

1,343,050.

C. GOODWIN.
LENS GRINDING MACHINE.
APPLICATION FILED JAN. 7, 1918.

Patented June 8, 1920.
3 SHEETS—SHEET 1.

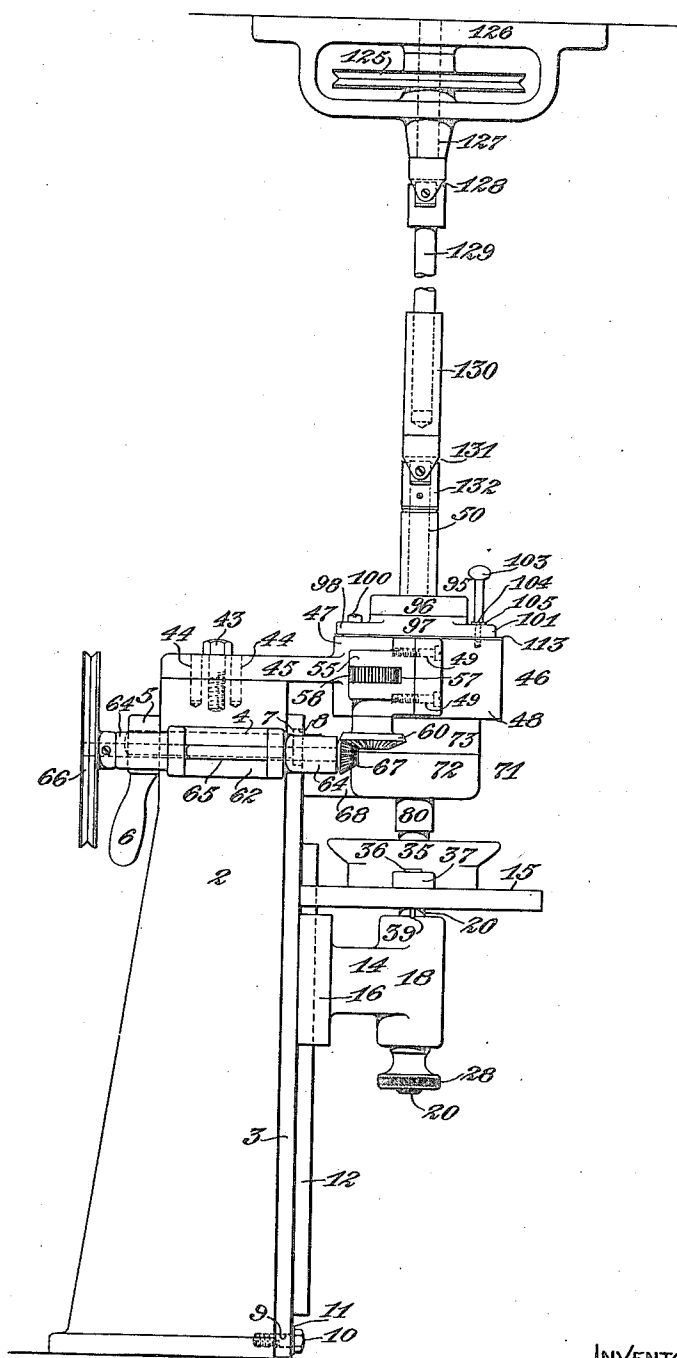


Fig. 1.

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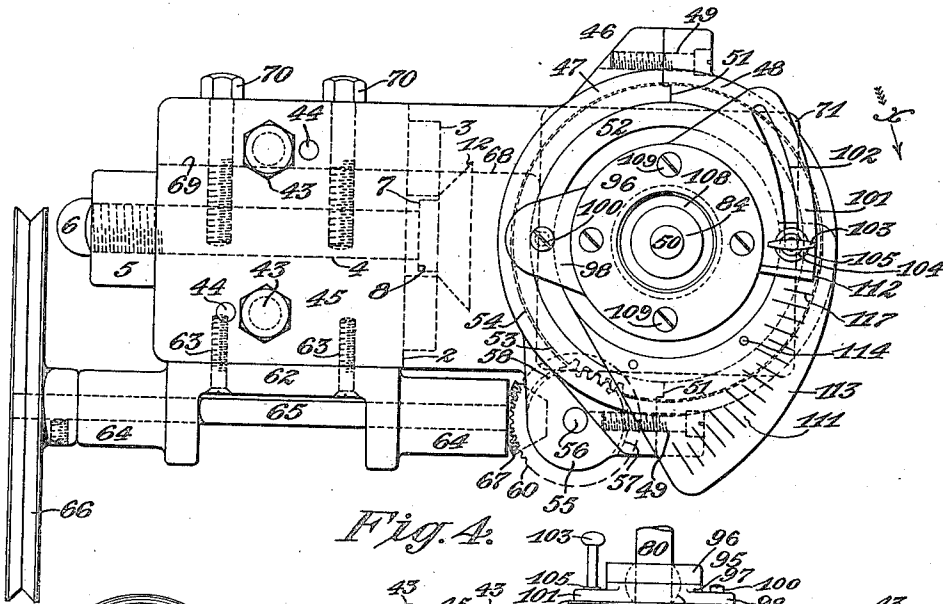


Fig. 4.

