W. TAYLOR.

GRINDING MACHINE.

APPLICATION FILED OCT. 28, 1916.

1,432,093. Patented Oct. 17, 1922.

9 SHEETS—SHEET 1.

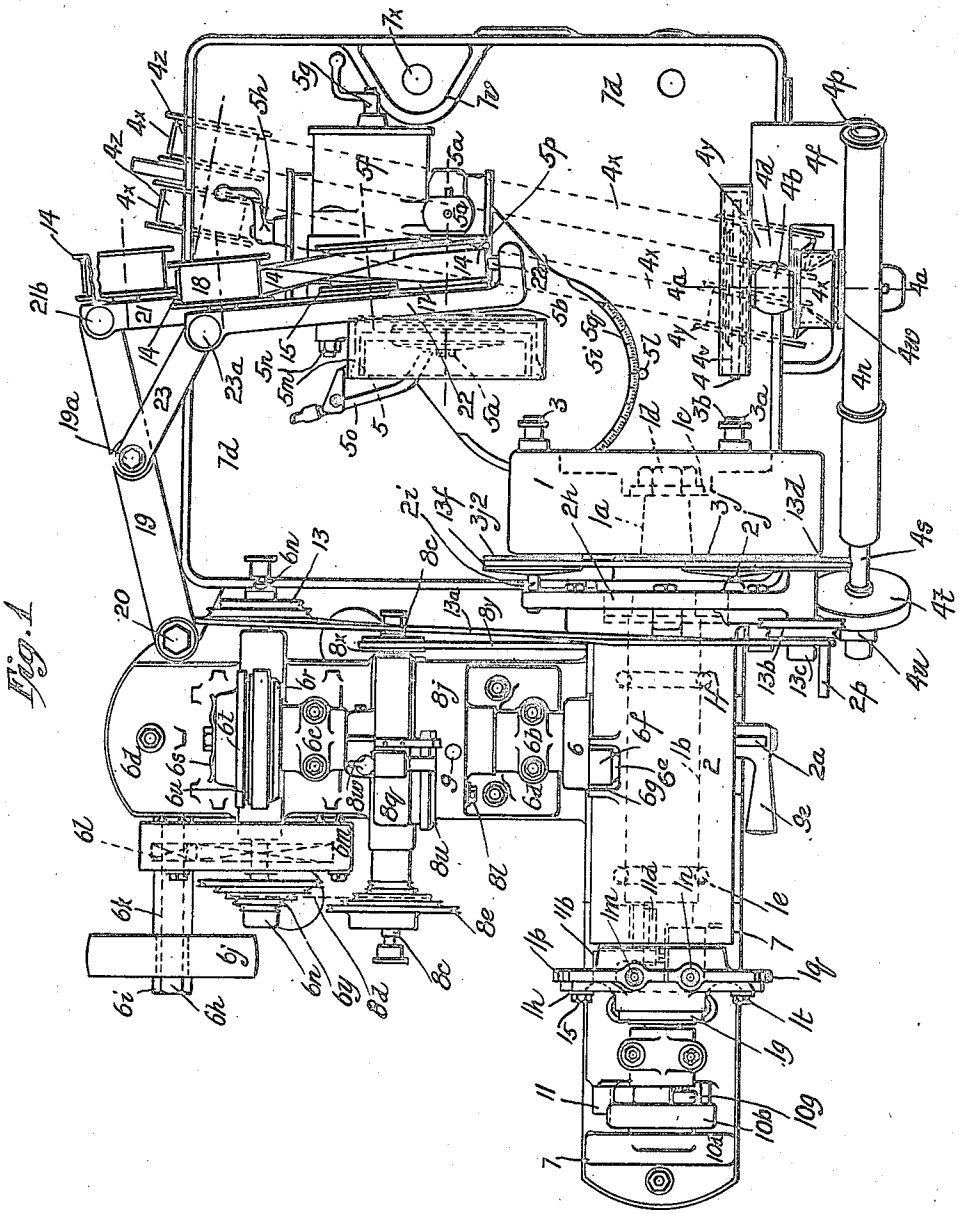

Fig. 1.

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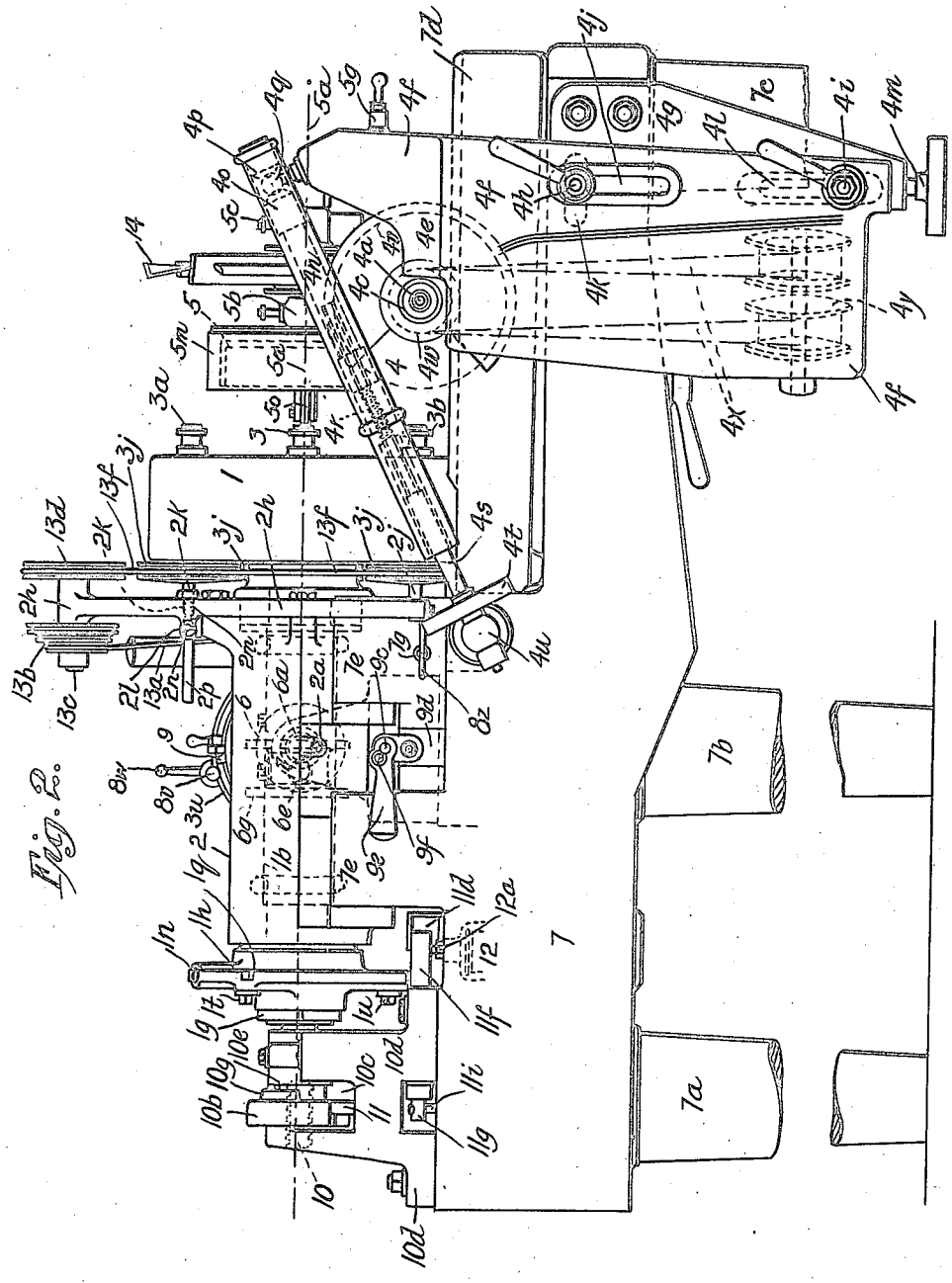

Fig. 2.

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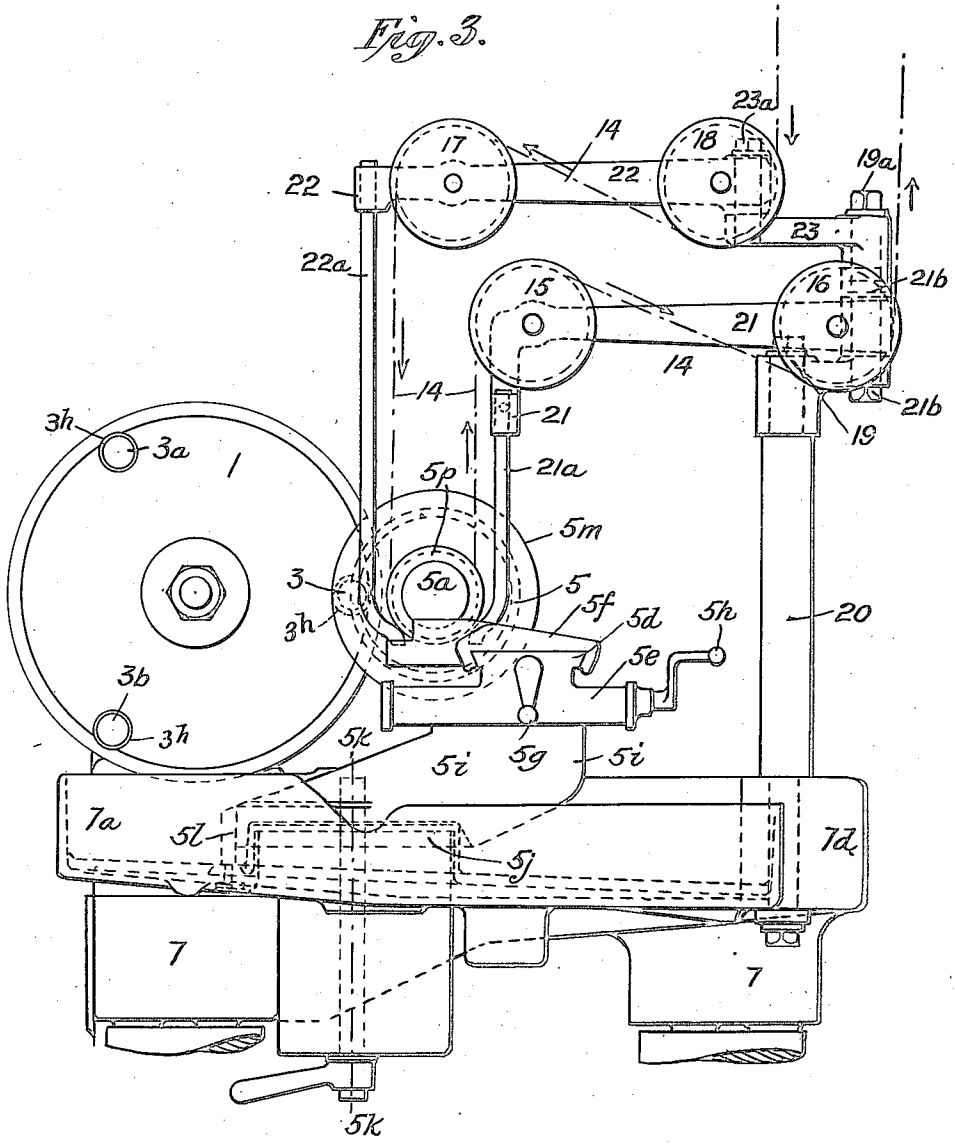
9 SHEETS—SHEET 3.

Fig. 3.



