Sept. 7, 1948. S. E. SCHROEDER 2,448,551

GRINDING MACHINE

Filed May 12, 1944 10 Sheets-Sheet 1

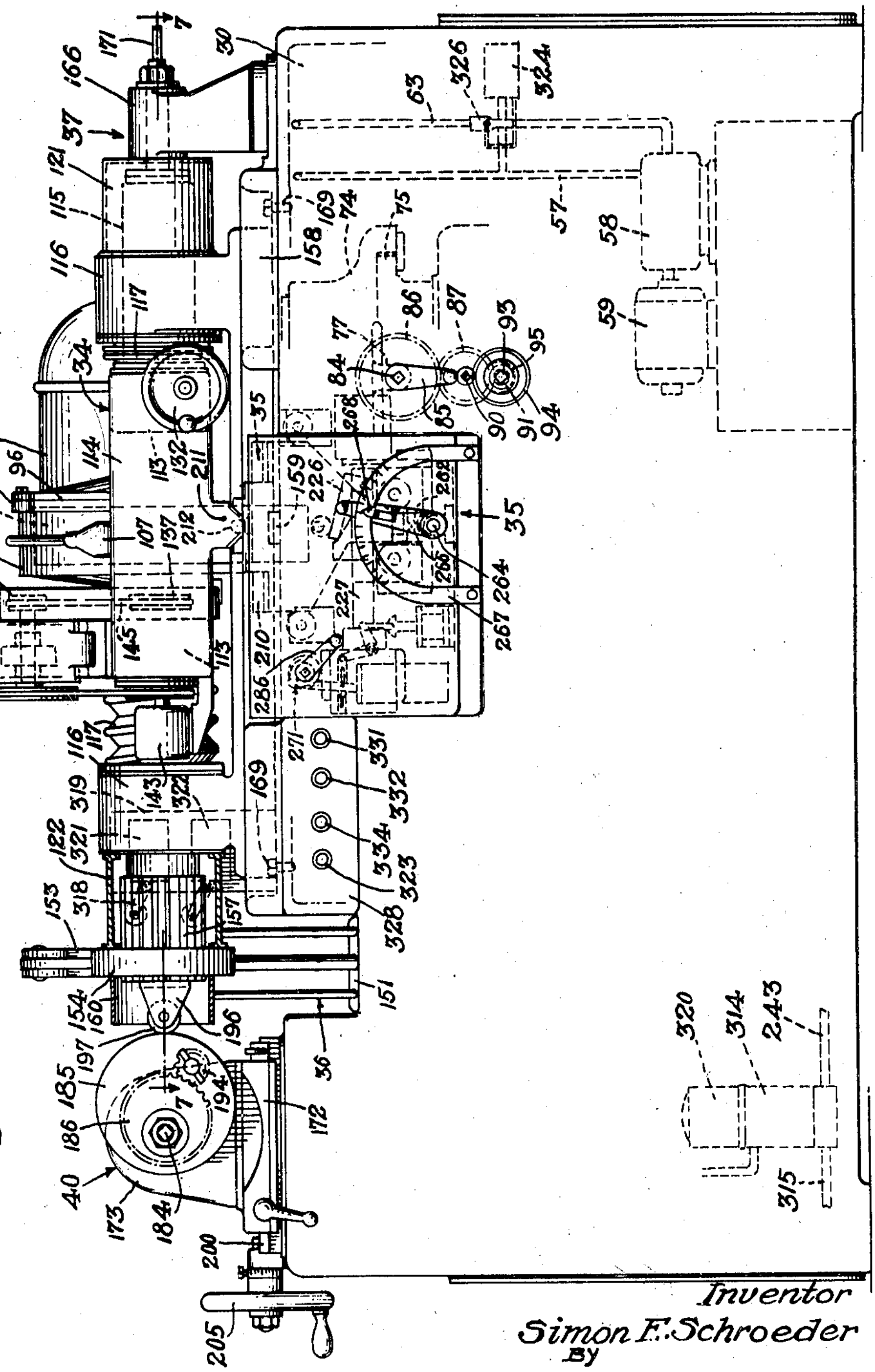

Fig. 1.

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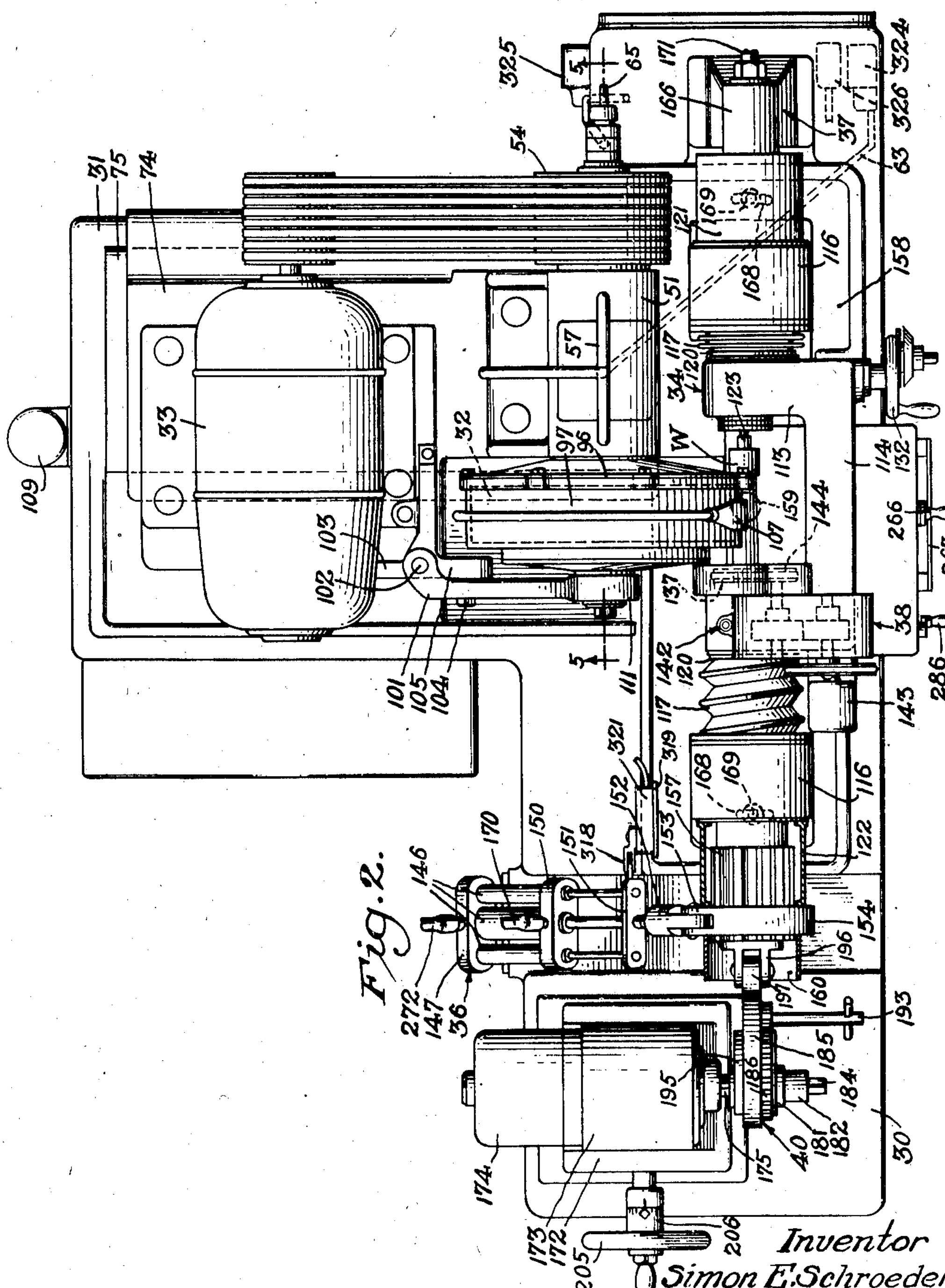

Fig. 2.

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GRINDING MACHINE

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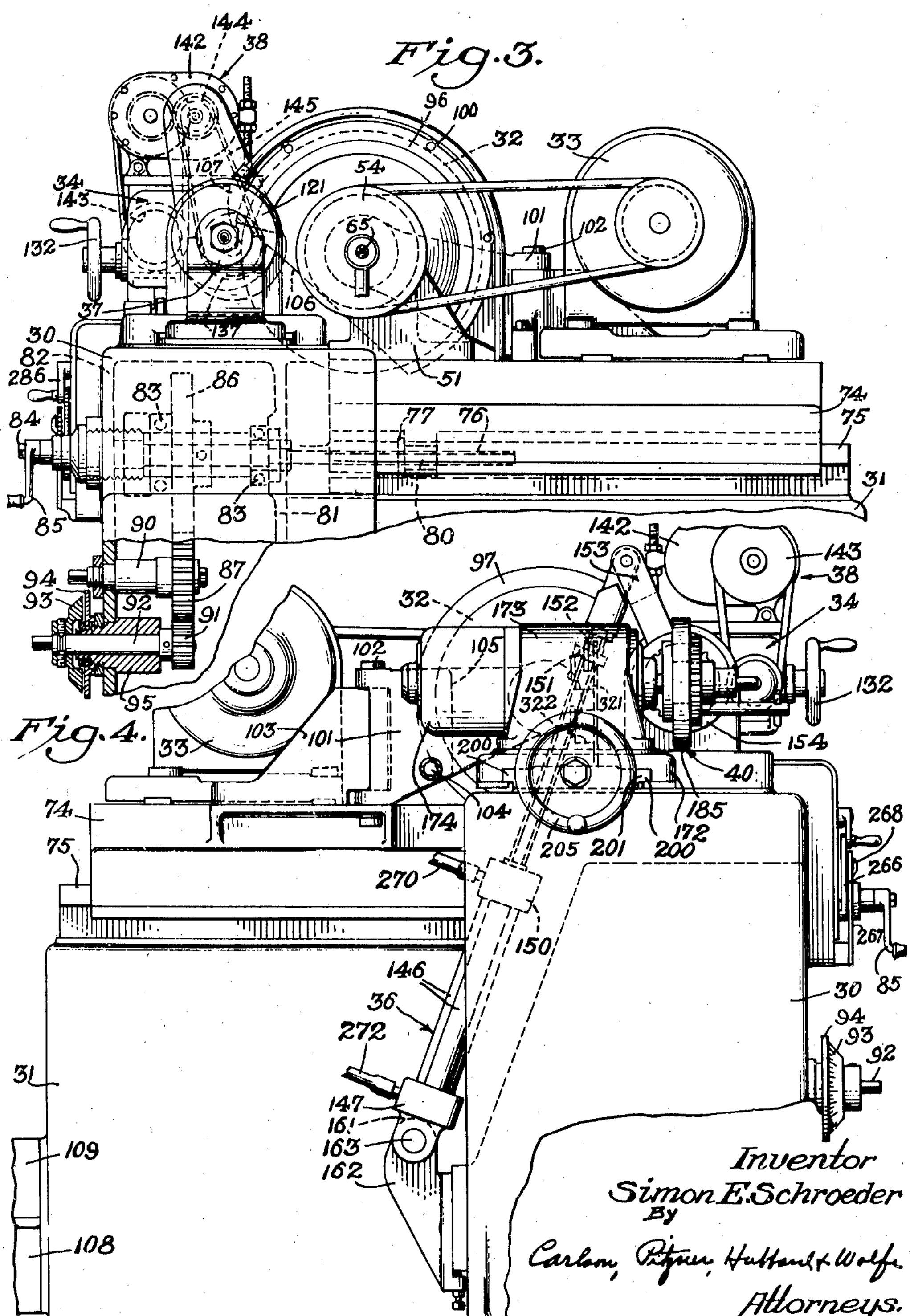

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GRINDING MACHINE

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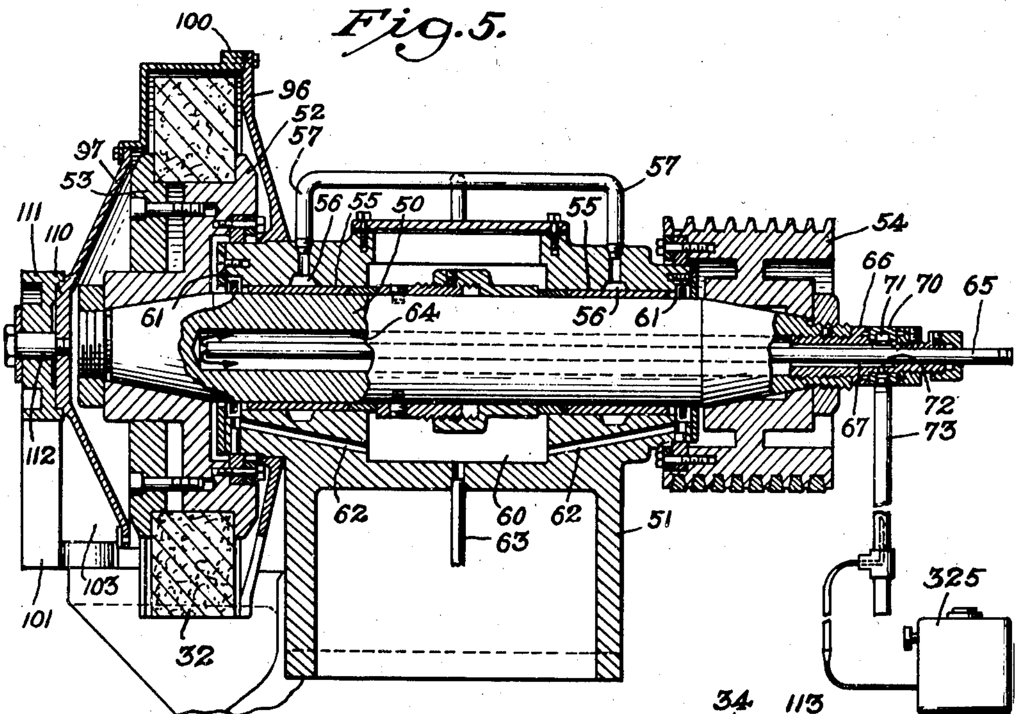
Fig. 5.



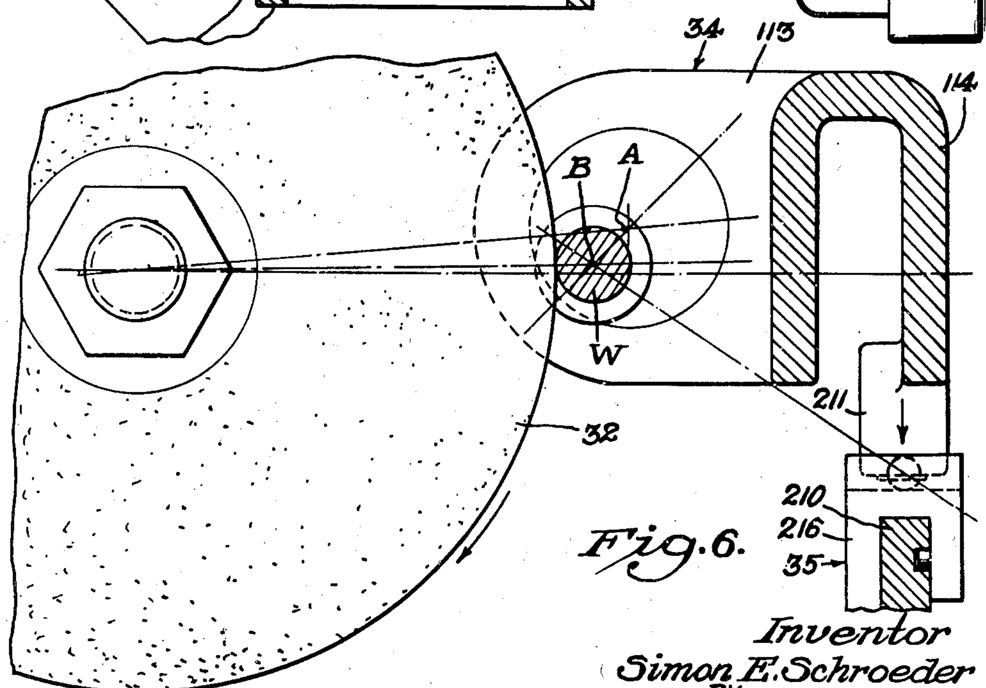


Fig. 6.

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GRINDING MACHINE

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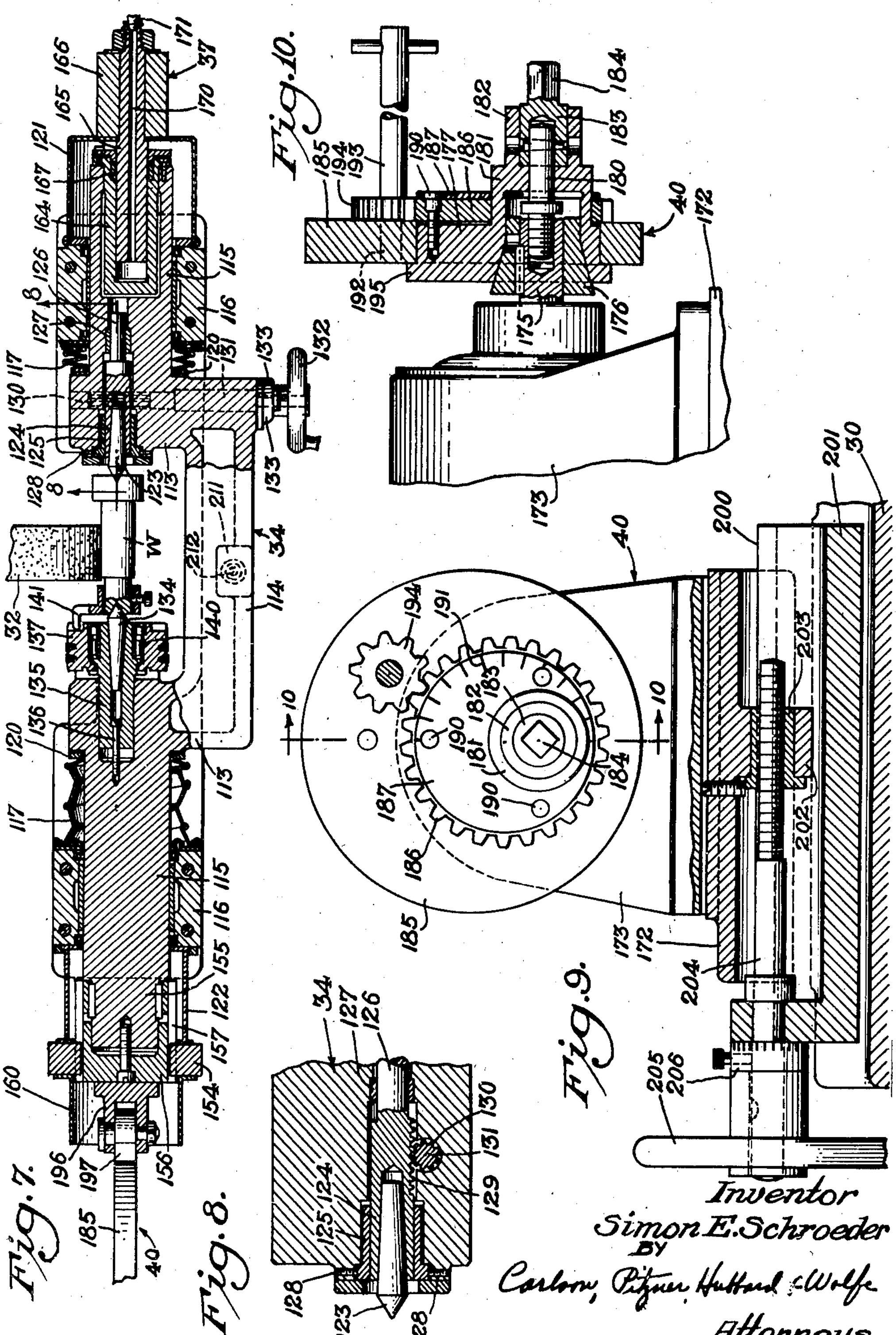

