condition.

To effect deenergization of holding coil 350, there is provided on the grinding wheel carriage 41 (see now Figure 3) a cam 355 in the form of a bar extending in the direction of movement of the carriage 41. Cam 355 has a cam face or edge that is substantially stepped, providing a low cam face 355^a and a high cam face 355^b. Cam 355 controls, according to the position of the wheel carriage 41 lengthwise of its ways, two switches 356 and 357 of any suitable construction, such as the plunger type of switch, each being provided with a roller for contacting the face or edge of the cam 355, the switches themselves being mounted on the rear bed extension 30^b. Both of these switches are arranged so that when their plungers are depressed, as when the carriage 41 is withdrawn and is hence moved toward the right so that the lower cam edge 355^a depresses the plunger of the two switches, the circuits in which these switches are controlled are broken. Now holding coil 350 (Figure 14) is in the circuit of switch 357 and accordingly holding coil 350 is deenergized to release the switch mechanism 340 after a substantial retraction of the grinding wheel carriage has taken place. Switch 356, actuated in substantial synchronism with switch 357, serves purposes later described.

The circuit arrangement in which certain of the above described apparatus is included is shown in Figure 17, to which reference may now be made. Any suitable source of electrical energy (not shown) energizes a main power circuit comprising conductors 360 and 361; this source may be illustratively but not by way of limitation a direct current source. From the main circuit 360—361 the above described motors receive their energy.

Thus, for example, motor 52 which drives the grinding wheel and the work table reciprocating mechanism (see Figure 2) is shown in Figure 17 as connected to the power line through a suitable starting or control switch 363 for, as will later be clearer, that motor and hence the grinding wheel may be and preferably are first set into operation and continued in operation.

Headstock motor 38 has a shunt field 38^a in series with which is a resistance 364. This motor may also be compounded and hence may have a series field winding 38^b. Its connection to the main circuit 360—361 is by way of a suitable starting switch generally indicated by the reference character 365, the switch having a control coil 366. Closure of the switch completes the connection of the motor and its field circuits from main circuit conductor 361, conductor 380, switch 365, conductor 368, thence through the motor and its shunt field, conductor 369, switch 365, and by way of conductors 370 and 371 back to the main line conductor 360. It is this circuit that is completed upon energization of the control coil 366 and that is broken upon deenergization of the latter, coil 366 controlling the position of the switch 365.

Coil 366 is in turn controlled by switch 325 described above in detail in connection with Figures 12 and 13. More specifically (see Figure 17) one side of coil 366 is connected to conductor 370 which leads by conductor 371 to main line conductor 360; the other terminal is connected by conductor 372 to fixed contact 317 of switch 325. A suitable conductor 373 (Figure 17) connects fixed contact 316 of switch 325 to the remaining side of the main circuit. Accordingly, contacts 306 and 307 of switch 325, electrically connected with each other and with contact 308, effect a bridging of fixed contacts 316 and 317 when the switch shaft 303 is first rotated in response to movement of the main starting lever 197 (Figure 1), thereby energizing switch coil 366 (Figure 17) and starting the motor 38.

The subsequent and remaining portion of rotary movement of switch shaft 303, as above described, moves switch contact 306 out of engagement with fixed contact 316, thereby breaking the above-outlined circuit of switch coil 366, but before that takes place another circuit for coil 366 is completed and retained completed by contacts 307—317 and 308—318; that latter circuit may be traced in Figure 17 as follows:—main line conductor 360, conductor 371, conductor 370, switch coil 366, conductor 372, contact 317, contact 307, contact 308, contact 318, conductor 374, switch contact 393, switch member 394, switch contact 395 (of a switch 396 later described in detail), conductor 379, through switch 365 (now closed), conductor 380 to the other main line conductor 361.

The motor 38 is thus started and continued in operation. Furthermore, provision is made for changing the speed of that motor and illustratively that may be brought about by way of conductors 381 and 382 which lead from a portion of the shunt field resistance 364 of motor 38 to a switch 383 that is at this stage open but later closed in a manner later described. Thus, the work piece W is set into rotation by the motor 38 and its speed of rotation may be reduced at a later stage.

Motor 90, which operates the grinding wheel carriage feed drive, is controlled in a somewhat similar way, through switch 326 (Figure 12) which controls the coil 384 of a main motor switch generally indicated by the reference character 385 in Figure 17. Motor 90, illustratively, may also be a shunt motor and hence has a shunt field 90^a with a resistance 386 in series therewith, as shown. The motor may be compounded and accordingly may have a series field winding 90^b. Its circuit, when switch 385 is closed, may be traced as follows:—From main line conductor 360, conductor 371, conductor 370, switch 385, conductor 387, through motor 90, conductor 388, switch 385, and by way of conductor 389 to the other main line conductor 361.

Switch coil 384 is controlled by switch 326. The first part of the rotary movement of switch shaft 303 causes electrically connected contacts 309, 310 to bridge fixed contacts 319 and 320, completing a circuit for switch coil 384 which extends from main line conductor 361, conductor 390, contact 319, contact 309, contact 310, contact 320, conductor 391, switch coil 384, conductor 370, conductor 371, to the other main line conductor 360. Switch 385 is thereby closed.

But the continued rotary movement of switch shaft 303 into its final position interrupts that circuit of switch coil 384 but before that interruption takes place has completed a new circuit for coil 384 which circuit is maintained thereafter; that new circuit extends from main line conductor 360, conductor 371, conductor 370, switch coil 384, conductor 391, contact 320, contact 310, contact 311, contact 321, conductor 392, to a switch contact 375, switch member 376, switch contact 377 (of a switch 378 later described in detail), conductor 397 to switch 385 (now closed), and then by way of conductor 389 to the other main line conductor 361.

The grinding wheel carriage feed drive, subject, however, to connection or disconnection mechanically under the control of the switch 250 (Figures 10 and 17) is thus made operative, but placed under the control of switch 378, just as was the headstock motor 38 placed under the control of switch 396.

Provision is also made to change the speed of drive transmitted by the motor 90 and this may be carried out by way of conductors 398 and 399 which are connected to a suitable portion of the shunt field resistance 386, leading to a switch 400, open at this stage but later closed in a manner later described. Thus, the increment of feed given the grinding wheel carriage may be varied.

Optional provision is also made to change the cutting speed of the tool or grinding wheel and the rate of reciprocation of table 32. This may be carried out by way of conductors 555—556 which are connected to a suitable portion of resistance 557 in the field 558 of the driving motor 52, conductors 555—556 leading to a switch 559 open at this stage but later closed as described hereinafter.

Motor 57 which drives the rapid traverse gear train of the grinding wheel carriage 41 (Figure 3) may also be a shunt motor and as shown in Figure 17 may have a shunt field 57^a and that may be and preferably is directly energized from the main line conductors 360 and 361 to which it is connected by conductors 401 and 402. The motor 57 may be compounded, if desired, and hence may have a series field 57^b. It is, however, provided with two starting switches; one of these switches, generally indicated at 403 and controlled by a switch coil 404, is so connected up that the drive of the motor 57 is in a direction (referring now to Figure 3) to rapidly move the wheel carriage 41 toward the work W (to the left), while the other switch, generally indicated at 405 and provided with a switch coil 406, is so connected up that motor 57 rotates in the opposite direction and hence is effective rapidly to retract the wheel carriage 41 (Figure 3) from the work W (toward the right). Switch 403 will thus be referred to as the forward starter switch and switch 405 as the reverse starter switch.

Switch coil 404 of the forward starter switch 403 is controlled by the switch 327 (Figures 12 and 17). The first portion of the rotary movement of switch shaft 303 causes a circuit to be closed through coil 404, as follows:—Main line conductor 361, conductor 407, fixed contact 322, contact 312, contact 313, contact 323, conductor 408, switch coil 404, conductor 370, conductor 371 to the other main line conductor 360. Switch 403 thus closes and motor 57 starts moving (Figure 3) the grinding wheel carriage 41 rapidly toward the work (toward the left).

But the remaining portion of the rotary movement of switch shaft 303 interrupts that circuit of switch coil 404 and before that interruption takes place switch 327 has placed switch coil 404 in a different circuit which may be traced as follows:—from main line conductor 360, conductor 371, conductor 370, switch coil 404, conductor 408, switch contact 323, contact 313, contact 314, contact 324, conductor 409 to mercury switch 346, then conductor 410 through switch 403 (now closed), and by way of conductor 411 to the other main line conductor 361.

Switch coil 404 is thus placed under control of the mercury switch mechanism 340 (Figures 3 and 14) above described in detail, and the motor 57, as it continues to rapidly move the grinding wheel toward the left in Figure 3, derives its energy from the main power line, with switch 403 now closed, by way of a circuit substantially as follows:—From main line conductor 361, conductor 411, switch 403, conductor 412, the armature of motor 57, conductor 413, switch 403, conductor 414, conductor 370, conductor 371, to the other main line conductor 360.

At the start of this rapid traverse of the wheel carriage 41 (Figure 3) toward the left, cam edge 355a was in a position to hold open switches 356 and 357, but as the wheel carriage 41 moves rapidly toward the left, cam 355 brings its cam edge 355b into action upon these two switches and the latter become closed. Now switch 357 (Figure 17) is in the circuit of holding coil 350 and the closure of switch 357 therefore puts the circuit of holding coil 350 in position to be energized by mercury switch 347 at the appropriate time.

That time arrives when the wheel 45 (Figures 3 and 14) contacts the lever contact member 343 to swing the latter and hence mercury switch carriage 345 in counter-clockwise direction to bring about, as above described, a circuit opening tilting movement of mercury switch 346 (Figure 17), thus interrupting the above described circuit of the switch coil 404, deenergization of which effects opening of the forward starter switch 403 and thus halts the operation of motor 57 and halts the rapid traverse movement of carriage 41.

That same actuation of the switch lever 341 (Figures 3 and 14), however, tilts the mercury switch 347 into circuit-closing position and, switch 357 (Figure 17) having been closed as just described, mercury switch 347 thus completes the circuit for holding coil 350, that circuit extending (Figure 17) from main conductor 361, conductor 415, switch 357, holding coil 350, mercury switch 347, and by way of conductor 434 to the other main line conductor 360.

