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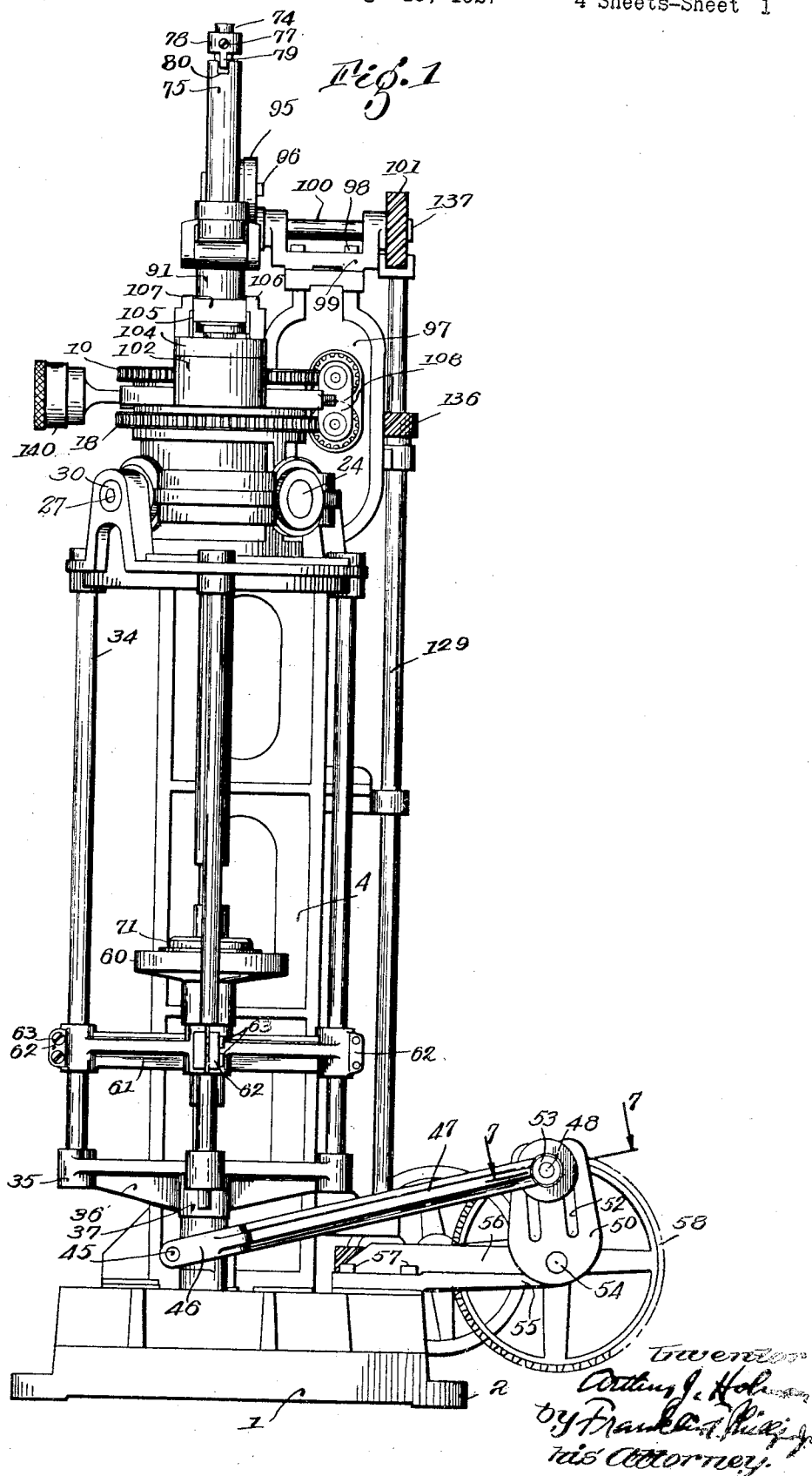
A. J. HOLMAN

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APPARATUS FOR GRINDING AND POLISHING SPHERICAL LENSES

Filed Aug. 18, 1927

4 Sheets-Sheet 1



Oct. 20, 1931.