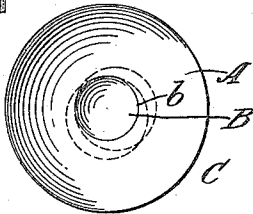


Fig. 8.

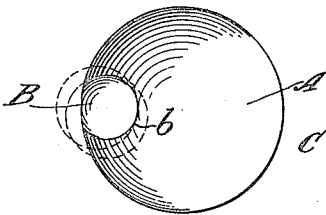


Fig. 9.

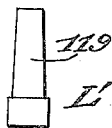


Fig. 7.

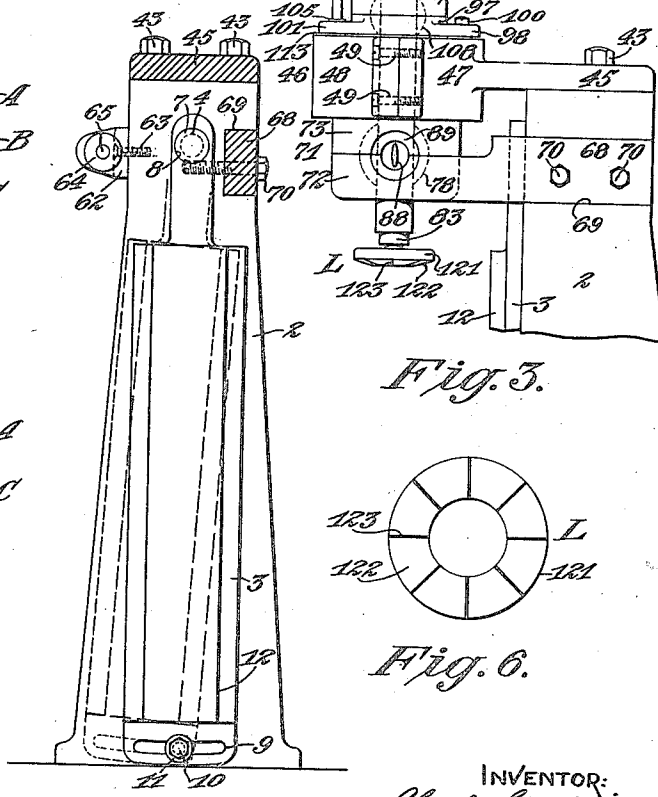


Fig. 2.

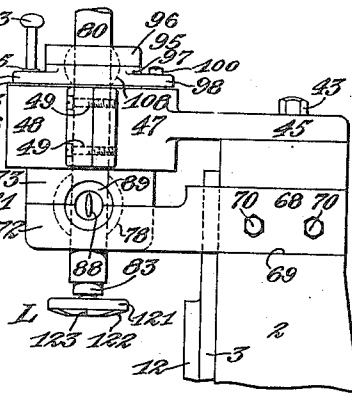


Fig. 3.

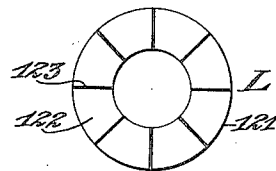


Fig. 6.

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Fig. 5. BY *Arthur J. Armstrong*
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UNITED STATES PATENT OFFICE.

CHARLES GOODWIN, OF EAST PROVIDENCE, RHODE ISLAND, ASSIGNOR TO EDGAR W. MARTIN, OF BARRINGTON, RHODE ISLAND, LAURENCE C. MARTIN, OF PROVIDENCE, RHODE ISLAND, AND GEORGE W. BLEECKER, OF CHICAGO, ILLINOIS, TRUSTEES OF MARTIN-COPELAND COMPANY.

LENS-GRINDING MACHINE.

1,343,050.

Specification of Letters Patent.

Patented June 8, 1920.

Application filed January 7, 1918. Serial No. 210,751.

To all whom it may concern:

Be it known that I, CHARLES GOODWIN, a citizen of the United States, residing at East Providence, in the county of Providence, State of Rhode Island, have invented certain new and useful Improvements in Lens-Grinding Machines, of which the following is a specification.