As already above indicated, the circuit-opening condition of mercury switch 346 thus achieved interrupts the circuit of switch coil 404, thereby opening the forward starter switch 403 and halting the motor 57; likewise the wheel carriage 41 ceases movement and thereby the grinding wheel 45 is positioned in appropriate operative relation to the work W as determined by the setting of the lever 341 (Figures 3 and 14) of the switch mechanism 340. Though motor 57 has thus been stopped headstock motor 38 and the grinding wheel feed motor 90 continue in operation, for the switch shaft 303 (Figures 17, 12 and 13) remains in the position corresponding to the leftmost position of starting lever 197 and shaft 198 (Figures 1 and 12). The switch shaft 303 with its various contacts remains in that position due to the holding action of solenoid winding 335 (Figures 12 and 17), that winding 335 having been energized immediately upon the closure of the switch 365 (Figure 17) that controls the motor 38. Solenoid 335 (Figure 17) will be seen to be connected by conductors 416 and 417 in shunt relation to the terminals of motor 38 itself. The solenoid (Figure 12) thereby holds the switch shaft 303 as well as the main starting lever 197 in operating positions against the action of spring 332, and continues to do so until deenergized in a manner later described at which time spring 332 returns the switch shaft 303 to its initial and circuit-opening position, returning also the lever 197 to starting position.

Thus, headstock motor 38 rotates the work, feed motor 90 periodically feeds the wheel carriage and grinding wheel 45 into the work at the ends of the strokes of the latter, as determined by the switch 250 of Figure 10, as above already described, and reduction in dimension of the work W proceeds.

But before considering in detail the control of such reduction in work dimension by the tool and referring again to Figure 17, it is to be recalled that switch 356 (see also Figure 3) has been closed by the rapid traverse of the wheel carriage toward the work. Closure of switch 356 has in part conditioned another control circuit that is to coact in the rapid traverse of the wheel carriage away from the work at a time later described in detail. While the reduction in dimension of the work W is going on, as above mentioned, switch 403 controlling motor 57 stands open because switch coil 404 has had its circuit interrupted by the mercury switch 346, an interruption maintained by the holding coil 350 under the control of switch 357. Reverse starter switch 405 for motor 57 stands open during the operation on the work W because the circuit of its control coil 406 stands interrupted by a switch 418, which switch, when it closes at the conclusion of the operation of the grinding wheel on the work W, closes a circuit for switch coil 406 as follows:—from main line conductor 360, conductor 371, conductor 370, switch coil 406, conductor 419, conductor 420, switch contact 421, switch member 422, switch contact 423 (all of switch 418), conductor 424, and thereby back to the other main line conductor 361.

When that circuit is closed switch coil 406 closes reverse starter switch 405 and energizes the armature of motor 57 by way of a circuit as follows:—from main line conductor 360, conductor 371, conductor 370, conductor 425, switch 405, conductor 426, armature of motor 57, conductor 413, conductor 427, switch 405, conductor 428, and by way of conductor 411 back to the other main line conductor 361. The circuit thus closed by reverse starter switch 405 causes the current from the main line to pass through the motor armature in reversed direction as compared to the direction in which the current flow therethrough when forward starter switch 403 had closed the circuit to motor 57 and accordingly motor 57 is now energized but rotates in reverse direction, these arrangements being illustrative of one possible arrangement for achieving control of the direction of drive of the motor 57 and hence of the wheel carriage 41 (Figure 3).

The wheel carriage 41 is therefore rapidly traversed to the right, as viewed in Figure 3, but since switch 418 which, with switches 378 and 396, is controlled by a winding 429 in a manner later described, is held closed only for a relatively short time interval, and would interrupt the circuit of switch coil 406 before the rapid traverse of the wheel carriage away from the work is completed, the above-mentioned switch 356, controlled by the wheel carriage (see Figure 3) is arranged to maintain the circuit of coil 406 closed even though switch 418 relatively quickly opens again.

Switch 356 maintains the circuit of coil 406 over a circuit which will be seen to be as follows:—From main line conductor 360, conductor 371, conductor 370, switch coil 406, conductor 419, conductor 430, switch 356, conductor 431, switch 405, conductor 428, and then by way of conductor 411 to the other main line conductor 361.

Accordingly, rapid rearward traverse of carriage 41 (Figure 3) continues until the cam 355 opens switches 356 and 357 by bringing into action thereon the lower cam edge 355ª (Figure 3), it being satisfactory and preferable if these two switches are substantially simultaneously actuated by the cam 355.

Opening of switch 356 (Figure 17) thus breaks the last above described circuit of switch coil 406, deenergizes the latter, switch 405 opens, and motor 57 stops, halting the rearward rapid traverse of carriage 41.

The opening of switch 357 interrupts the above described circuit of holding coil 350 of the mercury switch mechanism 340 (Figure 14) and, the grinding wheel 45 having already been withdrawn materially out of range of the lever 341, the deenergization of holding coil 350 permits the mercury switch mechanism to return to its initial or normal position in which mercury switch 347 is in circuit-opening condition and mercury switch 346 is in circuit-closing condition, and thus in readiness for subsequent actuation by the grinding wheel as above described.

The same actuation of switch 418 (Figure 17) that initiated the reverse starting of rapid traverse motor 57 and its subsequent stoppage as just above described is accompanied by a simultaneous actuation of switches 378 and 396, all of these switches being controlled by the above-mentioned winding 429, all being structurally embodied in an illustrative structure later described. Both switches 396 and 378 are opened and interrupt the circuits of switch coils 384 and 366, respectively, of the switches 385 and 365 of the grinding wheel feed motor 90 and the headstock motor 38, the circuits of both motors being thereby interrupted and the motors stopped. The interruption of the circuit of motor 38, solenoid winding 335 being in shunt relation to the latter, likewise achieves deenergization of the winding 335, thus releasing spring 332 (Figure 12) to swing the control shaft 198 in clockwise direction, as viewed in Figure 12, thereby restoring the switch structures related to switch shaft 303 to normal or circuit-opening condition and likewise restoring main starting lever 197 (Figure 1) to its initial or starting position.

In Figure 16 is shown a structural embodiment of the switches 396, 418, 378 and solenoid winding 429, all of these parts being mounted upon a suitable panel 435, all being housed within a casing 436 at the front of the machine (see Figure 1).

Winding 429 is in the form of a solenoid winding having a core 437 to which is connected a switch rod 438 preferably of insulating material, the lower end of the latter having connected to it a piston rod 439 carrying a piston 444 slidable within a cylinder 445 and acting in coaction therewith and with certain ports and valves thereof to control the time rate of movement of the switch rod 438 in response to energization or deenergization of the winding 429, as later described.

Suitably alined with respect to the path of movement of the switch rod 438 and carried by the panel 435 are the contacts of the switches 396, 418 and 378 of Figure 17. More specifically, contacts 393 and 395 of switch 396 appear each to one side of the switch rod 438 and on the latter is slidably carried the switch member 394, a spring 446 abutting against a shoulder 447 urging the switch member 394 downwardly, another shoulder 448 limiting the extent of relative movement between switch member 394 and the switch rod 438.

As shown in Figure 16, winding 429 is deenergized and the switch rod 438 is in its lowermost position, spring 446 thus causing switch member 394 to be held in bridging relation to the contacts 393 and 395.

Switch 418 has its contacts 421 and 423 likewise mounted on the panel 435 while switch member 422 is slidably carried on the switch rod 438 between the shoulder 448 and another shoulder 449 between which and the switch member 422 is a spring 450 that urges the switch member yieldably upwardly against the shoulder 448. With winding 429 deenergized, switch 418 is open as shown in Figures 16 and 17.

Switch 378 has its contacts 377 and 375 similarly mounted on the panel 435 while switch member 376 is slidably carried by the switch rod 438 between shoulder 449 and shoulder 451, a spring 452 yieldably urging the switch member 376 toward the shoulder 451. With the winding 429 deenergized switch 378 is closed as shown in Figures 16 and 17.

When winding 429 is energized, solenoid core 437 and the switch rod 438 are drawn upwardly preferably at a low rate as later described. As the switch rod 438 moves upwardly, it first picks up switch member 376 to open the switch 378, thus, referring to Figure 17, to interrupt the circuit of switch coil 384 to open switch 385 to stop the feed motor 90, as above described in connection with Figure 17.

Continued upward movement of switch rod 438 causes shoulder 448 to pick up switch member 394 thus to open switch 396 and stop the headstock motor 38, as was described above in connection with Figure 17, and at about the same time switch member 422 of switch 418 is brought into engagement with switch contacts 421 and 423, thus to close switch 418 with results as were described above in connection with Figure 17.

Other features of action of this switch mechanism of Figure 16 are later described.

This upward movement, as above noted, of switch rod 439 takes place relatively slowly, due to the fact that the check valve 450 (Figure 16) prevents egress of air from the cylinder 445, while adjustable valve 451 permits egress of air from the cylinder at a sufficiently low rate to give the switch rod 438 the desired slow or delayed upward movement for purposes later described.

Deenergization of solenoid winding 429, however, is allowed to achieve a more rapid descent of the switch rod 439 with consequently rapid restoration of the three switches to the positions shown in Figure 16, due to the fact that the cylinder head is vented as at 452 and due to the ingress of air through the valve 451 and principally through the check valve 450.

The circuit of solenoid winding 429 is shown in Figure 17, and it will be seen to extend from main line conductor 360, conductor 371, conductor 455, switch 456, conductor 457, winding 429, conductor 458, to movable switch contact 337 carried by the main switch shaft 303, thence by way of fixed switch contact 336 and conductor 459 to the other main line conductor 361. Accordingly, when the starting lever 197 of Figure 1 is thrown to the left, thus to set the switches controlled by switch shaft 303 of Figures 12 and 17 in circuit-closing position, switch 338 is closed and thereby places the solenoid winding 429 under control of the switch 456.

Switch 456 is electromagnetically operated and controlled by two coils or windings 461 and 462. The energization of coil 461 is later described but for present purposes it is to be noted that energization of coil 461, effected when the dimension of the work W has been sufficiently reduced as later described, effects the closure of switch 456, thus to energize solenoid winding 429, as above described, and effects the closure also of a switch or contact 463. Switch 463 is in circuit with coil 462 which acts as a holding coil to hold switches 456 and 463 closed. But the circuit of holding coil 462 thus completed is under the control of switch 338 (actuated by the switch shaft 303) over a circuit substantially as follows:—from main line conductor 360, conductor 371, conductor 455, conductor 464, switch 463, conductor 465, holding coil 462, conductor 466, conductor 458, switch contacts 337 and 336, and by way of conductor 459 to the main line conductor 361. Holding coil 462 is thus in effect placed in parallel with solenoid winding 429 and both are thus conditioned to be deenergized when switch 338 of switch shaft 303 is opened at the conclusion of the operation of the machine on the work.

