Aug. 16, 1938. C. H. SCHMALZ 2,127,071

APPARATUS FOR GRINDING

Original Filed Nov. 16, 1928 3 Sheets-Sheet 1

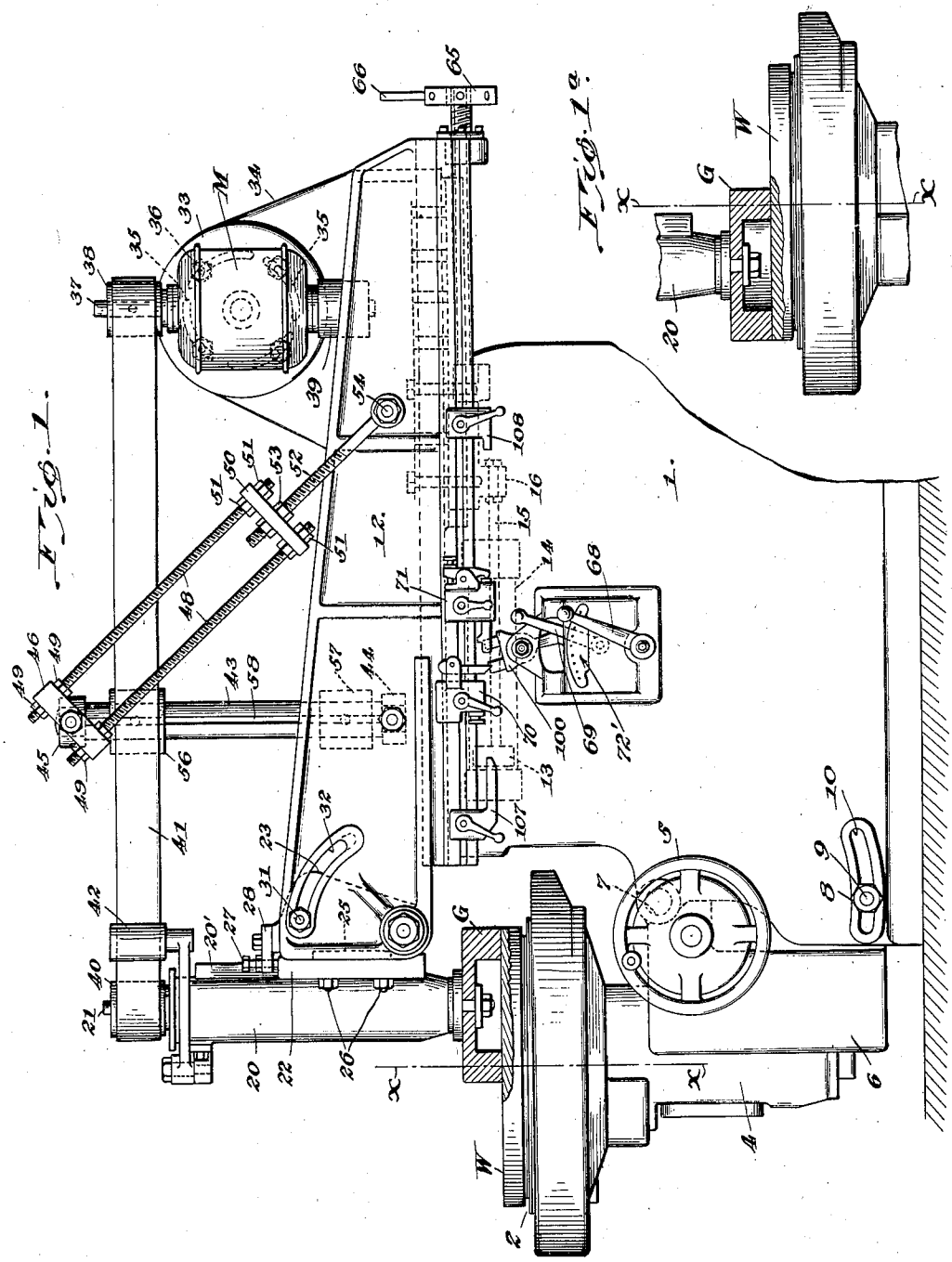


Fig. 1.

Fig. 1a.