My invention relates to apparatus for forming and finishing the faces of bifocal lenses used in spectacles and eye-glasses or for other purposes. The object of my improvement is to provide a machine for grinding and polishing a plurality of lenses or visual faces on the surface of a crystal or single piece of glass or the like; with means for adjusting the operative relation between the tool and the work, whereby lenses of different powers or dioptries may be produced, and wherein the axial relation of the lenses may be varied in accordance with any desired degree of eccentricity. Further objects of the improvement are to combine the operating elements of the machine in a simple, compact mechanism, with its parts easily and quickly accessible for manipulation and control, and capable of a wide range of adjustment for practically all types of work.

The manner and means for carrying out these improvements are fully described in the following specification, illustrated by the accompanying drawings, in which like reference characters designate like parts. In the drawings:—

Figure 1 is a side elevation of the complete machine;

Fig. 2, a front elevation of the main frame or standard on which the operating-mechanism of the machine is mounted, showing the adjustable support for the work-table or lens-holder.

Fig. 3, a side elevation of the grinding-spindle bearings;

Fig. 4, an enlarged, plan view of the grinding-spindle adjusting-devices, illustrating the driving-connections for oscillating the spindle gyroscopically;

Fig. 5, an enlarged, vertical, sectional view of the working parts of the mechanism taken on the axis of the grinding-spindle and showing the operative relation between the tool and the work;

Fig. 6, an enlarged, plan view of the working-face of the grinding-tool or lap;

Fig. 7, a view showing the type of grinding-tool or lap used for forming the minor face of the lens;

Fig. 8, a plan view of the ground lens-blank illustrating a concentric relation of the lens faces; and

Fig. 9, a similar view showing a blank having the minor lens face arranged eccentric to the major face.

Referring first to Fig. 1, the operating-mechanism of the machine is mounted on an upright frame or standard 2 which may be supported on any suitable base or bolted to the top of a table or work-bench. On the front of the standard 2 is an arm or hanger 3 pivotally supported at its upper end by a stud 4 to adapt it to be adjusted in angular relation to the perpendicular, as illustrated by the dash-lines in Fig. 2. The stud 4 on which the arm 3 pivots extends through the top of the frame 2 and is threaded at its inner end to receive a nut 5 formed with a handle 6. At its outer end the stud 4 is provided with a head 7 seated in a counter-bore 8 on the front of the arm 3 so that when the hand-nut 5 is tightened against the back of the frame 2 the arm will be clamped against its front. The lower end of the arm 3 is formed with an arcuate slot 9, through which extends a bolt 10 screwed into the base of the frame 2 with a washer 11 interposed between its head and the front of the arm. By loosening the bolt 10 and hand-nut 5 the arm 3 may be swung on its pivot to adjust it in angular position on the front of the frame 2 for a purpose as later described.

On the front face of the arm 3 is a longitudinally-extending, raised guideway or track 12 formed with inwardly beveled sides as illustrated by dotted lines in Fig. 4. Fitted to slide up and down on the track 12 is a bracket or support 14 which carries the work-table 15. As shown in Figs. 1 and 5, the bracket 14 is provided with a rectangular plate or slide 16 which is slotted to embrace the beveled sides of the track 12 and provided with a set-screw 17 which may be tightened against the track to clamp the bracket in place thereon. At the outer end of the bracket 14 is a cylindrical bearing 18 bored at 19 to receive a vertical spindle 20, see Fig. 5. The bearing 18 is counterbored at 21 throughout the greater portion of its length, and fitted to the upper end thereof

is a plug or collar 22 held in place by the set-screws 23. The spindle 20 is free to slide in the bore 19 at the bottom of the bearing 18 and also in the bore 24 of the plug 22.

5 Beneath the plug 22 is a collar 25, held fast on the spindle 20 by a set-screw 26, and a coiled spring 27 encircles the spindle with one end bearing against the collar and the other against the bottom of the counterbore

10 21. The spring 27 is held under tension to act against the collar 25 to slide the spindle 20 upwardly in its bearings and this axial movement of the spindle is limited by a finger-nut 28 screwed onto its lower end to

15 adapt it to abut the bottom of the bearing 18. By turning the nut 28 on the threaded end of the spindle 20 the vertical position of the latter in its bearing 18 may be adjusted as required to regulate the height of

20 the work-table 15 supported thereby. As illustrated in Fig. 5, the upper end of the spindle 20 is formed with an enlargement or flange 29 fitted to a socket 30 on the under side of the table 15 and secured thereto by

25 the screws 31, 31. The table 15 is circular in shape with its rearward side bearing against the front of the hanger-arm 3, and at this point its rim is cut away to straddle the track 12 to steady it against the arm 3