An analogous holding coil arrangement is provided for switches 400 and 383 (Figure 17) which, it will be recalled, effect, when they are closed, a change in speed (specifically a reduction) of headstock motor 38 and wheel feed motor 90, for switch 383 when closed short-circuits resistance 384 in the field circuit of motor 38 and switch 400 short-circuits resistance 386 in the field of motor 90 to achieve this speed change. These two switches and switch 559, which changes the speed of motor 52, are brought into circuit-closing position by a winding 467 energized in a manner later described but winding or coil 467 also closes a switch 468 to energize a holding coil 469 to hold all three switches in closed position.

But holding coil 469, like holding coil 462 and solenoid winding 429, as above described, is also in circuit with the main control switch 338 of switch shaft 303 so that holding coil becomes deenergized when that switch is finally opened. More specifically, the circuit of holding coil 469 will be seen to extend from main line conductor 360, conductor 371, conductor 455, conductor 470, switch 468, conductor 471, holding coil 469, conductor 472, conductor 458, switch 338, and by way of conductor 459 to the other main line conductor 361. Thus, opening of switch 338 effects deenergization not only of holding coil 462 and solenoid winding 429 but also of holding coil 469.

Switches 559, 400, 383, 468, and the windings 467 and 469 may be embodied in any suitable physical structure, preferably in the form of a so-called relay, and for convenience in differentiation will be referred to as relay switches or relay windings. And the same is true of switches 456, 463, and windings 461 and 462.

The energization of relay windings 467 and 461 in a certain sequence takes place under the control of the condenser 285—286 of the gaging apparatus of Figure 11 above described in detail, the capacitance of which, it will be recalled, is variable in accordance with the change in dimension or diameter of the work W as effected by the tool or grinding wheel 45. But plate 285 of that condenser is held in substantially ineffective position by the solenoid 290 (Figure 11) which holds it in uppermost position, thus to keep the work-contacting point 282 out of engagement with the work W but is brought into effective relation to the companion condenser plate 286 by deenergization of solenoid 290 whose circuit is opened at the ends of the strokes of reciprocation of the table 32 by the switch 250, as was above described, its actual spacing from the plate 286 and hence the effective capacitance of the condenser being determined by the work-contacting point 282. In Figure 17 the stationary condenser plate is shown at 286 and juxtaposed thereto is the movable condenser plate 285 under the control of the diagrammatically represented solenoid winding 290. Conductors 473 and 474 connect windings 290 and 260 in parallel, and thus connected in parallel, they are connected to main line conductor 361 by conductors 475 and 424 and are connected through switch 250 and conductors 476, 370 and 371 to the other main line conductor 360.

The capacitance of the condenser 285—286, which, as will now be clear, varies in accordance with the change in the dimension of the work W as the machine operates upon the latter, is made to affect the energization of relay windings 467 and 461 (Figure 17), preferably in a certain sequence, and by way of illustrative circuit arrangements, as shown in Figure 17.

There is first provided a suitable source of alternating current energy in the circuit of which the gaging condenser may be made effective and that source is preferably a high or radio frequency source; it may and preferably does comprise a so-called oscillating circuit in which is included a three-element electronic conduction device such as the thermionic vacuum tube 480 (Figure 17) whose cathode 481 is supplied with heating current from a suitable portion of the secondary winding 482 of a transformer T′ whose primary winding 483 is connected by conductors 484 and 485 to a suitable source of alternating current indicated at 486, the latter source being illustratively of the usual 110-volt, 60-cycle type.

The secondary winding 482 serves to impress upon the plate 487 of the tube 480 a suitable potential, being connected to one side of the secondary 482 by conductor 488 and by a radio frequency choke coil 489, the other side of the winding 482 being connected as shown to the cathode 481. Thus a suitable potential difference between these two electrodes is furnished.

A suitable oscillating circuit comprising a condenser 490, preferably variable, in parallel with an inductance 491, also preferably variable, these two parts being connected in parallel as shown, are included in the plate or output circuit of the tube 480 but through a plate blocking condenser 492, the circuit being from cathode 481, plate anode 487, conductor 488, blocking condenser 492, conductor 493, parallel circuit 490—491, and by way of conductor 494 back to the cathode 481.

A feed back or coupling between the plate circuit and the circuit of the grid 495 is also provided, so that the circuit or system will oscillate; that coupling may comprise an inductance 496 variably coupled to the inductance 491 of the plate circuit, inductance 496 having one terminal connected to the grid 495 and having its other terminal connected by conductors 497 and 494 to the cathode 481, a grid condenser 498 being similarly interposed between the grid 495 and the cathode 481, in the usual way and for purposes as known in the art.

With this arrangement, therefore, suitable high frequency oscillations are produced, the frequency of which, as is known, depends upon the constants of the circuit and on the variability of any one or more of these constants.

This oscillator circuit is coupled to a circuit in which the condenser 285—286 is included; the latter circuit, referred to later as a "head circuit", preferably comprises an inductance 499 in parallel with a condenser 500, preferably variable, the variable or gaging condenser 285—286 being in parallel with these parallel-connected reactances. Change in the capacitance of the condenser 285—286 therefore changes the constants of the head circuit.

Now this head circuit is coupled to the above described oscillator circuit by means of what will be termed an "intermediate circuit"; the intermediate circuit may be considered as a closed circuit comprising an inductance or coupling coil 501, coupled to the inductance 499 of the head circuit, conductor 502, inductance 503, conductor 504, conductor 505, a condenser 506, preferably variable, and conductor 507 which leads back to the coupling coil 501, thus closing this circuit.

This intermediate circuit is also coupled to the oscillator circuit; thus conductors 508 and 509 connect one side of the variable condenser 506 of the intermediate circuit to one side of the oscillator circuit 490—491 and a variable condenser 510, with conductor 493, connect the other side of variable condenser 506 to the other side of the parallel or oscillating circuit 490—491, the variability of condenser 510 making this coupling in effect a variable coupling.

Thus, the high frequency energy of the oscillator circuit energizes the coupled intermediate and head circuits and accordingly a high frequency potential is made effective across the condenser 506, the value of which may, by suitable selection of the constants of the circuit in a manner well known in the art, be made to vary through relatively wide ranges in response to relatively small changes in the capacitance of the gaging condenser 285—286. For example, the constants may be so selected or adjusted that change in the capacitance of the gaging condenser may effect an approach to or achievement of or departure from a condition of resonance in the intermediate circuit, with corresponding change in potential across the condenser 506. Bearing in mind the general characteristic or shape of the resonance curve of a resonating circuit and bearing in mind that it can be made to have a slope as steep as desired, depending upon the "sharpness" of tuning or sensitiveness of the circuit, the amplified response, in change of potential across the condenser 506, to small increments of change of capacitance of the gaging condenser, may be made to suit the particular conditions of action or operation desired.

Interposed between the condenser 506 and the relay coil 467 is an amplifying and rectifying device 515 and interposed between the condenser 506 and the relay coil 461 is a similar device 516; these devices may be of any suitable construction and illustratively and preferably are of the heated cathode vapor-filled type. Thus, the device 515 has a cathode 517 heated by a heater 518, a plate anode 519 and a grid anode 520. Similarly, device 516 has a heated cathode 521 heated by heater 522, a plate anode 523 and a control or grid anode 524.

Heaters 518 and 522 are connected in parallel as shown and connected to a secondary winding 525 of a transformer T^2 whose primary winding 526 is connected by conductors 484 and 485 to the 60-cycle source 486 of alternating current.

Relay coil 467 is connected in the output or plate circuit of the device 515, that circuit extending from cathode 517, plate 519, conductor 527, relay coil 467, conductor 528, conductor 529, to one side of a transformer secondary 530, and then by way of conductor 531 back to the cathode 517.

Relay coil 461 is connected in the plate circuit of the device 516, that circuit being as follows:—From cathode 521, plate 523, conductor 532, relay coil 461, conductor 533, conductor 529, transformer secondary 530, and by way of conductor 531 back to the cathode 521.

Both of these relay windings are thus supplied with rectified or uni-directional current at appropriate potential, but each under the control of the grids or control electrodes of the respective devices.

The two control electrodes are made to vary or change the power output in their respective plate circuits and hence to vary or change the energization of the respective relay coils in accordance with changes in the potential across the variable condenser 506, but subject preferably to certain manual adjustments. Thus, there is provided a resistance 540 with a shiftable tap 541, forming therewith in effect a potentiometer, the tap being connected to the grid 520 of the device 515. In like manner a resistance 542 is provided with a tap 543 connected to the grid or control electrode 524 of the device 516. Conductors 544 and 545 connect these resistors in parallel and by way of conductors 546 and 547 the resistors are connected in parallel to the high frequency condenser 506.

The transformer T^2 has another secondary

548 whose one terminal is connected to conductor 545 and hence to the taps 541 and 543 and hence to the control electrodes 520 and 524, respectively, its other terminal being connected by conductors 549 and 531 to the cathodes 517 and 521.

Thus, both grids are connected so that the potential thereof, that being the factor which controls or varies the flow of current in the respective plate circuits and hence in the relay coils 467 and 461 as well, varies with the radio frequency potential across the condenser 506, the actual potential of the grids being determined by the sum of a component which comprises the 60-cycle potential furnished by the secondary winding 548 of the transformer T^2 and a component which is the radio frequency potential across the condenser 506 of the intermediate circuit, the latter component being variable in response to change in the capacitance of the gaging condenser as above set forth but the effect of which radio frequency component may be made differently effective upon the two devices 515 and 516, due to the potentiometers 540—541 and 542—543 through which the radio frequency component is made effective upon the respective grids.

Preferably the adjustment of these potentiometers is such that the plate circuit of device 515 has its output sufficiently increased, thus to energize relay winding 467, at an earlier point in the complete range of change of capacitance of the gaging condenser than does the plate circuit (and hence relay winding 461) of the device 516.