WITNESSES

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APPARATUS FOR GRINDING

Original Filed Nov. 16, 1928 3 Sheets-Sheet 2

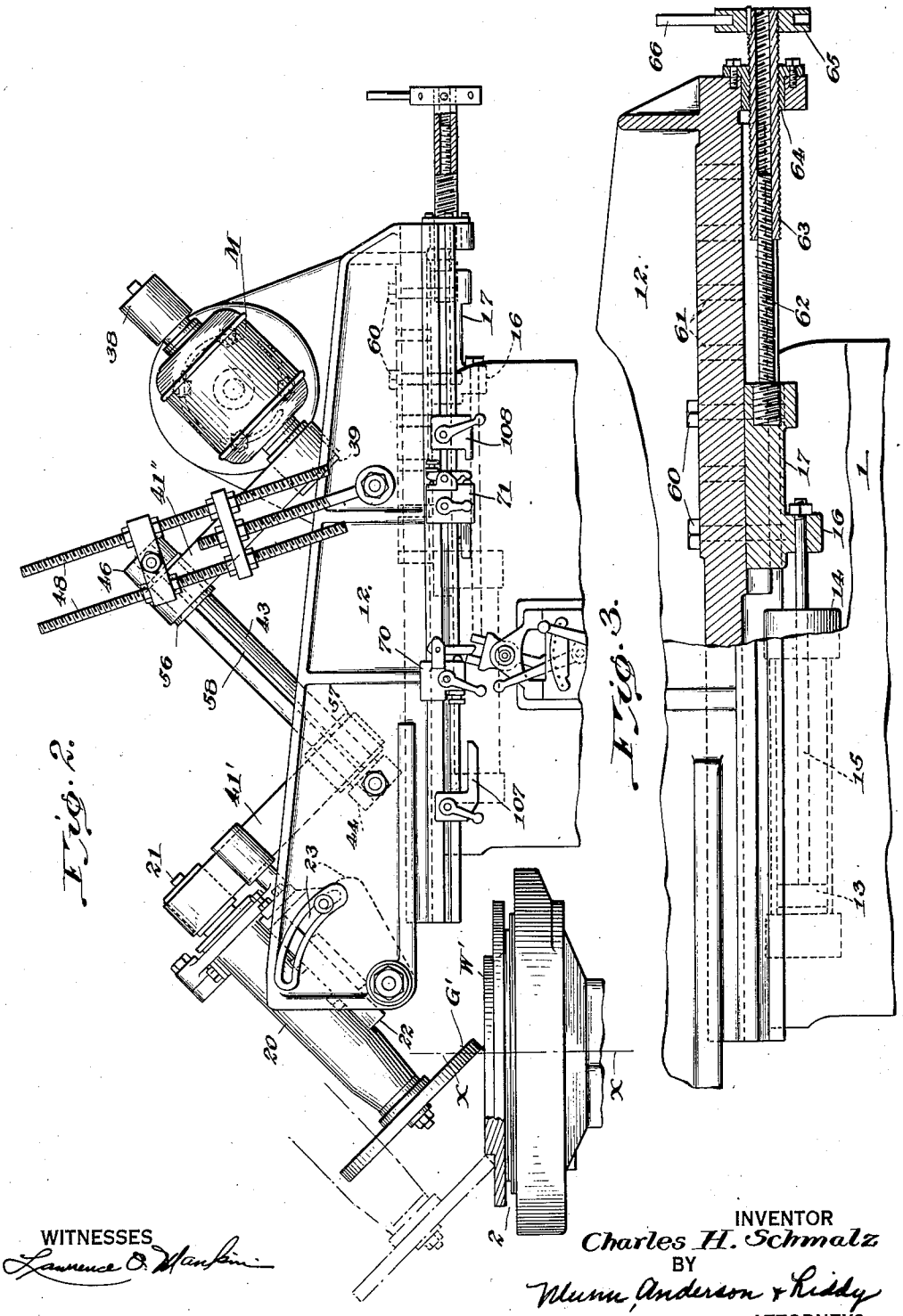


Fig. 2.

Fig. 3.

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APPARATUS FOR GRINDING

Original Filed Nov. 16, 1928 3 Sheets-Sheet 3

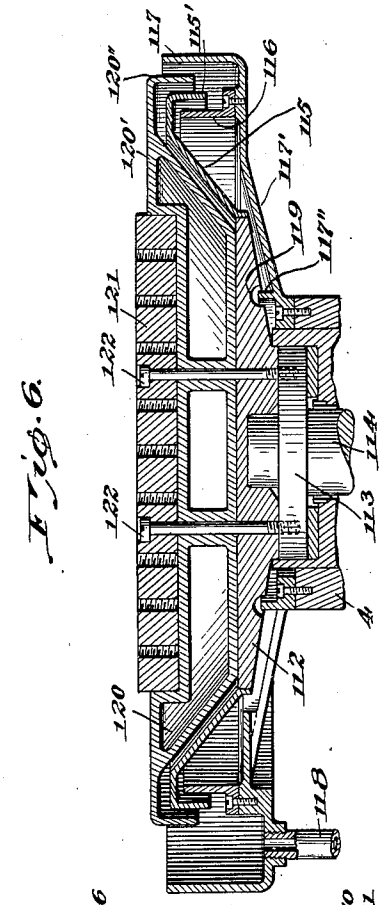


Fig. 6.

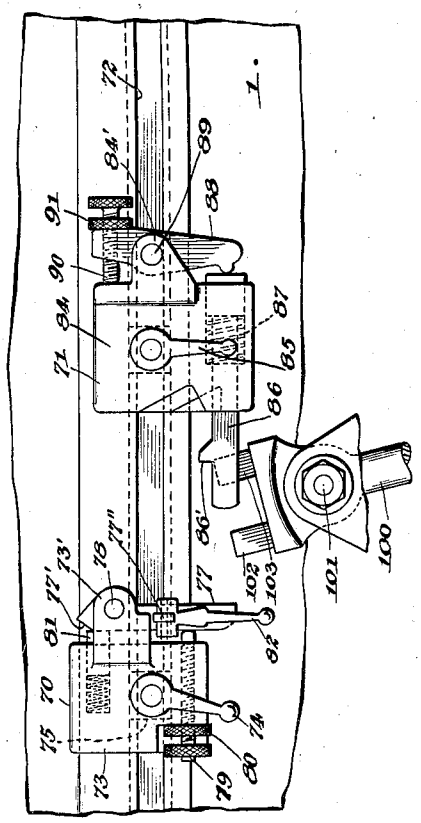


Fig. 5.

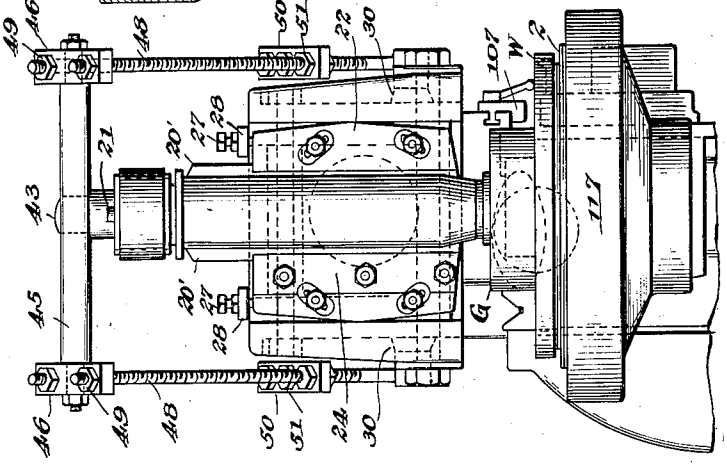


Fig. 4.

WITNESSES

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Patented Aug. 16, 1938 2,127,071

UNITED STATES PATENT OFFICE

2,127,071

APPARATUS FOR GRINDING

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Original application November 16, 1928, Serial No. 319,840. Renewed January 14, 1933, now Patent No. 1,973,511, dated September 11, 1934. Divided and this application August 9, 1934, Serial No. 739,171

4 Claims. (Cl. 51—56)

The present invention is a division of an application for patent on improved Method for grinding, filed November 16, 1928, Serial No. 319,840, renewed January 14, 1933, now Patent No. 1,973,511, dated September 11, 1934. In the present application reference is frequently made to the improved method and the same has been described in order to set forth in the present application the utility of the apparatus claimed herein.