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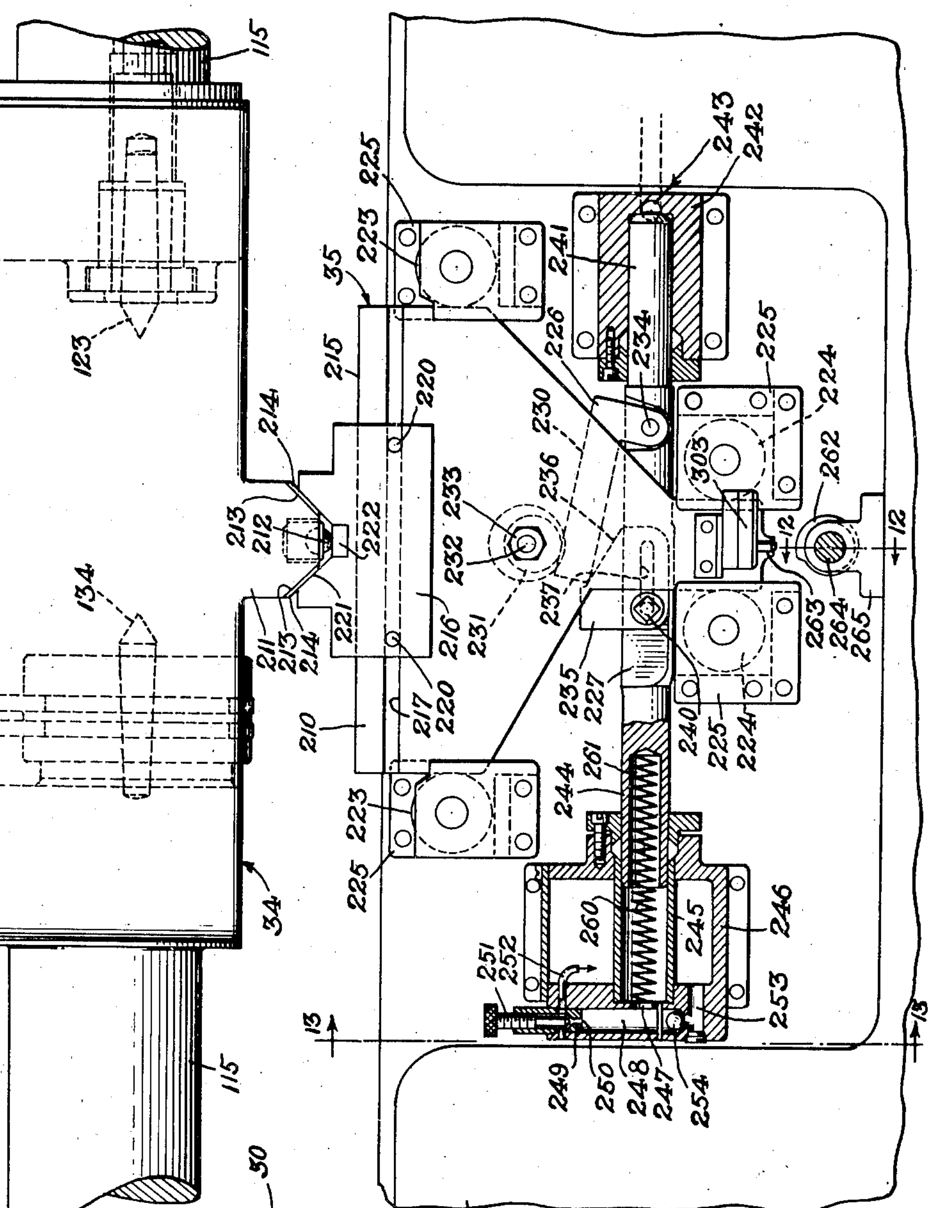

Fig. 11.

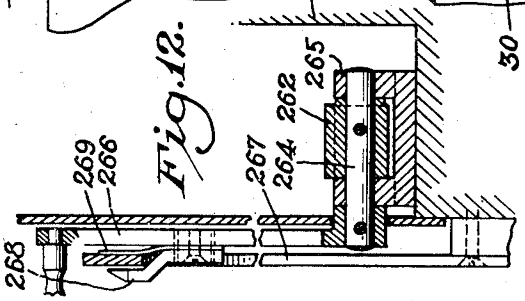

Fig. 12.

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GRINDING MACHINE

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Fig. 13.

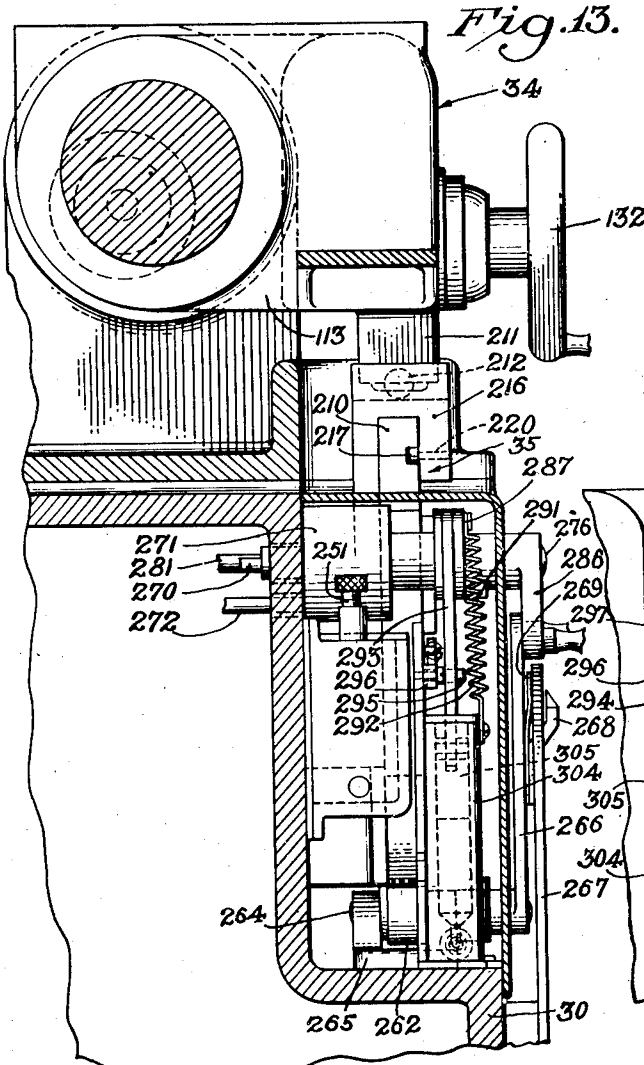

Fig. 14.

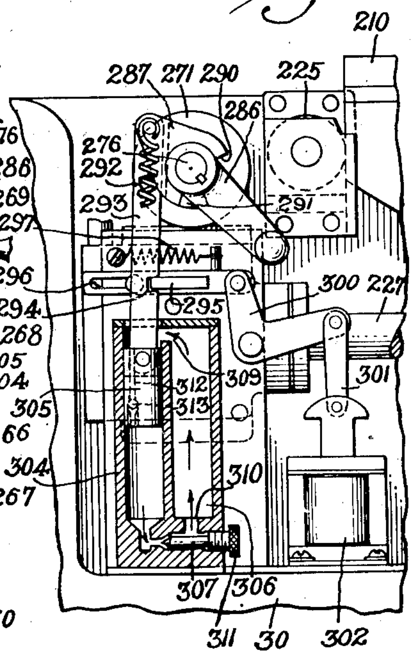

Fig. 15.

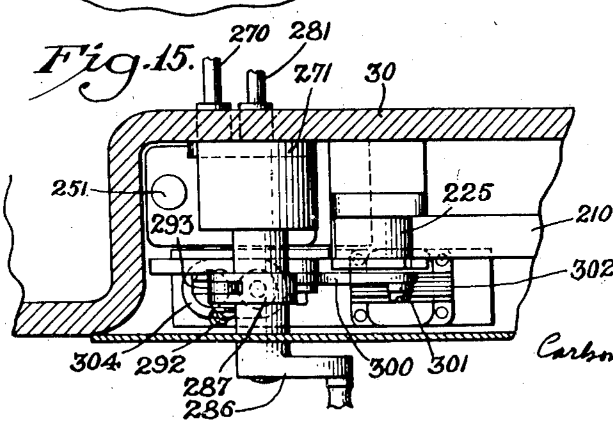

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Fig. 16.

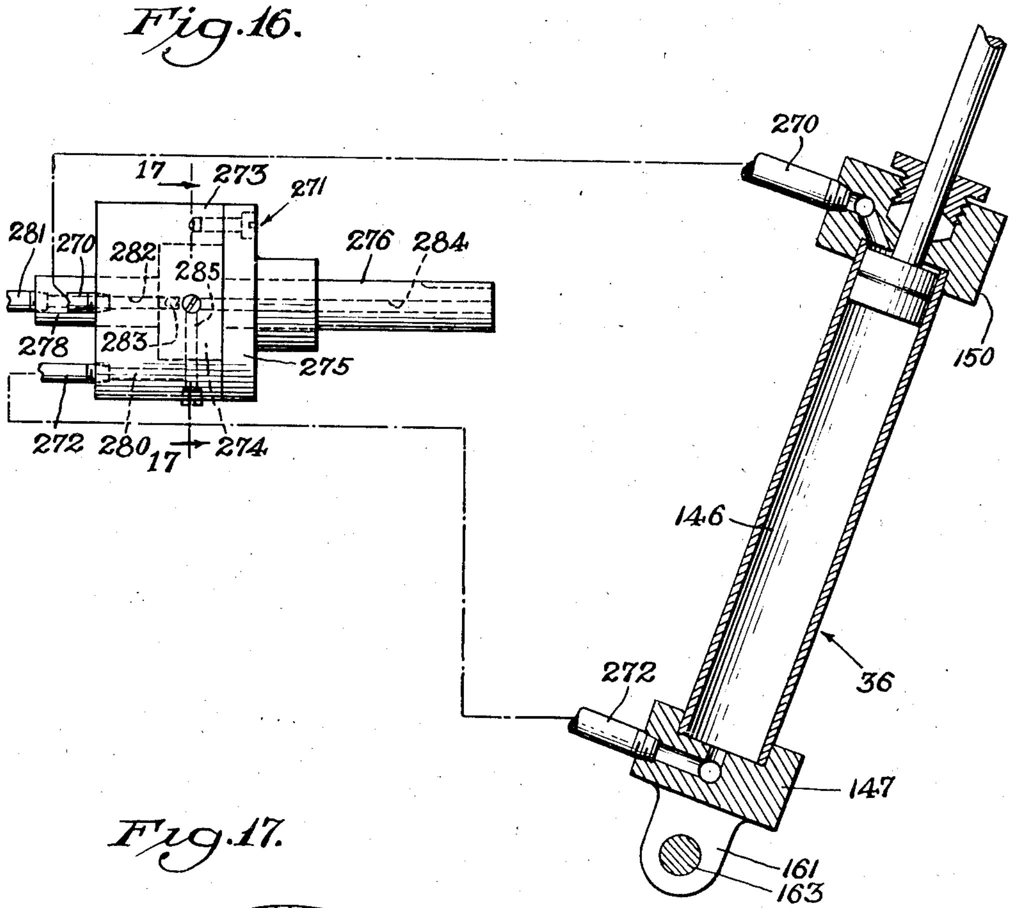
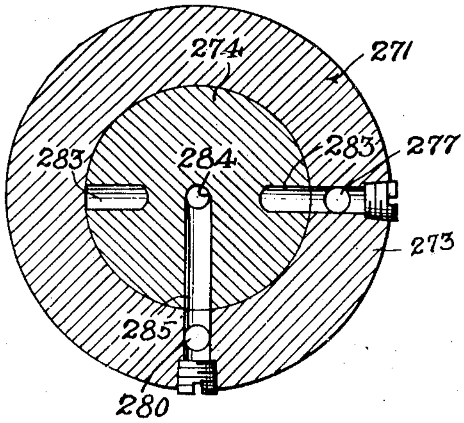


Fig. 17.



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GRINDING MACHINE

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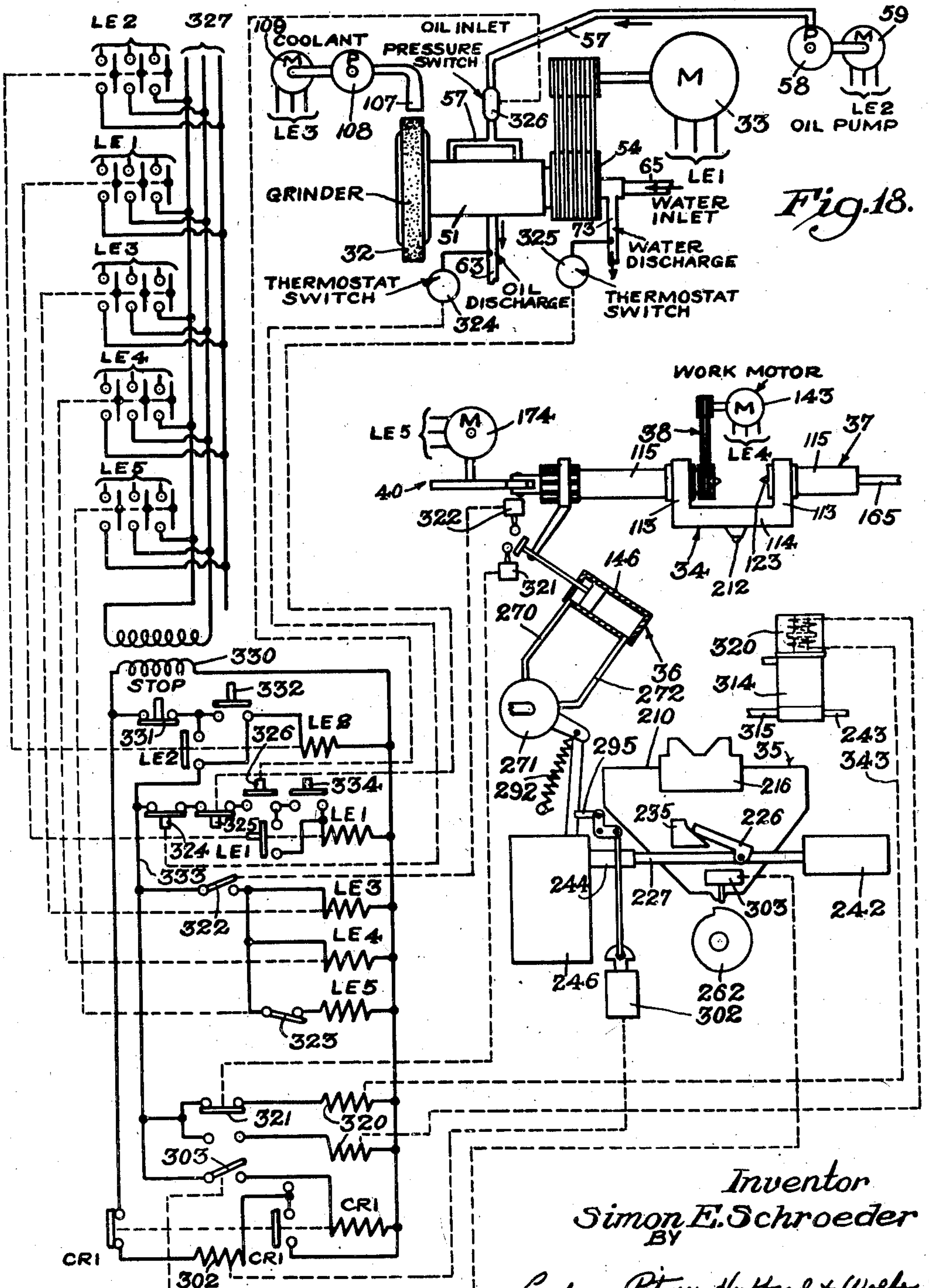

Fig. 18.

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GRINDING MACHINE

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Fig. 19.

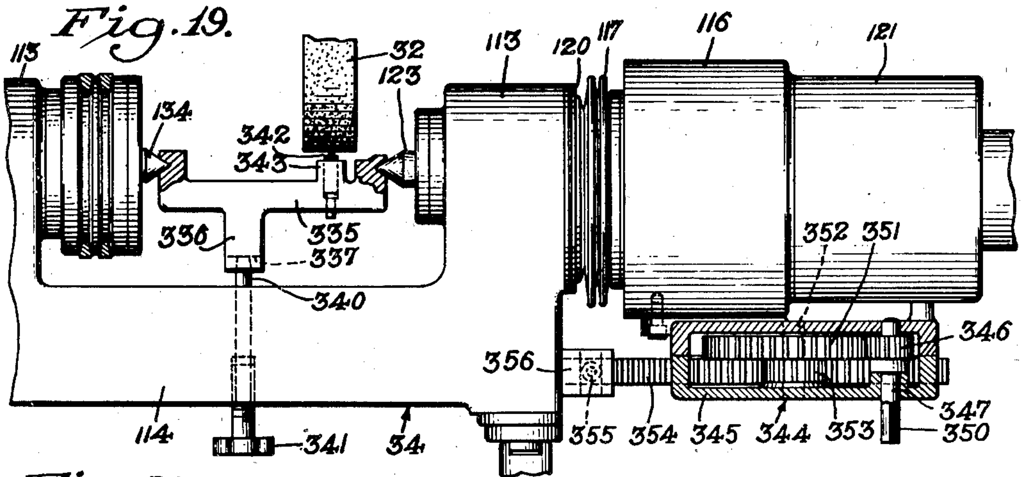


Fig. 20.

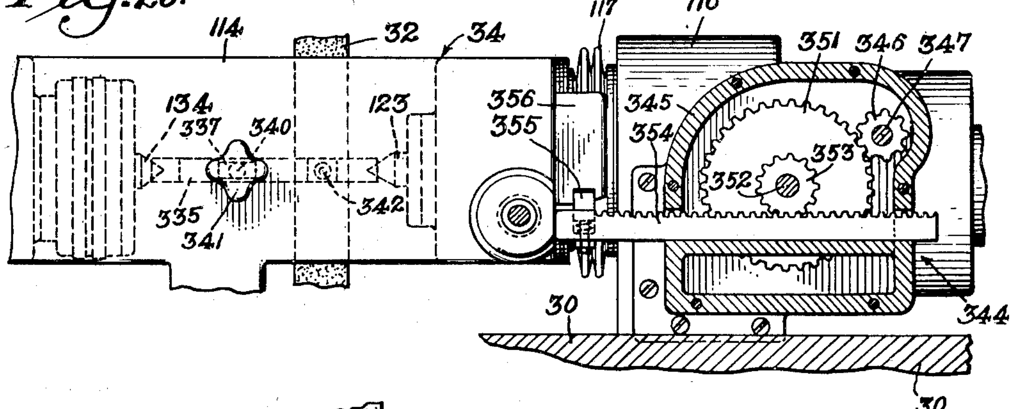


Fig. 21.