As the work carriage 32 is reciprocating, with the grinding wheel carriage 41 fed toward the work at the end of each stroke of the work carriage, the dimension of the work W is being progressively reduced preferably in relatively heavy grinding wheel cuts, one cut for each stroke of reciprocation of the table 32, and during this stage of the operation on the work W, relay windings 467 and 461 are ineffective to close their switches or contacts, and thereby reduction in dimension of the work piece may rapidly proceed. In this connection it is to be borne in mind that the rate of reciprocation of the work carriage 32 may be determined by appropriately setting the variable speed mechanism of Figure 8 in conjunction with the back gearing 158, 164, 165, 160, of Figure 7, the two giving a wide range of selection of traverse of the work. Likewise it is to be borne in mind that the speed of drive of the worm 101 (Figure 6) through which the feed of the grinding wheel carriage is effected as at the ends of the strokes may be varied or adjusted to suit conditions, in any suitable way, as, for example, by manually adjusting or setting the value of the field resistance 386 (Figure 17). And also the speed of rotation of the work piece W by the motor 38 (Figures 2 and 17) may be changed or adjusted in any suitable way, as, for example, by manually setting the field resistance 364 as is diagrammatically indicated in Figure 17.

Accordingly, these various factors may be appropriately adjusted or suited to achieve the desired rapidity or character of dimension-reducing operation on the work piece and that reducing operation continues step by step, the dimension of the work piece W (Figure 15) being gaged at the end of each stroke or step by the gaging device, the accompanying or corresponding change in capacitance of the gaging condenser 285'—286 (Figures 11 and 17) being during this stage ineffective to cause either of the devices 515 and 516 to effect an energization of the relay coils in their respective output circuits, this stage of operation being continued to any selective point, illustratively and preferably such a point that the dimension of the work piece W closely approximates the desired ultimate dimension.

When that point is reached, and it may be determined, for example by adjusting the condenser 500 or condenser 510, or other constants of the circuit involved, the capacitance of the gaging condenser 285—286 has reached such a value that the output circuit of device 515 becomes sufficiently energized in turn to energize the relay winding 467. Switch 468 is thereby closed to energize the holding coil 469, as above described, and switches 400 and 383 are likewise closed in order, respectively, to reduce the speeds of motors 90 and 38, all the other mechanism continuing their respective functioning just as before. There thus ensues a second stage in the grinding operation and during that second stage the work is being rotated at a changed speed, illustratively a lower speed for now the motor 38 is rotating slower, and the increment of feed of the grinding wheel carriage that occurs at the end of each stroke of the work table 32 is less than it was before since the speed of motor 90 and hence of worm 101 is reduced.

This above-mentioned second stage in the operation on the work may, if desired, be accompanied by a change in the cutting or surface speed of the operating tool or grinding wheel and that is effected by the actuation of switch 559 (winding 467) concurrently with the actuation of switches 400 and 383; switch 559 reduces the speed of motor 52 to an appropriate adjustable extent and that reduction in speed, particularly when coupled with a reduction in speed of rotation of the work W achieves a fine finishing action of the tool on the work. Preferably, also, the rate of reciprocation of the work W is at the same time reduced and that also is brought about by switch 559 which, in reducing the speed of motor 52, also reduces the rate of movement of the work carriage 32 during each stroke of its reciprocations.

The respective effects achieved by switches 383, 400 and 559 may be varied, since the connections to the field resistances are variable; furthermore, any one of them may be eliminated as, for example, by shifting the variable contactors related to the shunt field resistance of the particular motor so that they are substantially coincident, and, therefore, no portion of the shunt resistance is shunted out or short-circuited.

There thus ensues, during the above-mentioned second stage, a series of grinding steps which might be considered as each comprising a finishing or cleaning up cut, and at the end of each stroke the gaging condenser 285—286 is made effective as above described, its capacitance changing progressively or in steps commensurately with the progressive or successive traverse of the work relative to the grinding wheel. This continues until that critical value of capacitance in the gaging condenser is achieved corresponding to which the dimension (Figure 11) of the work W, specifically its diameter, is exactly what it is desired to be; at that point the voltage of condenser 506 (Figure 17) has reached a new value and through potentiometer 542—543 affects the device 516 to cause its plate or output circuit to be sufficiently energized in turn to cause the relay winding 461 to operate its contacts or switches 463 and 456. By appropriate relative adjustments of the two potentiometers 540—541 and 542—543, the points at which the plate circuits of the two devices become effective may thus be determined and illustratively, as just pointed out, a desired sequence of actuation with any suitable or desired interposed time interval of the two relays may be achieved.

Closure of switch 463 brings into action the holding coil 462. Closure of switch 456 closes the circuit of solenoid winding 429 to actuate the switches 396, 418, 378 (see also Figure 16) at the desired rate of speed to bring about the stopping of the headstock 38 and of the feed motor 90 and a reversal of the wheel carriage rapid traverse motor 57 to withdraw the grinding wheel from the work, all as above described in detail but preferably in a certain sequence substantially as follows:—

As earlier indicated the switch structure shown in detail in Figure 16 is adjustable and also adjustable to achieve a certain timed sequence of actuation of the individual switches, by the switch rod 439. This switch mechanism of Figures 16 and 17, when the winding 429 is energized, achieves first an opening of switch 378, which is first picked up on the upward movement of the switch rod 439, thereby initially stopping all feeding, by motor 90, of the grinding wheel, and making certain that the latter and its carriage can no longer take part in any feeding movement.

Due to the adjustable slow action of this switch structure, a suitable time interval is made to ensue, following the opening of switch 378, before switch 418 makes its circuit or switch 396 breaks its circuit, thereby permitting further grinding action on the work, that action being a "sparking-out" action which compensates for possible springing of the work from grinding wheel pressure and which also permits a higher quality of finish of the work and achieves better final precision and uniformity of precision or size throughout its length. By adjusting the valve 451 (Figure 16) this time interval may be controlled or determined and it may, for example, be set so that this sparking-out action takes place through at least one stroke of reciprocation of the work.

Next in order of actuation, in the preferred or illustrative embodiment, is switch 418 whose circuit is next closed to achieve among other things an immediate retraction of the wheel carriage. While this is going on motor 38 is still rotating the work and main switch holding coil 335 is still energized.

Next in the sequential actuation of the switch structure of Figure 16 switch 396 is actuated to break its circuit, thus interrupting the drive of headstock motor 38 and the circuit of the main switch holding coil 335.

By this sequence of steps, the grinding wheel is prevented from contacting the work while the latter is no longer rotating and thus grinding of flats or marring of the finished work is prevented. As a result of the above-mentioned deenergization of main switch holding coil 335 switch shaft 303 and starting lever 197 (Figure 1) are restored to normal. As the switch shaft 303 returns to normal, contacts 306, 309 and 312 by-pass the fixed contacts 316, 319 and 322, respectively, but the insulating blocks 328, 329 and 330, respectively related to the fixed contacts, prevent closure of the circuits of the windings of the motor starter switches. Likewise switch 338 in the circuit of solenoid winding 429, one of whose contacts 337 is carried by the switch shaft 303, is opened, thus allowing switches 396, 418 and 378 to restore to normal and to restore the circuits and parts controlled thereby likewise to normal and in readiness for a succeeding sequence of operations.

The operator may now remove the work pieces W from the head and tailstocks, put in another work piece W, and as soon as he has done that he need simply swing the starting lever 197 to the left (Figure 1) to start the cycle all over again. The operator, therefore, need merely replace the work and throw the starting lever.

To achieve a different reduction in dimension of the work, the constants of the head circuit or intermediate circuit or of even others of the immediately related circuits will suffice. Preferably, for an initial setting of the apparatus, condenser 500 of the head circuit (Figure 17) is appropriately adjusted. If it is desired to carry on the grinding operation in one stage rather than in the two successive stages above outlined, the two potentiometers 540—541 and 542—543 may be adjusted or set so that both relay circuits become substantially simultaneously energized.

In view of the foregoing the construction, arrangement, and operation of the system and apparatus will, it is believed, be entirely clear. By way, however, of brief summary but not by way of limitation, an illustrative sequence of the steps and operations performed in a complete cycle may be outlined substantially as follows:—

1. With switch 363 (Figure 17) closed motor 52 (Figure 1) drives the grinding wheel 45 at a suitable speed and applies power drive to the driving train for the reciprocation of the work table 32, that driving train including the clutch 182 (Figures 2 and 8) and the speed-change mechanism in the casing 171 (Figures 2 and 8) and also the speed-change mechanism in the lower left-hand portion of Figure 7, and also the reverse gearing at the lower right-hand part of Figure 7; clutch 182, however, interrupts this drive. By way of speed-change mechanisms just noted, the proper speed of reciprocation of the work table 32 (Figures 1 and 2) is selected, and the table dogs 223—224 (Fig. 1) are appropriately set. Likewise the gaging device (Figure 11) and its related electrical circuits are set or adjusted in the manner above described in detail. The grinding wheel 45 with its carriage 41 is in retracted position.

2. The operator mounts a work piece W on the centers of the headstock and tailstock on the work table 32, and swings the starting lever 197 (Figure 1) to the left.

3. Actuation of lever 197 operates clutch 182 to complete the driving train for table reciprocation so that the latter commences to reciprocate as above described but lever 197 also actuates switch shaft 303 (Figures 12 and 17), thereby to close switch 338 and effecting also, as above described in detail, the closure of motor starting switches 365, 385 and 403, headstock motor 38 to commence rotation of the work W, starting motor 90 to condition the grinding wheel carriage feed train for subsequent feeding movement of the grinding wheel, and starting rapid traverse motor 57 which (Figure 3) rapidly moves the grinding wheel from its retracted position toward the work W, the grinding wheel 45 being thereby brought into engagement with the switch lever 341 to operate the mercury switch structures 345 and 347 (Figures 14 and 17) which among other things stops the rapid traverse motor 57. This

movement of the grinding wheel carriage toward the work (Figure 3) has effected closure of switches 356 and 357, thereby conditioning circuits as above described in detail. The closure of the circuit of grinding wheel feed motor 90 has also effected an energization of solenoid winding 335 (Figures 17 and 12) thereby holding starting lever 197 and hence switch shaft 303 and the clutch 182 in actuated positions.