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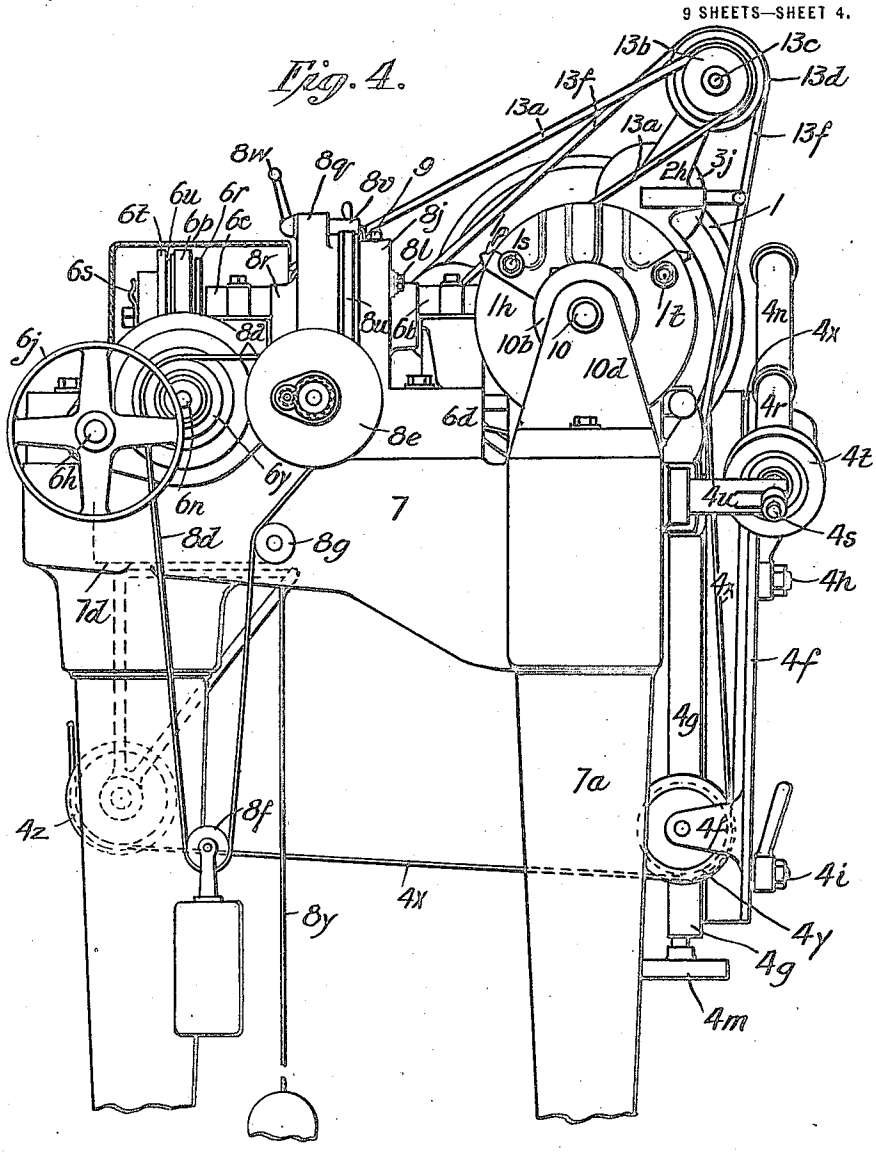
9 SHEETS—SHEET 4.

Fig. 4.



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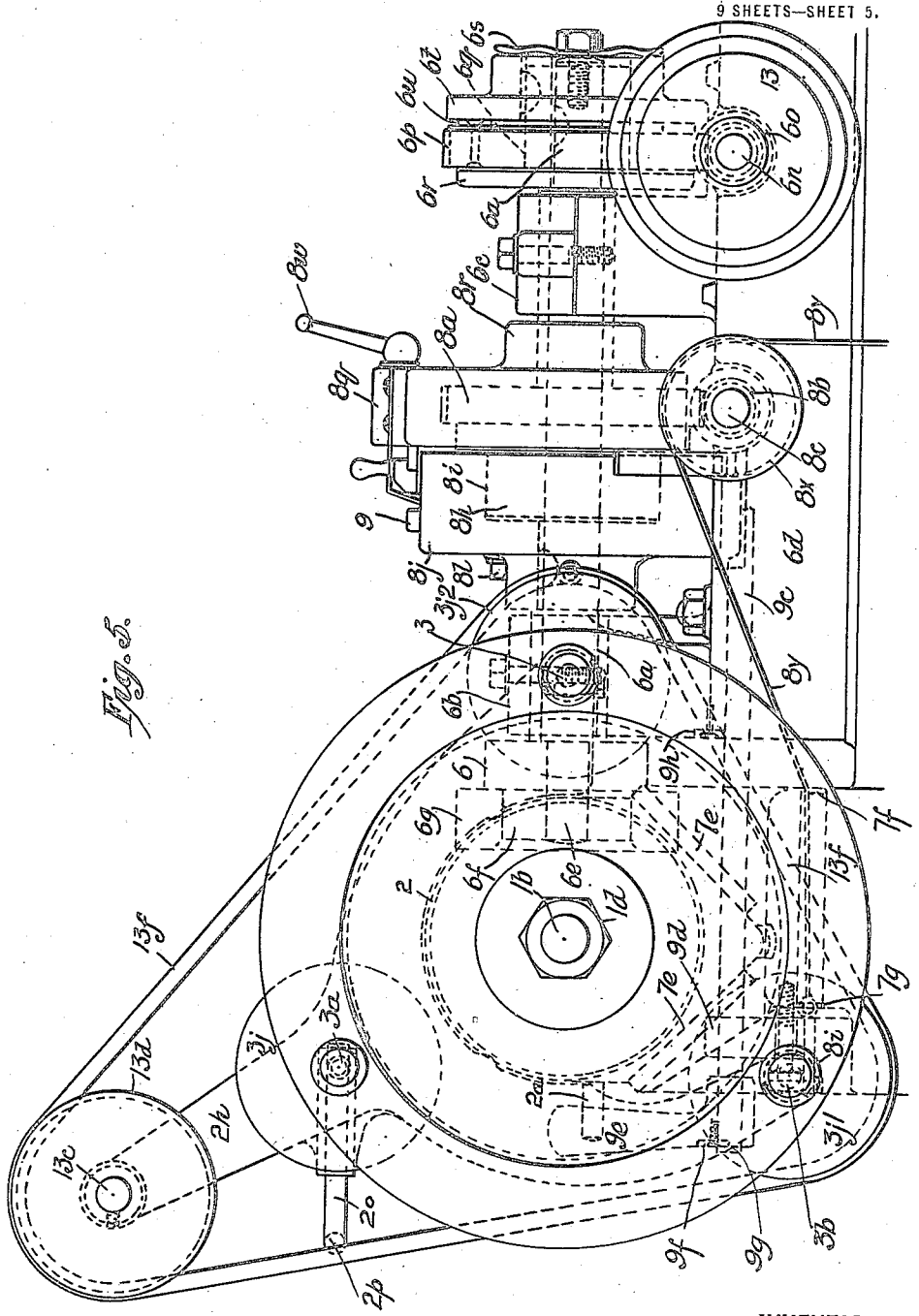

Fig. 5.

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9 SHEETS—SHEET 6.

Fig. 10.

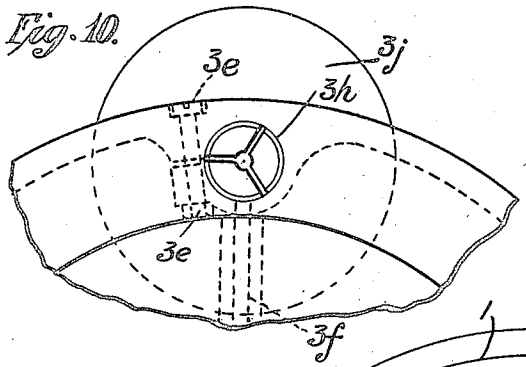
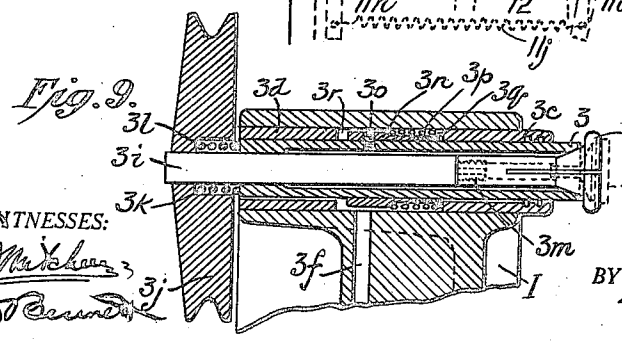


Fig. 6.

Fig. 9.



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9 SHEETS—SHEET 7.

Fig. 6a.

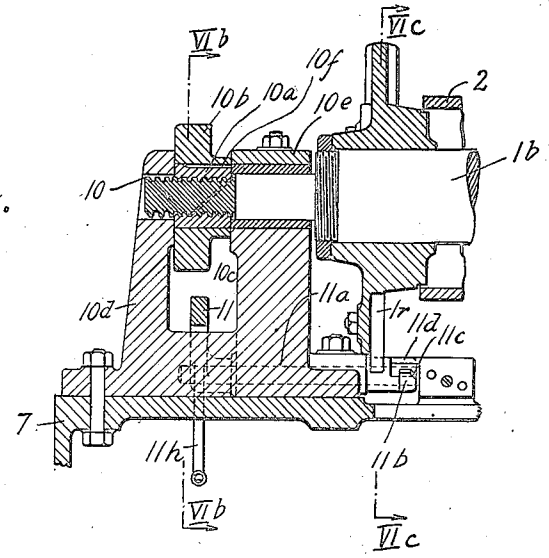


Fig. 6c.

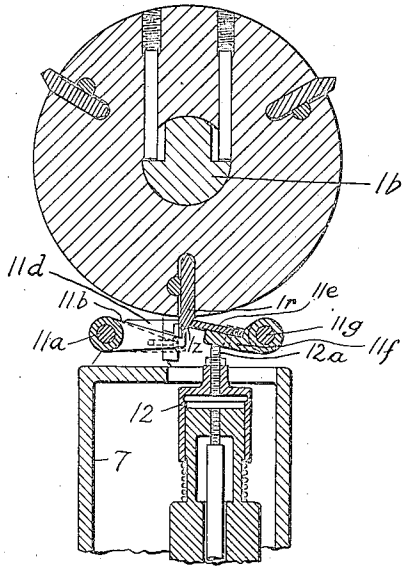
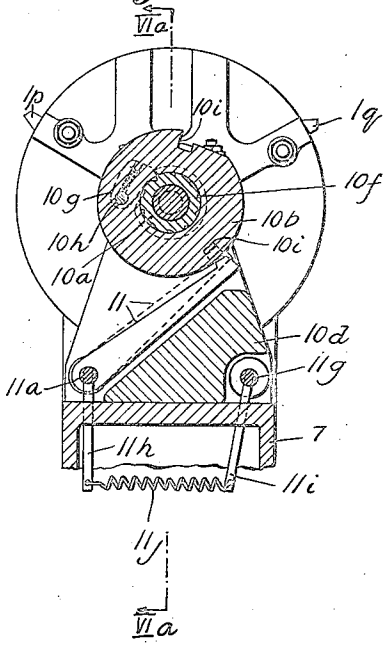


Fig. 6b.



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9 SHEETS—SHEET 8.

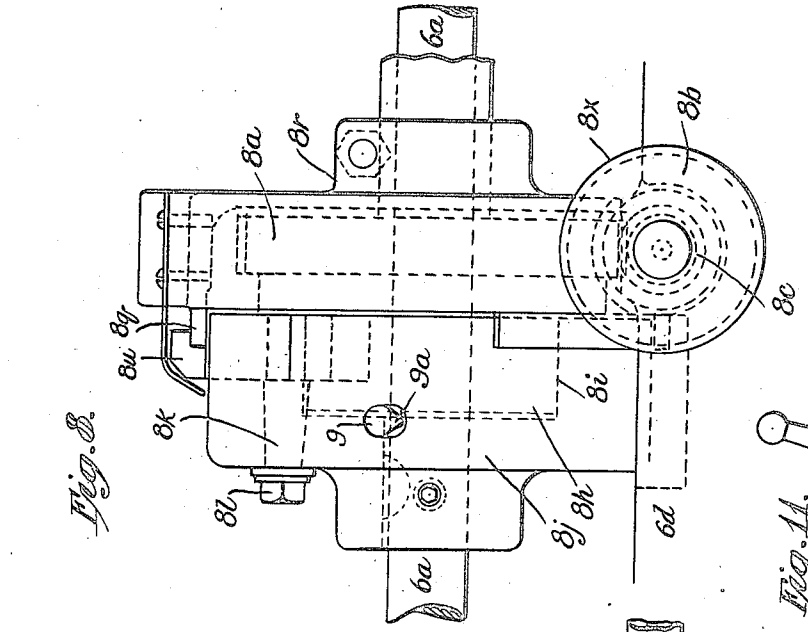

Fig. 8.

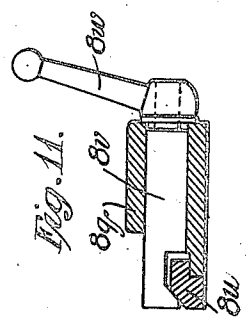

Fig. 11.