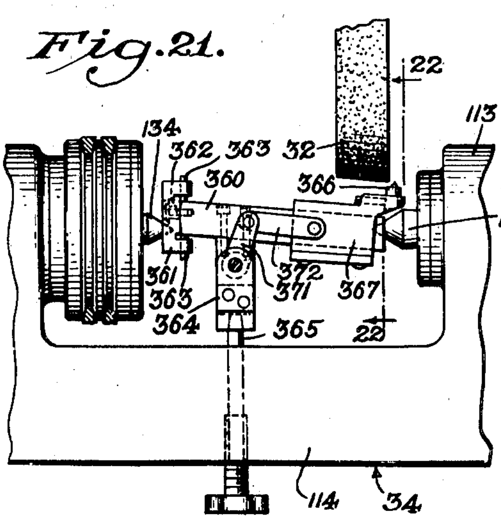
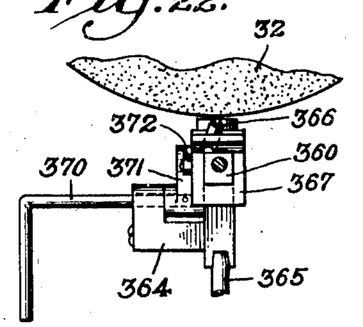


Fig. 22.



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UNITED STATES PATENT OFFICE

2,448,551

GRINDING MACHINE

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Application May 12, 1944, Serial No. 535,339

58 Claims. (Cl. 51—95)

1

The invention relates generally to grinding machines and more particularly to a machine for grinding cylindrical surfaces.

The general object of the invention is to provide a novel grinding machine for grinding cylindrical or tapered surfaces, which is capable of grinding such surfaces to very close limits.

Another object of the invention is to provide a grinding machine in which the relative feeding movement between the work and the grinding wheel is controlled by a means movable through a large distance relative to the actual feeding movement, thereby permitting very accurate control of the feeding movement.

It is also an object to provide a novel grinding machine which is automatic to the extent that when a workpiece is placed in the machine and the machine is manually started, the machine will automatically continue the operation and stop when the grinding operation has been completed and the work moved to a position convenient for removal.

Still another object is to provide a grinding machine for grinding peripheral surfaces of workpieces in which the rate of relative feed between the work and the grinding wheel gradually decreases as the work approaches its final dimension.

A still further object is to provide a grinding machine for grinding peripheral surfaces of workpieces, in which the work is swung from a loading position to a grinding position and in which the feeding movement of the work toward the grinding wheel constitutes a continuation of such swinging movement.

Another object is to provide a grinding machine for grinding peripheral work surfaces in which the relative feeding movement between the work and the grinding wheel is accomplished by a swinging movement of the work, and in which the work is reciprocated parallel to the axis of the grinding wheel during such feeding movement in the same bearings that support the work for the swinging movement.

A still further object is to provide a grinding machine in which the grinding wheel spindle must be operating properly, that is, without overheating, the machine being automatically shut down in case such overheating occurs.

Still another object is to provide a grinding machine for grinding peripheral surfaces of workpieces, which is provided with means and mechanisms for accomplishing various movements of the parts of the machine including swinging of the work to the grinding position,

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thereafter feeding the work toward the grinding wheel by a continuation of such swinging movement, reciprocating the work in a line substantially parallel to the axis of the grinding wheel and rotatably driving the work, during the entire grinding operation, and swinging the work out of grinding position with simultaneous cessation of the reciprocation and the rotary work drive.

It is also an object to provide a novel grinding machine of the general character set forth in the preceding object, which is fully adjustable in all of its principal parts so that a wide variety of sizes and kinds of workpieces may be ground in the machine.

A still further object is to provide a novel grinding machine normally used for cylindrical grinding but also adaptable for grinding tapers by means of a plunge cut.

Other objects and advantages will become apparent from the following description, taken in connection with the accompanying drawings in which:

Figure 1 is a front elevational view of a machine embodying the features of the invention.

Fig. 2 is a plan view of the machine.

Fig. 3 is a fragmentary elevational view of the right end of the machine.

Fig. 4 is a fragmentary elevational view of the left end of the machine.

Fig. 5 is a fragmentary sectional view taken on the line 5—5 of Fig. 2.

Fig. 6 is a diagrammatic view showing the relation between the grinding wheel and the work supporting means.

Fig. 7 is a fragmentary sectional view taken on the line 7—7 of Fig. 1.

Fig. 8 is an enlarged fragmentary sectional view taken on the line 8—8 of Fig. 7.

Fig. 9 is a fragmentary front elevational view, partially in section, of the left-hand portion of the machine.

Fig. 10 is a fragmentary vertical sectional view taken on the line 10—10 of Fig. 9.

Fig. 11 is an enlarged fragmentary front elevational view, partially in section, of the central portion of the machine.

Fig. 12 is a vertical sectional view taken on the line 12—12 of Fig. 11.

Fig. 13 is a vertical sectional view taken substantially on the line 13—13 of Fig. 11.

Fig. 14 is a fragmentary front elevational view of the structure shown in Fig. 13.

Fig. 15 is a plan view of the structure shown in Fig. 14.

Fig. 16 is a diagrammatic view showing the actuator and control valve for the work supporting means.

Fig. 17 is a sectional view of the valve taken on the line 17—17 of Fig. 16.

Fig. 18 is a diagrammatic view showing the electrical and pressure fluid circuits of the machine.

Fig. 19 is a plan view, partially in section, showing a wheel dressing device for dressing the grinding wheel for cylindrical grinding.

Fig. 20 is a front elevational view partially in section showing the dressing device illustrated in Fig. 19.

Fig. 21 is a plan view of a wheel dressing device for dressing a grinding wheel for taper grinding.

Fig. 22 is a sectional view taken on the line 22—22 of Fig. 21.

While the invention is susceptible of various modifications and alternative constructions, I have shown in the drawings and will herein describe in detail, the preferred embodiment, but it is to be understood that I do not thereby intend to limit the invention to the specific form disclosed, but intend to cover all modifications and alternative constructions falling within the spirit and scope of the invention as expressed in the appended claims.

General description of the machine

A machine embodying the features of the invention comprises generally a base on which is mounted a grinding wheel and means for supporting a workpiece. The work supporting means preferably comprises a yoke swingable about an axis substantially parallel to the grinding wheel axis and arranged to support a workpiece on an axis which is also parallel to the grinding wheel axis but is eccentric to the axis of swinging of the yoke. Swinging movement of the yoke is controlled by a feed mechanism which acts on the yoke at a relatively great distance from the swinging axis, while the work is a relatively short distance from such swinging axis. Moreover, the work is so positioned that when it is moving toward the grinding wheel during the grinding operation, it moves at an angle to the peripheral surface of the wheel. Thus, because of such angular movement and the difference in the above-mentioned distances, movement of the feeding means may be through a relatively great distance to produce a minute feed of the workpiece. Accurate control of the feeding of the workpiece is therefore readily attained.

During the grinding operation, the work is rotatably driven and also reciprocated axially, such reciprocation being held accurately in line with the axis of swinging movement by virtue of the fact that the yoke is both reciprocated and swung in the same bearings. If the reciprocation were slightly out of line with the axis of swinging, as might readily occur in the case where ways were provided for such reciprocation separate from the bearings for the swinging movement, such misalinement would cause the work to be ground on a slight taper. The difficulties involved in alining such ways with the axis of swinging are readily apparent and are completely eliminated by the present structure which utilizes the same bearings for both movements. Moreover, these bearings are turned, instead of being in the form of flat ways, and consequently may be much more easily machined to the desired accuracy.

The feeding mechanism which controls the swinging movement of the work supporting yoke during the grinding operation is constructed to impart a decreasing rate of feed to the yoke. Thus as the work approaches its final ground diameter, such decrease in feed rate tends to produce greater accuracy in the final ground dimension. The reciprocation is constant during the entire grinding operation so that with a decreasing feed rate, the number of reciprocations per unit depth of feed increases, which results in a uniform diameter throughout the length of the ground portion of the work.

The various movements of the machine are coordinated by a control means which permits the machine to operate as an automatic machine to the extent that when a workpiece is put into the machine and initial movement instituted, the machine auomatically carries through its operations to the point where the workpiece is ready to be removed and a new one inserted. With such automatic operation, interlocks between the various parts of the machine are provided so that the various steps will take place only in their proper sequence. Furthermore, in order to insure accuracy of grinding, the grinding wheel spindle and its support are so constructed that no distortion thereof will occur by overheating, and should any overheating occur, the machine will automatically stop.

As shown in the drawings, the machine comprises a base 30 which is elongated from left to right and is of generally L-shape (see Fig. 2) to provide a rearwardly extending portion 31 at the right side of the machine. On the rearwardly extending portion 31 is mounted a grinding wheel 32 which is driven by an electric motor 33.

Supported on the front portion of the base 30 is a work supporting yoke indicated generally at 34 (see Figs. 1, 2, and 7). The yoke 34 comprises a central U-shaped portion between the arms of which is supported a workpiece. At the ends of the arms of the U are alined bearing portions extending outwardly therefrom on an axis which parallels the front of the machine and is substantially parallel to the grinding wheel axis. The work supporting means in the arms of the U-shaped portion of the yoke hold the workpiece on an axis eccentric to the axis of swinging of the yoke and in such position that as the yoke is swung, the workpiece is moved toward the grinding wheel 32.

The swinging movement of the yoke may be said to be divided into two portions, namely, a swinging movement through a relatively wide angle to move the yoke from a work loading position to a grinding position, and then through a very much smaller angle to feed the work toward the grinding wheel. Preferably when the yoke is in work loading position, the arms of the U extend generally upwardly so that access to the space therebetween may be readily obtained at the front of the machine. To move the work into grinding position the yoke is preferably swung forwardly so that the arms of the yoke extend horizontally forward during the grinding operation and the yoke thus provides a protecting guard about the work at such time.

The workpieces are rotated during the grinding operation. To this end a work driving means, indicated generally at 38 (see Figs. 1 and 2), is mounted on one of the arms of the yoke 34 and has a driving connection with a portion of the work supporting means so as to rotatably drive the work during the grinding operation.

During the part of the swinging movement of the yoke which is utilized for grinding, the yoke is under the control of a feed mechanism, indicated generally at 35 (see Figs. 1 and 11), which is located at the front of the machine centrally thereof. The feed mechanism acts as a control means for the swinging movement of the yoke, while the actual swinging of the yoke is effected by a means, indicated at 36, located at the back of the machine adjacent the left-hand end of the yoke (see Figs. 2, 4, and 16). The yoke swinging means 36 thus swings the yoke between the work loading position and the grinding position and also during the feed for the grinding operation. However, the swinging movement during the grinding operation is controlled by the feed mechanism 35.

The yoke 34 is also reciprocated during the grinding operation. Such reciprocation, since the work is gradually fed toward the grinding wheel, is at a rate to provide a number of reciprocations during the feed. Since, as mentioned above, the rate of feed gradually decreases toward the end of the feeding movement, and since the reciprocation is at a constant rate, the workpiece is uniformly ground throughout its length. Furthermore, as will hereinafter be described, there is a dwell of the yoke 34 at the end of the grinding operation for "sparking out" which insures uniformity of diameter throughout the length since the reciprocation of the yoke continues during such dwell.

For reciprocating the yoke, means is provided tending to move the yoke in one direction while a second means is provided for intermittently moving it in the opposite direction. Thus as shown in Figs. 1 and 2, the means constantly tending to move the yoke in one direction is located preferably at the right-hand end of the yoke and in the present instance comprises a fluid pressure actuator, indicated generally at 37. The actuator 37 tends to move the yoke to the left, as viewed in said figures. For intermittently moving the yoke to the right against the force exerted by the actuator 37, a power driven reciprocating means 40 (see Figs. 1, 2, 4, 9, and 10) is mounted on the left end of the base 30.

With the machine thus generally described, a brief general statement of the operation of the machine will facilitate the understanding of the more detailed description to be hereinafter given. Thus, assuming that the yoke 34 is in its idle or work loading position, that is, with its arms extending generally upwardly, a workpiece is loaded in the work supporting means between the arms of the yoke 34. The yoke is then swung forwardly and downwardly by the yoke swinging means 36 to bring the arms of the yoke into a substantially horizontal position, by which movement the workpiece is moved into grinding position. Such swinging movement of the yoke also brings it into position to place it under the control of the feed mechanism 35 which operates to control the further swinging movement while the work is being ground. During the feeding movement, the reciprocating means 40 acts, in cooperation with the actuator 37, to effect reciprocation of the yoke to move the workpiece substantially parallel to the grinding wheel axis and thus grind the entire length of the portion of the workpiece to be ground. Also during the feeding movement, the work is rotated by the work driving means 38. At the conclusion of the feeding movement there is a short dwell for the purpose of "sparking out," and the yoke is then swung upwardly by the yoke-swinging means 36 to permit removal of the workpiece and insertion of a new workpiece.

The foregoing cycle is initiated manually, but the machine is so constructed as to carry through the various steps of the cycle automatically and to stop when the yoke swings back to the work loading position. The machine is also so constructed that, at the conclusion of the grinding operation, the reciprocating means 40 and the work driving means 38 are stopped so that the workpiece may be readily removed. Also, the feed mechanism is reconditioned so that it will be ready to control the swinging movement of the yoke when the next workpiece is moved into grinding position.

The grinding wheel and its support

As heretofore mentioned, the grinding wheel 32 is supported by the rearwardly extending portion 31 of the base. It is so mounted that its axis extends substantially parallel to the front of the machine, with the wheel extending into the space between the arms of the yoke 34, as shown in Fig. 2. The grinding wheel is carried on one end of a spindle 50 (see Fig. 5) which is journaled in a head 51. The grinding wheel is of annular form and is mounted on a flanged member 52 rigidly secured to the left end of the spindle 50. To clamp the grinding wheel in place on the flanged member 52, a clamping plate 53 is provided which is bolted to the flanged member 52. On the opposite end of the spindle 50 a pulley 54 of the V-belt type is secured and has a driving connection with the motor 33 which is positioned rearwardly of the grinding wheel.

Accuracy of grinding depends upon the accuracy with which the grinding wheel rotates. Because of the speed at which it is desirable to rotate a grinding wheel, there is a tendency for the wheel supporting spindle to heat up and thereby become distorted sufficiently to materially affect the accuracy of grinding. Moreover, the bearings which support a spindle subjected to such heating cannot be made with a particularly tight fit because of the expansion of the spindle due to heating. Thus, inaccuracies of grinding occur between the time when the spindle is first started and is relatively cool, and the time when the spindle heats up.

In the present instance the spindle is journaled in the head 51 in such a manner that practically no material heating occurs. A very close fit between the bearings and the spindle may therefore be utilized, thus resulting in increased accuracy of grinding. To this end the head 51 is provided with spaced bearings 55 which are made of porous metal such as cintered bronze, or metal known in the trade as Oilite Bearing Bronze. Outside of the bearings annular wells 56 are provided to which oil is supplied under pressure by means of pipes 57. The oil in the wells 56 is forced through the porous bearings 55 over the entire area thereof to lubricate the spindle. Since the oil is thus supplied to the spindle surface at a multitude of points throughout the entire area of the bearings, very little clearance need be provided between the bearings and the spindle, and the spindle is therefore held accurately positioned at all times. Furthermore, by supplying oil in this manner it is found that very little heating of the spindle occurs.

The oil as it works along the spindle is collected in a central well 60, or in end wells 61 which are connected to the central well 60 by drains 62. The oil collected in the central well 60 may then be carried back to the source of supply through a return pipe 63. Oil is supplied to the bearings 55 through the pipes 57 by means of an oil pump 58 driven by a motor 59 located in the lower right hand portion of the base, as shown in Fig. 1, the return pipe 63 being connected to a reservoir for the pump 58.

In addition to preventing the spindle from overheating by use of the porous bearings, the spindle is also water cooled. To this end it is provided with a central cavity 64 into which a pipe 65 extends, the pipe 65 also extending beyond the end of the spindle for connection to a source of water under pressure (not shown). The pipe 65 is of substantially smaller diameter than the interior of the cavity 64 to permit water entering the cavity by means of the pipe to flow through the cavity. To support the pipe, a bushing 66 is secured to the spindle for rotation therewith as by being threaded into the outer end of the cavity 64. The bushing 66 at its outer or right-hand end, as viewed in Fig. 5, fits snugly around the pipe to prevent leakage of water therefrom. The interior of the bushing 66 at its inner end is enlarged as at 67 to provide a space in communication with the central cavity 64. On the outer end of the bushing is mounted a collecting ring 70 held against rotation relative to the bushing 66 and provided with an annular chamber 71. The chamber 71 is in communication with the enlarged interior 67 of the bushing by means of radial apertures 72 in the bushing. The annular chamber 71 is connected with a discharge pipe 73 to carry off the water after it has passed through the central cavity 64. Thus there is a constant flow of water through the interior of the spindle 50 to carry away what little heat may be generated.

The head 51 is mounted on a table 74 (see Figs. 2 and 3) which is slidably mounted on the rearwardly extending portion 31 of the base for movement toward and from the workpiece so that the grinding wheel may be positioned for grinding workpieces of different diameters. To this end the rearwardly extending portion 31 of the base is provided with ways 75 supporting the table 74. The table 74 is adapted to be adjusted on the ways 75 by means of a manually operable screw 76 carried by the base of the machine and threaded into a nut 77 fixed in a lug 80 extending downwardly from the bottom of the table 74. The screw 76 extends forwardly through an intermediate wall 81 (see Fig. 3) in the base and the front wall 82, and is held against endwise motion by thrust bearings 83. The front end of the screw 76 is provided with a squared end 84 to receive a hand crank 85 by which the screw may be rotated to effect rough adjustment of the grinding wheel.

For fine adjustment of the grinding wheel, the screw 76 immediately inside of the front wall 82, carries a gear 86 of relatively large size meshing with a smaller idler gear 87 (see Fig. 1) carried on a stub shaft 90 mounted on the front wall 82. The idler gear 87 also meshes with a pinion 91 carried on a shaft 92 rotatably supported by and extending through the front wall 82. The front end of the shaft 92 is also squared to receive the hand crank 85 and is provided with a calibrated dial 93 and a relatively fixed indicator plate 94 to facilitate accurate setting of the grinding wheel.

In order to facilitate turning the screw 76 manually for rough adjustment of the grinding wheel and to avoid rotating the calibrated dial 93 at such times, the pinion 91 is mounted so that it may be shifted out of mesh with the idler gear 87. To this end the shaft 92 which carries the pinion 91 is eccentrically carried in a bushing 95 mounted in the front wall 82. By rotating the bushing 95 in the front wall, the pinion 91 may thus be moved out of mesh with the idler gear 87. The eccentric bushing 95 likewise facilitates assembly of the structure since the shaft 92 is readily adjustable relative to the stub shaft 90 to take up backlash between the pinion and the idler gear.

The grinding wheel 32 is provided with a guard structure which is so constructed that it may be readily moved away from the wheel to facilitate replacement of the wheel when necessary. As shown in Figs. 2 and 5, the guard structure comprises a disk 96 mounted on a hub portion of the head 51 adjacent the inner face of the grinding wheel. Covering the periphery and the outer face of the wheel is a dished structure 97 provided with peripherally spaced lugs 100 into which screws are inserted to secure the dished structure 97 to the disk 96. The dished structure 97 is carried by an arm 101 extending radially of the grinding wheel and pivotally supported on a vertically extending pin 102 carried by a bracket 103 rigidly secured to the table 74. By such pivotal support the dished structure 97 may be swung away from the wheel to permit ready removal of the wheel from its spindle. When the dished structure 97 is in place and secured to the disk 96, the arm 101 is rigidly secured against swinging movement by means of a screw 104 extending through the arm 101 and threaded into a lug 105 on the bracket 103.