30 while preventing it from turning on the axis of its supporting-spindle or plunger 20. The table 15 is flat on the top and formed with a downwardly extending rim or flange 32 to stiffen its structure. Fastened to the

35 top of the table 15 is a removable chuck or work-holder 35 for supporting the glass or crystal C to be ground. The chuck 35 is secured in place by means of bolts 36 extending downwardly through ears or flanges

40 37 on its sides and reaching through suitable holes or slots 38 in the table 15 with thumb-nuts 39 screwed onto their ends. A cylindrical plug 40 secured in a bore on the bottom of the chuck 35 seats in a central opening

45 41 in the table 15 to align the chuck axially with the spindle 20. The top of the chuck 35 is formed with a saucer-like rim 42 providing a concaved seat for receiving the crystal C which is cemented in place

50 therein.

Secured to the top of the frame 2 by means of bolts 43 and dowels 44 is an arm 45, see Figs. 1, 2 and 4, which supports a bearing-ring 46 carrying the driving-connections for

55 oscillating the grinding-spindle 50. As shown in Figs. 1 and 3, the ring 46 is split diametrically into two sections, one part 47 being formed integral with the arm 45 and the other 48 bolted thereto by means of the

60 screws 49, the joint between the sections being mortised at 51, see Fig. 4, to insure a true fit. Fitted to turn in the bearing-ring 46 is a cylindrical sleeve 52, see Fig. 5, formed on its periphery with a radially-pro-

65 jecting gear-ring 53. The gear-ring 53 is

received in an annular groove 54 on the interior of the bearing-ring 46 whereby the sleeve 52 is restrained from vertical movement therein, a clearance being provided for the teeth of gear as shown in Fig. 5. Pro-

70 jecting from one side of the fixed section 47 of the bearing-ring 46 is a bearing 55, shown in Figs. 4 and 5, in which is journaled a vertical stud-shaft 56. Inserted in a cross-slot 57 in the bearing 55 is a spur-gear or pinion

75 58, keyed onto the shaft 56 at 59, and adapted to mesh with the gear-ring 53. The shaft 56 projects below the bearing 55 and carries a bevel-gear 60 on its lower, reduced end which is held rotatively therewith by

80 suitable means such as the set-screw 61, illustrated in Fig. 5.

Projecting from the side of the frame 2, see Figs. 1, 2 and 4, is a bracket 62 which may be constructed integral therewith or

85 made separate and fastened in place by the screws 63, 63, as shown in the drawings. The bracket 62 is formed with bearings 64, 64 for a horizontal shaft 65 carrying a belt-pulley or other driving-element 66 at its

90 rearward end. On the forward end of the shaft 65 is a bevel-pinion 67 held in mesh with the gear 60 to adapt it to drive the shaft 56 and gear 58, whereby to rotate the sleeve 52 through its gear-ring 53.

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On the opposite side of the frame 2 from the bracket 62 is a horizontal arm 68 fitted to a slot 69 and secured in place by the bolts 70, 70, see Figs. 2 and 3. Supported at the outer end of the arm 68 is a box-like bearing

100 71 comprising two halves 72 and 73 divided in a horizontal plane. The two parts of the bearing 71 are united with a mortise joint 74, see Fig. 5, and held together by suitable bolts 75. Where the halves 72 and 73 meet

105 they are formed with semi-spherical sockets or concaved recesses 76, 77 adapted to receive a ball-member 78. The ball 78 is held between the bearing halves 72 and 73 to allow it to turn freely in the sockets 76, 77

110 and is provided with a diametrically-extending bore 79 to which is fitted a cylindrical bearing-sleeve 80 for the grinding-spindle 50. As shown in Fig. 5 the bearing-sleeve 80 is constructed in the form of a tube, with

115 its bore slightly larger than the diameter of the spindle 50 to provide a clearance therebetween, and is formed with conical bearing-seats 81, 81 at its ends. Preferably, the bearings 81 are formed in the bores of hardened bushings 82, 82 spliced onto the ends

120 of the main tube 80 and are adapted to receive bearing-cones 83, 84 secured fast on the spindle 50. The lower cone 83 is held fixedly in place on the spindle 50 by means

125 of the set-screw 85; while the upper cone 84 is screwed onto threads 86 formed on the periphery of the spindle to adapt it to be adjusted therealong, toward and away from the fixed cone. Through this arrangement

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the cones 83, 84 may be adjusted in relation to their bearing-seats 81 at the ends of the sleeve 80 to provide for a free fit without play and to compensate for wear when required. After the cones have been adjusted to their bearings in this manner the upper cone 84 is locked in place by means of a set-screw 87 which binds against the threads 86 on the spindle 50.