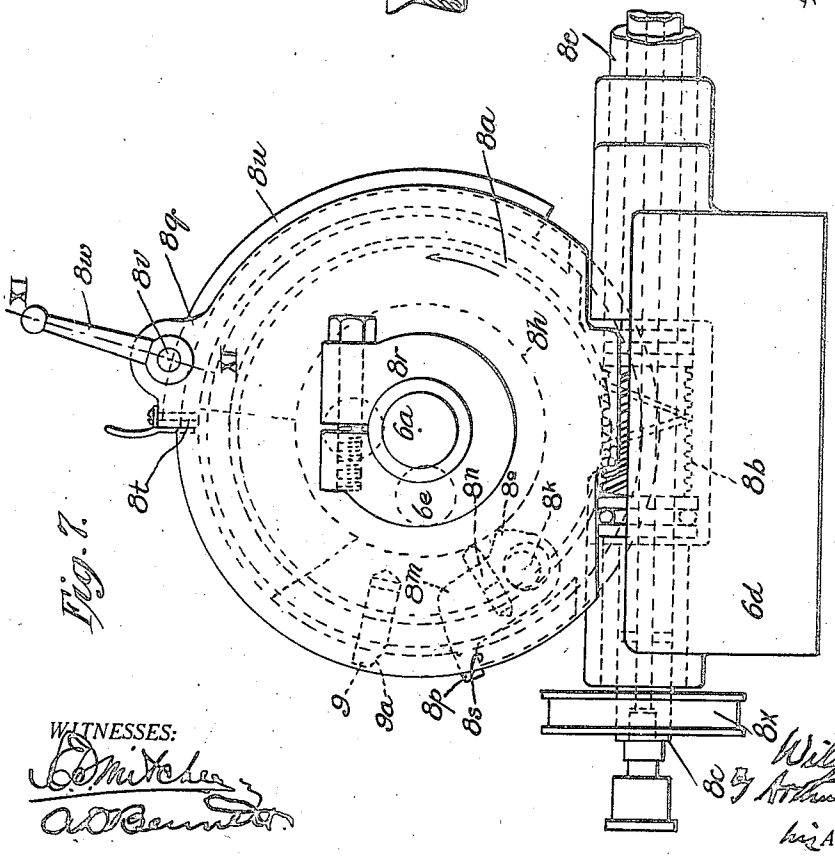

Fig. 7.

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9 SHEETS—SHEET 9.

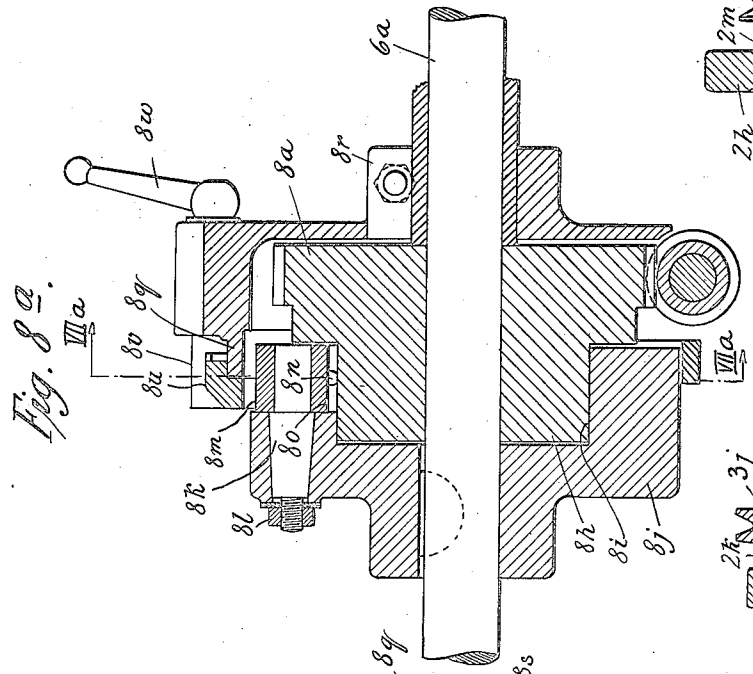

Fig. 8a.

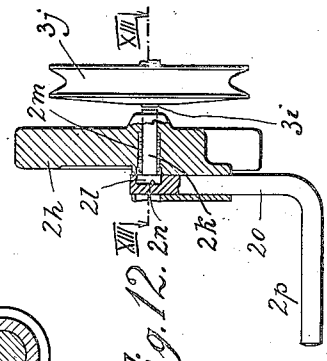

Fig. 12.

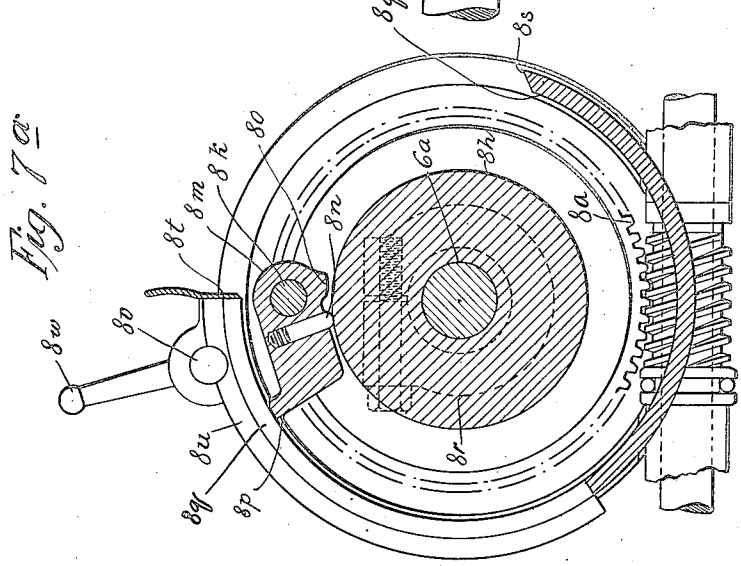

Fig. 7a.

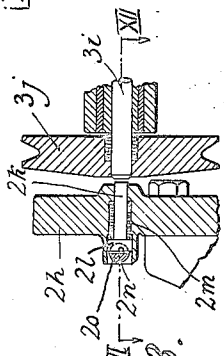

Fig. 13.

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Patented Oct. 17, 1922. 1,432,093

UNITED STATES PATENT OFFICE.

WILLIAM TAYLOR, OF LEICESTER, ENGLAND.

GRINDING MACHINE.

Application filed October 28, 1916. Serial No. 128,236.

To all whom it may concern:

Be it known that I, WILLIAM TAYLOR, a citizen of Great Britain, residing at Leicester, in the county of Leicestershire, England, have invented certain new and useful Improvements in Grinding Machines, fully described and represented in the following specification and the accompanying drawings, forming a part of the same.

This invention relates to machines for performing grinding and similar operations, and contemplates particularly the provision of apparatus by which a number of similar objects may be operated upon rapidly, and preferably, as far as possible automatically. Certain features of the invention are applicable to grinding and like machinery generally, but the invention is intended chiefly to provide apparatus for grinding lenses or other objects of glass and it is especially adapted to the grinding of the surfaces of lenses.

Among the objects of the invention are to provide apparatus of the character referred to, which will operate in a rapid and economical manner, a plurality of operations preferably being carried on simultaneously; to provide apparatus which will require little attention on the part of the operator and which will be largely automatic in its operation; to provide mechanism which will grind lens surfaces with accuracy, without depending upon the skill of the operator to produce such results; and to provide an apparatus of such character that blanks which are not of uniform dimensions will be so operated upon as to produce a uniform product.

A more specific object of this invention is to provide a glass disc and lens grinding machine in which a number of work carrying spindles are mounted in a turret which, for the purpose of positioning and feeding the work to suitable power driven abrasive cutting or grinding tools, is advanced and retracted with respect to the tools and intermittently rotated to bring the work carrying spindles successively into proper operative position with respect to the tools, the extent of each successive rotation being such that at any time one or more of the spindles will be retained in a position wherein a finished disc or lens can be removed from its holder on a spindle and a fresh glass blank inserted. Thus these operations can be performed while the grinding processes on other lenses are proceeding, and also where means are provided for performing more than one operation on a lens or blank, the various operations can be carried on simultaneously on blanks in different stages of completion. Saving of time and the maximum efficiency in the use of the machine are thus attained.

The invention will be described as applied to a machine whose turret is fitted with, for example, three work spindles, and with the aid of the accompanying drawings in which:—

Fig. 1 is a plan view of a glass disc grinding machine embodying the invention;

Fig. 2 is a front elevation of the machine;

Figs. 3 and 4 are side elevations viewed from the right and left hand respectively, some portions being omitted;

Figs. 5 and 6 are elevations, viewed from the right and left hand respectively, of the turret and mechanism for operating it on a larger scale than Figs. 1 to 4;

Fig. 6^a is a front elevation of the turret rotating mechanism sectioned on a vertical plane through the axis of the turret shaft 1^b, and Figs. 6^b and 6^c are vertical sections taken on the lines VI^b—VI^b and VI^c—VI^c of Fig. 6^a respectively;

Figs. 7 and 8 are respectively right side and rear elevations of mechanism for the slow feed motion of the turret, Fig. 7 showing the clutch pawl engaged for slow feed;

Fig. 7^a is a large side elevation sectioned on the line VII^a—VII^a of Fig. 8^a, and Fig. 8^a a rear elevation sectioned on a vertical plane through the axis of the shaft 6^a, of the slow feed mechanism, Fig. 7^a showing the clutch pawl disengaged to permit the operation of the fast feed;

Figs. 9 and 10 are details showing a work spindle mounted in the turret;

Fig. 11 is a detail sectional view taken on line XI—XI on Fig. 7; and

Figs 12 and 13 are detailed views showing the chuck releasing means, Fig. 12 being a horizontal section on the line XII—XII of Fig. 13, and Fig. 13 a vertical section on the line XIII—XIII of Fig. 12.

In the drawings, 1 is the turret which is mounted on a shaft rotatable in a longitudinal slide 2, and carries at three equidistant points in its face work spindles 3, 3^a and 3^b similarly constructed and adapted to be ro-

tated by some suitable means. The axes of the work spindles, as shown, are parallel to and at equal distances from the axis of rotation of the turret. The spindles carry at their outer ends, in suitable chucks 3^h, (Figs. 3 and 9) the discs of glass 24 which are to be formed by grinding into lenses.

In the positions of these spindles as shown in Figs. 1 and 2, the disc carried by the spindle 3^b is ready to be operated on by an adjustably mounted abrasive wheel 4, which is here regarded as a roughing wheel and may be set either to grind the centre of the disc so as to make it concave or to grind the outer edge of the disc so as to make its face roughly convex or bevelled.

The disc carried by the spindle 3 is in position to be operated on by the adjustably mounted wheel 5, which is of cup form and provided with an annular grinding edge, and may be applied to grind on the face of the glass disc a spherical curve either convex or concave, and whose radius may be varied either by varying the diameter of the abrasive wheel or the angle at which its axis is inclined to the axis of the work spindle 3 or by varying both of these factors.

While these wheels are operating on discs in spindles 3 and 3^b, the spindle 3^a is in a position where the operator may remove the finished work and replace it by a fresh disc.

In order to advance the turret and its work spindles toward the abrasive wheels to effect the grinding, the slide 2 is reciprocated at suitable times and speeds by a crank 6, (see Fig. 1) and at each reciprocation the turret, in the case of the machine herein shown, is rotated on its shaft one third of a turn so as to bring the spindle 3 with the finished glass into the position 3^a, to carry the fresh disc to the roughing wheel 4, and the disc which has been roughed thereby to the finishing wheel 5.

The machine comprises a bed 7 on legs 7^a, 7^b, and 7^c, and carrying a pan 7^d with upturned edges to catch liquid and detritus from the abrasive wheels, and having a weir 7^v, (Figure 1) to retain the silt precipitated from the liquid and an outlet pipe 7^x to drain the liquid away.

The bed is adapted to carry, as shown in Fig. 1, the various mechanisms now to be described for operating the work spindles, rotating the turret, advancing and withdrawing the turret and work spindles to and from the abrasive wheels at suitable speeds, and for setting and driving the roughing and finishing wheels 4, 5.

Turret and work spindles.

The turret 1 is best seen in Fig. 5 and comprises a body, preferably of aluminium for lightness, bored with a conical and chambered central hole 1^a, by which it is centered and fixed to its shaft 1^b.

Each work spindle is hollow and is rotatably mounted in bushes 3^c and 3^d (Figs. 9 and 10), of which the first is conveniently fixed by being forced into the hole in the turret, and the other removably clamped by means of a screw and nut 3^e which is arranged to close a split part of the hub containing the bush. To lubricate the spindle bearings from within, and carry the lubricant outward so as to prevent access of dirt, grease is supplied to the annular space between the bushes through radial holes 3^f, and a chamber in the turret bore from a lubricator, not shown, communicating with that chamber and placed so as to be accessible from the back of the turret.

Each of the spindles 3, 3^a and 3^b is adapted to receive changeable split chucks 3^h of the kind well known in connection with watch machinery and lathes, these chucks being suitably bored and recessed according to the diameter and thickness of the glass discs to be held.