4. The grinding wheel 45 having thus been brought into close proximity with the work W, switch member 250 (Figures 10 and 17) moved into open position at the end of each stroke of reciprocation of the work table 32, thereby effects deenergization of solenoid windings 290 (Figures 11 and 17) and 260 (Figures 6, 15 and 17), the former allowing the gaging contact point 282 (Figure 11) to contact the work W and thereby correspondingly set the condenser plate 285 with respect to the condenser plate 286 and the latter completing the driving train of feed motor 90 to the grinding wheel carriage 41, through the resultant bringing of worm 101 (Figure 6) into driving engagement with the worm wheel 102, thereby to feed the grinding wheel 45 forward to determine the depth of cut that the grinding wheel will take on the next stroke of the work carriage 32. The switch member 250 returns to circuit-closing position, solenoid 290 (Figure 11) lifts the contact point 282 out of contact with the work W and solenoid 260 interrupts the feed drive of the grinding wheel carriage, all of this happening while the reverse gearing in the lower right-hand part of Figure 7 reverses the drive of the work table 32. The amount of feed thus given the grinding wheel 45 during this interval may be determined, for example, by adjustment of the speed of the motor 90, as above described, or by adjusting the speed of response of the solenoid 260—261 (Figure 15).

5. The operations outlined in the preceding paragraph numbered "4" are repeated until the dimension of the work piece W is reduced to such a value that the condenser 285—286 (Figures 11 and 17) is given such a value of capacitance that, through the circuits above described in detail relay winding 467 is energized to close switches 400, 383 and 468, the latter energizing the holding coil 469; switches 400 and 383 effect a reduction in speed of the headstock motor 38 and the grinding wheel feed motor 90 by short-circuiting an appropriate amount of resistance in the field circuits of these motors, and thereafter the sequence of operations set forth in the above paragraph numbered "4" continue to be repeated but now with the work W being rotated at a slower speed and with the increment of feed that is given the grinding wheel carriage 41 at the end of each stroke of the work table 32 diminished, the grinding wheel now taking lighter or smaller cuts in the work, a feature which, incoaction with the slower surface speed of the work W, may be considered to be analogous to "finish" grinding or similar to a final grinding step in which the final precision of shape and dimension of the work piece W are achieved. Switch 559 may be made effective concurrently with switches 400 and 383 to reduce the speed of motor 52, thereby accompanying the just described "finish" grinding with reduced tool-cutting speed and with reduced rate of work traverse.

6. As soon as the gaging condenser 285—286 achieves a capacitance corresponding to the desired dimension of the work piece W, relay winding 461 (Figure 17) is energized to close switches 463 and 456, the former energizing holding coil 462 and the latter effecting energization of solenoid winding 429, the circuit of which had been previously conditioned for such energization by switch 338 on the main switch shaft 303. Accordingly, solenoid 429 effects actuation of switches 378, 418 and 396. The opening of switch 378 de-energizes solenoid 384 and effects the opening of switch 385 of the circuit of feed motor 90. Due to the location of switches 378, 418 and 396 upon element 438 there is a time interval between the opening of switch 378 and the closing of switch 418 during which "spark-out" grinding occurs. The closing of switch 418 energizes coil 406 of reverse switch 405, thereby effecting the drive of rapid traverse motor 57 in a reverse direction so as to retract grinding wheel carriage 41. After carriage 41 has been retracted sufficiently, cam 355 opens switches 357 and 356; the opening of switch 356 interrupts the circuit of coil 406 of the reverse switch 405, thus interrupting the circuit of rapid traverse motor 57. The opening of switch 357 de-energizes holding coil 350 of the mercury switch and lever mechanism 341 (Figures 3 and 14) and permits the latter to return to normal position in readiness to be actuated by the next forward movement of grinding wheel 45. Shortly after the closing of switch 418, switch 396 opens so as to open the circuit of headstock motor 38 and of the main switch holding winding 335. Due to the de-energization of holding winding 335, spring 332 (Figure 12) rotates switch shaft 303 to the normal stopped position of the machine in which switches 325, 326, 327 and 338 are open and in which lever 197 is in the right-hand position (Figure 1). This movement of lever 197 interrupts the reciprocating drive of the work carriage 32 at the clutch 182. The opening of switch 338 controlled by the main switch shaft 303 interrupts the circuit of solenoid winding 429, allowing switches 378 and 396 to return to normal, and interrupts also the circuit of relay holding coils 469 and 462. Thus, all the parts, as described earlier above in complete detail, are returned to normal or starting position and interrelation.

7. Reciprocation of the work table 32 having been halted and rotation of the work W having been halted, the operator removes the work piece W and substitutes for it another work piece that is to be operated upon or ground. Having done that, he throws the starting lever 197 (Figure 1) to the left, and the above outlined illustrative cycle of events is repeated.

The above illustrative cycle illustrates also how, by way of my invention, the various objects hereinabove noted, together with many thoroughly practical advantages, are successfully achieved. It will be seen that the apparatus and system are of wide flexibility and that the widely varying conditions met with in practice may thus be efficiently and quickly and effectively met. Uniformity of work production will, moreover, be seen to be achieved at high efficiency and high speed; for example, it will be appreciated that, depending upon the nature of the work operated upon, heavy or roughing cuts can be taken off of the work piece in the initial stages of the operation thereon and under conditions of relative work and tool speeds best suited to such heavy or rough cutting operations, while in the later or finishing stages of operation, lighter or finishing cuts may be taken off of the work and again at relative work and tool speeds best suited to the material operated upon and to such finishing operations.

For example, the system and apparatus may be readily adjusted or set to perform a cycle of "plunge" grinding or cutting, as, for example, where the work is of short axial length, a length within the width of the operative face of the grinding wheel. In such case, reciprocation of the work carriage 32 need not be had. In such case, the above illustrative cycle may be carried out for "plunge" cutting by disengaging the clutch 128 (Figure 4) to interrupt the reciprocating drive of the work carriage 32 or by shifting the lever 166 (Figure 1) thereby to interrupt the driving connection between the shafts 157 and 153 (Figure 7).

Also, and for this purpose I arrange to have the circuit of coil 260 (Figures 17, 6 and 15) interrupted in order thereby to maintain in engagement the worm 101 and the worm wheel 102 (Figure 6) which are included in the train of driving gears through which the feed motor 90 gives to the wheel carriage a feeding movement, and I also prefer to have the feeler or contact point 282 of the gaging mechanism (Figure 11) remain continuously in contact with the work piece W. For the latter purpose I effect also an interruption of the circuit of the coil or winding 290 (Figures 17 and 11).

This interruption in the circuit or circuits of windings 260 and 290 (Figure 17) I achieve preferably by way of a switch 560 arranged in series with the switch 250 above described in detail and which controls the energization and deenergization of these two windings. The movable member or part of the switch 560 is connected by a rod 561 to a core 562 related to a solenoid winding 563 and to another core 565 related to a solenoid winding 567, a spring 564 acting in a direction to keep the switch 560 closed. Winding 563 is connected by conductors 568 and 569 in parallel with the armature circuit of the feed motor 90, a manually controlled switch 566 being in the circuit of one of these conductors. Winding 567 is connected by conductors 570 and 571 in parallel with the armature circuit of rapid traverse motor 57, a switch 572, mechanically connected, if desired, to switch 566 being in the circuit of one of these conductors.

Switch 566—572 is normally kept open, being positioned, with the switch structure which it controls, conveniently in the casing or cabinet 573 (Figure 1) accessible from the front of the machine, and is maintained open when the grinding operations or cycle earlier above described in detail are desired to be carried out, for, when switch 566—572 is open, spring 564 keeps switch 560 closed and thus coils 290 and 260 remain under the control of the periodically-actuated switch 250 above described.

But for carrying on a cycle of "plunge" grinding, switch 566—572 is manually closed, after, of course, having interrupted the reciprocating drive of the work table 32, leaving, however, switch 250 (Figures 10 and 17) closed. The operator then mounts a work piece on the centers of the headstock and tailstock of the work table 32 and swings starting lever 197 (Figure 1) to the left.

Switch shaft 383 is thereby actuated in the manner above described, resulting in the starting of headstock motor 38 to commence rotation of the work, starting the feed motor 90 and starting rapid traverse motor 57. But thereby solenoid windings 563 and 567 are energized, but since they are of equal strength and act in opposition to one another, their effect on rod 561 is nil and spring 564 is free to hold switch 560 closed. Thus solenoid 260 (Figures 6 and 15) effects disconnection of the worm 101 from worm wheel 102, and hence mechanically disconnects motor 90 from the wheel carriage, and leaves rapid traverse motor 57 free to move the grinding wheel rapidly into operative relation to the work, this rapid traverse movement being stopped by the mercury switch structure 340 of Figure 14 in the manner above-described in detail. Stoppage of motor 57 deenergizes solenoid winding 567, leaving solenoid 563—562 unopposed except for the spring 564 but the latter is overcome by solenoid 563, 562 and switch 560 is opened, deenergizing windings 260 and 290.

Thus, worm 101 and worm wheel 102 are again connected to complete the driving train between the feed motor 90 and the grinding wheel carriage, thus initiating the slow feeding movement of the grinding wheel in a radial direction with respect to the work.

Also, by the deenergization of solenoid winding 290, the contact point 282 (Figure 11) of the dimension-gaging mechanism 270 is allowed to remain always in contact with the work W.

Accordingly, grinding continues, the grinding wheel being fed at an appropriate rate, adjustable in any suitable manner as by having initially adjusted the speed of the motor 90, and this continues until a certain dimension of the work piece has been achieved as also outlined in step numbered "5" above.

When that dimension has been achieved, switches 383, 400 and 559 (Figure 17) are closed, thus changing the rate of rotation of the work W by the motor 38, changing the rate of feed achieved by the motor 90, and changing the cutting speed of the grinding wheel by changing the speed of rotation of its driving motor 52, each optionally and/or to the desired extent.

There then ensues a second stage of operation analogous to the "finish" cutting operation earlier above described in paragraph numbered "5" above (disregarding in the latter the reciprocation of the work table 32).

As soon, thereafter, as the gaging condenser 285—286 achieves a capacitance corresponding to the desired dimension of the work piece W, relay winding 461 (Figure 17) is energized to close switches 456 and 463 and thereby solenoid 429 is energized to actuate the switches 378, 418 and 396, sequentially, however, and in appropriate timed relation.

In this latter connection, switch 378 is first actuated to interrupt the circuit of motor 90, thus stopping the motor 90 but at the same time winding 563 is deenergized so that switch 560 is promptly and quickly closed, thus energizing winding 260 to disconnect worm 101 from worm wheel 102 (Figure 6). Thus, the feeding movement of the grinding wheel carriage is at once stopped and the driving train between the carriage and the motor 90 interrupted, all for several purposes.