The sleeve 80 is free to slide through the bore 79 in the ball 78 to adjust the spindle 50 longitudinally in its bearings, and suitable means, such as the thumb-screw 88, is provided for holding the sleeve in its adjusted position. As shown in Fig. 5, the thumb-screw 88 extends through a flaring opening 89 in the side of the bearing 71, and is screwed through the side of the ball 78 to bind its end against the sleeve 80. The opening 89 is enlarged to allow for the rocking motion of the thumb-screw 88 when the ball 78 oscillates in its sockets, and it is also to be noted that the bearing-members 71 and 72 are cut away at 90 and 91 to allow for the oscillation of the sleeve 80 which extends therethrough.

Referring still to Fig. 5, the bearing-sleeve 80 for the grinding-spindle 50 is also held in another ball-and-socket bearing 95 spaced a short distance above the main bearing 71. This upper bearing 95 is carried on the rotatable sleeve 52 which is driven from the train of gearing previously described. The bearing 95 is adapted for adjustment eccentrically of the axis of the sleeve 52 to provide for oscillating the spindle-sleeve 80 about the axis of its lower bearing 78, whereby to revolve the grinding-tool carried by the spindle 50 in an orbital path in relation to the work, as more fully explained hereinafter. As shown more particularly in Figs. 1, 3 and 5, the bearing 95 comprises two ring-like halves 96 and 97, the lower one of which is pivotally secured to the top of the sleeve 52. Referring to Figs. 1 and 4, the lower base-ring 97 is formed with a lug or arm 98 projecting from its side, through which extends the pivot-stud 100 screwed into the sleeve 52. On the opposite side of the ring 97 is a segmental projection or flange 101 formed with an arcuate slot 102 arranged concentrically with the axis of the pivot 100. A thumb-screw 103 extends through the slot 102 and is screwed into the top of the sleeve 52, the shank of the screw being shouldered at 104 and provided with a washer 105 adapted to be clamped against the segment 101. The bearing-rings 96, 97 are socketed at 106, 107, to receive a ball-element 108, and are held together by screws 109 while allowing for a turning movement of the ball as in the case of the lower bearing 71. The bearing-sleeve 80 extends through a diametrical bore 110 in the ball 108, and through the above described con-

struction the spindle 50 is permitted to oscillate at an inclination to the vertical when the upper bearing 95 is displaced in eccentric relation to the lower bearing 71. This eccentric adjustment of the bearing 95 is effected by swinging it laterally on its pivot 100, and to secure it in its adjusted position on the supporting sleeve 52 the thumb-screw 103 is tightened against the slotted segment 101. For convenience in setting the bearing 95 a scale 111 is provided to cooperate with an index 112 to indicate the degree of eccentricity of the adjustment. The indicating-means may be of any preferred construction and, as shown in Fig. 4, consists of a thin plate 113 let into a slot on the upper end of the sleeve 52 and secured thereto by the pins or rivets 114. On the upper face of the plate 113 is the scale or dial 111, and the beveled edge 112 of the segment 101 on the bearing 95 serves as the index to register with the graduations 117 to indicate the extent of adjustment of the bearing.

Referring back to Fig. 5, the lower end of the spindle 50 is provided with a tapered bore or socket 118 adapted to receive the shank 119 of the grinding-tool or lap L. This latter may be of any suitable form for grinding the particular type of lens required, and as shown more in detail in Fig. 6, it comprises an enlarged disk 121 cut away at the center to provide an annular grinding face 122 similar to that of a hollow milling-cutter. The working face 122 is of convex form corresponding to the curvature of the lens surface to be produced and is usually provided with radial grooves 123 for holding the emery dust or other abrasive employed with the tool or lap. The style of lap L illustrated in Figs. 4 and 6 is intended for use in forming the major faces of bifocal lenses and for the minor faces a smaller tool L' such as that shown in Fig. 7 is employed.

The grinding-spindle 50 is driven rotatively from any convenient source of power through connections at its upper end. As illustrated in Fig. 1, a belt-pulley 125 is mounted in a bracket or hanger 126 which may be bolted to the ceiling or fastened to any other suitable support. The pulley 125 is keyed to a shaft 127 which is provided with a universal joint 128 connecting it with the end of a telescopic shaft 129. The lower end of the shaft 129 is fitted to slide in a sleeve 130 and keyed rotatively therewith, the end of the sleeve being connected by a universal joint 131 to a cap 132 secured on the upper end of the spindle 50. Through these connections the spindle 50 may be driven rotatively on its own axis while allowing it to oscillate gyroscopically to revolve the grinding-tool in an orbital path in the manner as more fully explained hereinafter. Any other suitable arrange-

ment of flexible shafts or connections could be employed to drive the spindle 50, and these might be coupled directly with the driving mechanism for the sleeve 52 if desired. The present arrangement, however, is the preferred form of embodiment of the driving-means as being the simplest and most direct, although it is to be understood that the invention is not herein limited as to this particular feature of construction.