The chuck 3^h is drawn into the conical mouth of the spindle 3 so as to grip the glass disc, by the draw-in spindle 3^i which has fixed upon it a driving pulley 3^j, in a chamber 3^k of which is a compression spring 3^l adapted to close the chuck by pulling out the draw-in spindle, which is attached to it in the well known manner by being screwed into the chuck at 3^m. The strength of this spring is such that while it holds the glass securely in the chuck it does not crush it.

In order to secure uniformity in the thickness of the lenses, the overall lengths of the three spindles 3^i and of the chucks 3^h are made quite uniform, and during the grinding operation the outer end of the draw-in spindle 3^i is thrust by the corresponding abrasive wheel against an abutment, that is hereafter mentioned, and fixed on the machine.

In order that a spindle 3 may be free endwise for this purpose while being unable to stray unduly, a retaining collar 3^n (see Fig. 9) is fastened to the spindle by a screw 3^o, and a light compression spring 3^p is provided to thrust against the collar 3^n, and a loose sleeve 3^q, so as to move the spindles 3 and 3^i toward the fixed abutment aforesaid, and a suitable but limited end shake in the bearings is permitted by the space 3^r between the collar and the bush 3^d.

Turret mounting.

The turret mounting is best seen in Figs. 1 and 2.

The turret 1 is fixed by its tapering bore 1^a on a corresponding tapered end of the shaft 1^b and is clamped thereon in suitable manner, as by means of a washer 1^c and nut 1^d screwed on a threaded outer end of the shaft.

The shaft 1^b is carried, preferably in ball

bearings 1^e, 1^f at either end of a housing 2, which is adapted to slide longitudinally in a V-shaped cradle formed by part of the bed 7 and having sliding surfaces, or supporting ways, shown in Fig. 5 at 7^d and 7^e. The housing 2 rests in the ways by gravity alone.

Keyed to the shaft 1^b and clamped thereon by the nut 1^g, Fig. 2, so as to take end shake out of the shaft bearings, is a three armed spider 1^h, (see Fig. 6), whose function is to hold the turret against rotation in its three equidistant operative positions; and in order to provide for slight adjustment rotationally in such positions of the turret, the spider 1^h is keyed to the shaft 1^b, as is shown especially in Fig. 6, by means of two thrust rods 1^i and 1^j which are adapted to thrust against diametrically disposed faces 1^k and 1^l of recesses formed in the shaft 1^b, the thrust rods being acted upon by screws 1^m and 1^n, so that by unscrewing one and screwing up the other the spider 1^h may be slightly rotated or securely held against rotation on the shaft 1^b.

The arms of the spider which position the turret are preferably formed as pieces of steel 1^p, 1^q and 1^r, hardened and ground, and held by bolts and nuts 1^s, 1^t and 1^u, in equidistant radial slots formed in the spider drum 1^h.

The spider arms are adapted to engage in turn an abutment fixed on the bed 7, and which will be more particularly described hereafter.

Turret traverse mechanism.

In order to move the turrent 1 with its work spindles and work to and from the abrasive wheels, the housing 2 is made to reciprocate in its supporting ways 7^e by means of a crank 6, Figs. 1 and 2, which is carried at one end of a crank shaft 6^a housed in bearings 6^b and 6^c in a suitable frame 6^d bolted upon the cross member of the bed 7.

The crank 6 has a pin 6^e which actuates a block 6, Fig. 1, sliding between the sides of a vertical slot 6^g in the rear side of the housing 2. By this means rotation of the crank shaft 6^a communicates a reciprocating motion to the sliding housing 2 and the turret associated with it.

Fast and slow feeds.

It is desirable that in order to secure a smooth finish on the lens, the rate of advance of the work toward the abrasive wheels should diminish just before the end of the operation, and that the work should dwell for a short time in its most advanced position.

This is secured by my using a crank to effect the reciprocating motion of the turret, for thereby the rate of such motion diminishes (and the work dwells for a time) as the crank respectively approaches and passes its dead centre.

In order to save time in operation it is desirable to provide means whereby this reciprocating motion of the turret while taking place at a suitable but variable slow speed during the actual grinding operation, should at other times be as fast as is practicable to effect the withdrawal and exchange in position of the work spindles.

For rotating the crank shaft at variable speeds for these purposes the following mechanism is used, and for convenience is formed as a self-contained unit on the frame 6^d. It is shown in elevation and part section in Figs. 1 and 5.

Upon a stud 6^h fixed in the side of the frame 6^d and confined by a collar 6^i is mounted a pulley 6^j which has attached to it a sleeve 6^k and a pinion 6^l.

The pulley is driven at a constant speed by a belt from any convenient source of power, and the pinion 6^l drives a toothed wheel 6^m keyed to a worm shaft 6^n housed in bearings in the frame 6^d and carrying between the bearings a worm 6^o, Fig. 5, which drives a worm wheel 6^p, rotatably mounted on a hub 6^q keyed to the crank shaft 6^a and having a flange 6^r against which the worm wheel 6^p is thrust by a star shaped spring 6^s through the medium of a plate 6^t slidably keyed to the hub 6^q and bearing against the other side of the worm wheel 6^p so as to attach it frictionally to the crank shaft 6^a. To enhance this friction the worm wheel 6^p may be faced with a ferodo ring 6^u riveted to it.

By these means the crank shaft 6^a tends to be driven at a fixed speed, and this speed is such as to withdraw the turret and the work spindles from the abrasive wheels after the completion of each grinding operation, and to return the same for the next operation as fast as is practicable in order to save time.

As the fresh discs of glass then approach the abrasive wheels it is necessary to retard the speed of rotation of the crank shaft, and for this purpose a second worm wheel 8^a, Fig. 5, is rotatably mounted on the crank shaft 6^a, and is driven by a worm 8^b on a worm shaft 8^c housed in bearings in the frame 6^d and driven at speeds which may be varied by means of a band 8^d and stepped cone pulleys 8^e and 6^v fixed to the shafts 8^c and 6^n respectively. (See Fig. 1.)

Suitable means are provided for tensioning the band 8^d and those shown in the drawings comprise a weighted pulley 8^f, Fig. 4, suspended by the band, which can be carried round a fixed idler pulley 8^g to keep it clear of other mechanism.

The worm wheel 8^a has a hub 8^h, (Figs. 7, 7^a, 8, 8^a,) which is free to rotate both on

the shaft 6^a and within a chamber 8^i in a casing 8^j keyed to the shaft 6^a.

On a pin 8^k, Figs. 7, 7^a, 8^a (which for convenience of adjustment can be fixed to the casing 8^j by an eccentric tapered stem and secured by the nut 8^l) is rotatably mounted a friction pawl 8^m urged by the spring plunger 8^n to engage by its cam shaped edge 8^o with the worm wheel hub 8^h as shown in Fig. 7, so as to clutch it to the casing 8^j, and thereby to the crank shaft 6^a.

Normally, however, the pawl 8^m is held from so engaging the hub 8^h by its tail end 8^p lying within an encircling casing 8^q, as shown in Fig. 7^a, adjustably clamped by a bolt and its split hub 8^r to a projecting part of one of the bearings of, and concentric with, the crank shaft 6^a in the frame 6^d (Figs. 1, 7, 8, 7^a, 8^a).

That part of the casing 8^q which extends, as Fig. 8 shows, only half way across the tail end 8^p of the pawl 8^m, has a gash or slot formed in it between the points 8^s and 8^t (Figs. 7, 7^a).

The effective length of this gash may be varied by sliding more or less over it a segment 8^u which is adjustably clamped to the casing 8^q by the bolt 8^v and the hand nut 8^w (Figs. 8^a, 11).

The worm wheel 6^p and the crank shaft 6^a, with the clutch casing 8^j, normally rotate in the direction of the arrow in Fig. 7, and at the speed determined by the friction wheel 6^p until the time when the crank has caused the work spindles to approach near to the abrasive wheels.

At such points, which may be varied by setting the segment 8^u aforesaid, the end 8^p of the clutch pawl 8^m escapes from the end of the segment 8^u, passing into the above mentioned gash or slot whereupon its cam part 8^o engages the hub 8^h of the worm wheel 8^a, and, causing the friction wheel 6^p to slip, compels the crank shaft to assume the slower rate of rotation of the worm wheel 8^a.

This slow rotation, and consequent slow advancement of the work to the abrasive wheels, continues during the grinding operation until the crank pin 6^e, having reached its centre and having advanced the work as far as possible is ready to withdraw it. At this point the end 8^p of the clutch pawl 8^m, as is shown dotted in Fig. 7, encounters the end of gash 8^s in the casing 8^q and the pawl is turned so that the clutch is disengaged and the crank shaft set free to assume the higher rate of rotation proper to its friction driven worm wheel 6^p.

When glass discs of various thicknesses are to be formed into similar lenses, the segment 8^u must be set to suit the thickest discs to avoid crushing them or the abrasive wheels, and for such cases to avoid the waste of time which would occur when a thin glass is put into the machine I make provision for rotating the crank shaft manually by means of the pulley 8^x, Fig. 7, attached to the end of the worm shaft 8^c, which may be turned by a weighted band 8^y passing through porcelain eyes 7^t and 7^s, Fig. 5, in the bed 7, and having a handle 8^z (Fig. 2) by which the band may be pulled so as to rotate the pulley 8^x, and thereby accelerate the motion of the crank shaft 6^a. Upon releasing the handle 8^z the band 8^y slips over the pulley 8^x without rotating it backwards.

In order to arrest withdrawal movement of the turret after each grinding operation, until such time as the operator has changed the work in the idle work spindle, I fix in the clutch casing 8^j a radially projecting pin 9. Fig. 1, 5, 7 and 8, having a face 9^a, adapted to engage the end of a bar 9^c, rotatably journaled in the frame 6^d and in a bracket 9^d at the front of the bed 7. Part of the rear end of the bar is cut away so that in the position of rotation as shown in Fig. 5, the pin 9 can rotate past it, but when the bar is turned through a suitable angle of, for instance, about 30 degrees, the pin 9 is obstructed by it so as to prevent rotation of the crank at the time when the grinding operation is just completed.

In order to limit the rotation of the bar 9^c so that it may be placed in either of these two operative positions, and at the same time to prevent its withdrawal from its bearings, a disc shaped key 9^h (Fig. 5) is fixed in the frame 6^d, and enters a slot cut in one side of the bar 9^c of such size and position as to limit the rotation of the bar as aforesaid.

The outer end of bar 9^c has rotatably upon it a handle 9^e (Figs. 2 and 5) confined by a key 9^f which engages a slot 9^g in the side of the bar 9^c in such a way that while confined against endwise motion on the bar the handle 9^e can rotate upon it through an angle of about 70 degrees.

When the handle 9^e is lifted to the position shown in Fig. 5, its key 9^f rotates the bar 9^c until it encounters the key 9^h, and in this position the pin 9 is released so as to permit rotation of the crank and withdrawal of the turret.

Projecting from the front of the sliding housing 2 is a pin 2^a so placed that upon such withdrawal of the turret it encounters the handle 9^e in its upright position, Fig. 5, and moves it so that it falls by gravity into the position shown in Fig. 2, and in so falling turns the bar 9^c into the position where it obstructs the passage of the pin 9 and further withdrawal of the turret.

By these means, the operator who may be attending several machines, is assured that the withdrawal movement of the turret will be arrested until he has changed the work

and lifted the handle 9^e to its upright position.

Turret rotating means.

In order that, upon each withdrawal of the turret, it may be rotated to transfer the work spindles progressively forward, I form upon the tail end of the turret shaft 1^b a screw 10, of suitable coarse pitch, and fit loosely thereto a nut 10^a having a cylindrical exterior upon which a collar 10^b is rotatably mounted (Figs. 2, 6, 6^a, 6^b, 6^c) and the nut and collar are confined against end shake by being lodged between the faces of a gash 10^c in a bracket 10^d fastened to the bed 7 (Fig. 6^a).

The bracket 10^d has a cap 10^e removably attached to confine the shaft 1^b against lifting or permit of its removal.

The nut 10^a has cut in its periphery a number of longitudinal equidistant slots or teeth 10^f adapted to engage a spring pawl 10^g pivoted at 10^h to the collar 10^b, so as to permit rotation of the nut within the collar in one direction only (Figs. 6, 6^a, 6^b).

The number of teeth 10^f may equal, or be a multiple of, the number of work spindles in the turret.

The collar 10^b has in its periphery a notch 10^i adapted to engage a spring urged pawl 11 pivoted to a shaft 11^a journalled in the base of the bracket 10^d. (Figs. 6, 6^b.)

Upon this shaft is a crank arm 11^b having a bevelled end 11^c adapted to engage, and be depressed by, a corresponding bevel on the end of each of the spider arms 1^p, 1^q, 1^r when the spider is positioned for a grinding operation by encountering an abutment plate 11^d, preferably of hardened steel; attached to the bed 7 (Figs. 6^a, 6^c).