Firstly, the "sparking-out" operation or action above described may be carried out, the headstock motor 38 continuing to rotate the work and avoiding marring of the work or grinding of flats therein.

Secondly, the interruption of the driving train of gears conditions matters so that rapid traverse motor 57 may be set into operation to rapidly withdraw the grinding wheel carriage. Though motor 57 is now energized and solenoid winding 567 becomes energized, the latter merely aids spring 564 in keeping switch 560 closed.

This rapid withdrawal of the wheel carriage is effected by the closure of switch 418, which effects a reverse starting of motor 57 after an appropriate time delay. It will be recalled that the switch structure of Figure 16 is such that it can be set to interpose a suitable time interval between the opening of switch 378 and the closure of switch 418 and it will now be seen that it is during this time interval that the driving train between the grinding wheel carriage and the feed motor 90 is interrupted and that the "sparking-out" operation takes place. Stoppage of motor 57, subsequently, is accompanied by deenergization of solenoid winding 567, leaving switch 560 still closed under the action of spring 564.

In the actuation of the time-delay switch structure, switch 396 is next opened, thus to stop the headstock motor 38 and to bring about a restoration of the switch shaft 303 and starting lever 197 to normal positions. The operator next replaces the work piece W, and the apparatus is now ready for a repetition of the above-described steps in this cycle of "plunge" grinding.

Furthermore, the apparatus will be seen to be compact and self-contained; for example, such electrical equipment as the principal parts of the "head" circuit, intermediate circuit, oscillating circuit, rectifying and amplifying circuits and relays and relay circuits, may be accommodated in the front bed portion 30ª (Figure 1) of the machine in a suitable compartment provided therein, access to which may be gained as, for example, by way of the door 575 (Figure 1). Thus, any adjustments as need be made as, for example, adjustments of the circuit or circuits, potentiometers, condensers, or the like, may thus be easily and quickly accomplished for the corresponding parts are thus made readily accessible.

As many possible embodiments may be made of the above invention and as many changes might be made in the embodiment above set forth, it is to be understood that all matter hereinbefore set forth, or shown in the accompanying drawings, is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. In apparatus of the character described, in combination, means for supporting and rotating a round work piece, a grinding wheel for operation upon the latter, means mounting said supporting means and said grinding wheel for relative movement therebetween in a direction to effect relative traversing between the work piece and the grinding wheel and also in a direction transversely to the axis of rotation of the work piece, means for driving said grinding wheel, means driven from said wheel-driving means and including a clutch for effecting relative reciprocation between said grinding wheel and said work piece in said first direction, means set into operation substantially concurrently with an actuation of said clutch to effect relative movement rapidly between said grinding wheel and said work piece in said first direction to bring the two into substantial operative relation, means responsive to the achievement of said operative relation for halting said last-mentioned relative movement, a dimension-gaging device for operation upon the work piece, and means responsive to the achievement of a certain gaging indication of said device for effecting a rapid separating relative movement between said wheel and work piece and for actuating said clutch to halt said reciprocating movement.

2. In apparatus of the character described, in combination, means for supporting and rotating a round work piece, a grinding wheel for operation upon the latter, means mounting said supporting means and said grinding wheel for relative movement therebetween in a direction to effect relative traversing between the work piece and the grinding wheel and also in a direction transversely to the axis of rotation of the work piece, means for driving said grinding wheel, means driven from said wheel-driving means and including a clutch for effecting relative reciprocation between said grinding wheel and said work piece in said first direction, means set into operation substantially concurrently with an actuation of said clutch to effect relative movement rapidly between said grinding wheel and said work piece in said first direction to bring the two into substantial operative relation, means responsive to the achievement of said operative relation for halting said last-mentioned relative movement, a dimension-gaging device for operation upon the work piece, means for effecting a slow relative approaching movement between said grinding wheel and said work piece, means causing said device periodically to make effective, during a short interval of time, said last-mentioned means, and means responsive to a subsequent indication of said gaging device for disconnecting said clutch and for effecting a rapid relative movement between the wheel and the work piece in a direction to separate them.

3. In apparatus of the character described, in combination, means for supporting and rotating a round work piece, a grinding wheel for operation upon the latter, means mounting said supporting means a nd said grinding wheel for relative movement therebetween in a direction to effect relative traversing between the work piece and the grinding wheel and also in a direction transversely to the axis of rotation of the work piece, motive means for effecting said relative movement in said first direction in successive strokes of reciprocation, motive means for effecting said relative movement in said second direction, motive means for effecting a rapid relative separation between said grinding wheel and said work piece, a work dimension-engaging device operatively related to said work piece, means responsive to a certain gaging of said device for reducing the speed of drive from said second motive means, and means responsive to a subsequent gaging of the work by said device for stopping the drive by said first motive means and for initiating a drive by said third motive means.

4. In apparatus of the character described, in combination, means for supporting and rotating a round work piece, a grinding wheel for operation upon the latter, means mounting said supporting means and said grinding wheel for relative movement therebetween in a direction to effect relative traversing between the work piece and the grinding wheel and also in a direction transversely to the axis of rotation of the work piece, motive means for effecting said relative movement in said first direction in successive strokes of reciprocation, motive means for effecting said relative movement in said second direction, motive means for effecting a rapid relative separation between said grinding wheel and said work piece, a work dimension-gaging device operatively related to said work piece, means con-

trolled by said gaging device for controlling the drive by said second motive means, thereby to effect successive reductions by said grinding wheel in the work dimension, means responsive to a certain gaging by said device of the work piece for changing the speed of rotation of said work piece, and means responsive to a subsequent gaging by said device for halting said reciprocating drive and for initiating a drive by said third motive means.

5. In apparatus of the character described, in combination, a carriage having thereon a grinding wheel, a reciprocable table having means for rotatably supporting work in operative relation to said grinding wheel, means for rotating the work, a work dimension-gaging device, means making said device effective to gage the work dimension periodically and in a certain time relation to the reciprocation of said table, means controlled by said gaging device for effecting a feeding movement of said carriage and hence of said grinding wheel, each time that said device is made effective, whereby the dimension of the work is progressively reduced, and means controlled by said gaging device after a certain work dimension has been achieved for discontinuing grinding operation of said wheel on the work.

6. An apparatus as claimed in claim 5 in which there is means controlled by said dimension-gaging device and made effective by the latter after a certain work dimension reduction has taken place, for causing said work-rotating means to change the speed of rotation of the work.

7. An apparatus as claimed in claim 5 in which there is means controlled by said dimension-gaging device and made effective by the latter after a certain work-dimension reduction has taken place, for changing the increment of feed given said carriage and grinding wheel.

8. In apparatus of the character described, in combination, a carriage having thereon a grinding wheel, a reciprocable table having means for rotatably supporting work in operative relation to said grinding wheel, means for rotating the work, a variable condenser, means for varying the capacitance of said condenser in accordance with change in dimension of the work by said grinding wheel, means effecting feeding movement of said carriage and grinding wheel in increments appropriate to effect the desired grinding operation on the work by said wheel, means for changing the rate of rotation of the work by said work-rotating means, and means including circuit means the impedance of which is changed by said condenser for controlling said work-rotation-rate-changing means.

9. In apparatus of the character described, in combination, a carriage having thereon a grinding wheel, a reciprocable table having means for rotatably supporting work in operative relation to said grinding wheel, means for rotating the work, a variable condenser, means for varying the capacitance of said condenser in accordance with change in dimension of the work by said grinding wheel, means effecting feeding movement of said carriage and grinding wheel in increments appropriate to effect the desired grinding operation on the work by said wheel, electro-responsive means for causing said wheel carriage feeding means to effect feeding movement thereof in increments of different magnitude, electro-responsive means for causing said work-rotating means to rotate the work at a different rate, electro-responsive means for halting the grinding operation of said wheel on the work, and circuit means energized by a suitable source of current and controlled by said variable condenser for making said third electro-responsive means effective when said condenser achieves a capacitance corresponding to the desired work dimension and for making said first and second electro-responsive means effective at some time prior thereto.

10. In apparatus of the character described, in combination, a carriage having thereon a grinding wheel, a reciprocable table having means for rotatably supporting work in operative relation to said grinding wheel, means for rotating the work, a variable condenser, means for varying the capacitance of said condenser in accordance with change in dimension of the work by said grinding wheel, means effecting feeding movement of said carriage and grinding wheel in increments appropriate to effect the desired grinding operation on the work by said wheel, electro-responsive means for causing said wheel carriage feeding means to effect feeding movement thereof in increments of different magnitude, electro-responsive means for causing said work-rotating means to rotate the work at a different rate, electro-responsive means for halting the grinding operation of said wheel on the work, electronic conduction means for controlling said first and second electro-responsive means, electronic conduction means for controlling said third electro-responsive means, both of said electronic conduction means having control elements, means subjecting said control elements to the influence of said variable condenser, and means causing said third electro-responsive means to become effective when desired work dimension has been achieved.

11. In apparatus of the character described, in combination, a carriage having a grinding wheel mounted thereon, means for supporting work for operation thereon by said grinding wheel, rapid traverse means for moving said carriage toward or away from said work-supporting means, means making said traversing means effective to move said carriage toward said supporting means, a member positioned in the path of movement of said wheel as it is moved by said traversing means for making the latter ineffective at a point such that said wheel and work are brought into operative relation, means responsive to actuation of said member for partially conditioning said traversing means to move said carriage away from said supporting means, and means responsive to the completion of a certain grinding action of the wheel on the work for completing the conditioning of said traversing means and thereby make the latter effective to move said wheel away from the work.

12. In apparatus of the character described, in combination, a support for work, a support having thereon a tool for operation on said work, means movably mounting one of said supports for reciprocation relative to the other, means for reciprocating said last-named support, means operating in timed relation to the strokes of reciprocation of said last-named support for effecting feeding movement between said tool and work at certain rates, said work support being constructed to support the work rotatably, means rotating the work at certain surface speeds, means for gaging the progress of the operation of said tool on the work, and means responsive to said gaging means to control the means to rotate the work and for changing the work surface speed.

13. In apparatus of the character described,

in combination, a support for work, a support having a tool for operation on the work, means for rotating the work in said first support at a certain rate, and means responsive to the size of said work for causing said rotating means to rotate the work at a different rate.