The method of operation of the complete apparatus is as follows: The lens-blank or crystal C is usually molded in concavo-convex form to be ground and finished on both sides. In producing bifocal lenses for optical uses the major or distant-view face A, see Figs. 8 and 9, is formed on the concave side of the crystal with the minor or near-view lens B occupying a portion of its area. Lenses having these two faces finished in accordance with varying specifications as to their dioptries or powers are furnished to opticians to be ground to prescription on the convex side as required for different users. While the present machine could be adapted for convex grinding, its main purpose is for the manufacture of lenses of the bifocal type by forming the two faces on the concave side of the glass. To prepare the apparatus for this work the circular piece of glass or crystal C is set in the holder 35, in coaxial relation therewith, and secured firmly in place by cementing it on its under side and around its rim as shown at *c, c* in Fig. 5. It will be understood, of course, that different forms of chucks or holders 35 may be provided for different shapes of lenses, but usually only one type is required as the variation in curvature of the lens-blanks is relatively slight and may be compensated for by filling in beneath them with cement.

The major face A of the lens is usually ground on the crystal first and in adjusting the machine for this operation a lap is selected in accordance with the required curvature to be produced. That is to say, the power of the lens is determined by its focal distance, and this corresponds with the radius of curvature of the face of the forming-tool. After the proper tool or lap L has been applied to the grinding-spindle 50 by forcing its shank 119 firmly into the socket 118, to insure its rotation therewith, the machine is adjusted in the following described manner: The sleeve 80 which carries the spindle 50 is slid through its bearings in the balls 78 and 108 to adjust the lap L with its lower, working face 122 at a distance from the axis of the lower ball 78 equal to its radius of curvature, or, in other words, to the focal distance of the lens-face to be ground. After the spindle 50 has been adjusted in this manner the thumb-screw 88 is tightened against the side of the bearing-

sleeve 80 to secure it fixedly in the bore of the ball 78.

The work-table 15 is next adjusted to bring the crystal C into operative relation with the lap L. This is accomplished by sliding the bracket 14 upon its track 12 to carry the upper surface of the crystal into contact with the working-face of the lap. During this adjustment the bracket 14 is raised high enough to cause the table 15 to be depressed slightly by the pressure of the tool against the work, whereby to slide the plunger-spindle 20 downwardly in the bearing 18 to compress the spring 27. The feed-regulating nut 28 is then adjusted on the end of the spindle 20 in accordance with the required thickness to which the crystal is to be ground. For instance, if the upper face of the lens is to be ground down to certain depth, the nut 28 is set an equal distance away from the bottom of the bearing 18. This provides that during the grinding operation the spring 27, acting against the collar 25, will force the table 15 and the work upwardly to the required extent, and then after the grinding is finished the feed of the work will cease automatically. If the amount of feed of the work is not sufficient from this first setting to grind out all the irregularities and produce a smooth, uniform surface on the crystal, then the nut 28 is unscrewed to a slightly further extent.

After the work-feeding mechanism has been set as above described the eccentric adjustment of the upper bearing 108 for the grinding-spindle is regulated to give the required degree of oscillation or throw to the lap L. This adjustment is made by releasing the screw 103, see Figs. 3 and 4, and swinging the bearing-member 95 laterally on its pivot 100. As the bearing 95 is swung in the direction indicated by the arrow *a*, Fig. 4, the beveled edge 112 of the segment 101 registers with the graduations 117 to indicate the degree of eccentricity of the adjustment. After the operating-mechanism has been adjusted in this manner the machine is set in motion by applying power to the driving-elements 66 and 125. Usually, the drive-pulleys are connected to a line-shaft, motor or other prime-mover by belts, not here shown, or through any other suitable means. The pulley 66 turns the shaft 65 to drive the train of gearing 67, 60, 58, 53 to rotate the sleeve 52 which carries the bearing 95. At the same time the pulley 125 drives the universally-jointed shaft 129—130 to rotate the spindle 50 on its axis within the bearing-sleeve 80.