The disk 96 and the dished structure 97 are cut away at their front lower portion, as shown at 106 in Fig. 3, to provide access for the workpieces to the grinding wheel. Carried by the peripheral portion of the dished structure 97 is a nozzle 107 for supplying coolant to the workpiece at the point of grinding. Preferably the nozzle is located at the forward or front edge of the cut away portion 106 of the guard structure.

It is of course desirable to hold the nozzle closely adjacent the work so that the coolant will be supplied directly to the point of grinding. In grinding different diameters, it is therefore desirable to be able to adjust the nozzle so that it may be placed closely adjacent a workpiece of any size. In the present instance such adjustment is effected by rotatably adjusting the dished structure 97 on the arm 101. To this end the dished structure 97 is provided with a hub 110 fitting in a round boss 111 on the end of the arm 101. The hub 110 is rotatable in the boss 111 and is adapted to be rigidly clamped thereto by means of a screw 112. The guard structure may thus be rotatably adjusted on the arm 101 to place the nozzle 107 immediately adjacent the portion of the workpiece being ground. When the guard structure is moved away from the wheel for replacement of the latter, the nozzle 107 is likewise moved away since it is carried by the guard structure. Coolant is supplied to the nozzle 107 through a pipe extending from a pump 108 driven by a motor 109 located at the rear of the base 30, as shown in Figs. 2 and 4.

Work supporting structure

As heretofore mentioned, the work to be ground is supported by the yoke 34 which is swingable through a relatively large angle from a work loading position to a grinding position, and then by a continuation of such swinging movement through a relatively small angle to feed the work toward the grinding wheel. The yoke is in the form of a central U-shaped portion (see Figs. 1, 2, and 7) comprising arms 113 and an intermediate portion 114, the workpiece being supported in the space between the arms and the grinding wheel entering such space to contact the work. Extending outwardly from the ends of the arms 113 are bearing portions 115 rotatably journaled in bearings 116 mounted on the base of the machine to support the yoke for its swinging movement.

The yoke is reciprocated, as mentioned above, during the grinding operation to insure that the entire length of the part being ground is ground to a uniform diameter. If the yoke were mounted for such reciprocation on ways which were separate from the bearings 116, any misalinement between such ways and the bearings would cause the work to be ground with a taper. Moreover, such ways are usually in the form of longitudinally extending flat surfaces which require very accurate hand scraping. With such a construction it would therefore be difficult to obtain the accuracy desired.

The manner in which the yoke 34 is mounted both for its reciprocation and its swinging movement eliminates any chance of obtaining an undesired taper on the workpiece and furthermore avoids the difficulties of hand scraping. To this end the bearings 116 which support the yoke for its swinging movement also serve to support the yoke for its reciprocating movement. Thus the bearing portions 115 are made considerably longer than the bearings 116 so that the bearing portions 115 may move longitudinally in the bearings 116 and may also rotate therein.

To avoid exposing any part of the bearing portions to dust or grit in the grinding operation, covering means are provided on both sides of each bearing 116 to protect the parts of the bearing portions 115 which project therebeyond. On the inner side of each bearing 116, or the side nearest the U-shaped portion of the yoke, the covering means extends from the bearing 116 to the arm 113 and is collapsible to provide for the reciprocation of the yoke. Thus cover members 117 are provided which are in the form of bellows, each of which is attached at one end to the bearing 116 and is provided with a ring 120 at the other end held against the arm 113. The cover member 117 is of flexible material, such as heavy canvas, and includes a coiled spring secured to the canvas which tends to expand and hold the ring 120 in contact with the arm 113. Thus, with the reciprocation of the yoke, the cover members 117 are alternately collapsed and expanded.

The outer ends of the bearing portions 115 are likewise covered. For this purpose the right-hand bearing 116 is provided with a cup-shaped cover 121 secured to the bearing 116 and of sufficient length to permit the reciprocation of the bearing portion 115 therein. At the outer end of the left-hand bearing 116 is a cylindrical cover 122 secured to the bearing 116.

As mentioned above, the workpiece is supported in the space between the arms 113 on centers to permit rotation of the work during grinding. The right-hand center, indicated at 123 (see Figs. 7 and 8), is mounted in a center supporting member 124 carried in a bushing 125 in the right-hand arm 113. One of the centers is made longitudinally movable to permit insertion of a workpiece and to accommodate workpieces of different length. To this end the center supporting member 124 is slidable longitudinally relative to the yoke. For such longitudinal movement, the center supporting member 124 is permitted to slide in the bushing 125 and also has a reduced end portion 126 slidable in a bushing 127 in the yoke. To move the center longitudinally, the supporting member 124 is provided with rack teeth 129 on its lower face meshing with teeth 130 cut on a manually operated shaft 131 extending transversely to the axis of the center 123. The shaft 131 is journaled in the right-hand arm 113 of the yoke and has a portion projecting forwardly therefrom, on which is mounted a handwheel 132 for rotating the shaft. Thus, rotation of the shaft 131 moves the center 123 longitudinally to permit insertion and removal of the work. To lock the center in any adjusted position, suitable locking means, indicated at 133, is provided for the shaft 131.

The center 123 is also laterally adjustable so that it may be accurately alined with the opposite center. To this end the bushing 125 fits loosely in the arm 113 and four radially extending set screws 128 are threaded into the arm 113 to hold the bushing 125 in its adjusted position.

The left-hand center, indicated at 134, is mounted in a center supporting member 135 rigidly secured in a bore in the left-hand arm 113 as by a screw 136. The work is rotatable on the centers 123 and 134 and is driven during the grinding operation. To this end a pulley 137 is rotatably mounted on the center supporting member 135, suitable antifriction bearings 140 being provided therebetween. The pulley 137 is adapted to be connected to the work for driving the latter by means such as a dog 141, similar to a lathe dog, clamped on the adjacent end of the workpiece. To drive the pulley 137, the driving means 38 is provided which is preferably mounted on the adjacent arm 113 of the yoke. In the present instance the driving means comprises a reduction gearing enclosed in a housing 142 (see Figs. 2 and 3) and driven by a motor 143 mounted on the side face of the arm 113. The reduction gearing has a pulley 144 connected to the pulley 137 by a belt 145. The housing 142 is pivotally supported on the arm 113 so that it may be shifted to provide a take up for the belt.

Swinging movement of the yoke is effected by the means 36 located on the rear side of the left-hand end of the base 30, as heretofore mentioned (see Figs. 2, 4, and 16). Preferably, such means comprises a pressure fluid actuator which in the present instance utilizes air as the pressure fluid. The actuator comprises a plurality of cylinders 146 provided with a common lower head 147 and a common upper head 150. The pistons within the cylinders 146 are all connected to a common cross bar 151 which in turn is connected to the yoke.

The connection to the yoke comprises a rod 152 pivotally attached to the free end of a lever arm 153 extending from a collar 154 mounted on the left end of the yoke 34. The collar 154 is connected to the yoke to swing it, but since the yoke is reciprocated, the connection between the collar and the yoke is arranged for such reciprocation. For this purpose the end of the yoke is provided with a reduced portion 155 to which is keyed a cup-shaped member 156 provided with splines 157 on its external surface for connection with the collar 154. The yoke may thus be swung by its actuator but is permitted to reciprocate relative thereto. To hold the collar 154 against endwise movement, the cylindrical cover 122 for the adjacent end of the bearing portion 115 extends into abutment with the collar 154. On the outer face of the collar 154 is mounted a sleeve member 160 which forms a further protection for the end of the yoke.

Since the end of the lever arm 153, to which the rod 152 is attached, swings in an arc, the actuator 146 is swingably supported. To this end the lower head 147 of the actuator is provided with a pair of spaced ears 161 straddling a bracket 162 secured to the rear face of the left-hand end of the base 30, the ears 161 being pivotally connected with the bracket 162 by means of a pivot pin 163. In order to facilitate assembly of the machine, and particularly to locate the range of swinging movement of the yoke in the proper position, the bracket 162 is attached to the base 30 in such a manner that it may be adjusted vertically through a short distance.

While the machine is principally used for grinding cylindrical workpieces, it is also constructed so that it may be used for grinding tapers by means of a so-called plunge cut. For such grinding the yoke is moved so that its axis is out of parallelism with the grinding wheel axis. To provide for adjustment of the yoke to such position, the yoke supporting bearings 116 are mounted on a sub-base 158 (see Figs. 1 and 2) carried on the upper face of the main base 30. The sub-base 158 is shiftable on the main base about a vertical axis located midway between the arms of the yoke, a pivot pin 159 being provided for such shifting movement. To hold the sub-base 158 in any adjusted position arcuate slots 168 are provided adjacent the ends of the sub-base and clamping screws 169 extend through said slots and into the main base for clamping the sub-base in place.

When the sub-base is adjusted by the foregoing means so that the yoke axis is out of parallel with the grinding wheel axis, reciprocation of the yoke is stopped and feeding movement of the yoke toward the grinding wheel will cause the work to be ground with a taper. For such taper grinding the grinding wheel is preferably dressed to a true cylinder and is not tapered.

Reciprocation of the yoke

Reciprocation of the work occurs throughout the grinding period and during the subsequent dwell to insure uniform grinding throughout the length of that portion of the workpiece to be ground. The reciprocation is not merely one stroke, as it would be in the case of a feed axially of the workpiece, but is a plurality of strokes during the grinding operation and at least one complete stroke back and forth during the dwell period at the conclusion of the feed so that "sparking out" will occur throughout the entire length of the part being ground.

The reciprocating mechanism includes means exerting a constant force on one end of the yoke to urge it in one direction and actuating means at the other end of the yoke periodically moving the yoke in the opposite direction. The means exerting a constant force against one end of the yoke in the present instance acts on the right end of the yoke and preferably utilizes fluid pressure, particularly pneumatic pressure, to exert the constant force. To this end the outer end of the right-hand bearing portion 115 is bored out to receive a cylinder 164 (see Fig. 7) which is flanged at its outer end and rigidly secured to the end face of the yoke. Extending into the cylinder 164 is a piston 165 fixed in a bracket 166 extending upwardly from the base 30, packing 167 being provided around the piston to prevent leakage. The piston 165 is provided with a central longitudinally extending passage 170 opening at its inner end into the interior of the cylinder 164 and connected at its outer end by means of a pipe 171 to a source of air under pressure (not shown). Since the piston 165 is fixed by means of the bracket 166, pressure in the cylinder 164 exerts a force constantly urging the yoke to the left. To provide for the swinging movement of the yoke, the piston 165 is coaxial with the bearing portions 115 of the yoke.

The means for intermittently moving the yoke in the opposite direction, here indicated at 40, is located at the left end of the yoke and includes a power driven eccentric acting on the yoke. As shown in the drawings, said means comprises a carriage 172 (see Figs. 2, 4, 9, and 10) carried on the left-hand end of the base 30. The carriage 172 is provided with a housing 173 containing reduction gearing driven by a motor 174 attached to the rear face of the housing 173. The reduction gearing in the housing 173 includes a drive shaft 175 projecting horizontally forward from the front end.

On the drive shaft 175 is mounted the eccentric means for intermittently moving the yoke to the right. Since different workpieces may have parts of different length to be ground, it is desirable to be able to adjust the extent of reciprocation. Thus, the eccentric means comprises a tapered member 176 keyed on the projecting end of the shaft 175. Mounted on the tapered member 176 is an inner eccentric 177. The inner eccentric is clamped to the tapered member 176 by means of a screw 180 threaded into the end of the shaft 175. The screw 180 extends forwardly through a hub 181 on the inner eccentric and into a socket portion 182 on the front end of the hub 181. Secured to the front end of the screw 180 as by a pin is a head 183 turnably mounted in the socket portion 182 and having a squared end 184 extending forwardly of the socket portion 182. The screw may thus be turned by means of a wrench placed on the squared end 184. When the screw 180 is threaded into the shaft 175, the inner eccentric 177 is clamped onto the tapered member 176 by means of the head 183 bearing against the inner end face of the socket portion 182. When the screw is loosened, the inner eccentric 177 may be rotated about the tapered member 176, the hub portion 182 being externally hexagonal in shape so that the inner eccentric 177 may readily be turned.

Mounted on the periphery of the inner eccentric 177 is an outer eccentric 185. The outer eccentric 185 is normally clamped to the inner eccentric 177 but may be readily adjusted thereon to vary the aggregate eccentricity of the two eccentrics. To this end a gear 186 is mounted on the hub 181 of the inner eccentric which gear is concentric with the periphery of the inner eccentric. Also mounted on the hub 181 is a clamping plate 187, the gear 186 and the clamping plate 187 being secured to the inner eccentric as by screws 190. The clamping plate 187 may be provided on its front face with indicia 191 cooperating with a mark fixed on the outer eccentric to indicate the aggregate eccentricity of the two eccentrics. To adjust the outer eccentric, an aperture 192 is provided in the outer eccentric to removably receive the end of a manually operated shaft 193. The shaft 193 carries a pinion 194 adapted to mesh with the gear 186 so that by rotating the pinion 194 the outer eccentric 185 is turned on the periphery of the inner eccentric 177. When the outer eccentric has been adjusted to the point desired, the screws 190 holding the gear 186 in place are tightened, causing the outer eccentric 185 to be clamped between the gear 186 and a flange 195 provided on the rear part of the inner eccentric 177.

The aggregate eccentricity of the two eccentrics depends upon the direction of the outer eccentric relative to the inner eccentric. Preferably the individual eccentricities of the two eccentrics are equal. Thus when the inner eccentric is adjusted relative to the tapered member 176 to place its eccentricity in one direction, and the outer eccentric is adjusted relative to the inner eccentric to place its eccentricity in the opposite direction, the aggregate eccentricity is zero. When the eccentricities of the two eccentrics are in the same direction, the aggregate eccentricity of the two is double the value of either one. It is obvious therefore that any amount of eccentricity may be obtained between zero and double the eccentricity of either of the eccentrics merely by suitable adjustment of the two eccentrics.

The outer eccentric acts on the yoke to force it to the right against the pressure exerted by the actuator 37. To insure smooth operation, the cup-shaped member 156 on the left end of the yoke is provided with a bracket 196 (see Figs. 1 and 7) carrying a roller 197 bearing against the periphery of the outer eccentric 185. The roller 197 is positioned substantially in the plane of the outer eccentric 185 when the yoke is in grinding position. When the yoke is turned to the work loading position, obviously the plane of the roller 197 is transverse to the plane of the outer eccentric 185. However, at such time, the eccentric is not being driven.

In addition to providing for adjustment of the extent of reciprocation, the reciprocating means 40 is also adjustable to vary the position of such reciprocation. Thus, on certain workpieces portions at opposite ends of the workpiece may have to be ground. Obviously it is desirable to reciprocate the work relative to the grinding wheel only to the extent that is necessary to insure complete grinding of the particular portion being ground. For this purpose the carriage 172 is adjustably mounted relative to the base by being supported on ways 200 (see Figs. 4 and 9) extending parallel to the direction of reciprocation of the yoke. Preferably the ways 200 are formed on a table 201 fixedly mounted on the base 30. To move the carriage 172 along the ways 200 and to hold it in any adjusted position, the carriage is provided on its under face with a downwardly extending lug 202 having secured therein a nut 203. Threaded into the nut is a screw 204 rotatably mounted in the table 201 but held against endwise movement therein. On the outer end of the screw is a handwheel 205 for rotating the screw, and a dial 206 may be provided to facilitate setting of the position of the carriage 172.

The rate of reciprocation may also be varied to suit workpieces of different character. To this end the gearing in the housing 173 may be of the variable speed type or, if preferred, the motor 174 which drives the reciprocating means, may be of the variable speed type. Thus the reciprocating means is constructed to provide adjustment of the extent of reciprocation, adjustment of the position of such reciprocation, as well as adjustment of the rate of reciprocation.

At the conclusion of the grinding operation, the drive of the eccentric means is stopped and the eccentric means coasts to a stop. Such stopping occurs substantially when the eccentric is at its low point or when the yoke is at its extreme left position, because the pressure exerted by the constant pressure means 37 at the right end of the yoke tends to urge the eccentric means to such position and to oppose any movement beyond such point. Thus the yoke is in its extreme left hand position when swung to the work loading position.

Feed mechanism

As mentioned heretofore, the yoke 34 swings the work from a work loading position to a grinding position, and during the grinding operation the feed mechanism, which has been indicated generally at 35, controls the swinging movement of the yoke. The feed mechanism includes a feed plate 210 (see Figs. 11 and 13) movable in a controlled manner and provided with an abutment for the yoke so as to control the movement thereof in accordance with the movement of the feed plate 210.

One of the principal features of the feed mechanism lies in the fact that it may move through a relatively great distance to effect a small movement of the workpiece toward the grinding wheel. Thus the actual feeding movement of the work is readily controlled. In order to permit of such relatively large movement of the feeding plate, the intermediate portion 114 of the yoke is the part which is controlled by the feed plate, and since the intermediate portion 114 is at a relatively great distance from the axis of swinging of the yoke, the desired extent of movement is obtained. To provide for the abutment between the yoke and the feed plate 210, a downwardly extending lug 211 is provided on the intermediate portion 114 of the yoke, and into the lower face of the lug 211 is secured a hardened ball 212. The lug on either side of the ball 212 is beveled, as at 213, the beveled surfaces being provided with wear plates 214.

The feed plate 210 is movable vertically, and since the yoke is reciprocated horizontally during grinding, means is provided to permit of such reciprocation of the yoke while the feed plate moves downwardly. To this end the top edge, indicated at 215, of the feed plate constitutes ways for a slide 216 mounted thereon. The slide 216 has a channel shaped form straddling the top portion of the feed plate and slidable on the top edge or ways 215. To hold the slide 216 on the feed plate, a groove 217 is cut in the front face of the plate parallel to the top edge 215, and a pair of pins 220 extend from the slide 216 into the groove 217. The upper face of the slide 216 is provided with a transversely extending V-shaped notch 221 to receive the wear plates 214 on the beveled surfaces of the lug 211. By this construction when the yoke is lowered into contact with the slide 216, the beveled surfaces and the V-shaped notch cause the lug 211 to be centered within the notch. At the bottom of the

V-shaped notch is a hardened anvil 222 serving as a bearing surface for the ball 212.

The yoke when it is in its raised or work loading position is out of contact with the slide 216. However, upon lowering or swinging the yoke forwardly to the grinding position, the ball 212 contacts the anvil 222 on the slide 216 and further swinging movement of the yoke is thus placed under control of the feed plate 210.

The feed plate 210 comprises a wide portion at the top so that the top edge 215 is of sufficient length to provide for the reciprocation of the slide 216. The lower portion of the feed plate 210 is preferably of reduced width, such reduced width permitting ready access to other parts of the mechanism located behind the feed plate. The feed plate must be guided so that its top edge 215 is at all times held parallel to the axis of swinging of the yoke when cylindrical workpieces are being ground. This is necessary in order to avoid grinding the workpiece on a taper since if the top edge 215 of the feed plate were slightly out of parallel relative to the axis of swinging of the yoke, the reciprocation of the yoke would cause the work to be ground on a taper. The feed plate 210 is therefore accurately guided by means secured to the base of the machine. As shown herein, the guide means comprises a pair of guide rollers 223 mounted at opposite sides of the upper wide portion of the feed plate and a pair of guide rollers 224 mounted at opposite sides of the lower portion of reduced width, all four guide rollers being rotatably mounted on brackets 225 secured to the front face of the base of the machine.

The feed plate 210 is moved slowly or gradually in order to effect the proper feeding movement of the work toward the grinding wheel. Such movement of the feed plate is adjustable in a number of ways in order that it may be readily adapted for workpieces of different sizes. One of the prominent features of the machine lies in the fact that the rate of feeding movement of the workpiece relative to the grinding wheel gradually decreases during the grinding operation. The advantage of this is that the final grinding in the grinding operation is very light, resulting in great accuracy of the finished workpiece.