In this operative position, one of the arms of the spider, for instance, arm 1^r, is held against the abutment 11^d by a spring urged bevelled lock piece 11^e, engaging the bevelled face 1^z of the spider arm, the lock piece being attached to an arm 11^f pivoted at 11^g to a shaft journalled in the bracket 10^d (Fig. 6).

Cross pins 11^h and 11^i fixed in the shafts 11^a and 11^g respectively have between them a helical tension spring 11^j, which tends to urge the pawl 11 and the lock piece 11^e rotationally as aforesaid (Fig. 6^b).

The action of this mechanism is as follows:—

During each grinding operation, the turret with its work spindles is positioned rotationally by one of the spider arms, 1^r in the drawings, resting against the abutment 11^d under the action of the spring urged lock piece 11^e, which exerts a wedging action against the bevelled surface 1^z (Figs. 6^b, 6^c).

Upon the completion of the grinding operation, the pin 9 being freed from obstruction by the shaft 9^e, the crank withdraws the turret by sliding its housing 2 lengthwise, and during the first period of such withdrawal while such rotation of the turret is prevented by the abutment 11^d the screw 10 moves endwise within the nut, 10^a, which is thereby rotated in the direction of the arrow 10^j and carries with it the collar 10^b, which is sufficiently held to it by the spring pawl 10^g, until the collar reaches the position shown in Fig. 6 where the pawl 11 encounters the notch 10^i and thereby prevents further rotation of the collar.

During the remainder of the withdrawal of the turret the nut 10^a is rotated within the collar 10^b by the screw 10, such rotation being permitted by the pawl 10^g.

Shortly before the withdrawal of the turret is completed the spider arm 1^r passes clear of one end of the abutment 11^d and of the end 11^c of the crank arm 11^b, which thus sets free the pawl 11 to enter completely the notch 10^i in the collar 10^b (as shown in dotted lines in Fig. 6^b) and lock it against rotation in either direction.

The turret with its housing 2 now commences to return under the action of the crank 6, but reverse rotation of the nut 10^a being prevented by the pawls 10^g and 11, the turret itself is compelled to rotate under the action of the screw 10, and does so during the first part of such reverse motion of its housing 2 until the next spider arm 1^q, encounters the abutment 11^d, and in reaching this position depresses once more the end 11^c of the arm 11^b, and withdraws from the collar 10^b the locking pawl 11.

Rotation of this collar with the nut 10^a now takes place during the last phase of the sliding motion of the turret until the grinding operation is once more completed.

In order to permit quick movement and rotation of the turret without undue shock when a spider arm encounters the abutment 11^d, an air or liquid check 12, (Fig. 6^c) which may comprise a cylinder with a suitably leaky piston therein and a spring to lift the piston, is fixed in the bed of the machine so that the end 12^a of the piston rod is pressed upon by the arm 11^f when this is encountered by the spider arm just before it reaches the abutment 11^d, and thereby the energy of the rotating parts is absorbed without shock.

Work spindle drive.

In order to rotate at suitable variable speeds the two work spindles, which during any grinding operation carry respectively the disc of glass being rough ground and the disc being finish ground, I fix upon one end of the constant speed worm shaft 6^n a stepped cone pulley 13, Fig. 1, adapted to

drive a band 13^a, which in turn drives another stepped cone pulley 13^b on one end of a small countershaft 13^c mounted on an arm of the bracket 2^h fastened to one end of the housing 2 (Figs. 2, 4 and 5).

The stepped cone pulleys 13 and 13^b are preferably arranged to give a series of speeds progressing in geometric ratio, and may be exchanged so as to extend the series.

It is to be understood that I do not limit myself to the particular means described for varying the speed of the counter shaft 13^c.

Upon the other end of the countershaft 13^c I mount a pulley 13^d adapted to drive a band 13^f, which in turn drives the pulleys attached to the work spindles, which are respectively in the roughing and finishing positions, and which in the positions shown in the drawing are the spindle 3^b and 3 and pulleys 3^{j1} and 3^{j2}.

Upon the rotation of the turret, after the completion of each grinding operation, when the finished lens of the spindle 3 is transferred to the top position marked 3^a, its pulley passes out of range of the band 13^f and ceases to be rotated, as is seen to be the case in Fig. 5.

Clamped in holes in suitable bosses in the bracket 2^h coaxially with the work spindles in the positions 3 and 3^b are cylindrical flat-ended abutments 2^i and 2^j (Figs. 1 and 2) respectively adapted as aforesaid to take the end thrust of the grinding wheels on the said work spindles and secure uniformity in the thickness of the lenses ground.

Sliding in a counterbore hole in the bracket 2^{hf}, coaxially with the idle work spindle in the position 3^a, is a spring urged plunger 2^k (Figs. 2, 12, 13) with a head 2^l adapted to be thrust by a spring 2^m against a diametrical flat face 2^n formed by cutting a gash half way through one side of a shaft 2^o journalled in a cross hole in the bracket 2^h, and having a cranked lever 2^p by which it may be rotated manually so as to thrust the plunger 2^k against the tail end of the spindle 3^l so as to open the chuck 3^h and set free the finished lens, which is then replaced by a fresh disc (Figs. 5, 12, 13).

Rough grinding wheel.

The abrasive wheel 4 (Figs. 1 and 2) which is used for the first rough grinding operation, may conveniently be as indicated in the drawings of ordinary disc form and be mounted in the usual manner on a spindle 4^a housed in suitable bearings 4^b and 4^c, which may be provided with any well-known form of adjustment for wear, and have spherical exteriors so as to be self aligning, and be attached to bosses 4^d and 4^e on a carrier frame 4^f adjustably mounted on the bed 7 of the machine.

In order to provide for setting the axis of the wheel 4 to lie in the same plane as and to intersect the axis of the roughing work spindle 3^b, and thereby grind a cavity in the face of the glass disc corresponding to the curve of the wheel 4, or to set the wheel above or below said position so that it may grind a bevel toward the outer edge of the face of the disc and prepare it for receiving convex curvature from the finishing wheel; also in order to adjust the thickness of the lens and for wear of the wheel, I attach the carrier frame 4^f to the front of the bed 7 so that it may slide on a vertical faced bracket 4^g attached to the bed, and be secured adjustably thereto by bolts 4^h and 4^i, the former of which passes through a vertical slot 4^j, Fig. 2, in the frame 4^f and a horizontal slot 4^k in the bracket 4^g, whereby vertical and horizontal movement and adjustment of the wheel 4 is permitted.

In order to effect such vertical adjustment, the bolt 4^i fits freely in a hole in the carrier 4^f, and is confined in a vertical slot 4^l in the bracket 4^g, wherein its head is free to move vertically, and in which it may be moved by means of the screw and hand wheel 4^m so as to move the carrier up or down.

In order to effect movement of the wheel in a more or less horizontal direction, the carrier 4^f may be swung round the bolt 4^i by means of the adjustable stay 4^n, (Figs. 1 2, and 4) which is shown as comprising a tubular member containing at one end spherical seatings 4^o and 4^p adapted to engage a ball-ended stud 4^q projecting from the upper end of the carrier 4^f. Near its other end the stay 4^n is threaded internally to form a nut 4^r in which engages an adjustment screw 4^s operable by a hand wheel 4^t, and journalled against end shake in a bearing 4^u pivotally attached to the bed of the machine.

One of the side faces of the wheel 4 should be arranged, as in Fig. 1, at or about the axis of the work spindle 3^b, so that in the manner described in my co-pending application Serial No. 128,235 a radial step or terrace may be formed on the glass.

The wheel 4 may be partially encircled by a guard 4^v, and water is supplied to the wheel in the manner usual in grinding operations and by suitable piping, which, however, to save confusion is not shown in the drawing.

Any suitable means for driving the wheel may be employed. As shown the shaft of the wheel has fixed to it a pulley 4^w over which passes a driving belt 4^x. The belt is carried down under guide pulleys 4^y and 4^z (see Figures 1, 2 and 4) from which latter pulleys it passes over a driving wheel, not shown, which may receive power from any suitable source. The pulleys 4^y are mounted on the carrier 4^f so that they follow the adjustments of the grinding wheel and prop-

erly guide the belt to the pulley 4^w in any position of the latter.

Finishing wheel.

In the present embodiment of my invention I have shown the means for finishing the grinding of the lens surface as comprising a cup shaped wheel 5 provided with an annular grinding edge. This cup shaped finishing wheel 5 is mounted on shaft 5^a (see Figures 1, 2 and 3) which is journalled in self aligning bearings 5^b and 5^c, which are mounted on brackets projecting from a carriage 5^f, the axis of rotation of said wheel being located in the same horizontal plane as the axis of the work spindle 3 supporting the work for the finishing operation. This carriage is mounted to reciprocate in a direction parallel to the shaft 5^a upon a guideway 5^d formed on a second carriage 5^e. A hand screw 5^g is provided to reciprocate the carriage 5^f upon the carriage 5^e. The carriage 5^e is in turn mounted to reciprocate on a guideway on the swivel head 5^i, hand screw 5^h being provided to move the carriage. The direction of movement of the carriage 5^e on the swivel head 5^i is at right angles to the direction of movement of the carriage 5^f upon the carriage 5^e. The swivel base 5^i is rotatably mounted on an annular bearing 5^j formed on the machine bed 7, and is adapted to be clamped in any desired angular position by a clamping screw 5^k. To facilitate the proper setting of the swivel head the latter is shown as provided with a graduated scale 5^q, the desired marking on which may be placed opposite to a pointer 5^l, fixed to the machine bed 7. With the construction illustrated it will be seen that a universal mounting of the wheel 5 is provided so that the periphery of the latter may be brought into any desired relation to the face of the work on the work spindle 3. The axis of the swivel 5^i intersects the work spindle axis at or near the operative point of the wheel so that the latter may be moved on its swivel without being displaced laterally on the work.

The grinding wheel 5 is set with its axis of rotation in, or approximately in, a plane in which the axis of the work spindle 3 lies and the wheel is so set that as it rotates its annular grinding edge will sweep over the center of the glass disc carried by the work spindle 3. The axis of the grinding wheel 5 is set at an angle to the work spindle 3 so that there is ground on the face of the glass disc on the spindle 3 a portion of a sphere whose radius depends on the diameter of the annular edge of the wheel and on the angular relation between the axis of the work spindle 3 and the axis of the grinding wheel, which angle is indicated by the graduated scale 5^q and the pointer 5^l. By setting the axis of the grinding wheel at an angle at one side of the axis of the work spindle 3, a convex surface may be ground upon the glass disc, and by setting it at an angle at the other side of the axis of the spindle 3, by swinging it upon the swivel 5^i, a concave surface may be ground upon the glass disc.

The wheel 5 is preferably surrounded by a casing 5^m secured to the carriage 5^f by bolt and nut 5^n, and a pipe 5^o is provided for supplying water or other cooling agent to the wheel. As illustrated, the pipe 5^o discharges the water near the center of the wheel from which position the water will be gradually fed out to the periphery by centrifugal action.

Means are provided for rotating the wheel 5 in any position in which it may be set. In the construction illustrated these means comprise the pulley 5^p on the shaft 5^a, over which passes a driving belt 14. The driving belt is carried over the guide pulleys 15 and 16 and then over a suitable driving pulley, not shown, then passing over guide pulleys 17 and 18, and back to the pulley 5^p. The pulleys 15, 16, 17 and 18 are movably mounted so as to maintain the belt in proper relation to the pulley 5^p for any adjustment of the wheel 15. As shown a standard 20 rises from the machine bed 7 and has swivelled to its upper end a horizontally projecting arm 19, which carries between its ends a stud 19^a, and at its outer end a second stud 21^b. Mounted on the stud 21^b is an arm 21, the outer end if which is downwardly turned and connected to a supporting rod 21^a, the lower end of which is mounted on the carriage 5^f. Two studs project from the sides of the arm 21 and carry respectively the pulleys 15 and 16. Pivotally mounted on the stud 19^a is an arm 23, which carries at its end stud 23^a upon which in turn is swivelled an arm 22 which carries pulleys 17 and 18. At its outer end the arm 22 is supported by a rod 22^a connected to the carriage 5^f.

Operation.