Fig. 4 shows the bearing 95 at the rearward limit of its adjustment with the axis of the ball 108 concentric with the rotatable sleeve 52. With this setting the sleeve 80 which extends through the two balls 108

and 78 will be held in coaxial relation with the sleeve 52, with the axis of the grinding-spindle 50 assuming the perpendicular. If the parts were fixed in this relation the sleeve 80 would have no oscillating movement, but when set for operation the bearing 95 is thrown into eccentric relation with the sleeve 52 as illustrated in Fig. 5. This causes the bearing 95 to be revolved bodily about the axis of the sleeve 52, when the latter is rotated, and the bearing-sleeve 80 is thereby given an oscillating movement about the axis of its lower bearing 78 so that the spindle 50 travels in a gyroscopic path. The lap L at the lower end of the spindle is therefore caused to revolve in an orbital path to travel it on the face of the crystal C. The degree of eccentricity of adjustment of the bearing 95 determines the orbit of the lap L to regulate the extent of surface operated upon, and also controls the size of the minor lens face B which is left protruding above the major face A as the latter is ground down. As indicated in Fig. 5, the hollow form of the lap L causes it to grind in a ring-like zone encircling the central, unexposed surface of the crystal which remains projecting above the ground surface in the form of a circular spot. The inner edge of the annular grinding-face 122 defines the boundary between the two lens-faces and the minor lens must necessarily be of circular outline as the lap revolves in a circular orbit. The revolving movement of the lap L is indicated by the dash-lines in Fig. 8, which illustrates a lens-blank having its minor face B concentric with its major face A. In some instances it is desirable to form the minor face B of the lens in eccentric relation to its major face A, and this is accomplished by setting the crystal C "off center" with respect to the axis of generation of the lap. That is to say, the lens crystal C is set in eccentric relation to the axis of oscillation of the grinding-spindle 50 through a lateral adjustment of the work-table 15. The pivotal mounting of the arm 12 which supports the bracket 14 provides for this adjustment and to throw the table 15 and work-holder 35 off center with respect to the tool it is only required to loosen the nut 5 and bolt 10, see Fig. 1, to swing the track-arm 3 away from the perpendicular as illustrated by the dash-lines in Fig. 2.

During the grinding operation moistened emery dust or any other suitable abrasive is applied between the tool and the work and this is taken up by the grooves 123 on the face of the lap and ground against the glass to cause the abrading action thereon. After the distant view or major-lens face A has been ground down and polished in this manner the tool is removed from the work and the machine is adjusted for forming the

minor face B. The bracket 18 is first lowered on its track 12 by releasing the set-screw 17 in its slide 16, and the lap L is then detached from the end of the spindle 50. A smaller lap L', such as shown in Fig. 7, is then selected in accordance with the power of the lens-face to be produced, its radius of curvature being less than that of the lap L first used. The lap L' is applied to the grinding-spindle 50 by inserting its shank in the socket 118 in the same manner as with the lap L. The set-screw 88 in the ball 78 is then loosened and the spindle bearing-sleeve 80 slid through its bearings to adjust the working face of the lap to the proper distance below the axis of the ball. That is to say, the lower face of the lap L' must be set at a distance away from the axis of the ball 78 equal to its radius of curvature as in the case of the first adjustment of the lap L above explained. After this setting the bracket 14 is raised again on the track 12 and secured in place with the work held against the tool under the pressure of the spring 27 which acts to slide the plunger 20 upwardly. The nut 28 is now adjusted very carefully to prevent the lap L' from grinding too deep into the major lens-face A already formed, and usually the feed for the minor lens is regulated by turning the nut 28 slightly at intervals while inspecting the work being performed. The minor-face B is ground down until its marginal edge b merges into the surface of the major-face A, the finished lens having a uniform thickness at this point with a circular line of demarcation defining its two visual faces.

For grinding the minor face B of the lens a lap L' of the proper size could be used so that it would not be required to oscillate the grinding-spindle 50. Such a method of grinding, however, is objectionable because the lap would have a tendency to wear down unevenly either at the center or on its edges in accordance with varying degrees of hardness of the metal or of the piece being ground. The present method of oscillating the lap during the grinding operation to cause it to generate the curvature of its working surface serves to keep its face constantly accurate and true. This feature of the invention is an important improvement in the art and results in the production of more precise and accurate work. Furthermore, it obviates the necessity of regrinding and finishing the tools and therefore insures uniform grinding, once the machine is properly set, without chance for error from carelessness or inattention on the part of the operator.

The provision for varying the position of the minor lens in relation to the major face allows for grinding the crystals more nearly approximating the size of the finished lens required. That is to say, it is usual in mak-

ing up the eye-glasses or spectacles to trim the whole lens down so that the near-vision face occupies a position at one side of the major face, or, in other words, offset from its center. With my present, improved apparatus the ultimate relation of the lens-faces can be approximated during the forming of the blank so that the whole crystal need not be made so large and therefore the trimming off will require less time with less waste of material.