To accomplish this end, means is provided for effecting the movement of the feed plate which embodies structure attaining these advantageous features. As shown in the drawings, the vertical movement of the feed plate is controlled by a cam member 226 (see Fig. 11) carried on a rod 227 movable transversely of the direction of movement of the feed plate, or, in the present instance, horizontally. The cam member 226 is provided with a slanting cam surface 230 contacted by an abutment 231 on the feed plate. With the cam surface 230 positioned as shown in Fig. 11, movement of the rod 227 to the left lowers the feed plate 210. In order to permit adjustment of the position of the movement of the feed plate, the abutment 231 is in the form of an eccentric mounted on a stud 232 and adapted to be locked in place by a nut 233 threaded on the end of the stud. Rotation of the eccentric abutment 231 about the stud 232 thus will raise or lower the feed plate 210 relative to the cam surface 230 to adjust the position of the movement of the feed plate.

The range of movement of the feed plate is likewise adjustable. To this end the cam member 226 is of L-shape and has one end pivotally attached to the rod 227 as by a pin 234. The other end of the cam member 227 is supported by a shiftable member 235. The member 235 is provided with a slanting surface 236 on which the free end of the cam member 226 rests, and is adjustable longitudinally of the rod 227 to raise or lower the free end of the cam member 226. For this purpose the shiftable member 235 is provided with an elongated slot 237 through which a bolt 240 extends to lock the shiftable member 235 to the rod 227 in its adjusted position. Thus by adjusting the shiftable member 235 the angle of the cam surface 230 may be changed to vary the extent or range of movement of the feed plate.

The rod 227, as referred to above, is shiftable horizontally to effect the movement of the feed plate, and its movement is such as to provide a decreasing rate of feed. For this purpose the right-hand end of the rod 227 constitutes a piston 241 operating in a cylinder 242, and fluid pressure, in the present instance pneumatic pressure, is supplied to the cylinder to effect such movement of the rod. Thus pneumatic pressure may be supplied to the end of the cylinder 242 through a pipe 243.

The movement of the rod 227 to the left under the pressure exerted in the cylinder 242 is controlled to provide a slow feeding movement of decreasing rate. To this end the left-hand end of the rod 227 also constitutes a piston 244 operating in a cylinder 245. The cylinder 245 is adapted to be filled with oil drawn from a reservoir 246, and the slowness of movement is obtained by causing the oil to be forced through a restricted orifice. Thus, oil is forced from the cylinder 245 through an opening 247 in the end thereof into a chamber 248. The upper end of the chamber 248 is closed by a plug 249 provided with the above-mentioned restricted orifice, here indicated at 250. In order to provide adjustment for the rate of feed, the flow through the restricted orifice 250 may be adjusted by means of a needle valve 251. The oil flowing through the orifice is conducted to the reservoir 246 by means of a short pipe 252. When the piston 244 moves to the right, oil is returned to the cylinder 245 through a passage 253 controlled by a ball check valve 254, the oil thus being permitted to flow freely into the chamber 248 and back into the cylinder through the opening 247.

While the fluid pressure in the cylinder 242 effects movement of the rod 227 to the left to lower the feed plate 210, movement of the rod 227 to the right to raise the feed plate after the grinding operation and in preparation for another workpiece, is effected by spring means. As shown herein, said spring means comprises a coiled spring 260 located in the cylinder 245 and abutting at one end against the end wall of the cylinder. At the other end the spring 260 is positioned in a bore 261 in the end of the piston 244. Thus when the rod 227 is moved to the left by the pressure fluid in the cylinder 242, the spring is compressed. After the grinding operation the pressure fluid in the cylinder 242 is released and the spring 260 moves the rod to the right and consequently lifts the feed plate 210.

The decreasing rate of feed is attained by the structure just described. The pressure exerted on the piston 241 in the cylinder 242 is constant. Such constant pressure, neglecting for the moment the counter pressure exerted by the spring 260, would produce a constant flow of oil through the restricted orifice 250, and a consequent constant rate of feed. However, movement of the rod 227 to the left gradually compresses the spring 260 and consequently an increasing counter pressure is exerted by the spring. Because of such increasing counter pressure, the portion of the pressure exerted by the pressure fluid in the cylinder 242, which is available to force oil through the restricted orifice 250, decreases. The flow through the restricted orifice 250 therefore decreases, since flow through an orifice is proportional to the pressure, and the rate of movement of the rod 227 to the left thus decreases. Since the rate of movement of the rod to the left decreases, the actual feeding movement of the work toward the grinding wheel as a result thereof decreases. Such decrease in feed rate is substantial since, it will be noted from Fig. 11, the spring 260 is materially compressed in length during the movement of the rod 227 to the left so that a substantial increase in counter pressure by the spring 260 occurs.

The movement of the feed plate 210 is limited, and to this end a positive stop 262 is provided. The lower end of the reduced portion of the feed plate 210 is provided with a finger 263 adapted to abut the stop 262 and thus limit the downward movement of the feed plate. Since the extent or range of movement of the feed plate is adjustable by means of adjusting the cam surface 230, the positive stop 262 is similarly adjustable so that for any point of adjustment for the cam surface 230 the positive stop 262 may be utilized. For this purpose the peripheral surface of the positive stop 262 is in the form of a spiral, and the stop is carried on a shaft 264 mounted in a bracket 265 (see Figs. 11 and 12) on the base of the machine. On the front end of shaft 264 is an arm 266 provided with a handle for rotating the shaft 264 and the stop 262. To facilitate setting the stop in any desired position, the arm 266 is also provided with a pointer 268 cooperating with indicia provided on an arcuately shaped plate 267 fixed to the base of the machine (see Figs. 1 and 12). The arm 266 is held in any position to which it is adjusted by means of a leaf spring 269 secured to the arm and frictionally bearing against the rear face of the arcuate plate 267.

Controls for the machine

One of the principal features of the machine lies in the provision of controls whereby the machine may be started through a manual control and thereafter automatically performs the grinding cycle and returns all parts to a position ready for another cycle. The controls utilized for operation of this character are of such construction that interlocks are provided so that the various movements in the machine will take place in the proper sequence. Such controls are best understood by consideration of the diagram of Fig. 18, which shows the interconnection of the various control members in relation to the principal parts of the machine. However, before describing the various circuits involved in such controls, the apparatus utilized will first be described.

As heretofore mentioned, the yoke 34 is swung from a work loading position to a grinding position by the swinging means or actuator 36. The actuator 36 being pneumatic, air under pressure is supplied alternately to the upper and lower heads 150 and 147 to swing the yoke from one position to another. The upper head 150 has a pipe 270 (see Figs. 2, 4, 13, 14, 16, and 17) connected to a valve 271 located on the front of the machine adjacent the feed mechanism. The lower head 147 is likewise connected to the valve 271 by a pipe 272. The valve 271 may be of any desired form but preferably comprises a cup-shaped casing 273 in which a valve member 274 is rotatably mounted, the valve member being secured in the casing by a cover 275 which also serves as a bearing for a stem 276 on the rotatable valve member. The valve member 274 is likewise provided with a stem 278 on its opposite end projecting outwardly beyond the casing.

The pipe 270 from the upper head of the actuator 36 enters one end of the valve casing 273 to connect with a longitudinal passage 277 therein, while the pipe 272 likewise enters the end of the valve casing 273 to connect with a longitudinal passage 280, the passages 277 and 280 being spaced 90° apart, as shown in Fig. 17. Entering the stem 278 is a pipe 281 connected to a source of pneumatic pressure (not shown), the pipe 281 being in communication with a central passage 282 which leads into the main portion of the valve member 274. Within the main portion of the valve member the passage 282 connects with a diametric passage 283 which is bowed so that its respective ends may communicate with the two passages 277 and 280 when the valve member is properly turned, and will provide space for another passage hereinafter described. Thus when the valve member 274 is turned so that one end of the passage 283 is in communication with, for example, the passage 277 connected with the upper end of the actuator, pneumatic pressure will be supplied to said end through the passages 283 and 277 and the pipe 270. The other end of the diametric passage 283 will be blanked off by the casing 271. Such position is clearly shown in Fig. 17. By rotating the valve member 274 through 90°, in a counterclockwise direction as shown in Fig. 17, the left-hand end of the diametric passage 283 will be turned to communicate with the passage 280 and the lower end of the actuator 36. Thus by rotating the valve member 274 through 90°, pneumatic pressure from the supply pipe 281 may be selectively supplied to either end of the actuator 36 to move the piston therein in opposite directions.

When pneumatic pressure is supplied to one end of the actuator, it is of course necessary to release the pressure in the opposite end. For this purpose, the stem 276 of the valve member 274 is provided with a central longitudinally extending passage 284 which at the outer end of the stem 276 vents to the outside atmosphere. Within the valve member proper the passage 284 stops short of the passage 282 so as to be separate therefrom and is provided with a radially extending portion 285 adapted to be placed in communication with the passages 277 and 280 alternately by rotation of the valve member 274. The radially extending portion 285 is positioned at right angles to the diametric passage 283 so that when the latter is connected with one of the longitudinal passages 277 or 280, the radial portion 285 will be in communication with the other and will be turned from one to the other with the rotation that is necessary to turn the diametric passage 283 from one to the other.

It will be apparent from the foregoing description of the valve that when pneumatic pressure is connected to one end of the actuator 36, the other end will be relieved of pressure by exhausting through the passage 284 in the stem 276 of the valve, and that this condition may be reversed. Thus the piston in the actuator 36 may be forced to the upper end of the actuator or to the lower end thereof by pneumatic pressure under control of the valve 271. Movement of the piston upwardly results in swinging the yoke 34 from its work loading position to the grinding position while reverse movement of the actuator moves the yoke back from the grinding position to the work loading position.

Mounted on the front end of the valve stem 278 is a hand crank 288 (see Figs. 13, 14, and 15) having its hub portion keyed to the stem 278. Thus the valve member may be rotated manually to properly position the passages therein. Also mounted on the valve stem 278 is a means for automatically rotating the valve member 274 at the conclusion of the grinding operation to cause the actuator to swing the yoke back to the work loading position. As shown herein said means comprises a valve lever 287 having a portion of its hub cut away, as at 290. The cut away portion 290 extends for somewhat more than 90° to receive a lug 291 on the hub of the hand crank 286.

To explain the operation of the foregoing parts, when the hand crank 286 is turned clockwise through 90° to the position shown in Fig. 14, the valve lever 287 is likewise moved to the corresponding position shown in that figure by engagement of the lug 291 with valve lever 287. Movement of the valve lever 287 counterclockwise through 90° by means hereinafter described will result in moving the hand crank 286 back to its original position, the valve lever 287 contacting the lug 291 to effect such movement. Should it be desired to swing the yoke back to the work loading position at any time before the completion of the grinding operation, the hand crank 286 may be manually turned counterclockwise through 90° without effecting any movement of the valve lever 287 since the cut away portion 290 of the valve lever permits the lug 291 to be so moved. However, in normal operation of the machine, the hand crank 286 is utilized to move the valve member 274 in a clockwise direction to swing the yoke from a work loading position to a grinding position, and the valve lever 287 is moved in a counterclockwise direction to so move the valve member 274 and thus cause the yoke to be swung from its grinding position back to its work loading position.

Movement of the valve lever 287 is effected by means of a tension spring 292 (see Figs. 13, 14, and 15) connected at its upper end to the free end of the valve lever and anchored at its lower end to a fixed part of the machine. The spring obviously will be tensioned at the time the hand crank 286 is turned to the position shown in Fig. 14. To prevent the spring 292 from acting immediately after the hand is removed from the hand crank 286, a bar 293 is also connected to the free end of the valve lever 287, the lower end of the bar being suitably guided as hereinafter described. Intermediate the ends of the bar is a notch 294 adapted to receive a horizontally acting locking member 295. The notch 294 and the locking member 295 are so positioned that when they are engaged, the valve lever 287 will be held in the position shown in Fig. 14. The locking member 295 is carried on a slide 296, the latter being urged in a direction to cause engagement of the locking member 295 and the notch 294 by a tension spring 297. The spring 297 thus tends to move the locking member 295 to its notch engaging position and will do so when the valve lever is turned to the position shown in Fig. 14, which results in causing the yoke to move to the grinding position.

Release of the lock 295 may be effected by means of a bell crank 300 pivoted on a fixed part of the machine and having one arm connected to the slide 296. The other arm of the bell crank 300 is connected by a link 301 to the armature of a solenoid 302. Thus when the solenoid is energized, the armature thereof will be pulled downwardly as shown in Fig. 14 to release the lock 295. Release of the lock 295 permits the spring 292 to turn the valve lever 287 counterclockwise and thus cause the air pressure in the actuator 38 to swing the yoke to the work loading position.

Since the swinging of the yoke back to the work loading position is to take place after the completion of the grinding operation, the solenoid 302 is adapted to be energized at such time. The completion of the grinding operation occurs when the finger 263 on the feed plate 210 contacts the positive stop 262. Therefore simultaneously with such contact between the finger and the positive stop, the solenoid 302 is adapted to be energized. To this end the circuit for the solenoid is controlled by a micro switch 303 (see Figs. 11 and 18) mounted on the lower portion of the feed plate 210 adjacent the finger 263. The micro switch 303 is so positioned that its actuating member will contact the positive stop 262 and be actuated thereby at the same time that the finger 263 contacts the stop. The positive stop 262 is thus made long enough to be contacted not only by the finger but also by the actuating member of the micro switch 303. The micro switch 303 is of the normally open type so that when its actuating member is actuated by contact with the positive stop, the circuit for the solenoid 302 will be closed to effect release of the lock 295 and consequent release of the bar 293 so that the spring 292 may turn the valve lever 287.

As heretofore mentioned, at the conclusion of the feeding movement a dwell is provided for "sparking out." Such dwell or delay should be long enough to permit the yoke to complete at least one reciprocation during the dwell period. Means is therefore provided to slow down the action of the spring 292 in turning the valve lever 287 so that the time required for the valve to be rotated through its 90° movement and to the position for effecting the return swing of the yoke will provide the necessary dwell period. For this purpose the lower end of the bar 293 is connected to a dash-pot structure which slows down the turning movement of the valve lever 287. The dash-pot structure comprises a cylinder 304 in which is mounted a piston 305 connected to the lower end of the bar 293 (see Figs. 13 and 14). The cylinder 304 comprises a part of a casting which also includes an oil reservoir 306. Downward movement of the piston 305 caused by the tension spring 292 forces oil from the cylinder 304 through an adjustable needle valve 307 located in the base of the cylinder casting, and thence through a passage 310 into the lower end of the reservoir 306. A sufficient quantity of oil is provided so that as the piston 305 moves downwardly, oil in the reservoir 306 will overflow from the reservoir into the top of the cylinder 304, a passage 309 through the intervening wall being provided for this purpose. The needle valve 307 is adjustable by means of a knob 311 and the opening of the valve is adjusted to cause the time required for the piston 305 to force the oil out of the cylinder 304 to equal the desired dwell period. Obviously with this construction the dwell period may be varied by adjusting the opening of the valve. Since the valve lever 287 is connected through the bar 293 to the piston 305 the valve 287 will be moved slowly through its 90° of movement to shift the valve to the position for effecting return of the yoke.

When the hand crank 288 is turned to shift the valve for moving the yoke from work loading position to grinding position, such movement, as mentioned above, turns the valve lever 287 clockwise and consequently lifts the bar 293 and the piston 305. The oil in the top of the cylinder 304 will flow freely into the lower part of the cylinder at such time through a passage 312 extending through the piston 305 and controlled by a simple ball valve 313. The ball valve 313, however, automatically closes when the piston 305 moves downwardly to force the oil through the adjustable needle valve 307.

When the yoke 34 is returned to the work loading position and therefore no longer is controlled by the feed plate 210, the latter is shifted upwardly ready for the next cycle. To this end the pressure in the cylinder 242 (see Fig. 11) must be released to permit the spring 260 to shift the rod 227 to the right and thereby lift the feed plate. The supply of pneumatic pressure to the cylinder 242 through the pipe 243 is controlled by a valve 314 (see Figs. 1 and 18) located in the lower left hand corner of the base of the machine. The valve 314 is arranged to connect the cylinder 242 either with a source of pneumatic pressure through a pipe 315 or with the outside atmosphere to permit of exhaust from the cylinder 242. The valve 314 is actuated by a double acting solenoid 320, the valve and solenoid being constructed as a unit. The solenoid 320 is controlled by a limit switch 321 mounted on a bracket 319 secured to the rear side of the base 30 adjacent the left end of the yoke (see Figs. 1 and 2). The switch 321 is provided with an actuating arm 318 positioned in the path of the cross bar 151 for actuation thereby. The limit switch 321 when actuated by the swinging of the yoke to the grinding position so energizes the solenoid 320 as to shift the valve for supplying pneumatic pressure to the cylinder 242. When the yoke swings away from the grinding position the limit switch 321 is spring actuated to so energize the solenoid 320 as to cause the valve 314 to shift to connect the cylinder 242 with the outside atmosphere. At such time, then, the spring 261 will cause the lifting of the feed plate 210.

Since it is desirable to supply coolant through the nozzle 107 only during the actual grinding operation, the motor 109 driving the coolant pump 108 is adapted to be stopped at the conclusion of the grinding operation, and not be started again until the yoke has been moved back to grinding position. Likewise it is unnecessary, and in fact undesirable, to have the motor 174 for the reciprocating means 40 and the motor 143 for driving the work operating at the time that the yoke is out of the grinding position. In order to accomplish this result, the three motors 109, 143, and 174 are all controlled by a limit switch 322 mounted on the bracket 319 beside the switch 321 (see Figs. 1 and 2). The switch 322 is similarly provided with an actuating arm engageable by the cross bar 151 for actuation thereby.

The limit switch 322 thus is adapted to close the circuit to these three motors when the yoke is swung into grinding position and is spring pressed to open the circuit when the yoke swings away from the grinding position to the work loading position. A hand operated switch 323 (see Figs. 1 and 18) is also provided in the circuit to the motor 174 for the reciprocating means to render the reciprocating means inoperative for certain classes of work where it is not desired to reciprocate the yoke, such as grinding by means of a plunge cut for either cylindrical grinding or taper grinding, as hereinafter described. The switch 323 is preferably mounted on a switch panel 328 located on the front of the machine to the left of the center.

A further feature of the control of the machine lies in the fact that if oil is not supplied to the bearings 55 for the grinding wheel spindle 50 at the proper pressure by the pump 58, or if the oil returning through the pipe 63 from said bearings or the cooling water discharged through the pipe 73 from the interior of the spindle exceeds certain temperatures and thus indicate overheating of the spindle, the circuit for the grinding wheel motor 33 will be opened to stop the grinding wheel. To this end a thermostatically operated switch 324 is located in the right end of the base of the machine (see Figs. 1 and 2) to respond to the temperature of the oil in the discharge pipe 63. A similar thermostatically operated switch 325 (see Figs. 2 and 5) is located at the right end of the base, to respond to the temperature in the water discharge pipe 73. Further, a pressure operated switch 326, located in the base adjacent the switch 324, is mounted in the pipe connecting the oil pump 58 and the pipes 57 leading to the respective bearings 55 to respond to any lack of pressure in the pipe. The three switches 324, 325, and 326 are connected in series with each other and with the motor 33 for driving the grinding wheel. Thus, should there be a lack of oil supplied under the proper pressure to the bearings 55, or should there be overheating of the spindle 50, indicated either by the temperature of the returning oil or the temperature of the water discharged from the spindle, the circuit for the grinding wheel motor 33 will be opened and the grinding wheel will consequently be stopped.