The methods heretofore employed for grinding plane surfaces may be divided into three general classes, namely, (1) those in which a disk grinding wheel rotating on its own axis is reciprocated radially of the revolving work which is thus ground by the edge of the wheel; (2) those in which a cupped grinding wheel is revolved on its own axis and the work while revolving on its own axis not parallel thereto is moved radially across the end face of the wheel at a proper height with respect thereto until the wheel slightly overlaps the axis of the work; (3) those in which a cupped wheel is rotated on its own axis and the rotating work moved against the end face of the wheel in a direction parallel to the axis of rotation thereof, the wheel in this case being also usually of a diameter sufficient to slightly overlap the axis of the work. While all of these methods are capable of producing very accurate surfaces when carried on under proper conditions, none of them is entirely satisfactory in what is known as "precision work" for the reason, in the case of the first two methods, that the natural wear of the grinding wheel must be compensated for by suitable manipulation of the mechanism in accordance with the skill and judgment of the operator, while in the third method the operative face of the wheel very rapidly clogs up with particles of the metal ground off from the work and with particles of the wheel itself as they become detached therefrom. Consequently it is necessary to employ very highly skilled operatives if extremely accurate surfaces are to be produced by either of the two first mentioned methods while in the case of the third method the clogging up of the wheel results in much loss of time and also in inaccurate surfaces if it be permitted to proceed beyond a certain point; because of these facts none of the said methods is entirely satisfactory for the rapid and economical production of extremely accurate surfaces in large quantities.

It must always be borne in mind that as during the grinding operation the work is rotated on its own axis the speed of angular travel of the work progressively increases toward its periphery so that from a point of theoretical zero rotation at the axis of the work a maximum rotative speed determined by the radius of the work and its number of revolutions per unit of time is there obtained. Thus, when the edge of a disk grinding wheel rotating at a constant speed on its own axis is applied to the work and the wheel then reciprocated radially thereof in accordance with the first method, the relative movement between the edge of the grinding wheel and the work at the center of the latter is theoretically determined solely by peripheral speed of the grinding wheel, whereas at any other point along the radius of the work it is determined by a combination of two factors, namely, the peripheral speed of the wheel and the speed with which the work passes beneath it, which latter factor will vary at every point along the radius. In consequence, as the grinding wheel is reciprocated back and forth radially of the work, it wears unevenly with resulting production of an untrue surface unless the operator of the machine so manipulates the latter as to compensate for this wear in accordance with his skill and judgment under the particular conditions of operation present; thus, among other things, the operator must necessarily consider the character and hardness of the wheel, the size of its grain, its peripheral speed and the relation of its speed to the speed of the work, the direction of the rotation of the wheel with respect to the rotation of the work, the extent or length of wheel reciprocation and its relation to the speed of work rotation, the nature of the material being ground, and the nature and type of coolant, if any, which is being employed, as all of these factors directly bear upon and must be taken into consideration when determining the amount and character of compensation required to obtain a surface of the desired accuracy.

Equally so, these among other factors must be considered in effecting the requisite compensation when the second method of grinding is employed for the reason that as the rotating work is fed in across the operative end face of the wheel in a plane not normal to the axis of rotation thereof, the wheel first encounters the rapidly moving periphery of the work and then as the wheel progressively approaches the center of the work until it finally assumes a position in which it slightly overlaps the axis of work rotation, the rotative or angular travel speed of the work with respect to the wheel progressively decreases until the zero point is reached with the result that, as in the first case, an uneven wear

takes place in the wheel with corresponding inaccuracy in the finished work in the absence of requisite compensation by the operator which because of the large number of factors entering into its proper determination is obviously an extremely difficult thing to effect.

In the third case, while the wear on the wheel is not uneven, the efficiency of the wheel very rapidly decreases because of the clogging thereof to which I have referred, so that while the services of a skilled operator may be dispensed with the method is unsatisfactory for mass production because of the rapid loss of efficiency of the grinding wheel and the necessity of cleaning the same or replacing it with a new wheel at relatively frequent intervals.

An object of my invention is to provide a grinding machine or apparatus satisfactorily operative for the performance thereof and which, moreover, in its preferred embodiment, is so constructed as to lend itself to the performance of my improved method or any of the other three methods to which I have referred in case for any reason it be desired to use the same, thereby enabling the possessor of the machine by suitable adjustment, arrangement and manipulation thereof to utilize it either for the performance of my improved method, or, should circumstances so dictate, for any of the other three methods heretofore in use.

A further object of the invention is to provide a grinding machine so arranged that the grinding wheel can be disposed to operate on either side of the center of rotation of the work without unduly increasing the size and overall dimensions of the machine.

Still further objects of the invention are to provide in a grinding machine having a reciprocal carriage, an improved form of micrometer adjustment by means of which the exact length of stroke of the carriage may be very accurately controlled, and to provide in a grinding machine having a rotatable work table improved means for preventing the coolant from working into the table spindle bearings and other parts below the table after it has passed over the work and thus carrying thereinto particles of metal and abrasive with consequent damage thereto.

My invention further contemplates the provision of an improved machine for grinding plane surfaces and includes other objects and novel features of design, construction and arrangement of the various elements embodied in the machine and hereinafter more specifically mentioned or which will be apparent to those skilled in the art from the following descriptions of the machine as illustrated in the accompanying drawings.

Referring now to the drawings in which only so much of the machine is illustrated as is necessary to an adequate comprehension of the invention, Fig. 1 is a side elevation of the machine adjusted for the performance of my improved method of grinding and showing a piece of work on the work table with the grinding wheel in operative position with respect thereto, the wheel and a portion of the work being shown in fragmentary central section and Fig. 1*a* is a fragmentary view in side elevation with the wheel and a portion of the work in fragmentary central section as in Fig. 1 showing the wheel adjusted to operate on the opposite side of the center of the work from that shown in the preceding figure, this alternative adjustment being sometimes found to be of advantage.

Fig. 2 is a fragmentary side elevation of the principal parts illustrated in Fig. 1 but showing the machine adjusted to operate with a disk wheel in accordance with the first of the methods to which I have heretofore referred as being in common use; in this figure an alternative position of the grinding wheel is indicated in broken lines.

Figure 3 is an enlarged fragmentary view partially in side elevation and partially in vertical section showing the carriage positioning and adjusting mechanism;

Figure 4 is a fragmentary front end elevation of the carriage, grinding wheel spindle, work table and adjacent parts shown in Fig. 1;

Figure 5 is a fragmentary side elevation on an enlarged scale showing the mechanism for regulating the stroke of the carriage and,

Figure 6 is an enlarged fragmentary central vertical section through the work table and adjacent parts. The same symbols are used to designate the same elements in the several figures.