14. In apparatus of the character described, in combination, a support for work, a support having a tool for operation on said work, means for effecting reciprocating movement between said two supports, means operating in timed relation to said reciprocating movement for effecting feeding movement between said tool and the work, and means responsive to the size of said work for changing the rate of at least one of said movements.

15. In apparatus of the character described, in combination, a support for work, a support having a tool for operation on the work, means for effecting reciprocating movement between said supports, means operating in timed relation to said reciprocating movement for effecting feeding movement between said tool and said work, work dimension-gaging means, electro-responsive means for controlling the operative relation between said gaging means and said work, a switch controlling said electro-responsive means, means operating in timed relation with said reciprocating movement for actuating said switch, and means controlled by said gaging means for controlling the operation of said tool on said work.

16. In apparatus of the character described, in combination, a support for work, motive means for rotating the work in said support, a support having a tool for operation on said work, motive means for effecting relative feeding movement between said tool and said work at a plurality of predetermined speeds, motive means for effecting relatively rapid separating movement between said tool and said work, work-dimension gaging means including a variable capacitance and an element to vary said capacitance, means to intermittently relate said element to said work to give values to said capacitance corresponding to the dimensions of said work, high frequency circuit means affected by said capacitance including a plurality of relays actuated thereby in a certain sequence corresponding to the achievement of successive values of said capacitance, and means interposed between said plurality of relays and the plurality of said motive means for the regulation of said motive means.

17. An apparatus as claimed in claim 16 in which said high frequency circuit means and said plurality of relays have interposed therebetween electronic conduction devices, each with a control element, and in which there is provided means for causing said control elements to be differently responsive to the same changes in said capacitance with the result that the standard of operation of said tool on the work is changed when the work reaches a certain predetermined dimension and the operation is stopped when the work reaches another dimension.

18. In apparatus of the character described, in combination, a support for rotatably supporting work, a support having a tool for operating on said work, motive means for rotating said work, means including a relay for causing said motive means to change the rate of rotation of the work, means including a relay for halting operation of said tool on said work, condenser-forming means operatively related to the work and having a capacitance that varies in accordance with the change in dimension of the work as produced by said tool, and circuit means operatively relating said condenser-forming means and said relays to cause the latter to be sequentially operated in the order named in accordance with two time-spaced values of capacitance achieved by said condenser-forming means as the operation of said tool on the work progresses.

19. In apparatus of the character described, in combination, a support for rotatably supporting work, a support having a tool for operation on said work, a first motor for rotating said work, a second motor for effecting feeding movement between said tool and said work, a third motor for effecting separation between said tool and said work, relay means for changing the standard of operation on one of said first two motors, relay means for making effective said third motor, and means operatively related to the work and forming an impedance variable with change in dimension of the work and operatively related to said two relay means, the latter being arranged to become effective sequentially in the order named.

20. In apparatus of the character described, in combination, a support for rotatably supporting work, a support having a tool for operation on said work, a first motor for rotating said work, a second motor for effecting feeding movement between said tool and said work, a third motor for effecting separation between said tool and said work, relay means for changing the standard of operation of one of said first two motors, relay means for making effective said third motor, both of said relay means comprising electronic conduction devices each provided with a control member, means operatively related to the work and forming an impedance variable with change in dimension of the work, and circuit means operatively relating said conduction devices and said impedance-forming means, the critical points of control action of said control members being different with respect to change in said impedance, whereby said two relays means are operated sequentially.

21. In apparatus of the character described, in combination, a support for rotatably supporting work, a support having a tool for operation on said work, a first motor for rotating said work, a second motor for effecting feeding movement between said tool and said work, a third motor for effecting separation between said tool and said work, relay means for changing the standard of operation of one of said first two motors, relay means for making effective said third motor, circuit means having connected thereto a source of high frequency energy, said circuit means having operatively related thereto a variable impedance, means causing said impedance to vary in accordance with change in dimension of the work, said relay means being responsive to effects in said circuit means resulting from change in said impedance, and means causing said second relay means to become effective at a value of impedance achieved subsequent to the achievement of such a value of said impedance as causes said first-mentioned relay means to function.

22. In apparatus of the character described, in combination, a support for rotatably supporting work, a support having a tool for operation on the work, a first motor operative upon one of said supports to move it in a direction to bring said tool and work into operative relation, a second motor for rotating said work, a third motor for effecting a feeding movement between said tool and said work, said second motor also being

operative upon said one support for moving it in a direction to separate said tool and said work, main control means movable into starting position and making effective said first, second and third motors, means responsive to the achievement of a certain operative relation between the work and tool for halting the action of said first motor, and means responsive to the achievement of a certain operation of said tool on said work for halting the action of said second and third motors and for making effective said first motor.

23. An apparatus as claimed in claim 22 in which there is provided means operative after a certain separating movement between said work and said tool has taken place for halting the action of said first motor, the two action-halting means of said first motor being interlocked so that the actuation of one conditions the other for subsequent actuation.

24. An apparatus as claimed in claim 22 provided with means responsive to a certain separating movement between said tool and work for halting the action of said first motor, there being means interconnecting said main control means, and said two action-halting means for said first motor to cause them to be successively conditioned for control in repeated cycles, each cycle in the order named.

25. In apparatus of the character described, in combination, a support for rotatably supporting work, a support having a tool for operation on the work, power-driven means operative upon one of said supports to move it in a direction to bring said tool and work into operative relation, power-driven means for rotating said work, power-driven means for effecting relative reciprocation between said supports and hence between said tool and work, power-driven means for effecting feeding movement between said tool and work, power-driven means for effecting separating movement between said tool and said work, main control means which when actuated makes effective the first, second, third and fourth of said power-driven means, means responsive to achievement of a certain operative relation between said tool and work by said first power-driven means for making the latter ineffective, means operatively related to the work and responding to change in condition thereof as caused by said tool, and means controlled by said last-mentioned means and in response to a certain condition of the work for halting the action of said second, third and fourth power-driven means and for initiating actuation of said fifth power-driven means.

26. In apparatus of the character described, in combination, a support for rotatably supporting work, a support having a tool for operation on the work, power-driven means operative upon one if said supports to move it in a direction to bring said tool and work into operative relation, power-driven means for rotating said work, power-driven means for effecting relative reciprocation between said supports and hence between said tool and work, power-driven means for effecting feeding movement between said tool and work, power-driven means for effecting separating movement between said tool and said work, main control means which when actuated makes effective the first, second, third and fourth of said power-driven means, means responsive to achievement of a certain operative relation between said tool and work by said first power-driven means for making the latter ineffective, means operatively related to the work and responding to change in condition thereof as caused by said tool, means controlled by said last-mentioned means and responsive to one condition of the work for changing the standard of operation of one of said still-effective power-driven means, and means controlled by said condition-responsive means in accordance with the achievement of a subsequent condition of the work for halting the actuation of all of said still-effective power-driven means and for initiating actuation of said fifth power-driven means.

27. In apparatus of the class described, in combination, a support for rotatably supporting work, a support having a tool for operating on said work, means mounting one of said supports for movement relative to the other, means for causing relative reciprocation, relative feed movement, and relative cutting movement between said work and said tool, gage control means to determine the condition of said work and for causing changes in the rates of said reciprocation, feed and cutting when said work reaches a certain intermediate stage prior to the completed operation of said tool.

28. In control apparatus for an automatic grinding machine, having a fixed support and a movable support, one of which carries a work piece and the other of which carries a grinding wheel, wherein the movable support is rapidly moved from a rest position to a point where said wheel and said work piece approximately contact each other, is then fed slowly during the grinding operation, and is then returned to the rest position, the combination of, a feeler member mounted upon the support carrying said work piece and adapted to contact the grinding wheel when the grinding wheel and work piece approximately contact each other, a gaging means intermittently engaging said work piece, and means responsive to said feeler means and said gaging means for controlling the movement of said movable support.

29. In control apparatus for an automatic grinding machine, having a fixed support and a movable support, one of which carries a work piece and the other of which carries a grinding wheel, wherein the movable support is rapidly moved from a rest position to a point where said wheel and said work piece approximately contact each other, is then fed slowly during the grinding operation, and is then returned to the rest position, the combination of, a feeler member mounted upon the support carrying said work piece and in the path of movement of said grinding wheel contact the grinding surface of said grinding wheel when the grinding surface arrives in grinding position with respect to the work, and means responsive to said feeler for stopping movement of said movable support.

30. In control apparatus for an automatic grinding machine, having a fixed support and a movable support, one of which carries a work piece and the other of which carries a grinding wheel, wherein the movable support is rapidly moved from a rest position to a point where said wheel and said work piece approximately contact each other, is then fed slowly during the grinding operation, and is then returned to the rest position, the combination of, a feeler member mounted upon the support carrying said work piece and adapted to contact the grinding wheel when the grinding wheel and work piece approximately contact each other, a gaging means

intermittently engaging said work piece, means responsive to said feeler for stopping movement of said movable support, and means responsive to said gaging means for controlling the grinding operation and the return of said movable support to said rest position.

31. In apparatus of the class described, a movable support and a fixed support, a work piece carried by one of said supports and a grinding wheel carried by the other of said supports, means to move said movable support from and to the rest position and to and from the position of contact between said grinding wheel and said work piece, a feeler mounted adjacent said work piece so as to be actuated when said wheel and work piece are approximately in contact with each other, gaging means to intermittently engage said work piece during the grinding operation, and control means which disengages said means for moving said movable support upon actuation of said feeler means and which controls the grinding operation in response to the achievement of certain grinding conditions as indicated by said gaging means.

32. In apparatus of the class described, in combination, a support for work, motive means for rotating the work, a support having a tool for operation on said work, motive means for effecting relative movement between said tool and said work to bring said tool and said work into engagement with each other, a feeler means which is operated by relative movement between said work and said tool to detect the approach of said work and said tool to working engagement, a control mechanism operated by said feeler means, said mechanism controlling said motive means to stop said relative movement when said tool and said work arrive at said working engagement, motive means for effecting relative feeding movement between said tool and said work, work dimension-gaging means including an impedance operatively related to said work and variable depending upon the dimension of said work, an electrical circuit including said impedance and a plurality of relays which are actuated in a certain sequence as said impedance changes due to the change in dimension of said work by said tool, and control means responsive to said relays exerting control upon said motive means.