The circuits for the various electrical control devices heretofore described are shown in the diagram of Fig. 18 together with the circuits for the various motors. Thus current is supplied to the five motors of the machine from the power line, indicated in Fig. 18 at 327, and to the various control circuits through a transformer 330 connected to the line 327. Current from the transformer flows first to a hand operated switch 331 (see Figs. 1 and 18) carried on the switch panel 328, which normally is closed but may be opened in an emergency to open the circuits to all the motors of the machine. Connected to the switch 331 is a push button switch 332 (see Figs. 1 and 18) carried on the switch panel 328, and a relay LE2 in parallel with the push button switch and controlling the circuit to the oil pump. The push button switch 332 is adapted to be momentarily closed to energize the winding of the relay LE2 and thus close the relay to effect closing of the circuit for the oil pump motor 59.

One of the features of the machine lies in the fact that none of the other four motors, namely, the motors for driving the grinding wheel, the coolant pump, the work, and the reciprocating means can be started unless the oil pump motor is functioning. This insures a supply of oil to the grinding wheel spindle and consequent proper operation thereof. Thus closing of the relay

LE2, in addition to closing the circuit for the oil pump motor 59, energizes a line 333 for supplying current to the other four motors. Leading from the line 333 is the circuit for the grinding wheel motor 33 which includes a push button switch 334 (see Figs. 1 and 18) mounted on the switch panel 328, which is adapted to be momentarily closed to energize the winding of a relay LE1 for the grinding wheel motor 33 and thus effect locking of the circuit to this motor. However, as heretofore mentioned, the circuit to the motor 33 is also controlled by the thermostatically operated switches 324 and 325 and the pressure operated switch 326.

Current for the coolant pump motor 108, the work driving motor 143, and the reciprocating means motor 174 is also drawn from the line 333. As mentioned above, these motors are operating only when the yoke is in grinding position and are stopped when the yoke is swung to its work loading position. Thus the limit switch 322 is connected in the circuit from the line 333, and a relay LE3 for the coolant pump motor, a relay LE4 for the work drive motor 143, and a relay LE5 for the reciprocating means motor 174 are connected in parallel but are controlled by the switch 322. The hand operated switch 323 however is only in the line leading to the relay LE5 for the reciprocating means motor 174.

As heretofore mentioned, the solenoid 302 for releasing the lock 295 which controls the shifting of the valve 271 to move the yoke back to its work loading position, is energized by the closing of the micro-switch 303 carried on the feed plate 210. Thus the micro switch 303 is connected to the line 333 and when closed by contact with the positive stop 262 completes the circuit to the windings of a control relay indicated in the diagram by the designation CR1. Closing of the relay CR1 closes the circuit for the solenoid 302 which draws current direct from the transformer 330. Since the micro switch 303 is of the normally open type, as soon as the feed plate 210 has been lifted, the micro switch 303 thus deenergizes the windings of the control relay CR1 and thereby opens the circuit for the solenoid 302. The lock 295 is therefore free to shift back to its locking position.

Grinding wheel dressers

In grinding operations such as are contemplated on the present machine, the accuracy of the ground surface of the workpiece obviously depends upon the accuracy to which the grinding wheel 32 is dressed. Dressing of the peripheral surface of a grinding wheel such as utilized in this machine is performed by a diamond pointed tool. For use with the present machine a dresser for dressing the peripheral face of the wheel for cylindrical grinding, and a dresser for dressing the wheel to a taper are provided, which are of simple construction and produce accurate dressing of the wheel.

The dresser utilized for dressing the wheel for cylindrical grinding is shown in Figs. 19 and 20 of the drawings and comprises a U-shaped bar or supporting member 335 shaped to be mounted on the work supporting centers 123 and 134. The supporting member 335 in its intermediate portion is provided with a stem 336 projecting at right angles to the axis of the work supporting centers and toward the intermediate portion 114 of the yoke 34. The stem 336 has a transverse slot 337 cut across its end to receive the end of a stud 340 threaded in and extending through

the intermediate portion 114 of the yoke. The stud 340 on its front end is provided with a knob 341 so that it may be readily screwed into place. The stud 340 thus holds the supporting member 335 against rotation. The diamond pointed dressing tool, here indicated at 342, is adjustably mounted in a boss 343 formed on the intermediate portion of the supporting member 335 in such position as to contact the peripheral face of the grinding wheel.

The dressing tool 342 of course has to be moved across the peripheral face of the grinding wheel, that is, parallel to the axis thereof, in order to dress the entire area of the face. To this end the yoke 34 is adapted to be moved longitudinally, preferably by a manually operated means indicated generally at 344. In the preferred embodiment, the manually operated means 344 comprises a housing 345 adapted to be rigidly secured to a fixed part of the machine such as the right-hand yoke bearing 116. Within the housing 345 is gearing comprising a pinion 346 mounted on a stub shaft 347 projecting through the front wall of the housing 345 and having its front end squared as at 350 to receive a hand crank (not shown). The pinion meshes with a gear 351 keyed on a stub shaft 352 rotatably supported by the front and rear walls of the housing 345. The stub shaft 352 also has secured thereon a pinion 353 meshing with a rack 354 reciprocably supported by the side walls of the housing 345. The left end of the rack 354 is provided with an upstanding pin 355 adapted to fit in a socket in the lower face of a boss 356 secured to the outer face of the right-hand arm 113 of the yoke 34. Thus rotation of the stub shaft 347 by the hand crank drives the rack bar 354 and reciprocates the yoke in its bearings 116. Such reciprocation of the yoke moves the dressing tool 342 across the peripheral face of grinding wheel 32. Since this movement of the dressing tool is guided by the same bearings, namely, the bearings 116, which later guide the yoke for reciprocation during the grinding operation, the resultant grinding of the workpiece will be truly cylindrical. The extent or diameter to which the grinding wheel is dressed is determined by moving the grinding wheel table 74 to the desired position.

For taper dressing of the grinding wheel a different dressing device is utilized comprising a bar 360 (see Figs. 21 and 22) adapted to be supported by the work supporting centers 123 and 134 but held on an angle to the yoke axis. To this end one end of the bar 360 is mounted on one of the centers, namely, the center 123. The other end of the bar 360 is supported in such a manner that the angle of the bar relative to the yoke axis may be adjusted. Thus said other end of the bar 360 is mounted in a U-shaped member 361 extending transversely to the yoke axis and mounted on the work supporting center 134. The end face of the bar 360 abuts the intermediate portion of the member 361 and is secured thereto by a screw 362 extending through the intermediate portion of the member 361 and into the end of the bar 360. The member 361 is provided with an elongated slot through which the screw 362 extends so that the screw may be moved to different distances from the yoke axis and thus vary the angle between the bar 360 and the yoke axis. In the ends of the arms of the member 361 are set screws 363 to clamp the bar 360 in its adjusted position. Secured to an intermediate portion of the bar 360 is a bracket 364 which is provided with a slot to receive a manually operable stud 365, similar to the stud 340, to prevent the bar 360 from rotating on the work centers.

The diamond pointed dressing tool, here indicated at 366, is adjustably mounted in a carrier 367 slidable on the bar 360. Thus by movement of the carrier 367 along the bar which is mounted at an angle to the yoke axis, the dressing tool 366 will dress the peripheral surface of the grinding wheel 32 on a taper. To slide the carrier 367 along the bar 360, manually operable means is provided comprising a hand crank 370 pivotally supported by the bracket 364. Connected to the hand crank 370 is a lever arm 371 having its free end connected to the carrier 367 by means of a link 372. Thus by swinging the hand crank 370 the carrier 367 may be moved along the bar 360 and the dressing tool 366 will dress the grinding wheel on a taper.

When the grinding wheel is dressed with such a taper, the work will be ground to the same taper, with the sub-base 158 adjusted so that the yoke axis is parallel to the grinding wheel axis. Such taper grinding is performed by means of a plunge cut with the reciprocating means idle. Similar taper grinding may be performed by dressing the wheel cylindrically and offsetting the sub-base 158 so that the yoke axis is at an angle to the grinding wheel axis, as heretofore mentioned.

Operation of the machine

In the operation of the machine assume that all motors are idle when the machine is to be started. Since accuracy of rotation of the grinding wheel 32 is of prime importance in obtaining accurately ground workpieces, proper lubrication of the grinding wheel spindle 50 must be assured before any of the other parts of the machine are operated. The supply of oil to the spindle bearings 55 is provided by the pump 58 driven by the motor 59. The motor 59 therefore must be started as the first step in the operation of the machine. To accomplish this end, the push button switch 332 is momentarily closed, which effects energization of the windings of the relay LE2 for the motor 59 and consequent closing of the circuit for the motor. Such closing of the relay LE2 also provides for energization of the line 333 controlling the supply of current to all the other motors in the machine, as well as to the solenoids 302 and 328. The solenoid 328 draws its current from the line 333 while the solenoid 302 draws its current direct from the transformer 330, but has its controlling micro switch 303 in circuit with the line 333. In an emergency should it be desired to stop the entire machine at any time during the cycle, the manually operable switch 331 which is positioned between the transformer 330 and the relay LE2 may be opened.

After the oil pump motor 59 is started, the grinding wheel motor 33 may be started, provided the oil pump 58 supplies sufficient oil pressure to the bearings 55 to close the pressure operated switch 326. The grinding wheel motor 33 is started by momentarily pushing the push button switch 334 to effect closing of the relay LE1 in the circuit for the motor 33. During the operation of the machine, should the grinding wheel spindle overheat, as disclosed by the thermostats in the oil discharge line 63 leading from the bearings 55 or the water discharge line 73 leading from the interior of the spindle, the thermostatically operated switches 324 and 325 will open, thus opening the circuit for the grinding wheel motor 33.

When the machine is started, the yoke is in its work loading position. The pistons in the cylinders 146 of the actuator 36 for swinging the yoke are then at the bottom of the cylinders and the arms 113 of the yoke extend generally upward, so that the work supporting centers 123 and 124 are readily accessible. To insert a workpiece, indicated in the drawings at W, the right-hand work center 123 (see Figs. 7 and 8) is withdrawn by rotation of the handwheel 132 sufficiently to place the workpiece between the two centers. The center 123 is thereupon moved into engagement with the workpiece and the center locked in position by means of the locking means 133 on the shaft 131. Prior to the insertion of the workpiece between the centers, the dog 141 is secured to the workpiece, and when the workpiece is placed between the centers, the dog 141 is placed in engagement with the work driving pulley 137 on the left-hand center supporting member 135. It is assumed that the right-hand center 123 has been alined with the center 134 by means of the adjustment of the bushing 125 in which the right-hand center supporting member 124 is mounted. It is also assumed that the grinding wheel 32 has been properly dressed and that the table 74 on which the grinding wheel is mounted has been adjusted to properly position the grinding wheel relative to the workpiece.

The machine is now ready to be started on its cycle and to initiate such cycle the hand crank 286 (see Fig. 14) is turned downwardly through 90° to shift the valve member 274 in the valve 271 so that pneumatic pressure supplied by the pipe 281 (see Figs. 16 and 18) is conducted to the lower end of the cylinders 146. Such pneumatic pressure flows from the pipe 281 through the passage 282 in the valve casing 273, thence through one radial portion of the diametric passage 283 in the valve member, the passage 280 and the pipe 272 leading to the lower head 147 for the cylinders 146. When the valve member 274 is shifted to place the foregoing passages in communication, it also places the radial passage 285 and the exhaust passage 284 in communication with the passage 277 and the pipe 270 leading to the upper head 150 of the actuators. The pneumatic pressure thus will force the pistons in the cylinders 146 upwardly to swing the yoke forwardly and downwardly through the arm 153, the collar 154, and its splined connection with the left end of the yoke shown in Fig. 7.

Movement of the hand crank 286 downwardly as mentioned, also shifts the valve lever 287 (see Fig. 14) clockwise through the connection with the valve lever provided by the lug 291 on the hand crank abutting one face of the cut away portion 290 of the valve lever 287. Clockwise movement of the valve lever 287 tensions the spring 292 and also lifts the bar 293. Upward movement of the bar 293 carries with it the piston 305 in the cylinder 304, and oil from the reservoir 308 flows freely into the cylinder 304 since the ball valve 313 may be readily opened.

Lifting of the bar 293 also moves it in position so that the notch 294 therein may be engaged by the locking member 295, the spring 297 exerting a constant force tending to move the slide 296 to the left to effect engagement of the locking member as soon as the notch 294 is in proper position. The solenoid 302 is not energized at such time so that the armature thereof may be readily lifted by the force of the spring 287 and the locking member 295 will be engaged.

Should it be desired to return the yoke to its initial or work loading position at any time during the cycle of the machine, the hand crank 286 may be turned counterclockwise through 90° to shift the valve member 274 and thus reverse the pneumatic pressure in the actuator cylinders 146 to return the yoke. Such movement of the hand crank 286 is permitted without disturbing the locked position of the valve lever 287 since the cut away portion 290 of the valve lever permits such swinging movement of the lug 291 on the hand crank 286.

The swinging movement of the yoke from its upright or work loading position to the grinding position is, as mentioned above, forwardly and downwardly, so that the arms 113 and the intermediate portion 114 of the yoke extend forwardly and thus provide a protection around the workpiece when it is being ground. When the yoke is so swung, the wear plates 214 (see Fig. 11) on the lug 211 of the yoke enter the V-shaped notch 221 of the slide 218 on the feed plate 210. The slanting position of the slides of the notch and the wear plates center the lug 211 within the notch and bring the ball 212 into contact with the anvil 222 at the bottom of the notch.

The yoke is now in grinding position and further movement of the yoke by the actuator 36 is controlled by the movement of the feed plate 210. Such movement of the feed plate is effected by shifting the rod 227 to the left by pneumatic pressure supplied to the cylinder 242 through the pipe 243, the rod 227 shifting the cam surface 230 to the left to permit the feed plate 210 to be lowered. Pneumatic pressure is supplied to the cylinder 242 through the valve 314 (see Fig. 1) which is actuated by the double acting solenoid 320. When the yoke is in the work loading position and during the time when it is swung from such position to the grinding position, the solenoid holds the valve in such position as to connect the cylinder 242 with the outside atmosphere to permit exhaust therefrom.

To effect the feeding movement of the feed plate 210 by pneumatic pressure supplied to the cylinder 242, the solenoid 320 must shift the valve 314 to connect the supply of pneumatic pressure with the cylinder. For this purpose the limit switch 321 is positioned so that it will be actuated by the swinging movement of the yoke at the time the latter moves into grinding position. Such actuation of the limit switch 321 so energizes the solenoid 320 as to effect a shift of the valve 314 to supply pneumatic pressure to the cylinder 242. The limit switch 321 when not so actuated provides for energization of the solenoid in such manner as to hold the valve member to connect the cylinder 242 with exhaust.

Such supply of pneumatic pressure to the cylinder 242 shifts the rod 227 to the left and initiates the feeding movement of the feed plate 210. At the same time that such feeding movement is initiated, the work drive, the reciprocating means, and the supply of coolant must also all be started. The motors for driving these three means are thus started as an incident to the movement of the yoke into grinding position by closure of the limit switch 322 which controls the supply of current from the line 333 to these three motors. Driving of the workpiece when the motor 143 is operating is effected through the gearing in the housing 142 driving the pulley 144. The latter is connected by a belt with the pulley 137 which the work dog 141 engages. Coolant is supplied to the nozzle 107 mounted on the grinding wheel guard when the pump 108 is driven by the motor 109.

Reciprocation of the yoke is effected by the motor 174 through the gearing in the housing 173 (see Figs. 9 and 10) which drives the shaft 175. Since the gearing may be of the variable speed type or the motor may likewise be of variable speed, the rate of reciprocation can be adjusted to suit the work. Reciprocation of the yoke is effected by the inner and outer eccentrics 177 and 185 driven by the shaft 175. The inner eccentric 177 is clamped to the tapered member 176 on the shaft 175 by means of the screw 180, and the outer eccentric 185 is clamped to the inner eccentric by means of the gear 186. The position of the outer eccentric 185 relative to the inner eccentric and the position of the inner eccentric 177 relative to the tapered member 176 determines the aggregate eccentricity constituting the extent of reciprocation of the yoke. As heretofore described, such eccentricity may be adjusted to any point between zero and twice the individual eccentricities of the two eccentrics. The position of the reciprocation of the yoke, that is, whether it is reciprocating to grind a portion adjacent the right end of the workpiece, or a portion adjacent the left end, is determined by the position of the carriage 172 on the ways 200, the adjustment of the carriage being effected by the screw 204 and the handwheel 205.

The outer eccentric engages the roller 197 on the left end of the yoke to force it intermittently to the right. The yoke is held so that the outer eccentric and roller are in contact by means of the constant pneumatic pressure exerted in the cylinder 164 (see Fig. 7) enclosed in the right end of the yoke. The cylinder 164 and its piston 165 lie on the swinging axis of the yoke so that the piston may remain fixed in its support when the yoke swings. The constant pressure exerted in the cylinder 164 tends to turn the eccentric to the point where the yoke is at the extreme left position and to oppose movement toward the right, so that when motor 174 ceases to drive, the gearing coasts to a stop with the yoke in its left position.

As heretofore pointed out, the yoke is swung and reciprocated in the same bearings. Thus round bearings may be used, as distinguished from flat ways for reciprocation, so that accuracy of the reciprocating movement may be readily obtained. Moreover, by use of the same bearings for the two movements, reciprocation on the axis of turning is insured. If the reciprocation were out of line with the axis of swinging of the yoke, the work would be ground on a taper and true cylindrical grinding could not be obtained. Thus avoidance of any error due to misalinement between the direction of reciprocation and the axis of swinging is definitely avoided. The bearing portions 115 of the yoke are protected against dust and grit where they project beyond the bearings 116 by means of the collapsible cover members 117 between the bearings and the arms of the yoke and the covers 121 and 122 on the respective ends of the yoke.

The feeding movement of the yoke while it is in grinding position is effected by the actuator 36 but is controlled by the feed plate 210. As mentioned above, movement of the rod 227 and the cam surface 230 on the cam member 228 to the left permits the feed plate to move downwardly. Adjustment of the position of the feed plate movement may be effected by turning the eccentric abutment 231 on the feed plate (see Fig. 11) to the desired position to raise or lower the feed plate relative to the cam surface 230. Further, the extent of movement of the feed plate may be varied to suit different pieces of work, by pivotally adjusting the cam member 226 to vary the angle of the cam surface 230. Such adjustment is effected by moving the shiftable member 235 along the rod 227 to vary the point at which the free end of the cam member 226 contacts the slanting surface 238 on the shiftable member 235. The adjustments of the cam member 226 and the eccentric abutment 231 are coordinated with the adjustment of the positive stop 282 for the feed plate so that in any adjusted position of these parts, the finger 283 on the feed plate 210 will contact the positive stop 282 at the conclusion of the grinding operation.

Movement of the feed plate downwardly to effect the feeding movement of the work is held to the desired rate by virtue of the fact that the rod 227 at its left end constitutes a piston 244 operating in the cylinder 245 and must force the oil therein through the restricted orifice 250. Since a constant pneumatic pressure is exerted on the piston 241 in the cylinder 242, the movement of the rod 227 to the left would be constant for a given size of the restricted orifice if there were no other factors affecting such movement. However, the spring 260 located in the cylinder 245, which is utilized to return the rod 227 to the right, is gradually being compressed during the feeding movement to an extent sufficient to materially increase the counter pressure exerted thereby. Thus because of the constant pressure in the cylinder 242, the portion of the pressure available for forcing fluid from the cylinder 245 through the restricted orifice 250 is gradually decreased and the rate of movement of the rod 227 to the left consequently decreases. Such decrease in rate of movement of the rod 227 obviously results in a decrease in the rate of feed of the work toward the grinding wheel.