Referring more particularly to Figs. 1 and 4, the machine as therein illustrated comprises a base 1 in front of which, that is, adjacent the left hand end thereof when viewed as in Fig. 1, is disposed the rotatable work table generally designated as 2 upon which may be secured the work W so as to revolve therewith, the table being disposed within a trough supported from the work table spindle housing 4 which is arranged for vertical adjustment by means of a hand wheel 5 so that the table and in turn the work can be positioned at any desired height within the range of movement afforded the table. The spindle housing 4 may be arranged to slide vertically in a block 6 carried by the base; this block is pivoted to the base on a horizontal shaft 7 so that it can be swung through a short arc so as to tilt the surface of the work table if desired, a nut 8 threaded on a pin 9 carried by the block 6 and working in a segmental slot 10 in the base serving to secure it in any position of adjustment. As the several parts to which reference has just been made are found in one form or another in various grinding machines of well known type further reference thereto would be unnecessary as they are well understood by those familiar with the art.

On the upper end of the base is arranged a slide 12 adapted for horizontal reciprocation in ways carried by the base and having its front end in proximity to the work table. The movement of this slide is desirably effected hydraulically by means of a piston 13 disposed in a horizontal operating cylinder 14 housed within the base beneath the slide and carrying a piston rod 15 whose outer end is secured to a lug 16 on a block 17 hereinafter more particularly described and which, in turn, is operatively secured to the under face of the slide between the ways on which it moves so that any movement of the piston in the cylinder is effective to bring about a corresponding movement of the slide. Desirably the length of the cylinder is such that the slide can be moved in either direction for a distance at least as great as the radius of the work table or rather of the radius of the largest piece of work which the machine is designed to accommodate and which may, of course, be of somewhat greater diameter than the work table itself.

In accordance with my invention I arrange adjacent the front end of the slide a generally vertically extending housing 20 in which the grinding wheel spindle 21 is journaled on suitable bearings preferably of the ball type so that it can revolve very accurately yet freely. The spindle housing is supported upon the spindle

housing supporting plate 22 which is in turn supported on a head block 23 disposed between the laterally spaced side walls of the slide which is of channel section. To allow for vertical adjustment of the spindle housing the latter is provided with outwardly directed V-shaped ways 20' which engage in a vertically extending under cut slot in the outer end face of the plate 22, one side of the slot being conveniently formed by a removable overhanging gib 24 so as to allow the spindle housing to be withdrawn outwardly from the slot when the gib is removed and also to allow the housing to be clamped in any desired position of vertical adjustment in the slot by screwing down on the gib. The spindle housing plate, as stated, is mounted on the head block 23 and preferably in such manner as to permit limited angular movement thereof with respect thereto. To this end the front face of the block is provided with a countersunk bore of relatively large diameter and the plate on its rear face with a corresponding cylindrical lug 25 adapted to snugly seat therein when the plate is assembled on the block to which it is secured by bolts 26 extending through segmental slots in the plate. Thus, by loosening the bolts slightly the plate may be rotated through a limited arc in either direction about the axis of the lug 25 and then secured in any desired position of adjustment by tightening the bolts. To facilitate this adjustment and enhance its accuracy adjusting screws 27 are extended through lugs 28 carried by the head block so as to bear on the plate on opposite sides of its axis of rotation.

The wheel spindle is thus adjustable to a limited extent both axially and in a vertical plane normal to the path of movement of the slide, and means are provided for permitting adjustment of the spindle in a vertical plane parallel thereto as well. For this purpose the head block 23 is rotatably mounted on transversey extending trunnions 30 having their ends journaled in the side walls of the slide so that the block may be turned from a position in which the wheel spindle is substantially vertical to one in which it forms a considerable angle with the horizontal, the extent of movement of the block from one limit position to the other being determined by bolts 31 threaded into the head block through arcuate slots 32 in the walls of the slide and operative when tightened to hold the block in any desired position of adjustment. Thus, the head block may be so disposed that the grinding wheel spindle is vertical and thus normal to the path of movement of the slide as shown in Fig. 1, or by tilting it backward or forward from such a position the spindle may be rearwardly or forwardly inclined to said path as shown in Fig. 2 up to any desired angle, the magnitude of which depends on the length of the slots.

Means are provided for driving the grinding wheel spindle 21 in any of its various positions of adjustment and are preferably of such character as to be movable with the slide so as to constantly occupy the same relation to the wheel spindle throughout the travel of the former. Thus the said means may comprise an electric motor M mounted on the vertically extending face 33 of a bracket 34 supported upon the rear end of the slide and provided with segmental slots 35 through which are extended bolts 36 to operatively secure the motor to the bracket. Thus, by loosening these bolts the motor may be turned about a horizontal axis so as to maintain its shaft 37 in parallelism with the grinding wheel spindle irrespective of the position of adjustment to which the latter may have been brought by movement of head block 23 about its trunnions. The motor shaft 37 may be provided with pulleys 38 and 39 upon its opposite ends and the upper end of the spindle 21 with a pulley 40. Thus when the spindle is vertically disposed as in Fig. 1 it may be directly driven from the pulley 38 by means of a straight belt 41 which is kept taut by one or more spring controlled tension pulleys 42 which may be of any suitable form and construction, but when the spindle is inclined toward the rear from the vertical by rotation of the head block it is apparent that the spindle drive can no longer be effected directly from the pulley 38 and other means must therefore be provided for properly carrying out the drive. For this purpose I preferably provide a countershaft 43 between the wheel spindle and the motor; this countershaft is journaled at its lower end in a step bearing 44 extending transversely of the slide and pivotally secured thereto at its ends so as to permit oscillation of the countershaft in the vertical plane parallel to the path of travel of the slide. The upper end of the countershaft is correspondingly journaled in a transversely extending bearing block 45 whose ends in turn are journaled in guides 46 through each of which on opposite sides of the pivotal center of the block extend a pair of downwardly and rearwardly projecting exteriorly threaded rods 48 which may be secured in any desired position of adjustment with respect to the guides by nuts 49 disposed above and below each guide. Adjacent the lower end of each pair of rods another guide 50 is provided and nuts 51 disposed above and below it for holding it on the rods while a single rod 52, also preferably exteriorly threaded, is extended at its upper end through each guide 50 and adjustably secured thereto by nuts 53 and at its lower end pivotally connected to the adjacent side of the slide as at 54. Thus by suitable manipulation of the various nuts the countershaft may be swung about its pivotal connection with the slide to a position parallel to the adjusted position of the spindle shaft and then firmly secured in such position so as to adequately resist the pull of the driving belts. Similarly the shaft 37 of the motor may be brought into parallelism with the countershaft and wheel spindle by suitable adjustment of the motor on its supporting bracket after which either of the motor pulleys may be belted to a properly positioned pulley 56 on the countershaft 43 and another pulley 57 on that shaft with the pulley 40 on the wheel spindle by means of belts 41' and 41'' respectively, both of the pulleys on the countershaft being constrained to rotate therewith through the medium of a key 58 or other suitable means adapted to permit them to be slid longitudinally so they can be brought to proper position to secure straight line drives respectively to the spindle and motor pulley as shown in Fig. 2. It will thus be apparent that by suitable adjustment of the several parts to which reference has just been made the grinding wheel spindle irrespective of its position of vertical adjustment can be readily driven from the motor, the drive being carried either directly to the spindle or through the countershaft as the adjusted position of the spindle may require.