33. In apparatus of the class described, in combination, a support for work, motive means for rotating the work, a support having a tool for operation on said work, motive means for effecting relative movement between said tool and said work to bring said tool and said work into and out of engagement with each other, a feeler means which is operated by relative movement between said work and said tool to detect the approach of said work and said tool to working engagement, a control mechanism operated by said feeler means, said mechanism controliing said motive means to stop said relative movement when said tool and said work arrive at said working engagement, motive means for effecting relative feeding movement between said tool and said work, work dimension-gaging means including an impedance operatively related to said work and variable depending upon the dimension of said work, an electrical circuit including said impedance and a plurality of relays which are actuated in a certain sequence as said impedance changes due to the change in dimension of said work by said tool, and control means responsive to said relays exerting control upon said motive means.

34. In apparatus of the character described, in combination, a support for work, a support having a tool for operation on the work, means for effecting reciprocating movement between said supports, means for effecting feeding movement between said tool and said work at time intervals, work dimension-gaging means, electro-responsive means for controlling the operative relation between said gaging means and said work, a switch controlling said electro-responsive means, means associated with said reciprocating means for actuating said switch, said last-mentioned means being operable during the operation of said feeding means, and means controlled by said gaging means for controlling the operation of said tool and said work.

35. In apparatus for use with a reciprocating material processing machine, gaging means including a gaging member mounted upon a rockable arm, solenoid and spring means operative by means causing reciprocation movement between the tool and the work to move said gaging member to and from gaging position, and electrical control apparatus associated with said gaging means which exerts control depending upon the limit of movement of said gaging means as determined by said gaging member.

36. In apparatus of the class described wherein a predetermined cycle of processing work by a tool is carried on, the combination of, a work support, a tool support, a tool mounted upon said tool support, motive means for effecting a feeding movement between said tool and the work, a condenser means, gaging means associated with said condenser means effective to give said condenser means a capacity dependent upon the size of the work, electrical means associated with said condenser means including a first relay and a second relay, means associated with said first relay to change the rate of said feed, and means associated with said second relay to move said tool and the work out of working relationship, said first and second relays being such that they become effective sequentially upon the attainment of certain sizes of the work as indicated by the capacity of said condenser means.

37. In apparatus of the class described wherein a predetermined cycle of processing work by a tool is carried on, the combination of, a work support for movably supporting work, a tool support, a tool movably supported by said tool support, positioning means to move one of said supports relative to the other to bring said tool and said work into working relationship, motive means for causing relative movement between the working surface of said tool and the working surface of the work so as to maintain a predetermined rate of relative movement therebetween, said motive means including power-driven means for rotating the work and power-driven means for effecting relative reciprocation between said tool and the work, condition-responsive means intermittently operative by said relative reciprocation to determine the condition of the work, and cyclic control means responsive to the condition of said work as determined by said condition-responsive means to modify the action of said motive means to cause the relative movement between the working surfaces of said tool and the work to be less than said predetermined rate and later to disrupt said operative relationship between said tool and the work.

38. In apparatus of the class described, in combination, a first support, a second support mounted to have relative movement with respect to said first support, means to receive a work piece car-

ried by one of said supports, a tool means for operation on the work piece carried by the other of said supports, a motor for moving said second support relative to said first support to bring the engaging surfaces of said tool means and the work piece into or out of operative relation, feeler means mounted upon one of said supports in the path of movement of the engaging surface of the means carried by the movable support to detect the achievement of said operative relation, and means controlled by said feeler means for halting movement of said movable support by said motor when said operative relation is achieved, and means responsive to the achievement of a certain action of said tool means on the work piece for effecting movement of said support by said motor in a direction to disrupt said operative relation between said tool means and the work piece.

39. In apparatus of the class described, in combination, a first support, a second support mounted to have relative movement with respect of said first support, means to receive a work piece carried by one of said supports, a tool means for operation on the work piece carried by the other of said supports, a first motor for moving said second support relative to said first support to bring the engaging surfaces of said tool means and the work piece into operative relation, a second motor to impart feeding movement to said movable support, a sequential control means for said motors, a feeler positioned adjacent the work piece to contact the engaging surface of said tool means and cause said control means to stop said first motor when said operative relation is achieved, and a condition-responsive means to determine the progress of the operation of said tool means on the work piece and to cause said control means to stop said second motor when a certain predetermined condition of the work piece exists.

40. In apparatus of the class described, in combination, a first support, a second support mounted to have relative movement with respect to said first support, means to receive a work piece carried by one of said supports, a tool means for operation on the work piece carried by the other of said supports, a first motor for moving said second support relative to said first support to bring the engaging surfaces of said tool means and the work piece into or out of operative relation, feeler means mounted upon one of said supports in the path of movement of the engaging surface of the means carried by said second support to detect the achievement of said operative relation, and means controlled by said feeler means for halting movement of said second support by said motor when said operative relation is achieved, a second motor for causing feeding movement between said tool means and the work piece, and sequential control means including a means responsive to the achievement of a certain action of said tool means on the work piece for stopping said second motor and causing said first motor to move said second support in a direction to disrupt said operative relation.

41. In apparatus of the class described, in combination, a first support, a second support mounted to have relative movement with respect to said first support, means to receive a work piece carried by one of said supports, a tool means for operation on the work piece carried by the other of said supports, a first motor for moving said second support relative to said first support to bring the engaging surfaces of said tool means and the work piece into or out of operative relation, feeler means mounted upon one of said supports in the path of movement of the engaging surface of the means carried by said second support to detect the achievement of said operative relation, and means controlled by said feeler means for halting movement of said second support by said motor when said operative relation is achieved, a second motor for causing feeding movement between said tool means and the work piece, and sequential control means including a means responsive to the achievement of a certain action of said tool means on the work piece for changing the rate of feeding movement caused by said second motor and for stopping said second motor and causing said first motor to move said second support in a direction to disrupt said operative relation.

42. In apparatus of the class described, in combination, a first support, a second support mounted to have relative movement with respect of said first support, means to receive a work piece carried by one of said supports, a tool means for operation on the work piece carried by the other of said supports, a first motor for moving said second support relative to said first support to bring the engaging surfaces of said tool means and the work piece into operative relation, a second motor to rotate the work piece at certain rates, a sequential control means for said motors, a feeler positioned adjacent the work piece to contact the engaging surface of the tool means and operative to cause said control means to stop said first motor when said operative relation is achieved, and a condition-responsive means to determine the progress of the operation of said tool means on the work piece and operative to cause said control means to change the rate of rotation of the work piece and later stop said second motor when certain predetermined conditions of the work piece exist.

43. In apparatus of the class described, in combination, a first support, a second support mounted to have relative movement with respect of said first support, means to receive a work piece carried by one of said supports, a tool means for operation on the work piece carried by the other of said supports, a first motor for moving said second support to and from a position wherein the engaging surfaces of said tool means and the work piece are in operative relation, a second motor to rotate the work piece at certain rates, a sequential control means for said motors, a feeler positioned adjacent the work piece to contact the engaging surface of the tool means and operative to cause said control means to stop said first motor when said operative relation is achieved, and a condition-responsive means to determine the progress of the operation of said tool means on the work piece and operative to cause said control means to change the rate of rotation of the work piece, and later stop said second motor and start said first motor to move said second support and disrupt said operative relation, when certain predetermined conditions of the work piece exist.

44. In apparatus of the class described, in combination, a first support, a second support mounted to have relative movement with respect of said first support, means to receive a work piece carried by one of said supports, a tool means for operation on the work piece carried by the other of said supports, a first motor for moving said second support to and from a position wherein the engaging surfaces of said tool means and

the work piece are in operative relation, a second motor to rotate the work piece at certain rates, a third motor for causing feeding movement between said tool means and the work piece, a sequential control means for said motors, a feeler positioned adjacent the work piece to contact the engaging surface of the tool means and operative to cause said control means to stop said first motor when said operative relation is achieved, and a condition-responsive means to determine the progress of the operation of said tool means on the work piece and operative to cause said control means to change the rate of rotation of the work piece, and later stop said second and third motors and start said first motor to move said second support and disrupt said operative relation, when certain predetermined conditions of the work piece exist.

45. In apparatus of the class described, in combination, a support for rotatably supporting work, a support having a tool for operating on said work, means mounting one of said supports for movement relative to the other, means for causing reciprocation between said work and said tool and for causing relative cutting movement between said work and said tool, condition-responsive means for determining the progress of the operation of said tool on said work, and means controlled by said condition-responsive means for changing the speed of said reciprocation and said cutting movement when said condition-responsive means indicates that said work has reached a certain intermediate stage prior to the completed operation by said tool upon said work.

46. A mechanism for use upon a work processing machine to contact the tool when the tool and work are moved into working engagement comprising, a feeler arm rockably mounted with the work, a switch bracket mounted to be rocked by said feeler arm, a pair of switches mounted to be operated by movement of said switch bracket, said feeler arm being biased to a first position wherein a contacting point thereon is positioned adjacent the work to contact the tool as the tool and work are moved into working engagement, and electrical means controlled by one of said switches to hold said feeler arm in a second position out of contact with the tool.

47. In apparatus of the character described, in combination, a support for work, a tool for operation on said work, a support for said tool, motive means for causing certain predetermined rates of relative movement between the working surface of said tool and the work, work dimension gaging means including a variable capacitance and an element adapted to vary said capacitance, means to intermittently relate said element to said work to give values to said capacitance corresponding to the dimensions of said work, high frequency circuit means affected by said capacitance including a plurality of relays actuated thereby in a certain sequence corresponding to the achievement of certain predetermined successive values of said capacitance and means interposed between said plurality of relays and said motive means for regulating said motive means.

CARLTON EUGENE BROWN.

CERTIFICATE OF CORRECTION.

Patent No. 2,141,853. December 27, 1938.

CARLTON EUGENE BROWN.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, first column, line 37, strike out the word "then"; page 8, first column, line 8, for "cam 156" read cam 256; page 9, second column, line 1, for the word "substantial" read suitable; page 10, first column, line 3, for "is" read are; page 11, second column, line 38, before "tilt" insert would; page 16, first column, line 50, for "the" read this; page 20, first column, line 53, for the reference numeral "573" read 575; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 18th day of July, A. D. 1939.

Henry Van Arsdale,
Acting Commissioner of Patents.

(Seal)