The wheels 4 and 5 are first adjusted in the manner set forth with relation to the work spindles 3^b and 3, respectively, so that they will produce the desired cut upon the lens blanks held in the chucks of these spindles. The machine is then started, the turret being, however, held stationary and in its advanced position by the rod 9^c, which engages the pin 9, the handle 9^e being in its horizontal position as shown in Figures 1 and 2. The operator then moves the handle 2^p up to open the chuck 3^a so as to permit the glass disc or lens blank to be inserted. After this has been done the operator lifts the handle 9^e to its vertical position, which causes the end of rod 9^c to disengage the pin 9, this permitting the shaft

6^a, and the crank 6 to be rotated by the mechanism described, so as to draw back the slide 2 and the turret 1. This movement causes the spider arm 1^r to clear the stop 11^d, and also causes the screw 10 to rotate the nut 10^a, as already described. When the slide has reached the rearward limit of this movement the continued rotation of the crank 6 starts to advance the turret and slide which, through the action of the screw 10 and nut 10^a, which is now held stationary, results first in the rotation of the turret. The rotation of the turret, however, brings the spider arm 1^q into a position where it engages the stop 11^d, this preventing further rotation of the turret and holding it in a position where the glass disc, which has just been placed in the chuck on the spindle 3^a, is ready to be advanced into contact with the roughing wheel 4. The end of the arm 1^q in its rotation passes over and depresses the lock arm 11^e, which then springs up and holds the spider arm firmly against the stop 11^d, so as to lock the spider and turret firmly in the desired angular position. The continued movement of the crank 6 then advances the turret carrying the work spindles and the glass discs. It will be understood that during the withdrawal of the turret and slide by the crank 6, the shaft 6^a will be rotated by the fast feed mechanism including the worm wheel 6^p, but that during the latter part of the forward movement of the turret the slow feed mechanism, including the worm wheel 8^a, will come into play in the manner already described. This slow feed mechanism causes the worm to be advanced very gradually towards the grinding wheel as the actual grinding down of the glass takes place. Furthermore, as the turret approaches the forward limit of its movement it will be seen that the crank 6 is approaching its forward dead center, so that the advancement of the work becomes very gradual and eventually ceases altogether, this resulting in the work dwelling momentarily in its most advanced position, which permits the grinding wheel to produce a good finish on the lens surface. In cases where the lens blank is thinner than normal, so that the slow feed mechanism comes into action before the surface of the glass disc reaches the grinding wheel, then the operator may pull on the handle 8^z so as to operate the hand feed mechanism and advance the work rapidly, until it is brought to a position for the actual grinding to begin. The glass is then fed forward slowly by the slow feed mechanism as before. As the slide 2 and turret are withdrawn the pin 2^a engages the handle 9^e and knocks the same into horizontal position so that further withdrawal and further rotation of the turret cannot take place until the operator has removed the finished lens from the idle chuck and replaced it with a new blank and then moved the handle 9^e back to its vertical position.

Each time the turret is withdrawn and rotated it will be seen that the lens blank, which has been rough ground by the wheel 4 will be moved to a position where upon the next advancement of the turret it will be acted upon by the finishing wheel, at the same time that the newly inserted blank is acted upon by the roughing wheel 4.

The work spindles opposite to the wheels 4 and 5 are continuously rotated by the band 13^r, while the third spindle which is having the finished lens removed and the new blank inserted, remains stationary. Each time the turret rotates, the pulley on the spindle carrying the finished lens is moved out of contact with the band while the pulley on the spindle carrying the newly inserted blank is brought into driving engagement with the band.

From the foregoing it will be seen that I have provided a grinding mechanism, which is chiefly automatic in its action and in which the operations of removing the completed work and inserting a new blank, of rough grinding a blank, and of finish grinding the surface of the work, are carried on simultaneously. The feeding of the work to the grinding wheels is automatic. The machine requires attention on the part of the operator only for the insertion and removal of the work and for starting the machine, means being provided to prevent the operation of the turret before the finished lens has been taken out, and the new blank inserted. The machine is also adjustable so that the desired character of work can be produced.

By feeding the finishing wheel forward axially on the guideway 5^d as the wheel becomes worn I compensate such wear and secure uniformity of thickness of the lenses without changing the radius of the curve ground upon them; and by feeding the work and the said wheel relatively toward one another in the direction of the work axis during each operation I keep the abrasive edge of the wheel at all times crossing the lens axis and thereby promote both the durability of the wheel and accuracy of the surfaces formed on the lenses.

While I have described but one specific machine embodying my invention, which is particularly adapted for the grinding of lenses in accordance with the method which I have set forth in my aforesaid application for patent, Serial No. 128,235, this description is to be understood merely as illustrative of one preferred embodiment of the principle of my invention, and I, therefore, do not intend to limit myself to the particular structure described, but intend to

cover broadly the various embodiments of which the principle of my invention is susceptible. Various of the improved features set forth are adapted to grinding machines operating in other ways than in accordance with my improved method referred to, and are applicable to machines for the production of other articles than lenses.

What I claim is:

1. In grinding apparatus, the combination with operation performing means, of a turret carrying a plurality of work spindles, means for intermittently rotating the turret to bring the work spindles successively into operative axial position with relation to the operation performing means, and means comprising a shock absorbing device for arresting the rotation of the turret when said spindles are properly positioned.

2. In grinding apparatus, the combination with operation performing means, of a turret carying a plurality of work spindles, means for producing relative approaching and separating movements between the turret and operation performing means, and means operated by such movement for intermittently rotating the turret to bring the work spindles successively into operative axial position with relation to the operation performing means.

3. In grinding apparatus, the combination with operation performing means, of a member carrying a work spindle, means for intermittently moving said member to bring the work spindle successively into operative axial relation with the operation performing means and into an idle position in which the work may be attached to and removed from the spindle, and means comprising a shock-absorbing device for arresting the movement of said member as the spindle approaches each of said positions.

4. In grinding apparatus, the combination with operation performing means, of a turret carrying a plurality of work spindles, means for intermittently rotating the turret to bring the work spindles successively into operative axial position with relation to the operation performing means, and then into an idle position in which the work may be attached to and removed from the spindles, and means comprising a shock absorbing device for arresting the rotation of the turret when said spindles are properly positioned.

5. In grinding apparatus, the combination with operation performing means, of a turret carrying a plurality of work spindles, means for intermittently rotating the turret to bring the work spindles successively into operative axial position with relation to the operation performing means and then into an idle position in which the work may be attached to and removed from the spindles, means for rotating the spindles when in operative relation to the operation performing means, the spindles when in said idle position being disconnected from said spindle rotating means, and means comprising a shock absorbing device for arresting the rotation of the turret when said spindles are properly positioned.

6. In grinding apparatus, the combination of a plurality of means for performing different operations, a turret carrying a plurality of work spindles, means for producing a relative approaching and separating movement between the turret and the operation performing means, means operated by such movement for intermittently rotating the turret to bring the work spindles successively into operative axial position with relation to the successive operation performing means, and into an idle position where the work may be removed from and attached to the spindles, and means for rotating the spindles when in operative relation to the operation performing means, said spindle rotating means being inoperative with respect to the successive spindles when such spindles respectively occupy said idle position.

7. In grinding apparatus, the combination with operation performing means, of a turret carrying a plurality of work spindles, and means comprising coacting parts operable by a relative movement between the same longitudinally of the turret to intermittently rotate the turret to bring the work spindles successively into operative position with relation to the operation performing means.

8. In grinding apparatus, the combination of a grinding wheel, means for rotating said wheel, a turret, a plurality of work spindles rotatably supported by said turret, means for producing relative approaching and separating movements between said spindles and grinding wheel, means for intermittently rotating said turret so as to bring said spindles successively into operative position with respect to said grinding wheel, means for rotating each of said spindles when in operative position, and means for setting the axes of said grinding wheel and of the adjacent spindle into and out of a common plane.

9. In grinding apparatus, the combination of a rough grinding wheel, a finish grinding wheel, means for rotating said wheels, a turret carrying a plurality of work spindles, means for producing relative approaching and separating movements between said spindles and grinding wheels, means for intermittently rotating said turret to bring said spindles successively into operative position with relation, first to said rough grinding wheel and then to said finish grinding wheel, and finally into an idle position where the work can be attached to or removed from the spindles, means for rotating said

spindles when in alignment with said grinding wheels, said spindle rotating means being inoperative to rotate said spindles when the latter occupy said idle position, means for setting the axes of one of said grinding wheels and of the adjacent spindle into and out of a common plane, and means for setting the axes of the other grinding wheel and of the adjacent spindle at various angles to one another substantially in one plane.

10. In grinding apparatus, the combination of a grinding wheel, means for rotating said wheel, a turret, a plurality of work spindles rotatably supported thereby, means for producing relative approaching and separating movements between said spindles and grinding wheel, means for intermittently rotating said turret so as to bring said spindles successively into operative position with relation to said grinding wheel, means for rotating each of said spindles when in operative position, and means for setting the axes of the grinding wheel and of the adjacent work spindle at various angles to one another substantially in one plane.

11. In grinding apparatus, the combination of a rough grinding wheel, a finish grinding wheel, means for rotating said wheels, a turret, a plurality of work spindles rotatably supported thereby, means for producing relative approaching and separating movements between said turret and grinding wheels, means for intermittently rotating said turret so as to bring said spindles successively into operative position, means for rotating each of said spindles when in operative position, first with said rough grinding wheel and then with said finish grinding wheel, means for setting the axes of said rough grinding wheel and the adjacent spindle into and out of a common plane, and means for setting the axes of said finish grinding wheel and of the adjacent spindle at various angles to one another substantially in one plane.

12. In a spherical grinding machine, the combination of a work spindle, an annular grinding wheel arranged to operate across the face of the work carried by said spindle, and a support for said grinding wheel adapted to retain the axis of the grinding wheel substantially in a common plane with the axis of the work and comprising a member adjustably pivoted about an axis perpendicular to said common plane and a mounting for the grinding wheel upon said pivoted member including means for moving said grinding wheel perpendicularly to its axis in said common plane.

13. In spherical grinding apparatus, the combination of a work spindle, a rotary grinding wheel arranged to operate by its rotation across the face of the work carried by said spindle, and means whereby the axes of the grinding wheel and the work spindle may be set at various angles to each other substantially in one plane consisting of a mounting pivoted upon an axis at right angles to said plane and approximately intersecting the axis of said spindle at the face of the work and means for adjusting the mounting about the axis on which it is pivoted to change the radius of the spherically curved surface formed upon the work.

14. In grinding apparatus, rotatable work carrying means, a rotary grinding wheel adapted to work in continuous contact across the face and axis of the work, means for moving the wheel in the direction of its axis for setting it in adjusted position, and separate means for automatically causing a relative approaching feeding movement between the work and the wheel in the direction of the axis of the work.

15. In grinding apparatus, a work spindle and chuck for the work, a rotary grinding wheel adapted to operate in continuous contact across the face and axis of the work, means adapted to vary adjustably the mutual inclination of the work spindle and grinding wheel axes, means for adjustably moving the wheel in the direction of its axis to or from the work, and means for causing a relative approaching feeding movement between the work and the wheel in the direction of the axis of the work.

16. In grinding apparatus, the combination of a work spindle, a grinding wheel arranged to operate substantially diametrically across the face of the work carried by said spindle, means for adjusting the relative position of the axes of the grinding wheel and the work spindle for either convex or concave grinding and retaining said axes in fixed relation during a grinding operation, and means for causing a relative approaching feeding movement between the work spindle and the grinding wheel at a decreasing rate.

17. Grinding apparatus, comprising means for rotating the work about an axis passing through the surface to be ground, a grinding wheel rotary about an axis substantially in one plane with and substantially intersecting the axis of the work, said wheel being formed and arranged to contact with the ground surface of the work along a line extending from one side of said surface through the work axis, the grinding surface of the wheel moving along said line by the rotation of the wheel, and means for first causing a rapid relative approaching movement between the wheel and the work, then automatically causing a slow approaching movement, then maintaining said wheel and spindle in fixed relation, and then causing a rapid separating movement.

18. In grinding apparatus, the combination of a grinding wheel, a work spindle,

automatic means for causing a relative approaching feeding movement between the work spindle and the grinding wheel which is rapid at first and then automatically becomes slower, and manually operated means for temporarily increasing the rate of feed.

19. In spherical grinding apparatus, the combination of a work spindle, a rotary grinding wheel arranged to operate in continuous contact across the face and axis of the work carried by said spindle, the axes of the grinding wheel and the work spindle being set at an angle to one another and substantially in one plane for either convex or concave grinding, and automatic means for causing a relative approaching feeding movement between the work spindle and the grinding wheel at a decreasing rate.

20. In grinding apparatus, the combination of a work spindle, a grinding wheel adapted to operate substantially diametrically across the face of the work carried by said spindle, means for rotating said grinding wheel, means for adjusting the relative position of the axes of the grinding wheel and work spindle for either convex or concave grinding and retaining said axes in fixed relation during a grinding operation, and means for causing an approaching feeding movement between the work spindle and the grinding wheel at a decreasing rate, said last named means including a crank and means for rotating the crank at different speeds.