In accordance with my improved method, the grinding wheel G is positioned under ordinary conditions of operation substantially as shown in Fig. 1 with relation to the work, a grinding wheel

of slightly greater diameter than the radius of the work surface being utilized so that it will overlap the axis of rotation X—X of the work when the axis of the wheel spindle is disposed between the axis of the work and the adjacent end of the base and the peripheries of the wheel and the work are coincident as shown in said figure. However under certain conditions it is frequently desired to dispose the wheel so its axis of rotation lies on the opposite side of the axis of the work, as shown in Fig. 1*a*, which naturally requires a relatively different adjustment of the slide to its ways. While provision for this adjustment might be effected by making the slide very long and the operating cylinder 14 correspondingly so, such an arrangement would greatly increase the overall dimensions of the machine and the floor space consequently required thereby and would also tend to produce inaccurate work because of possible disalignment or the like of the overly long slide. With a view to obviating these difficulties by permitting the employment of a slide and actuating cylinder of normal length, I therefore provide means operative to effect adjustment of the slide with respect to the stationary operating cylinder in such manner that the axis of the grinding spindle may be positioned at any point along that diameter of the work which is parallel to the path of the slide whereby the grinding wheel may be correspondingly disposed at any point along said diameter on either side of the axis X—X in accordance with the particular requirements of the grinding job, and said means will now be described.

It has hitherto been stated that the piston rod 15 is connected to a depending lug 16 on a block 17 disposed between the ways on which the slide reciprocates. This block, in accordance with my invention, is preferably secured to the bottom of the slide by bolts 60 which can be respectively passed through any of a series of holes 61 provided in the bottom of the slide and longitudinally spaced apart. Rigidly fixed to and projecting from the rear end of the block is an externally threaded rod 62 the rear end of which extends into and is cooperative with a correspondingly internally threaded sleeve 63 also exteriorly threaded and rotatable in a correspondingly internally threaded bushing 64 disposed adjacent the rear end of the slide and non-rotatable with respect thereto. At the outer end of the sleeve 63 beyond the bushing is secured a drum 65 having radial holes in its periphery into which may be inserted a drift 66 by means of which the drum and in turn the sleeve 63 may be conveniently rotated. The threads on the rod 62 and exterior of sleeve 63 have similar but opposite pitch so that as the sleeve is rotated in one direction and thus moved longitudinally with respect to the slide the block 17 will be drawn toward the bushing 64 at the rear end of the slide and when the sleeve is rotated in the other direction the block will be pushed away from the bushing. It will thus be apparent that when the valves controlling the admission and discharge of fluid from operating cylinder 14 (which valves are not shown as they may be of any construction suitable for the performance of their intended functions as is well understood) are open so that no substantial resistance is offered to the movement of the piston in the cylinder and the bolts 60 are removed so as to free the block from the slide, rotation of drum 65 is effective to move the block one way or the other with respect to the slide until piston 13 is to one end or the other of the cylinder and its furthest movement in that direction thus arrested; thereafter additional movement of drum 65 is effective to move the slide with respect to block 17 and cylinder to thereby change its relative position with respect to the latter. The slide can thus be projected forwardly or withdrawn rearwardly by suitable manipulation of drum 65 until the axis of the wheel spindle is brought to any desired position along the diameter of the work and the bolts 60 may then be inserted in whichever of the holes 61 align with the subjacent holes in block 17 so as to firmly secure the block to the slide and relieve the threads on rod 62 and sleeve 63 from the thrust which would otherwise be imparted thereto when the slide is reciprocated as hereinafter described. I therefore prefer to use the bolts or other equivalent device for securely tying the block and slide together after the requisite adjustment of the slide has been made but it will be understood that when the threads and other parts which would receive the thrust in the absence of the bolts are made sufficiently heavy to adequately resist it the bolts can be omitted if desired. It sometimes happens that after the slide has been brought to the desired position in the manner described it will be found that the holes 61 do not align properly with the holes in the block; under such circumstances it is necessary to retract the block slightly by reverse rotation of drums 65 so as to bring the holes into proper alignment so that the bolts can be inserted as will be readily understood.

The reciprocation of the slide is effected by alternate admission of fluid under suitable pressure to the ends of actuating cylinder 14 by means of any suitable system of pipes and valves which, as they specifically form no part of the present invention, are not shown in the drawings and require no description as they may be of any preferred form and arrangement. The manual actuation of the valves, however, to start and stop the motion of the slide may be effected by a small hand lever 68 disposed on the side of the base in a position for convenient operation which also controls the speed of reciprocation of the slide, when moved to different positions on a locking quadrant 72' to vary the rate of admission and discharge of the fluid from the operating cylinder. Another lever 69 is arranged to reverse the direction of movement of the slide. It will of course be apparent that the maximum stroke of which the slide is capable is determined by the effective length of the piston travel in the operating cylinder and means are provided for regulating the length of this stroke irrespective of the position to which the slide itself may have been adjusted with respect to the work table by manipulation of the drum 65 as heretofore described. As it is frequently necessary to determine the length of the slide stroke with extreme accuracy, for example when grinding the bottom of a recess in the work, I provide, in accordance with my invention, improved means for effecting this determination and which also embody a safety device adapted to prevent injury to the machine in case it should be carelessly operated when removing or introducing the work thereto.