It will be observed that my improved machine is adaptable for the widest possible range of work, being only limited in this respect as to the extent of its adjustment. It can be set to grind lenses of the minimum or maximum power required, and once adjusted operates automatically without requiring constant attention. The adjusting mechanism is quickly and easily accessible and requires no great skill or expertness to set. It is also to be noted that the whole machine is simple and compact in arrangement, easy to operate, and proof against derangement or wear.

Various modifications might be made in the construction and method of operation of the mechanism of the apparatus without departing from the spirit or scope of the invention; therefore, without limiting myself to the precise embodiment herein shown and described, what I claim is:—

1. In an apparatus for grinding lenses, the combination with a work-holder for the lens-blank, of a rotary spindle, a grinding-tool operated from said spindle, means to rotate the spindle, a pair of spaced bearings for the spindle, one of which has a fixed relation to the work-holder, and means to revolve one of said bearings with respect to the other to oscillate the spindle gyroscopically to cause the tool to travel in an orbital path on the work.

2. In an apparatus for grinding lenses, the combination with a work-holder for the lens-blank, of a rotary spindle, a grinding-tool carried at the end of said spindle, means to rotate the spindle, a pair of spaced bearings for the spindle, one of which has a fixed relation to the work-holder, means to revolve one of said bearings about the axis of the other fixed bearing to oscillate the spindle gyroscopically, and means to adjust the spindle axially of its bearings to regulate the radius of curvature of the surface generated by the tool.

3. In an apparatus for grinding lenses, the combination with a work-holder for the lens-blank, of a rotary grinding-spindle, means to rotate said spindle, a pair of spaced bearings for the spindle, one of which has a fixed relation to the work-holder, means to revolve one of said bearings to oscillate the spindle gyroscopically about the axis of the other fixed bearing, and means to adjust

the relation of the bearings to regulate the extent of oscillation of the spindle.

4. In an apparatus for grinding lenses, the combination with the lens-holder, of a rotary grinding-spindle, means to rotate said spindle, a rockable bearing for the spindle, a second rockable bearing adjustable in eccentric relation to the first bearing, and means to revolve the second bearing while the latter remains fixed in relation to the lens-holder about the axis of the first bearing to impart a gyroscopic oscillation to the spindle.

5. In an apparatus for grinding lenses, the combination with a rotary grinding-spindle, of a rockable bearing for the spindle arranged in fixed relation to the work, a member rotatable about the axis of said bearing, a second rockable bearing for the spindle carried by said rotatable member, means to rotate said member, and means to adjust the second bearing in eccentric relation to the axis of the rotatable member.

6. In an apparatus for grinding lenses, the combination with a rotary grinding-spindle, of a tubular sleeve provided with bearings for the spindle, a rockable bearing for said sleeve arranged in fixed relation to the work, a second rockable bearing for the sleeve, a rotatable member carrying the second bearing, means to rotate said member, and means to adjust the second bearing in eccentric relation to the axis of rotation of said member.

7. In an apparatus for grinding lenses, the combination with a fixed bearing, of a gear-ring journaled in said bearing, gearing for driving said ring, a bearing-member mounted on the gear-ring to adapt it to be adjusted in eccentric relation to the axis thereof, a ball mounted to turn in the adjustable bearing-member, a rotary spindle extending through the axis of the ball, a second ball arranged coaxial with the spindle, and a bearing for supporting said second ball to allow for the oscillation of the spindle about its axis.

8. In a lens-grinding machine, the combination with a two-part socket bearing, of a ball adapted to turn in the sockets of said bearing, a tubular sleeve extending through a diametrical bore in the ball, a second ball bored diametrically to receive the sleeve, a split bearing for the second ball, a rotatable ring, and means to mount the last-named bearing on the ring to adapt its ball to be adjusted in eccentric relation to the axis thereof.

9. In a lens-grinding machine, the combination with a tubular sleeve, of a ball-member bored to receive the sleeve, a bearing-member socketed to receive the ball to adapt it to turn therein, a second ball on the sleeve, a bearing inclosing the second ball, means for revolving the last named bearing

in an orbital path in relation to the first bearing, and a rotary spindle journaled in the tubular sleeve.

10. In a lens-grinding machine, the combination with a work-holder for the lens-blank, of a rotary grinding-tool, means to rotate said tool, means to oscillate the tool

gyroscopically about a fixed axis arranged in spaced relation to the work, and means to adjust the work-holder laterally with respect to the axis of oscillation of the tool.

In testimony whereof I affix my signature.

CHARLES GOODWIN.