21. In grinding apparatus, the combination of, a slide, a turret rotatably carried by said slide, a plurality of work spindles carried by said turret, a grinding wheel, means for rotating the same, means for rotating the turret to bring the spindles successively into operative position with relation to said grinding wheel and means for reciprocating said slide at different speeds to advance the work spindles towards said grinding wheel, and to retract the same therefrom.

22. In grinding apparatus, the combination of, a slide, a turret rotatably mounted on said slide, a plurality of work spindles carried by said turret, a grinding wheel, means for rotating the same, means for rotating the turret to bring the work spindles successively into operative position with relation to said grinding wheel and means for reciprocating said slide rapidly and then slowly to advance said work spindles towards said grinding wheel.

23. In grinding apparatus, the combination of operation performing means, a slide, a turret rotatably mounted on said slide, a plurality of work spindles carried by said turret and means for reciprocating said slide rapidly and then slowly to advance said work spindles towards said operation performing means, and hand feeding means for increasing the rate of advance of said slide over the speed of movement which would otherwise be imparted to it by the slow feeding means of the machine.

24. In grinding apparatus, the combination of a slide, a turret rotatably mounted thereon, a plurality of work spindles carried by said turret, a grinding wheel, means for rotating the same, means for rotating the turret to bring the work spindles successively into operative position with relation to said grinding wheel, a crank for reciprocating said slide to move said work spindles towards and from said grinding wheel, and a plurality of means for rotating said crank. one of said means operating to rotate said crank rapidly during the first part of the movement of the turret towards the grinding wheel and during the retraction of said turret and another of said crank rotating means operating to rotate said crank slowly during the latter part of the movement of said turret towards said grinding wheel.

25. In grinding apparatus, the combination of operation performing means, work carrying means, a slide carrying one of said means and adapted to reciprocate to move said means toward and away from the other means, and means for reciprocating said slide at varying speeds, said means including a shaft and a plurality of members adapted to drive said shaft at different speeds, one of said members having constant frictional connection with said shaft, and automatic means for intermittently connecting the other of said members to said shaft, said frictional connection slipping when said second member is connected to said shaft.

26. In grinding apparatus, the combination of operation performing means, a slide, a turret rotatably mounted on said slide, a plurality of work spindles mounted on said turret and adapted to be moved towards and away from said operation performing means by reciprocation of said slide, and means for reciprocating said slide at varying speeds, including a rotatable shaft and a plurality of driving gears mounted on said shaft one of which is in constant frictional engagement therewith, and means for intermittently connecting the other gear with said shaft, said frictional connection between said first gear and said shaft slipping to permit the speed of rotation of said second gear to control the speed of rotation of said shaft when said second gear is connected to the shaft.

27. In grinding apparatus, the combination of operation performing means, a slide, a turret rotatably mounted on said slide, a plurality of work spindles mounted on said turret and adapted to be moved towards and away from said operation performing means by reciprocation of said slide, and means

for reciprocating said slide at varying speeds, said means including a shaft, a crank thereon connected to said slide, and means for rotating said shaft including a plurality of worm gears driven at different speeds, one of said worm gears having constant frictional connection with said shaft, and means for intermittently connecting the second of said worm gears to said shaft.

28. In grinding apparatus, the combination of operation performing means, a slide, a turret rotatably mounted on said slide, a plurality of work spindles mounted on said turret and adapted to be moved towards and away from said operation performing means by reciprocation of said slide, and means for reciprocating said slide at varying speeds, said means including a rotatable shaft, a pair of gears thereon one of said gears having permanent frictional connection with said shaft and having a hub attached thereon, a casing enclosing said hub and fixed to said shaft, a pawl carried by said casing, spring means tending to urge said pawl into engagement with said hub, a stationary casing engaging a portion of said pawl and holding it out of engagement with said hub during a part of the revolution of said shaft, said casing being formed with a slot for releasing said pawl during the remainder of the revolution of said shaft, means for adjusting the length of said slot and means for driving said gears at different speeds.

29. In grinding apparatus, the combination of rotatable work holding means, a grinding wheel having a grinding edge sweeping substantially diametrically across the face of the work in said holding means, means for causing a relative approaching feeding movement between the work holding means and the grinding wheel during the grinding operation, and automatic means for temporarily maintaining the work holding means and the grinding wheel in their nearest relative positions to complete the grinding operation.

30. In grinding apparatus, the combination of rotatable work holding means, a grinding wheel having a grinding edge sweeping substantially diametrically across the surface of the work in said holding means, and automatic means for causing a relative approaching movement between the work holding means and the grinding wheel, said movement taking place rapidly at first then more slowly and then very slowly and finally ceasing, and for thereafter causing a relative separating movement between said members.

31. In grinding apparatus, the combination of a grinding wheel, means for rotating the same, rotatable work holding means, means for rotating the same, manual means for causing relative approaching movement between the work holding means and grinding wheel to bring the work to grinding position, and automatic means for causing a relative approaching feeding movement at an automatically decreasing rate between the work and grinding wheel during the grinding operation.

32. In grinding apparatus, the combination of a turret, work holders carried thereby, a grinding wheel arranged to operate substantially diametrically across the face of the work in said holders, means for rotating the said wheel, means for advancing and retracting the turret to move the work holders into and out of operative proximity to the grinding wheel, means for intermittently rotating the turret after the same has been withdrawn from its most advanced position, and means whereby the axes of the grinding wheel and the adjacent work holder may be arranged in various angles to each other and maintained in fixed angular relation during a grinding operation to permit the grinding wheel to grind the face of the work to different shapes.

33. In grinding apparatus, the combination of a turret, a plurality of work holders carried thereby, a grinding wheel arranged to operate upon the work in said holders successively, means for rotating said wheel, means for advancing and retracting the turret to move the work holders into and out of operative proximity to the grinding wheel, and means for intermittently rotating the turret during the rearward part of its reciprocatory travel.

34. In grinding apparatus, the combination of operation performing means, a turret, a plurality of work holders carried thereby, means for reciprocating the turret towards and from the operation performing means and means functioned by said reciprocatory movement for rotating the turret.

35. In grinding apparatus, the combination of operation performing means, a slide mounted to reciprocate towards and from said operation performing means, a turret carried by said slide and mounted to have rotary movement thereon about an axis parallel to the direction of reciprocation of the slide, a plurality of work spindles carried by the turret, means for reciprocating the slide to move the work spindles towards and from the operation performing means, and means functioned by the reciprocation of the slide for intermittently rotating the turret to bring the successive work spindles into operative axial position with relation to said operation performing means.

36. In grinding apparatus, the combination of a turret and means for intermittently rotating the same, said means including a screw member, a nut member on said screw member, one of said members being

connected with said turret, means for causing a relative axial movement between said nut member and screw member, and means for alternately holding said nut member and screw member against rotation.

37. In grinding apparatus, the combination of a turret and means for intermittently rotating the same, said means including a screw member, means for reciprocating said screw member, a nut member working said screw member, means for holding said member against reciprocatory movement, one of said members being connected with said turret, a collar on said nut member, means for preventing relative rotary movement between said collar and nut member in one direction, while permitting such movement in the opposite direction, and means for alternately holding said screw member and collar against rotation.

38. In grinding apparatus, the combination of a grinding wheel, a slide reciprocable towards and from said wheel, a shaft mounted upon said slide and rotatable about an axis parallel to the direction of reciprocation thereof, a turret mounted on said shaft, a plurality of work spindles carried by said turret, means for reciprocating said slide to move said work spindles towards and from said grinding wheel and means for intermittently rotating said shaft to bring said work spindles successively into operative axial relation to said grinding wheel, said last named means comprising a screw on the rear end of said shaft, a nut on said screw, means for holding said nut against axial movement, a collar on said nut, means for preventing relative rotation between said nut and collar in one direction, a fixed stop, a plurality of stops rotatable with said turret and corresponding in number to the number of work spindles, said stops being adapted to engage successively with said fixed stop in certain positions of said turret and slide and to clear said fixed stop in other positions of said slide and means for locking said collar against rotary movement when said movable stops are cleared from said fixed stop so as to permit rotation of said turret.

39. In grinding apparatus, the combination of operation performing means, a turret, means for producing a relative approaching and separating movement between said operation performing means and said turret, means operated by such relative movement for intermittently rotating said turret while said operation performing means and said turret are separated from operative relation to each other, and means for locking said turret in predetermined angular position when said operation performing means and said turret are in operative relation to each other.

40. In grinding apparatus, the combination of a rotatable turret, means for reciprocating the same in the direction of its axis of rotation, a fixed stop, a plurality of stops movable with the turret, one of said movable stops co-operating with said fixed stop to prevent rotation of said turret when in its forward position, said movable stop clearing said fixed stop when the turret is moved rearward, and means for partially rotating said turret, so that on the next forward movement thereof another of said movable stops will engage said fixed stop to limit the rotation of said turret.

41. In grinding apparatus, the combination of a rotatable turret, means for reciprocating the same in the direction of its axis of rotation, and means operated by the reciprocation of the turret for producing step by step fractional rotation of the turret each time the same is reciprocated.

42. In grinding apparatus, the combination of a rotatable turret and means for locking the turret in predetermined angular position, said means including a projection rotatable with the turret and adapted to engage a fixed stop, said projection having an inclined rear face, and a spring actuated pivoted locking member adapted to exert a wedging action against said rear face so as to hold said projection firmly against said fixed stop.

43. In grinding apparatus, the combination of a rotary turret and means for stopping the same in predetermined angular positions, said means including a spider rotatable with the turret, a fixed stop, a plurality of projections carried by the spider, and adapted to successively co-operate with said fixed stop and means for holding a projection in contact with said stop when it engages the same.

44. In grinding apparatus, the combination of a rotatable turret and means for stopping the rotation of the same in predetermined angular positions, said means comprising a fixed stop, a spider rotatable coaxially with said turret, and carrying a plurality of movable stops adapted to successively co-operate with said fixed stop, and means for adjusting the angular position of said spider with relation to said turret.

45. In grinding apparatus, the combination of operation performing means, a turret, a plurality of work holders carried thereby, automatic means for moving the turret to bring successive work holders into operative proximity to said operation performing means, an automatic stop for stopping the operation of said turret moving means after each cycle of movements of the turret and manual means for releasing said stop.

46. In grinding apparatus, the combination of operation performing means, a turret, a plurality of work holders carried by said turret, means for reciprocating the tur-

ret to move said work holders towards and from said operation performing means, means for partially rotating said turret each time it is reciprocated, so as to present said work holders successively in operative proximity to said operation performing means, automatic means for causing the reciprocatory and rotary movements of said turret, a stop for preventing operation of said turret moving means, means for automatically setting said stop after each cycle of movement of the turret and manual means for releasing the said stop.

47. In grinding apparatus, the combination of operation performing means, a turret, a plurality of work holders carried thereby, means for producing relative approaching and separating movements between said operation performing means and said turret and for partially rotating said turret so as to present said work holders successively in operative proximity to said operation performing means, a stop for automatically preventing the operation of said feeding and rotating means after each cycle of movements effected thereby is completed, and manual means for releasing said stop.

48. In grinding apparatus, the combination of grinding means, a work spindle, a chuck upon said work spindle opened and closed by movement of the chuck longitudinal of said spindle, and means cooperating with said chuck to determine the relative position of the work and grinding wheel independently of the relative longitudinal position of said spindle and chuck and comprising an abutment having a predetermined positional relation to the grinding wheel.

49. In grinding apparatus, the combination of a rotatable turret, a plurality of work spindles carried thereby and having limited axial freedom thereon, a chuck carried by each work spindle, a grinding wheel adapted to operate on the face of the work carried by each chuck, and an abutment adapted through the rotation of the turret to cooperate with each of said chucks successively and take the thrust of the grinding wheel in the direction of the axis of the work in said chucks.

50. In grinding apparatus, the combination of a rotatable turret, a plurality of work spindles carried thereby and having limited axial movement thereon, a chuck carried by each work spindle, a member attached to each chuck, and an abutment adapted to be engaged by said members successively to take the thrust of the grinding wheel against the work in said chucks.

51. In grinding apparatus, the combination of a work spindle, a chuck carried thereby, a chuck operating member attached to said chuck, a spindle carrying member, a grinding wheel, means for advancing said spindle carrying member so as to bring the work on said chuck into engagement with said grinding wheel, said spindle having limited movement with relation to said spindle carrying member, and an abutment adapted to engage the rear end of said chuck operating member to take the thrust of said grinding wheel against the work on said chuck, said abutment being located in predetermined position, and said chuck and chuck operating member being of predetermined length whereby a uniform grinding of said work will result.