More particularly said means comprise a pair of tripping devices 70, 71 which are longitudinally slidable in a T-slot 72 in the side of the slide. The trip 70 comprises a body 73 arranged to be locked at any point along slot 72 by operation of a locking handle 74 which draws a block 75 against the side of the slot so that after the trip has been

brought to an approximately correct position of adjustment it may be readily secured therein. Extending rearwardly from the body 13 is a vertically slotted lug 13' within which a generally vertically extending trip lever 77 is pivoted on a transversely extending pin 78 so as to be movable in a vertical plane. The major portion of the trip lever depends below its pivotal point and a longitudinally extending adjusting screw 79 is threaded through an internally threaded bore in the lower part of the body so that the rear end of the screw bears against the trip lever so as to limit the extent to which the lower end of the trip lever can be swung to the left when viewed as in Fig. 5. For constantly urging the lever against the stop screw, a spring pressed plunger 81 is arranged in a bore in the body a little above the pin 78 so as to bear against the curved cam-like surface 77' on the adjacent portion of the lever. Upon the outer face of the lever a safety stop 82 is pivoted on a longitudinally extending horizontal pivot carried by a lug 77'' integral with the lever in such manner that the stop can be raised upwardly from its normal generally vertical position in which it depends below its pivot. The function of this stop will hereinafter more fully appear.

The tripping device 71 also comprises a body 84 slidable in the T-slot 72 and also adapted to be locked at any point therein by manipulation of a locking lever 85. In the lower part of the body is housed a longitudinally extending plunger 86 which projects beyond the front end of the body and is slidable therein, a suitably positioned spring 87 surrounding the plunger being operative to continuously urge it toward the rear. For positioning the plunger longitudinally with respect to the body, an adjusting lever 88 is pivoted on a horizontal pivot 89 within a slotted lug 84' extending from the rear of the body in such position that the lower end of the lever engages the rear end of the plunger and an adjusting screw 90 provided with a lock nut 91 is threaded through the opposite end of the lever so as to bear against the body 84. Thus by manipulation of the adjusting screw, the plunger may be very accurately adjusted with respect to the body 84 so that after the latter is locked to the slide in approximately correct position by means of the locking lever 85 the plunger may be brought to exactly the position desired for the purpose now to be described; in a similar way the trip lever 77 may be adjusted by the adjusting screw 79 after the trip 70 has been locked on the slide in approximately correct position.

The actuation of the valve by which the flow of fluid to the operating cylinder 14 is reversed so as to correspondingly reverse the direction of piston travel therein and, in turn, the direction of travel of the slide, is effected through the medium of an oscillatory reverse lever 100 mounted on a pivot 101 disposed below the slide. At its upper end this lever is provided with two dogs 102 and 103 which are transversely offset from each other and disposed on opposite sides of the center line of the lever, the dog 103 being in longitudinal alignment with the trip lever 77 and the dog 102 in similar alignment with the trip plunger 86, the two dogs being respectively cooperative with these parts. It will now be apparent that the requisite oscillation of lever 100 is effected by the engagement of trip lever 77 with dog 103 when the reverse lever is in the position shown in Fig. 5 and by similar engagement of trip plunger 86 with dog 102 when the reverse lever is in its other limit position as shown in Fig. 2 when through the movement of the slide, the trip lever or trip plunger as the case may be is brought into engagement with its respective dog. Thus by properly setting the tripping devices 70, 71 upon the slide, the trip lever and trip plunger can be positioned so as to throw the reverse lever from one position to another at the proper times to stop the movement of the slide in one direction at any predetermined point and then initiate its movement in the other direction and to then stop it and again reverse its direction of movement at the completion of a stroke of predetermined length. The tripping devices may therefore be set so as to give the slide a stroke substantially equal to the piston travel in the actuating cylinder or a stroke of any lesser amount as may be required by the exigencies of the work and this irrespective of the position to which the slide may have been initially adjusted by operation of drum 65 so as to bring the grinding wheel to a predetermined position with respect to the axis X—X of the work.

Mention has been made of the safety stop 82, the utility of which will now become apparent. Assuming that the machine has been properly adjusted for grinding a certain class of objects, that the grinding of one of them has been completed and that the operator desires to substitute a second one therefor upon the work table, it is, of course, desirable for him to bring the slide to a position in which the grinding wheel is out of the way of the table and work so as to permit the convenient removal of the finished piece from and the positioning of the unfinished piece upon the table. Thus, with this end in view, the operator at the conclusion of the first grinding operation manually lifts the trip lever 77 about its pivot so as to clear it from dog 103 on the back stroke of the slide and thus permit the latter to move further to the right, when viewed as in Fig. 1, that is, to the rear, than would be the case if the trip lever was in normal position and thus operative to engage dog 103 with resulting stoppage of the rearward movement of the slide at the conclusion of the normal predetermined stroke. When the tripping devices 70, 71 are at a considerable distance apart, it is apparent that this lifting of the trip lever can be readily performed but that when they are very close together, as when the slide reciprocation is very short, it would be impossible to lift the lever high enough to clear its end from the dog with possible resulting damage to the machine. I therefore provide the trip plunger 86 with a small lug 86' which is aligned with the safety stop 82 in such manner that when the tripping devices are very close together and an attempt is made to lift trip lever 77 the safety stop will engage lug 86' and thus block any material movement of the trip lever. The operator's attention is thus positively directed to the fact that the parts are in such position that the trip lever should not be raised while the slide is in motion; he can thus hardly overlook the necessity for stopping the machine by manipulation of lever 68, after which, by raising safety dog 82, he can clear the latter from lug 86' and then hold the trip lever 77 carefully from the path of dog 103 while the slide is moved slowly to the rear. To prevent excessive movement of the slide in either direction adjustable safety trips 107—108 are also provided and arranged to be respectively clamped in slot 72 outside of the tripping devices 70, 71 at such points with respect to the slide as to engage the dogs 103, 102 and thus reverse the move-

ment of the slide before the latter has exceeded a safe distance in either direction.