Perhaps the most important feature of the machine is the accuracy to which the workpieces are ground. One factor in attaining such accuracy is the accuracy of rotation of the grinding wheel which has heretofore been discussed and may be said to be due generally to the manner of mounting the grinding wheel spindle 50, the lubrication thereof, and the prevention of overheating. Another factor bearing on the accuracy attained for the workpiece is due to the fact that the yoke 34 is reciprocated in the same bearings that support it for its swinging movement.

A third important factor lies in the position of the workpiece in the yoke and the manner in which it is fed toward the grinding wheel. Various elements entering into this factor are illustrated in Fig. 6 of the drawings where the relative positions during grinding of the grinding wheel, the work, the yoke and the feed plate are shown. Generally stated, the workpiece is mounted in the yoke eccentric to the swinging axis thereof and so positioned in the yoke that, during the feeding movement, the work is swung at an angle toward the grinding wheel. At the start of the grinding operation when the swinging movement of the yoke is placed under the control of the feed plate 210, the arms 113 of the yoke extend substantially horizontally, as illustrated in Fig. 6, the axis of swinging of the yoke being shown at A. The axis of the work supporting centers, shown at B, is spaced from the axis A, and is nearer the grinding wheel so as to swing at an angle to the peripheral surface thereof. In the present embodiment, a line through the axes A, B is at substantially 45° to the horizontal, or in other words, 45° to the direction of the arms 113 of the yoke. The swinging movement of the yoke during the grinding operation under the control of the feed plate 210 is downward, so that with the axes A and B so positioned, the work is moved both upwardly and toward the grinding wheel.

Such positioning of the axes A and B involves two characteristics which inherently provide a very fine feed for the workpiece resulting from the relatively large movement of the feed plate 210. The first of these characteristics is that the distance between the axes A and B, which represents the radius defining the path of movement of the workpiece during the grinding operation, is very small compared to the effective radius at which the feed plate 210 acts on the yoke during the swinging movement. Thus because of this large difference in radii, a given movement of the feed plate 210 will produce a much smaller movement of the workpiece. The other characteristic is the fact that the workpiece during the feeding movement is moving at an angle to the peripheral surface of the grinding wheel rather than directly radially thereof. This fact means that the component of movement of the workpiece radially of the grinding wheel, which is the actual feeding movement, is substantially less than the movement of the workpiece along its arcuate path.

Because of these two characteristics, a very fine feed of the workpiece is obtained while the movement of the feed plate 210 is relatively large. The mechanism controlling the movement of the feed plate has sufficient accuracy so that any slight error therein is so minimized by the above-mentioned characteristics that a maximum accuracy is attained on the finished workpiece.

The decreasing rate of movement of the feed plate 210, referred to above, also tends to produce an accurate result. Thus, it will be evident from Fig. 6, that if the rate of downward movement of the feed plate is decreased toward the end of the grinding operation, the rate of movement of the workpiece radially of the grinding wheel is exceedingly small at that time. Thus accuracy of grinding is a result inherent from the structure of the machine.

At the conclusion of the grinding operation, the yoke is swung upwardly to move the work out of the grinding position and back to the work loading position. The conclusion of the grinding operation is determined by the finger 283 on the lower end of the feed plate 210 contacting the positive stop 282. At the same time that such contact between the finger and stop takes place, the micro switch 303 is actuated by engagement of its actuating member with the stop 282, and such switch, which is normally open, is closed to effect closure of the control relay CR1 through which current is supplied to the solenoid 302. The armature of the solenoid 302 (see Fig. 14) is drawn downwardly and such movement through the bell crank 300 releases the locking member 295 from the bar 293. The spring 292 thereupon tends to turn the valve lever 287 counterclockwise to shift the valve member 274 so that pneumatic pressure will be supplied to the upper end of the actuator 38 and the lower end thereof will be connected with exhaust. Such movement of the valve member 274 is effected by engagement of the valve lever 287 with the lug 281 on the hand crank 286 which is keyed to the stem 284 of the valve member 274.

The dwell provided at the conclusion of the grinding operation is effected by slowing down the turning movement of the valve member 274 so that the time taken to move the valve member through the required 90° is substantial. This result is attained by the dash-pot arrangement comprising the piston 305 of the cylinder 304 forcing the oil in said cylinder through the adjustable needle valve 307. The turning movement of the valve lever 287 carries with it the hand crank 286 to return the latter to the starting position.

Pneumatic pressure in the upper end of the actuator 36 swings the yoke upwardly, thus causing the limit switch 322 to open the circuit to the coolant supply motor 109, the work driving motor 143, and the reciprocating means motor 174. The reciprocating means and the work drive are therefore stopped, and the coolant supply is shut off when the yoke is swung out of the grinding position.

When the yoke is swung toward the work loading position, the feed plate 210 must be returned to its initial position to be ready for the next cycle. To this end the limit switch 321 is actuated as an incident to the return of the yoke to so energize the solenoid 320 as to shift the valve 314 to a position where the cylinder 242 (see Fig. 11) is connected with exhaust. The bar 227 may thereupon be moved to the right by the spring 260 to lift the feed plate through the abutment of the cam surface 230 with the eccentric abutment 231. Upward movement of the feed plate 210 disengages the actuating member of the micro-switch 303 from the positive stop 262. Since the micro switch 303 is of the normally open type, the spring therein will open the circuit for the solenoid 302, thus deenergizing the latter. The spring 297 (see Fig. 14) thereupon acts to move the locking member 295 toward the bar 293. The locking member 295 is therefore ready to engage the notch 294 in the bar 293 when the bar is raised, at the initiation of the next cycle, by movement of the hand crank 286 downwardly or clockwise.

The roller 197 on the left end of the yoke, which is actuated by the reciprocating means, is positioned in alinement with the outer eccentric member 185 when the yoke is in grinding position. When the yoke is turned to the work loading position, the roller 197 is positioned in a plane transverse to the plane of the outer eccentric 185. However, the reciprocating means is stopped at such time with the yoke in its left hand position so that the yoke is actuated only when the roller and eccentric member are alined. The constant pressure in the cylinder 164 at the right end of the yoke holds the roller 197 in contact with the outer eccentric 185 at all times so that the yoke when next moved back to grinding position is at the same point in its reciprocation. The lug 211 on the intermediate portion of the yoke is therefore substantially in alinement with the slide 216 on the feed plate 210 so that no material shifting of the slide 216 has to occur to properly seat the lug 211 in the V-shaped notch of the slide.

The foregoing description of the operation of the machine applies to cylindrical grinding. As heretofore mentioned, taper grinding may be performed, by means of a plunge cut, in two different ways. For effecting taper grinding in either way, the hand-operated switch 323 is opened so that the motor 174 for reciprocating the yoke is not driven. By adjusting the sub-base 158 which carries the yoke so that the yoke axis is out of parallel with the grinding wheel axis, and by having the grinding wheel dressed to a cylindrical form, the workpiece will be ground with a taper. The workpiece may be moved longitudinally so as to grind the correct portion of the workpiece on such taper by shifting the carriage 172 of the reciprocating means. A taper may also be ground on the workpiece by having the axis of the yoke set parallel to the grinding wheel axis and dressing the grinding wheel to a taper. However, it is obvious that for either form of taper grinding, the reciprocating means is idle and feeding movement of the work toward the grinding wheel results in a plunge cut.

From the foregoing description, it will be apparent that I have provided a novel grinding machine for grinding either cylindrical or tapered surfaces on workpieces, which is capable of grinding such surfaces to very close limits. Such accuracy is obtained through a combination of several factors, one of these factors being that the feeding movement of the work is controlled by the feed plate 210 which is movable through a relatively large distance to produce a fine feeding movement. Thus by controlling movement of the feed plate with normal accuracy, the actual feeding movement of the workpiece resulting therefrom closely approaches absolute accuracy. The fine feeding movement attained by the relatively greater movement of the feed plate is due both to the difference in distance of the workpiece and the feed plate from the axis of swinging, and the fact that the workpiece is moving at an angle to the periphery of the grinding wheel during feed.

Another factor entering into the attainment of such accuracy of grinding is the fact that the grinding wheel spindle is supported in close fitting bearings, permitting lubrication with much less clearance between the bearings and the spindle than is normally provided, and the fact that the spindle is prevented from becoming overheated during operation. A further factor lies in the fact that the work supporting yoke is reciprocated during the grinding operation in the same bearings that support it for its feeding movement. The rate of feed of the workpiece gradually decreases as the work approaches its final dimension so that the final cut taken on the workpiece is light and thus avoids any undue distortion due to grinding pressure.

The machine is convenient to operate since it is automatic in the sense that when a workpiece is placed in the machine and the machine is manually started, operation of the machine automatically continues through the grinding operation and will stop when the work has been moved to a position convenient for removal. The work supporting yoke is swingable from a position where the workpieces may be conveniently placed therein and removed therefrom, to the grinding position where the yoke serves as a guard extending around the yoke. The machine is provided with many adjustments which permit the grinding of a wide variety of types and sizes of workpieces, and the machine is so constructed that not only may cylindrical grinding be performed thereon, but it may be utilized to grind tapers by means of a plunge cut.

I claim as my invention:

1. A grinding machine comprising, in combination, a grinding wheel, a work holder comprising a pair of spaced arms extending generally radially with respect to said wheel and swingable

about an axis at the inner ends of said arms and extending substantially parallel to the grinding wheel axis, means for controlling the swinging movement of said work holder acting thereon at the other ends of said arms in a direction generally transverse to a line through the two axes, and work supporting means mounted on said inner ends of the arms adjacent but spaced to one side and inwardly from the axis of the work holder and having an axis substantially parallel to the other two axes, the axis of said work supporting means being nearer to the grinding wheel axis than is the axis of the work holder and adjacent the side of said arms toward which said other end swings, and said axis of said work holder being nearer than said axis of said work supporting means to said outer ends of said arms, whereby the feed of the work toward the grinding wheel is in a direction at an acute angle to the peripheral surface of the wheel.

2. A grinding machine comprising, in combination, a grinding wheel mounted on a horizontal axis, a work holder swingable on a horizontal axis substantially parallel to the grinding wheel axis at one side thereof, means for controlling the swinging movement of said work holder and acting thereon in a downwardly direction at a radius from the axis thereof, and work supporting means mounted in said work holder at a radius from the work holder axis considerably less than half of the first-mentioned radius and adapted to be swung in an arc upwardly and toward the grinding wheel at an acute angle to the peripheral surface thereof upon swinging movement of the work holder to feed the work toward the wheel, the difference in said radii and the angular movement of the work toward the grinding wheel thereby providing a relatively small feeding movement of the work for a relatively large movement of the controlling means.

3. A grinding machine comprising, in combination, a grinding wheel, a work holder movable to feed the work toward the grinding wheel, means for controlling the feeding movement of said work holder including an actuator exerting a constant force, means regulating the rate of movement of said actuator dependent upon the force exerted thereon by the actuator, and means for absorbing a part of the force exerted by said actuator in amounts increasing in proportion to the movement thereof whereby the rate of feed of the workpiece will be gradually decreased.

4. A grinding machine comprising, in combination, a grinding wheel, a work holder movable to feed the work toward the grinding wheel, and means for controlling the feeding movement of said work holder comprising a pressure fluid actuator, means to supply fluid under constant pressure to said actuator, a piston and cylinder device actuated by said actuator, a restricted orifice controlling the flow of fluid from said cylinder, and spring means opposing the actuation of said device and offering gradually increasing resistance thereto, whereby the rate of flow through said orifice will gradually lessen to decrease the rate of feed of said work holder.

5. A grinding machine comprising, in combination, a grinding wheel, a work holder movable to feed the work toward the grinding wheel, and means for controlling the movement of said work holder comprising a shiftable cam member, a pressure fluid actuator for actuating said cam member, means for supplying fluid under constant pressure to said actuator, a pressure fluid cylinder, a piston in said cylinder connected to

said actuator to force fluid therefrom, a restricted orifice for said cylinder, a spring opposing the movement of said piston and offering increasing resistance to the movement thereof whereby the pressure effective to force fluid through said orifice will be gradually decreased to decrease the rate of movement of the actuator and consequently to decrease the rate of feed of said work holder.

6. In a grinding machine of the character described, the combination of a grinding wheel, a U-shaped member for supporting a workpiece between the ends of the arms of the U and having alined cylindrical bearing portions extending outwardly at the ends of the arms of the U on an axis substantially parallel to the grinding wheel axis, annular bearings supporting said bearing portions, alined work supporting means mounted in said bearing portions eccentrically of said first mentioned axis, means coacting with the intermediate portion of said member for swinging the U-shaped member in said bearings, and means for reciprocating said U-shaped member in said bearings.

7. In a grinding machine of the character described, the combination of a grinding wheel, a work supporting yoke swingable about an axis substantially parallel to the grinding wheel axis, means for swinging the yoke between a work loading position and a grinding position, feed mechanism controlling the swinging of the yoke when in the grinding position, control mechanism for said yoke swinging means, and means separate of said feed mechanism and coacting with said control mechanism to provide a dwell at the completion of the feeding movement before returning the yoke to its work loading position.

8. In a grinding machine of the character described, the combination of a base, a grinding wheel mounted on said base, a yoke, bearing means mounted on said base for supporting said yoke for swinging movement, means for swinging said yoke in said bearing means, means mounted on said base for reciprocating said yoke in said bearing means, means for adjusting said reciprocating means to determine the length of reciprocation effected thereby, and means for adjusting said reciprocating means relative to said base to determine the position of said reciprocation.

9. In a grinding machine of the character described, the combination of a grinding wheel, a work supporting yoke swingable from a work loading position to a grinding position, feed mechanism including a movable member engaged by the yoke when in grinding position for controlling the movement of the yoke in such position, a stop for limiting the movement of said member, means for swinging the yoke between its two positions, and means delaying the return of the yoke by said yoke swinging means when said member engages said stop.

10. A grinding machine comprising, in combination, a base, a work supporting yoke mounted for swinging movement on an axis substantially parallel to the front of the base, and a grinding wheel positioned rearwardly of the yoke and mounted on an axis substantially parallel to the yoke axis, said yoke comprising a pair of spaced arms between which the work is adapted to be supported and connected at their free ends by a cross member adapted to extend along the work, said yoke being swingable to a position where the arms extend upwardly and said cross member is elevated when in a work loading position to afford access to the work for purposes of loading and

removal, and to a position where the arms extend forwardly and said cross member extends as a guard across the front of the work when in a grinding position.

11. In a grinding machine of the character described, the combination of a grinding wheel, a work supporting yoke swingable from a work loading position to a grinding position, feed mechanism controlling the swinging movement of the yoke when in a grinding position including a pressure fluid actuator, and a valve controlling the admission of pressure fluid to said actuator, said valve being opened to admit fluid to the actuator as an incident to the movement of the yoke into grinding position.

12. In a grinding machine of the character described, the combination of a grinding wheel, a work supporting yoke swingable from a work loading position to a grinding position, feed mechanism controlling the swinging movement of the yoke when in a grinding position including a pressure fluid actuator for imparting the swinging force, a valve controlling the admission of pressure fluid to said actuator, and electrical control means for said valve operable to open the valve as an incident to the movement of the yoke into grinding position.

13. In a grinding machine of the character described, the combination of a grinding wheel, a work supporting yoke swingable from a work loading position to a grinding position, feed mechanism controlling the swinging movement of the yoke when in a grinding position including a pressure fluid actuator, a valve controlling the admission of pressure fluid to said actuator, a solenoid for operating said valve, and an electrical circuit for said solenoid adapted to be closed by the movement of the yoke into grinding position to energize the solenoid and open the valve for admission of fluid to said actuator.

14. In a grinding machine of the character described, the combination of a grinding wheel, a work supporting yoke swingable between a predetermined work loading position and a grinding position, means for swinging the yoke between said positions, feed mechanism controlling the swinging movement of the yoke when in a grinding position, and control means for said yoke-swinging means operable by the feed mechanism to initiate the return of the yoke to the loading position upon completion of the feeding movement.

15. In a grinding machine of the character described, the combination of a grinding wheel, a work supporting yoke swingable between a work loading position and a grinding position, feed mechanism controlling the swinging movement of the yoke when in a grinding position, means for swinging said yoke including a pressure fluid actuator, and a valve controlling the admission of pressure fluid to said actuator, control means for said valve operable by the feed mechanism upon completion of the feeding movement to open said valve for returning the yoke to loading position, and means for temporarily delaying such opening of the valve to provide a dwell at the end of the feeding movement.

16. In a grinding machine of the character described, the combination of a grinding wheel, a work supporting yoke swingable between a work loading position and a grinding position, feed mechanism controlling the swinging movement of the yoke when in a grinding position, means for swinging said yoke including a pressure fluid actuator, and a valve controlling the admission of pressure fluid to said actuator, electrical control means for said valve operable by the feed mechanism upon the completion of the feeding movement to permit said valve to supply pressure fluid to the actuator for returning the yoke to loading position, and pressure fluid operated means for temporarily delaying such operation of said valve to provide a dwell at the end of the feeding movement.

17. In a grinding machine of the character described, the combination of a grinding wheel, a work supporting yoke swingable between a work loading position and a grinding position, feed mechanism controlling the swinging movement of the yoke when in a grinding position, means for swinging said yoke including a pressure fluid actuator, and a valve controlling the admission of pressure fluid to said actuator, spring means tending to shift the valve to a position to cause the yoke swinging means to return the yoke to loading position, a lock for holding the valve in position to cause the yoke swinging means to move the yoke to grinding position, control means for releasing the lock operable by the feed mechanism at the completion of the feeding movement, and means for temporarily delaying the shifting of said valve by the spring means to provide a dwell at the end of the feeding movement.

18. In a grinding machine of the character described, the combination of a grinding wheel, a work supporting yoke swingable between a work loading position and a grinding position, means for swinging the yoke, and feed mechanism for controlling the swinging movement of the yoke when in a grinding position including a movable feed plate, a pressure fluid actuator for moving the plate in one direction, a spring for moving the plate in the other direction, and means for controlling the supply of fluid to said actuator, said last mentioned means being rendered operable by the return of the yoke to its loading position to cut off the supply of pressure fluid to said actuator to permit the spring to return said plate to its initial position.

19. In a grinding machine of the character described, the combination of a grinding wheel, a work supporting yoke swingable between a work loading position and a grinding position, means for swinging the yoke, and feed mechanism for controlling the swinging movement of the yoke when in a grinding position including a movable feed plate, a pressure fluid actuator for moving the plate in one direction, a spring for moving the plate in the other direction, a valve for connecting said actuator either to a supply of pressure fluid or to exhaust, and electrical control means for said valve rendered operable by the return of the yoke to its loading position for shifting the valve to connect said actuator with exhaust and thereby permit the spring to return said plate to its initial position.

20. In a grinding machine of the character described, the combination of a grinding wheel, a work supporting yoke swingable between a work loading position and a grinding position, means mounted on the yoke for driving the work, means for reciprocating the yoke, control means operable by the swinging of the yoke to render said work driving means and said reciprocating means operable when the yoke is in grinding position and inoperable when the yoke is in loading position, and manually operable means for rendering said reciprocating means inoperable when the yoke is in grinding position.

21. A grinding machine of the character described comprising, in combination, a grinding wheel spindle, bearings supporting said spindle, means for supplying oil under pressure to said bearings, a motor for driving said oil supply means, a yoke swingable from a work loading position to a grinding position, feed mechanism controlling the swinging movement of the yoke when in grinding position, means for swinging the yoke, and an electrical control means for said yoke-swinging means and said feeding mechanism adapted to be operable only when the circuit for said motor is closed.