52. In grinding apparatus, the combination of a grinding wheel, a support, a work spindle carried thereby and having limited axial movement thereon, a chuck carried by said work spindle. a member attached to said chuck, and an abutment adapted to be engaged by said member to take the thrust of the grinding wheel against the work in said chuck.

53. In grinding apparatus, the combination of a grinding wheel, a rotatable turret, a plurality of work spindles carried thereby and having limited axial movement thereon, a chuck carried by each work spindle, a member attached to each chuck at one end of the member, and an abutment adapted to be engaged by the other end of said members successively to take the thrust of the grinding wheel against the work in said chucks, all pairs of said chucks and members being of a uniform length.

54. In grinding apparatus, the combination of a turret, a plurality of chucks carried thereby, a chuck operating member attached to each chuck, a grinding wheel, means for producing a relative approaching movement between said turret and grinding wheel, each chuck and chuck operating member having a limited movement with relation to said turret, and an abutment adapted to be engaged by the rear ends of said members successively to take the thrust of the grinding wheel against the work in said chucks, said abutment being located in a predetermined position and all pairs of said chucks and chuck operating members being of uniform length, whereby a uniform grinding of the said work will result.

55. In grinding apparatus, the combination of a turret, a plurality of tubular work spindles rotatably mounted thereon and having limited endwise movement with relation thereto, each of said work spindles carrying a chuck to which is attached a draw-in spindle projecting through the tubular work spindle, all pairs of said chucks and draw-in spindles being of a uniform length, and an abutment adapted to be engaged by the rear ends of successive draw-in spindles as the turret is rotated.

56. In grinding apparatus, the combina-

tion of a rotatable turret, rotatable work spindles carried thereby, chucks carried by said work spindles, abutments arranged to take the thrust on the chucks of certain of said spindles and chuck opening means arranged to open the chuck of another of said spindles.

57. In grinding apparatus, the combination of grinding means, a work spindle support, a work spindle having a limited axial movement in said support, a chuck upon said work spindle adjustable axially thereon, and means cooperating with said chuck to determine the relative position of the work and the grinding wheel independently of the relative axial position of said spindle and chuck.

58. In grinding apparatus, the combination of a grinding wheel, a work spindle, means for effecting a relative approaching feeding movement and then a relative separating movement between the work spindle and the grinding wheel, and means operating automatically to positively prevent such relative movement after each complete cycle of movement.

59. In grinding apparatus, a rotatable work carrier, a rotary grinding wheel adapted to work in continuous contact across the face and axis of the work, mountings for said work carrier and said grinding wheel positioning them so that their axes lie in substantially the same plane and cross at an acute angle at a fixed point throughout a grinding operation, means for causing an approaching feeding movement of the work carrier toward the wheel, and for automatically stopping said movement when the carrier is at a predetermined distance from the point of crossing of the work and wheel axes, and means for moving the grinding wheel longitudinally of its axis to adjust it relatively to the said point of crossing.

60. In grinding apparatus, a grinding wheel having an annular grinding edge, means for rotating the same, a work spindle, means for rotating said spindle, means for setting the axes of the work spindle and grinding wheel at various angles to one another substantially in one plane and for setting the grinding edge of the wheel so that it operates across the center of the face of the work, and means for automatically effecting a relative feeding movement between the grinding wheel and the work, whereby a spherical surface is formed on the work.

61. In grinding apparatus, the combination with operation performing means, of a turret carrying a plurality of work spindles, means for intermittently rotating the turret to bring the work spindles successively into operative position with relation to the operation performing means, and means comprising a cushioning device, including a fluid check, for arresting the rotation of the turret.

62. In grinding apparatus, a grinding wheel having an annular grinding edge, means for rotating the same, a work spindle, means for rotating said spindle, means for setting the axes of the work spindle and grinding wheel at various angles to one another substantially in one plane and for setting the grinding edge of the wheel so that it operates across the center of the face of the work, said setting means including means for adjusting said grinding wheel longitudinally of its axis, and means for automatically effecting a relative feeding movement between the grinding wheel and the work in the direction of the axis of said work spindle, whereby a spherical surface is formed on the work.

63. In spherical grinding apparatus, the combination of a work spindle, a grinding wheel adapted to operate across the face and axis of the work carried by said spindle, means for rotating said grinding wheel, the axes of the grinding wheel and the work being set at an angle to one another and substantially in one plane for either convex or concave grinding, and automatic means for causing a relative approaching feeding movement between the work spindle and the grinding wheel at a decreasing rate, said last named means including a rotary member and means for rotating the member at different speeds.

64. In grinding apparatus, the combination of a grinding wheel, means for rotating the same, a turret, a plurality of work spindles carried by said turret, means for rotating the turret to bring the spindles successively into operative position with relation to said grinding wheel, and means for causing relative approaching and separating movements between said work spindles successively and said grinding wheel, the approaching movement being effected at a different rate from that of the separating movement.

65. In grinding apparatus, the combination of a grinding wheel, means for rotating the same, a turret, a plurality of work spindles carried by said turret, means for rotating the turret to bring the work spindles successively into operative position with relation to said grinding wheel, and means for causing relative approaching and separating movements between said work spindles successively and said grinding wheel, the approaching movement being effected first at a rapid rate and then slowly during a grinding operation.

66. In grinding apparatus, the combination of operation performing means, a work spindle, automatic means causing relative approaching and separating movements be-

tween said work spindle and said operation performing means, and hand feeding means operable during the operation of said automatic means to increase the rate of the approaching movement over that imparted by automatic means alone.

67. In grinding apparatus, the combination of operation performing means, a work holder, automatic means for reciprocating the work holder into and out of operative proximity to said operation performing means, automatic means for stopping the operation of said reciprocating means after each reciprocation, and manual means for withdrawing said stopping means.

68. Grinding apparatus, comprising means for rotating the work about an axis passing through the surface to be ground, a grinding wheel rotary about an axis substantially in one plane with and substantially intersecting the axis of the work, said wheel being so formed and arranged that its grinding surface contacts with the ground surface of the work along a line extending from one side of said surface through the work axis and moves along said line by the rotation of the wheel, and automatic means for causing a relative approaching feeding movement between the work and the wheel.

69. Grinding apparatus, comprising means for rotating the work about an axis passing through the surface to be ground, a grinding wheel rotary about an axis intersecting the axis of the work, said wheel being so formed and arranged that its grinding surface contacts with the ground surface of the work along a line extending across the surface and through the work axis and moves along said line by the rotation of the wheel, and automatic means for causing a relative approaching feeding movement between the work and the wheel.

70. Grinding apparatus, comprising a rotary grinding wheel, a turret, a plurality of rotary work spindles supported thereby and adapted to be brought successively into operative position with relation to said grinding wheel by intermittent rotation of the turret, said wheel being formed and arranged to contact with the ground surface of the work upon the spindle in operative position along a line extending from one side of said surface through the spindle axis, the grinding surface of the wheel moving along said line by the rotation of the wheel, and means for causing a relative approaching feeding movement and a separating movement between the spindles and the wheel.

71. Apparatus for grinding spherically curved surfaces, comprising means for rotating the work about an axis passing through the surface to be ground, a grinding wheel rotary about an axis substantially in one plane with and substantially intersecting the axis of the work, said wheel being so formed and arranged that its grinding surface contacts with the ground surface of the work along a line extending from one side of said surface through the work axis and moves along said line by the rotation of the wheel, and means for causing a relative approaching feeding movement between the work and the wheel, and for automatically stopping said feeding movement at a predetermined point.

72. Apparatus for grinding spherically curved surfaces, comprising means for rotating the work about an axis passing through the surface to be ground, a grinding wheel rotary about an axis substantially in one plane with and substantially intersecting the axis of the work, said wheel being so formed and arranged that its grinding surface contacts with the ground surface of the work along a line extending from one side of said surface through the work axis and moves along said line by the rotation of the wheel, and means for causing a relative approaching feeding movement between the work and the wheel, and for automatically stopping said feeding movement at a predetermined point and thereafter causing a relative separating movement between the wheel and the work.

73. In grinding apparatus, the combination of a grinding wheel, a turret, a plurality of rotary work spindles carried by said turret, a work holder upon each of said spindles adapted to engage one face of the work, means for causing an intermittent rotation of the turret to bring said work spindles successively into operative position with relation to said grinding wheel, said wheel being so formed and arranged that its grinding surface contacts with the ground surface of the work upon the spindle in operative position along a line extending from one side of said surface through the work axis and moves along said line by the rotation of the wheel, means for causing a relative approaching feeding movement between said spindles successively and the operative surface of said grinding wheel, and for stopping the feeding movement when the work holders are successively at a predetermined distance from the operative surface of the wheel.

74. Apparatus for grinding spherically curved surfaces, comprising means for rotating the work about an axis passing through the surface to be ground, a grinding wheel rotary about an axis substantially in one plane with and substantially intersecting the axis of the work, said wheel being formed and arranged to contact with the ground surface of the work along a line extending from one side of said surface through the work axis, the grinding surface of the wheel moving along said line

by the rotation of the wheel, means for varying the angle between the axis of the work and the wheel, and automatic means for causing a relative approaching feeding movement between the work and the wheel.

75. Apparatus for grinding spherically curved surfaces, comprising means for rotating the work about an axis passing through the surface to be ground, a grinding wheel rotary about an axis substantially in one plane with and substantially intersecting the axis of the work, said wheel being formed and arranged to contact with the ground surface of the work along a line extending from one side of said surface through the work axis, the grinding surface of the wheel moving along said line by the rotation of the wheel, and means for adjustably varying the angle between the axes of the wheel and work holder, comprising a mounting for one of said members pivoted upon an axis perpendicular to the common plane of the work axis and the grinding wheel axis and substantially intersecting the work axis at the surface of the work, and means for adjusting said mounting about the axis upon which it is pivoted to change the radius of the spherically curved surface formed upon the work.

76. Means for grinding curved surfaces upon glass blanks, comprising a work holder including a rotary spindle having a conical recess at one end thereof, a contractable chuck having a portion adapted to support one face of the blank and a portion formed to surround the edge of the blank and normally of greater internal diameter than the blank, and a spring adapted to draw said chuck into said recesses so as to press it against the periphery of the blank with a predetermined force, a grinding wheel arranged to operate upon the opposite face of the blank, supporting means for said work holder and grinding wheel determining the positional relation of said first mentioned face of the blank to the grinding surface of the work, and automatic means for causing a relative approaching feeding movement between the blank and the grinding wheel.

77. Apparatus for grinding spherically curved surfaces, comprising a work holder adapted to position the rear surface of the work and adapted to rotate the work about an axis passing through the surface to be ground, a grinding wheel rotary about an axis substantially in one plane with and crossing the axis of the work, said wheel being so formed and arranged that its grinding surface contacts with the ground surface of the work along a line extending from one side of said surface through the work axis and moves along said line by the rotation of the wheel, and means for causing a feeding movement of the work holder toward the grinding wheel, and for automatically stopping said feeding movement when the rear surface of the work reaches a predetermined distance from the point of crossing of the axes of the wheel and work.

78. Apparatus for grinding spherically curved surfaces upon blanks, comprising a work holder adapted to rotate a blank about an axis passing through the front surface thereof and including a surface adapted to engage and position the rear face of the blank, a grinding wheel rotary about an axis substantially in one plane with and intersecting the axis of the work, said wheel being so formed and arranged that its grinding surface contacts with the ground surface of the work along a line extending from one side of said surface through the work axis and moves along said line by the rotation of the wheel, and means for causing a relative approaching feeding movement between the work holder and the grinding wheel and for automatically stopping said feeding movement when said surface of the work holder reaches a predetermined distance from the operative surface of the grinding wheel.

79. Apparatus for grinding spherically curved surfaces upon blanks, comprising a work holder adapted to rotate a blank about an axis passing through the front surface thereof and including a surface adapted to engage and position the rear face of the blank, a grinding wheel rotary about an axis substantially in one plane with and intersecting the axis of the work, said wheel being so formed and arranged that its grinding surface contacts with the ground surface of the work along a line extending from one side of said surface through the work axis and moves along said line by the rotation of the wheel, means for causing a relative approaching feeding movement between the work holder and the grinding wheel and for automatically stopping said feeding movement when said surface of the work holder reaches a predetermined distance from the operative surface of the grinding wheel, and means for adjustably varying said predetermined distance.

80. In grinding apparatus, the combination of grinding means, a work spindle, a chuck upon said work spindle opened and closed by movement of the chuck longitudinal of said spindle, and means cooperating with said chuck to determine the relative position of the work and grinding wheel independently of the relative longitudinal position of said spindle and chuck.

In testimony whereof I have hereunto set my hand in the presence of two subscribing witnesses.

WILLIAM TAYLOR.

Witnesses:
ARTHUR PIERCE,
DOROTHY FOSTER.