In my improved machine as hitherto stated the work W is operatively supported upon the work table 2 which is desirably of peculiar construction as best shown in Fig. 6. As is usual in machines of the general character to which my invention relates, a main circular work table 112 is provided which seats on a flange 113 near the upper end of the work table spindle 114 which is rotatably journaled in the work table spindle housing 4. In accordance with my invention I provide the main work table with an annular upwardly and outwardly flanged pan 115 which is secured at its lower inner edge to the outer edge of the table so as to form a unitary structure therewith. At its periphery this pan is provided with a depending flange 115' adapted to overhang a vertically disposed ring 116 which forms a continuation of the inner wall of the annular coolant receiving trough 117 surrounding the work table and supported through the medium of an inwardly directed web 117' upon the upper end of the spindle housing 4. The flange 115' is of sufficient length to extend considerably below the upper edge of the ring 116 with the result that any of the coolant which collects on the table to a sufficient depth to overflow the pan 115 is directed into the trough 117 from which it is continuously removed by a pipe 118 and returned to the coolant supply tank. Thus the spent coolant is prevented from traveling down the web 117' and from thence into the spindle bearings or other parts which might be damaged by the particles of metal and abrasive entrained with the coolant; however, as an additional precaution I preferably provide the web 117' near its inner edge with a short vertically extending annular wall 117'' which forms a dam against any small amount of coolant which might accidentally find its way to the web and travel inwardly along the same. To accommodate the wall 117'' the under surface of the main table may be provided with an annular groove 119 if necessary.

The work may be either clamped directly on the main table or preferably upon an auxiliary table 120 which is desirably in the form of a hollow casting so as to minimize its weight. The bottom of this table is of suitable diameter to rest on the upper face of the main table and from thence the wall of the auxiliary table is outwardly flared in correspondence with the flare of the pan 115 so as to support the top 120' of the table at a suitable height above the pan. The auxiliary table is desirably provided with a depending marginal flange 120'' surrounding its top which overhangs flange 115' of the pan and thus lies between the latter and the outer wall of the trough so as to direct the spent coolant running off the auxiliary table into the latter. I prefer to countersink the upper face of the auxiliary table for the reception of a removable plate 121 provided with a plurality of threaded holes to receive the bolts by which the work is secured thereto. The upper surface of this plate is preferably slightly elevated above the upper surface of the table top and as it can be readily removed should its face become damaged or out of true and another plate substituted I consider its use desirable. Plate 121, auxiliary table 120 and main table 112 are preferably secured together and to the flange 113 of the work table spindle by through bolts 122 so that these several parts will rotate with the spindle as a unit. A distinct advantage arising from the use of the auxiliary table is the increased area thereby afforded for the reception of the work thus enabling larger parts to be ground than could be conveniently disposed upon the main table.

It will thus be apparent that by reason of my improved construction the spindle bearings are entirely protected from the deleterious action of the spent coolant whether the auxiliary table be employed or not and that, in consequence, any amount of coolant may be used and no particular pains need be taken by the operator to avoid its entering the bearings of the work table spindle.

Having thus described with considerable detail a machine satisfactorily operative for the performance of my improved method of grinding, I shall now refer more specifically than I have hereto fore done to the said method itself and which consists, essentially, in imparting to a rotating cupped grinding wheel of such diameter and so positioned that it will overlie the axis of the rotating work, a reciprocating movement relative to the work and substantially radially thereof of sufficient amplitude to prevent the clogging of the wheel with particles of metal and abrasive but insufficient to cause the periphery of the wheel to cross the axis of rotation of the work. I have found that this method of grinding plane surfaces avoids the disadvantages inherent in the several methods heretofore in use and to which I have referred in the earlier part of the specification, for as the wear of the operative face of the wheel is uniform throughout its extent, the necessity for effecting compensation, in accordance with the judgment and skill of the operator, for uneven wheel wear is entirely obviated while, on the other hand, clogging of the wheel is avoided due, I believe, to the fact that the reciprocation of the wheel across the face of the work prevents the particles of loosened metal and abrasive from packing into the interstices between the grains of the wheel and ultimately filling them up with resulting diminution of the cutting ability of the wheel in a manner quite similar to the way in which particles of metal accumulate between the teeth of a file when operating on soft material such as lead or copper and thereby rapidly reduce and ultimately substantially nullify the cutting power of the file unless removed.

A further advantage residing in my improved method is the elimination of the circular abrasions or scratches which frequently appear in the work after being ground by the third of the usual methods of grinding to which I have referred, namely, that in which the rotating work is moved against the operative face of the grinding wheel in a direction parallel to the axis of rotation of the latter. In accordance with my improved method no such abrasions or scratches appear in the finished work even though a comparatively coarse grinding wheel be employed.

Ordinarily in the performance of my improved method it is only necessary to reciprocate the wheel for a relatively short distance, as for example, for ¼'' to ¾'' though under some conditions a greater or even a shorter length of reciprocation may be found desirable, due regard being had to the character of the wheel which is being employed, the speed of its rotation and that of the work, the depth of cut being taken and other factors, as will be readily appreciated by those familiar with the art, in order to obtain the best results under any given conditions of operation. However, in any case and as above noted

the amplitude of reciprocation should not be increased to a point which would cause the periphery of the wheel to cross the axis of rotation of the work or, in other words, the wheel should at all times be maintained in such a position that it will span the radius of the surface being ground, assuming the latter extends inwardly to its axis of rotation, and overlap said axis irrespective of its position at any movement along its path of reciprocative travel. Of course, certain special cases may arise in which it is unnecessary for the wheel to overlap the axis of rotation of the work as when a narrow annular raised surface surrounding said axis but outwardly spaced therefrom is being ground. Under such circumstances it is merely necessary that the wheel should at all times extend entirely across the surface which is being ground and thus need not overlap the axis of rotation of the work as a whole.

A brief reference may now be made to the method of operating a grinding machine of the character herein illustrated and described in the performance of my improved method of grinding plane surfaces.