22. A grinding machine comprising, in combination, a hollow grinding wheel spindle, bearings rotatably supporting said spindle, a motor for driving said spindle, a line for supplying oil under pressure to said bearings, an oil discharge line leading from said bearings, a line for supplying water to the interior of said spindle, a water discharge line leading from said spindle, a pressure operated switch in said oil supply line adapted to render said motor inoperable when the pressure drops below a predetermined value, and thermostatically operated switches in said oil and water discharge lines adapted to render said motor inoperable when the temperature of the oil or water rises above a predetermined value.

23. In a grinding machine of the character described, the combination of a pair of spaced alined bearings, a yoke comprising a central U-shaped portion located between said bearings and having elongated bearing portions extending from the ends of the arms of the U and journaled in said bearings, means for swinging said yoke in said bearings, means for reciprocating said yoke in said bearings, a pair of cover members enclosing said bearing portions between said bearings and the arms of the U and alternately collapsible upon reciprocation of the yoke, and cover members for the outer ends of said bearing portions.

24. In a grinding machine of the character described, the combination of a yoke comprising a central U-shaped portion, means to support a workpiece between the ends of the arms of the U, and bearing portions extending outwardly from the ends of the arms of the U, a pair of spaced bearings rotatably supporting said bearing portions, cam means engageable with the outer end of one bearing portion to move the yoke in one direction, fluid pressure means at the outer end of the other bearing portion exerting a constant force tending to move the yoke in the opposite direction, said bearing portions being substantially longer than the bearings to provide for the reciprocating movement of the yoke in the bearings.

25. In a grinding machine of the character described, the combination of a yoke having elongated oppositely extending bearing portions, bearings supporting said bearing portions for swinging movement and reciprocation relative thereto, a roller rotatably supported on the outer end of one bearing portion on an axis transverse to the axis of the bearing portion, cam means engaging said roller for positively moving the yoke in one direction longitudinally of the bearing portions, and means at the other end of the yoke exerting a constant force tending to urge the yoke in the opposite direction.

26. In a grinding machine of the character described, the combination of a work supporting yoke having oppositely extending alined elongated bearing portions, bearings supporting said bearing portions for swinging movement and for reciprocation, means acting on one end of the yoke for intermittently moving the yoke in one direction, a cylinder secured to the outer end of the bearing portion at the opposite end of the yoke, a relatively fixed piston extending into said cylinder, and means to supply pressure fluid to said cylinder to urge the yoke in the opposite direction.

27. In a grinding machine of the character described, the combination of a yoke provided with oppositely extending bearing portions, a pair of spaced bearings supporting said bearing portions for swinging movement and reciprocation, means for moving the yoke in one direction, and a piston and cylinder device mounted in one of the bearing portions for urging the yoke in the opposite direction, said piston and cylinder being coaxial with said bearing portion to permit swinging movement of the yoke.

28. In a grinding machine of the character described, the combination of a yoke having oppositely extending bearing portions, bearings supporting said bearing portions for swinging movement and for reciprocation, one of said bearing portions having an extension beyond the bearing, a splined member rigidly secured to said extension, a collar fitting over said splined member and provided with a lever arm, said collar being held against longitudinal movement with the yoke, means connected to said lever arm for swinging the yoke, and means for reciprocating the yoke.

29. In a grinding machine of the character described, the combination of a yoke having oppositely extending elongated bearing portions, bearings supporting said bearing portions for swinging movement and for reciprocation, one of said bearing portions having an extension beyond the bearing, a cup-shaped member secured on said extension and being externally splined, a collar having a splined connection with said cup-shaped member and being held against longitudinal movement with said member, said collar having a radially extending lever arm, means connected to the free end of said arm for swinging the yoke, a bracket secured to the outer end face of said cup-shaped member, a roller supported by said bracket, and cam means acting on said roller to move the yoke longitudinally in one direction.

30. In a grinding machine of the character described, the combination of a reciprocable work supporting yoke swingable from a work loading position to a grinding position, and feed mechanism for controlling the swinging movement of the yoke when in grinding position, said feed mechanism comprising a movable plate, means for guiding the plate, ways formed on the edge of the plate extending parallel to the yoke axis, and a channel shaped slide engaged by the yoke when in grinding position to reciprocate therewith, said slide fitting over said edge of said plate and supported by said ways.

31. In a grinding machine of the character described, the combination of a reciprocable work supporting yoke swingable from a work loading position to a grinding position, and feed mechanism for controlling the swinging movement of the yoke when in grinding position comprising a movable feed plate, means for guiding the movement of the feed plate in a direction transverse to the axis of the yoke, said feed plate having an edge extending parallel to the yoke axis, a channel shaped slide engaged by the yoke when in

grinding position and fitting over said edge of the plate for reciprocation with the yoke, a groove in one face of the plate parallel and adjacent to said edge, and a pin extending from said slide into said groove to retain the slide on the plate.

32. In a grinding machine of the character described, the combination of a work supporting reciprocable yoke mounted for swinging movement from a work loading position to a grinding position, and feed mechanism for controlling the swinging movement of the yoke when in grinding position comprising a feed plate movable transversely to the axis of swinging and having an edge extending parallel to said axis, a slide mounted on said edge and reciprocable with the yoke, an anvil carried by said slide, and a boss on said yoke provided with a ball bearing seated on said anvil when the yoke is in grinding position, said slide having a V-shaped slot and said boss being V-shaped at its end to fit within said slot.

33. In a grinding machine of the character described, the combination of a work supporting yoke swingable from a work loading position to a grinding position, a feed mechanism controlling the swinging movement of the yoke when in a grinding position, said feed mechanism comprising a plate movable in a direction transverse to the axis of swinging of the yoke, and a plurality of guide rollers at the respective sides of the feed plate for guiding said plate during its movement.

34. In a grinding machine of the character described, the combination of a reciprocable work supporting yoke swingable from a work loading position to a grinding position, and feed mechanism for controlling the swinging movement of the yoke when in a grinding position, said feed mechanism comprising a plate movable in a direction transverse to the axis of the yoke, said plate having a wide portion adjacent the yoke and a portion of reduced width extending therefrom, a slide engaged by the yoke when in grinding position and mounted on the wide portion of the plate for reciprocation with the yoke, and two pairs of guide rollers for the plate, one pair engaging the wide portion, and the other pair engaging the portion of reduced width.

35. In a grinding machine of the character described, the combination of a work supporting yoke swingable from a work loading position to a grinding position, means for swinging the yoke, feed mechanism for controlling the swinging movement of the yoke when in grinding position, said feed mechanism comprising a movable feed plate, means controlling the movement of the feed plate, an adjustable stop for limiting the movement of the feed plate, an electrical control circuit for said yoke swinging means, and a switch carried by said feed plate and adapted to be closed by abutment with said adjustable stop for energizing said control circuit.

36. In a grinding machine of the character described, the combination of a work supporting yoke swingable from a work loading position to a grinding position, and feed mechanism for controlling the swinging movement of the yoke when in grinding position, said feed mechanism comprising a movable plate, an adjustable projection on said plate, and a cam member in engagement with said projection and slidably movable transversely of the plate to control the movement thereof.

37. In a grinding machine of the character described, the combination of a work supporting yoke swingable from a work loading position to a grinding position, and feed mechanism controlling the swinging mechanism of the yoke when in a grinding position comprising a movable feed plate, a cam member shiftable transversely of the plate for controlling the movement thereof, and a projection on said plate for engaging said cam member, said projection comprising an eccentric rotatably adjustably on said plate to adjust the position of the movement of the plate.

38. In a grinding machine of the character described, the combination of a work supporting yoke swingable from a work loading position to a grinding position, and feed mechanism controlling the swinging movement of the yoke when in grinding position comprising a movable feed plate, a projection thereon, a cam member engaging said projection and movable transversely of the plate to control the movement thereof, said cam member having a slanting cam surface, and a bracket supporting said cam surface and adjustable to vary the angle thereof and thereby vary the extent of movement of the feed plate.

39. In a grinding machine of the character described, the combination of a work supporting yoke swingable from a work loading position to a grinding position, and feed mechanism for controlling the feed movement of the yoke when in a grinding position comprising a movable feed plate, a projection on said feed plate, a member shiftable transversely of the feed plate, an L-shaped cam member pivoted at one end on said shiftable member and having a surface engaging said projection, and a bracket on said shiftable member and having a slanting edge engaging the free end of said cam member to hold said surface at an angle to the direction of movement of the cam member, said bracket being adjustable longitudinally of said shiftable member to vary the angle of said surface and thereby vary the extent of movement of the feed plate.

40. In a grinding machine of the character described, the combination of a work supporting yoke swingable from a work loading position to a grinding position, and feed mechanism for controlling the swinging movement of said yoke when in a grinding position comprising a movable plate, a member shiftable transversely of the plate and provided with a cam surface for controlling the movement of the plate, a pressure fluid actuator for urging the shiftable member in one direction, a valve for alternately connecting said actuator with a supply of pressure fluid and exhaust, and spring means opposing the movement of the shiftable member by the actuator and adapted to shift said member when the valve connects said actuator with exhaust to move the feed plate to its starting position.

41. In a grinding machine of the character described, the combination of a work supporting yoke swingable from a work loading position to a grinding position, and means for controlling the swinging movement of the yoke when in a grinding position comprising a movable feed plate, a rod shiftable transversely of the feed plate and provided with a cam surface controlling the movement of the plate, a pressure fluid cylinder having one end of said rod as its piston for urging the rod in one direction, a pressure fluid cylinder surrounding the other end of the rod in which said other end acts as a piston, a restricted orifice for controlling the flow of fluid from said second cylinder and connected with a reservoir, a spring in said cylinder and bearing against said rod for opposing the movement effected by said first cylinder, and a valve permit-

ting free flow of fluid from the reservoir to the second cylinder when the spring moves the rod on its return stroke.

42. In a grinding machine of the character described, the combination of a work supporting yoke, and means to reciprocate the yoke comprising drive means including a drive shaft extending transversely of said yoke, an inner circular member eccentrically mounted on said shaft and adjustable rotatably relative thereto, means for clamping said member to said shaft for rotary motion therewith an outer circular member eccentrically mounted on said inner member and adjustable rotatably relative thereto, means for clamping said outer member in adjusted position to said inner member for rotation therewith, and a follower associated with said yoke and operatively associated with the periphery of said outer member.

43. In a grinding machine of the character described, the combination of a work supporting yoke, and means for reciprocating the yoke comprising drive means including a drive shaft, an inner circular member eccentrically mounted on said shaft and adjustable rotatably relative thereto, means for securing said inner member in adjusted position rigidly to said shaft, an outer circular member eccentrically mounted on said inner member and adjustable rotatably thereto, means for securing said outer member in adjusted position rigidly to said inner member the eccentricity of the inner member relative to the drive shaft and of the outer member relative to the inner member being equal whereby the eccentricity of the outer member relative to the drive shaft may be adjusted from zero to double the eccentricity of the individual members, and a follower coacting with the periphery of said outer member for effecting reciprocation of said yoke in accordance with the aggregate throw of said members.

44. In a grinding machine of the character described, the combination of a work supporting yoke, and means for reciprocating said yoke comprising driving means including a drive shaft, a tapered member keyed to said drive shaft, an inner member eccentrically mounted on said tapered member and rotatably adjustable thereon, means for clamping said inner member to said tapered member, an outer member eccentrically mounted on said inner member and rotatably adjustable relative thereto, a gear secured to said inner member, and a manually rotatable pinion rotatably carried by said outer member and meshing with said gear for rotatably adjusting the outer member relative to the inner member, said gear being arranged to clamp the outer member to the inner member in the adjusted position.

45. In a grinding machine of the character described, the combination of a swingable yoke comprising a pair of spaced arms, means on the respective arms for supporting a workpiece, a pulley rotatably supported on one arm and constructed to provide a driving connection with the workpiece, a motor mounted on said one arm, a base plate mounted on said one arm, a gear housing pivotally supported by said base plate, gearing in said housing driven by said motor and having a belt connection with said pulley, and means for pivotally adjusting said gear housing relative to said base plate to tighten said belt connection.

46. In a grinding machine of the character described, the combination of a work supporting yoke swingable from a work loading position to a grinding position, feed mechanism controlling the swinging movement of the yoke when in a grinding position, a hydraulic actuator for swinging said yoke, a valve shiftable from one position to supply pressure fluid to one end of said actuator to effect swinging movement in one direction and to a second position to supply pressure fluid to the other end of said actuator to effect swinging movement in the opposite direction, said valve having an intermediate range of movement between said positions to cut off the supply of pressure fluid from both ends of the actuator, means for shifting the valve to its first position, and means controlled by the feed mechanism to shift the valve to its second position, the movement of the valve through said intermediate range thereby providing a dwell at the conclusion of the feeding movement.

47. In a grinding machine of the character described, the combination of a work supporting yoke swingable from a work loading position to a grinding position, feed mechanism controlling the swinging movement of the yoke when in a grinding position, a hydraulic actuator for swinging said yoke, a valve shiftable from one position to supply pressure fluid to one end of said actuator to effect swinging movement in one direction and to a second position to supply pressure fluid to the other end of said actuator to effect swinging movement in the opposite direction, said valve having an intermediate range of movement between said positions to cut off the supply of pressure fluid from both ends of the actuator, means controlled by the feeding mechanism at the conclusion of the grinding operation to move the valve from its first position to its second position, and a dash-pot for slowing down the movement of the valve through said intermediate range to provide a dwell at the conclusion of the grinding operation.

48. In a grinding machine of the character described, the combination of a work supporting yoke swingably mounted for moving the work between a work loading position and a grinding position, a lever arm attached to said yoke, a hydraulic actuator connected to said lever arm and operable in opposite directions to swing the yoke, a rotatable valve for controlling the flow of pressure fluid to opposite ends of said actuator, a hand lever for rotating the valve in either direction, and electrically controlled means for rotating the valve in one direction to cause said actuator to swing the yoke from the grinding position to the loading position.

49. In a grinding machine of the character described, the combination of a work supporting yoke swingable between a work loading position and a grinding position, a pressure fluid actuator for swinging said yoke between said positions, a valve having a member rotatable to two positions to cause the actuator to swing the yoke in opposite directions, a hand lever rigidly secured to said rotatable member and provided with a lug, a lever arm coaxial with said hand lever and engageable with said lug to rotate the valve in one direction for returning the yoke from grinding position to loading position, and means for swinging the lever arm in said direction, said hand lever being swingable in said direction independently of said lever arm.

50. In a grinding machine of the character described, the combination of a work supporting yoke swingable between a work loading position

and a grinding position, a hydraulic actuator for swinging the yoke in opposite directions, a rotatable valve for controlling the flow of pressure fluid to said actuator, a hand lever for rotating said valve, a coaxially mounted lever arm engageable with said hand lever in one direction for causing the yoke to swing from grinding position to work loading position, a spring tending to turn said lever arm in said direction, a bar connected to said lever arm, a releasable lock for said bar to hold the lever arm against movement by the spring, and electrically controlled means for releasing said lock.

51. In a grinding machine of the character described, the combination of a work supporting yoke swingable between a work loading position and a grinding position, a pressure fluid actuator for swinging said yoke, a valve controlling the flow of fluid to said actuator, a lever arm for turning said valve to a position to cause swinging of the yoke from grinding position to loading position, a spring for swinging said arm in said direction, a bar connected to said lever arm, a lock adapted to engage the bar to prevent operation of the lever arm by said spring, a second spring for urging the lock into engagement with said bar, a solenoid adapted when energized to release the lock, and means for controlling the energization of said solenoid.

52. A grinding machine comprising, in combination, a base, a grinding wheel mounted on said base for rotation about an axis extending longitudinally thereof, a work supporting yoke swingable transversely of said axis from a work loading position to a grinding position, a sub-base having axially spaced bearings supporting said yoke for said swinging movement and for axial reciprocation and said sub-base being adjustably mounted on said base for pivotal adjustment about an axis located intermediate said bearings and extending transversely of said first mentioned axis to position said yoke on an axis parallel or at an angle to the grinding wheel axis, means for reciprocating said yoke on said sub-base when its axis is parallel to the grinding wheel axis to effect cylindrical grinding, and means for rendering said reciprocating means inoperable to permit taper grinding when said sub-base is adjusted to position the axis of the yoke at an angle to the grinding wheel axis.

53. In a grinding machine of the character described, the combination of a work supporting yoke swingable from a work loading position to a grinding position, feed mechanism controlling the swinging movement of the yoke when in grinding position, said feed mechanism comprising a movable feed plate, and an adjustable stop for limiting the movement of the feed plate, said adjustable stop comprising a rotatably adjustable member having a peripheral surface in the form of a spiral providing an abutment for said feed plate, and manual means for rotating said member to adjust the point on its periphery against which said feed plate abuts.

54. In a grinding machine of the character described, the combination of a work supporting yoke swingable from a work loading position to a grinding position, and means for controlling the swinging movement of the yoke when in a grinding position including a pressure fluid cylinder, a movable piston determining the movement of the yoke, means for moving the piston, a restricted orifice controlling the flow of fluid from said cylinder, and a needle valve for varying the size of said orifice to vary the rate of movement of said piston.

55. In a grinding machine of the character described, the combination of a work supporting yoke mounted for axial reciprocation, means exerting a constant force tending to move said yoke axially in one direction, a follower movable with said yoke, an eccentric supported for rotation on an axis perpendicular to the axis of said yoke and having a peripheral surface coacting with said follower for moving said yoke in the opposite axial direction against the action of said force, and a motor for driving said eccentric, said means upon deenergization of said motor being adapted to cause said eccentric when in contact at either side of its high point with said follower to revolve to a stop at its low point with the yoke in its extreme position in said one direction.

56. In a grinding machine of the character described, the combination of a work supporting yoke swingable from a work loading position to a grinding position, a hydraulic actuator for swinging said yoke, a valve shiftable between two positions to supply pressure fluid to opposite ends of said actuator and having an intermediate range of movement between said positions to cut off supply of pressure fluid from both ends of the actuator, spring means for shifting the valve in one direction, and a dash-pot for slowing down the movement of the valve through said intermediate range when the valve is shifted by said spring means, said dash-pot comprising a cylinder and a piston movable with said valve by said spring means to force fluid from said cylinder, and an adjustable needle valve controlling the flow of fluid from said cylinder to vary the time required for said valve to move through said intermediate range.

57. In a grinding machine of the character described, the combination of a work supporting yoke swingable from a work loading position to a grinding position, a hydraulic actuator for swinging said yoke, a valve shiftable between two positions to supply pressure fluid to opposite ends of said actuator and having an intermediate range of movement between said positions to cut off the supply of pressure fluid from both ends of the actuator, spring means for shifting the valve in one direction, and a dash-pot for slowing down the movement of the valve through said intermediate range when the valve is shifted by said spring means, said dash-pot comprising a cylinder, a reservoir, a piston in said cylinder connected to said valve and movable by said spring means when shifting the valve to force fluid from one end of said cylinder into said reservoir and from said reservoir into the other end of the cylinder, an adjustable needle valve for controlling the flow of fluid from said one end of the cylinder into the reservoir, and a valve in said piston permitting free flow from said other end into said one end of the cylinder when the piston is moved in the opposite directions.

58. In a grinding machine of the character described, the combination of a work supporting yoke, and means for reciprocating said yoke comprising driving means including a drive shaft, an inner member eccentrically mounted on said shaft for rotation therewith, an outer member eccentrically mounted on said inner member and rotatably adjustable relative thereto, a gear secured to said inner member, and a manually rotatable pinion rotatably carried by said outer member and meshing with said gear for rotat-

ably adjusting the outer member relative to the inner member, and means for clamping said outer member to said inner member.

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