The work W which, for convenience, may be assumed to be a flat circular plate, is first secured in any convenient way to the plate 121 of the auxiliary table and a cupped wheel of a diameter sufficiently in excess of the length of the radius of the work to meet the requirements of the method is secured to the wheel spindle which is then, or previously, adjusted as heretofore described so as to bring the axis of the spindle normal to the face of the work and the operative face of the wheel parallel thereto and to the plane of travel of the slide. By suitable manipulation of the drum 65 the slide is also so positioned with respect to the work table spindle as to bring the wheel into proper relation with the work, that is, in a position in which its major portion either lies between the axis X—X and the base of the machine as shown in Fig. 1 or beyond the axis X—X as shown in Fig. 1*a* but, of course, in either case, with the balance of the wheel overlapping the said axis to a limited extent as shown in both of said figures. The tripping mechanisms 70, 71 are then so set and adjusted that the slide will be reciprocated through a path of a length sufficient to prevent the clogging of the wheel yet insufficient to cause the wheel to cross the axis X—X and the belt 41 is arranged to impart a direct drive to the wheel spindle from the motor. The machine is now in condition for operation so that the motor M and the mechanism for rotating the work table spindle (which mechanism is not shown and can be of any suitable construction) may be set in motion and the work then raised by means of the hand wheel 5 until the grinding wheel bears thereon with the desired pressure. The machine is then continued in operation for a suitable time to grind the surface of the work to the required degree during which period, of course, the grinding wheel rotates on its own axis and is also reciprocated across the face of the work in correspondence with the movements of the slide. Upon completion of the grinding operation the work is lowered by means of the hand wheel 5 so as to disengage the wheel therefrom and the rotation of the work table arrested; the slide may then be retracted so as to clear or partially clear the wheel from alignment with the work and the latter removed from the table and a second work piece substituted, thus completing the cycle of operations after the slide has been once more returned to its normally operative position.

The ground surfaces produced in this manner in accordance with my improved method are of extreme accuracy without marks or scratches, and as once the machine has been put into operation no further attention is required by the operator until the work surface has been completely ground and at no time throughout the operation is any manual adjustment or compensation required because of uneven wear of the wheel, the machine can be readily operated by relatively unskilled labor with consequent reduction of labor cost as well as avoiding the necessity of keeping the machine out of commission when highly skilled grinders are not available.

While my improved method may be utilized for grinding many sorts of plane surfaces and for the reasons stated is to be preferred wherever it may conveniently be employed, conditions sometimes arise which make it desirable to use a disk wheel for grinding a given job or even to grind the latter by either of the other two methods in common use in which a cupped wheel is employed, and for these purposes a machine of the character of that herein disclosed may be utilized very conveniently and satisfactorily as will now be pointed out. Thus, for example, if it be desired to grind a certain job with a disk wheel the wheel spindle housing of the machine may be readily adjusted to an angular position as shown in Fig. 2 so that the corner of the disk wheel G' can be brought to bear upon the work W' as shown in full lines in Fig. 2. When using a wheel of this character it is desirable that the length of the stroke of the slide be sufficient to cause the wheel to pass the axis X—X so that the relative position of the slide with respect to the work table can be adjusted by manipulation of drum 65 and the trip mechanisms 70, 71 also adjusted so as to effect this result, the stroke of the slide being set to a length somewhat greater than the radius of the surface to be ground. In Fig. 2 an alternate position of the wheel is indicated in broken lines which might be utilized when grinding an annular depressed surface adjacent the periphery of the work; of course in this case the stroke of the slide would necessarily be reduced to a length merely sufficient to carry the wheel back and forth over the depressed surface instead of across the axis of the work.

By utilizing a cupped wheel and adjusting the wheel spindle not normal to the face of the work the machine may also be used to perform the second of the commonly employed methods of grinding to which I have referred. For this purpose the slide is retracted or projected sufficiently to entirely clear the wheel from the work and the latter then elevated by the hand wheel 5 to proper height for cooperation with the operative face of the cupped wheel. The work and wheel are then set in motion and the slide moved in the proper direction to carry the wheel inwardly across the face of the work until it overlaps the center thereof, thus completing the grinding operation. The machine may, moreover, be utilized for the third method of grinding by adjusting the parts substantially to the position shown in Figs. 1 or 1*a*, maintaining the slide stationary and then raising the revolving work until it is brought into engagement with the revolving wheel. However, as any grinding operation which can be performed by either of these two last mentioned methods can be performed much more efficiently and satisfactorily by my

improved method as above described, there is but little or no occasion under ordinary conditions of shop operation to make use of either of the said two methods, but conditions do sometimes arise in which the first of the said three usual methods may be efficiently utilized as heretofore described.

I claim:

1. A grinding machine comprising a base, a rotatable work table supported therefrom, a reciprocal slide carried by the base, means for reciprocating the slide, a grinding wheel spindle supported from the slide and adapted to support a grinding wheel adjacent the table, said spindle being adjustable in a vertical plane parallel to the path of the slide, driving means for the spindle carried by the slide and also adjustable in said plane, a countershaft disposed between the driving means and the slide and similarly adjustable, and means for supporting the countershaft in adjusted position whereby said spindle, countershaft and driving means may be disposed in parallel relation throughout the range of adjustment of the spindle.

2. A grinding machine as specified in claim 1 in which said driving means comprise an electric motor having a shaft provided with a driving pulley, said spindle with a pulley and said countershaft with a plurality of pulleys slidable thereon whereby by adjustment of said sliding pulleys on the countershaft a straight line drive can be transmitted from the motor thereto and from the countershaft to the spindle when the spindle, motor shaft and countershaft are disposed in parallel relation at an angle to the path of the slide.

3. A grinding machine comprising a base, a rotatable work table supported therefrom, a reciprocal slide carried by the base, a rotatable wheel spindle supported from the slide and adapted to support a grinding wheel adjacent the table, means for effecting angular adjustment of the spindle relative to the path of the slide, spindle driving means carried by the slide and also angularly adjustable with respect to its path, a countershaft disposed between the driving means and the spindle and similarly angularly adjustable, means extending from the upper end of the countershaft to the slide for maintaining it in adjusted position, a pulley carried by the wheel spindle, a plurality of pulleys carried by the driving means and a plurality of pulleys carried by the countershaft and respectively slidable longitudinally thereon whereby when the spindle is disposed substantially normal to the path of movement of the slide it may be belted directly to the driving means and when disposed in angular position with respect to said path the drive for the spindle may be transmitted to one of the pulleys on the countershaft and from the other pulley thereon to the pulley on the spindle.

4. In a grinding machine, a rotatable work table outwardly and upwardly flared to receive and hold the coolant to a predetermined depth, a work table spindle affording support thereto, a housing for the spindle, a coolant receiving trough surrounding the said work table and having its inwardly extending flange seated on and secured to the housing, said work table having a marginal overhanging flange depending into said trough and adapted to direct into the trough the coolant collecting upon the work table to a depth sufficient to overflow said work table, and an auxiliary table seated upon and secured to said work table having a marginal flange also depending into said trough and overhanging the corresponding marginal flange of the work table, to direct into said trough the coolant overflowing said auxiliary table.

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