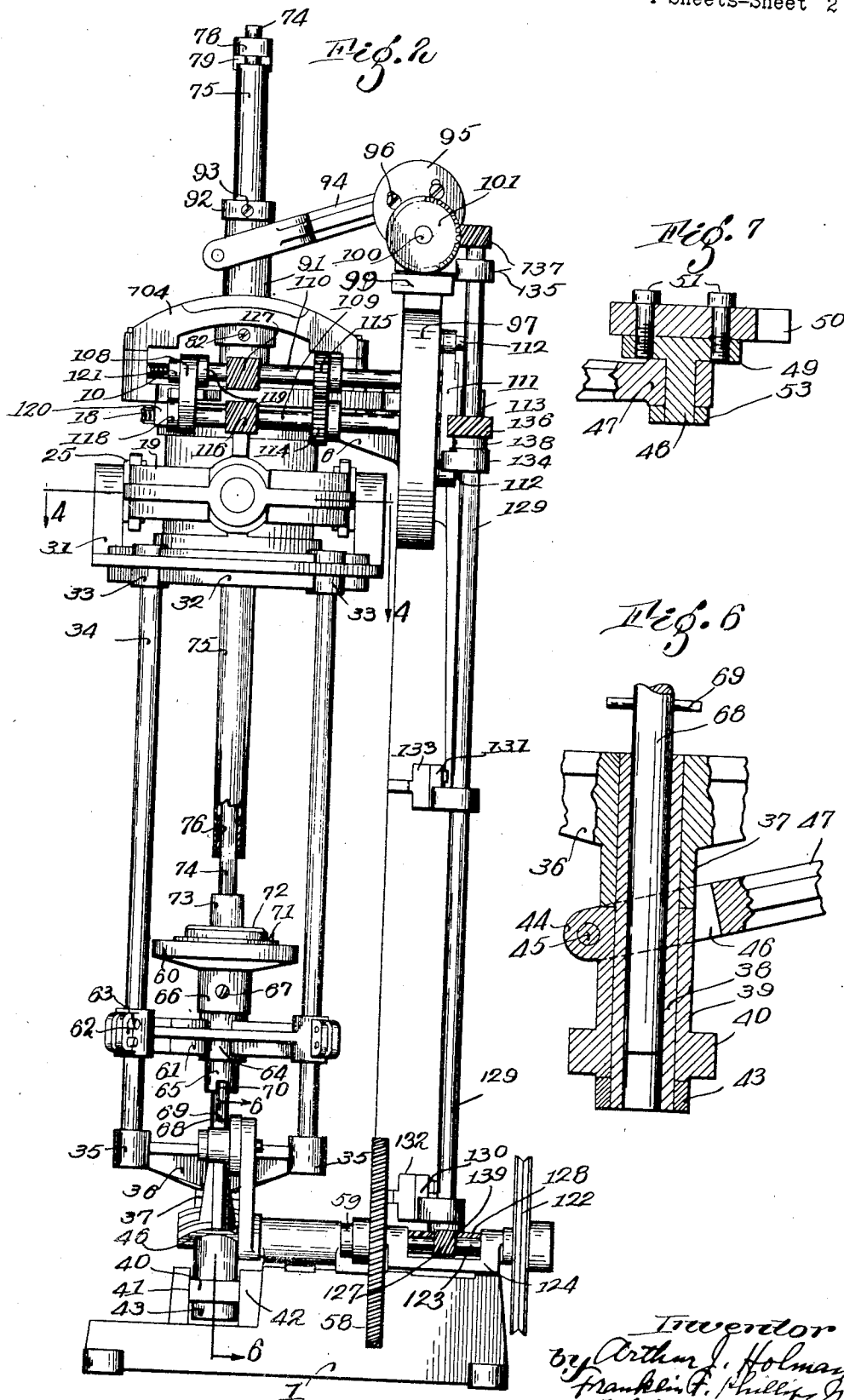
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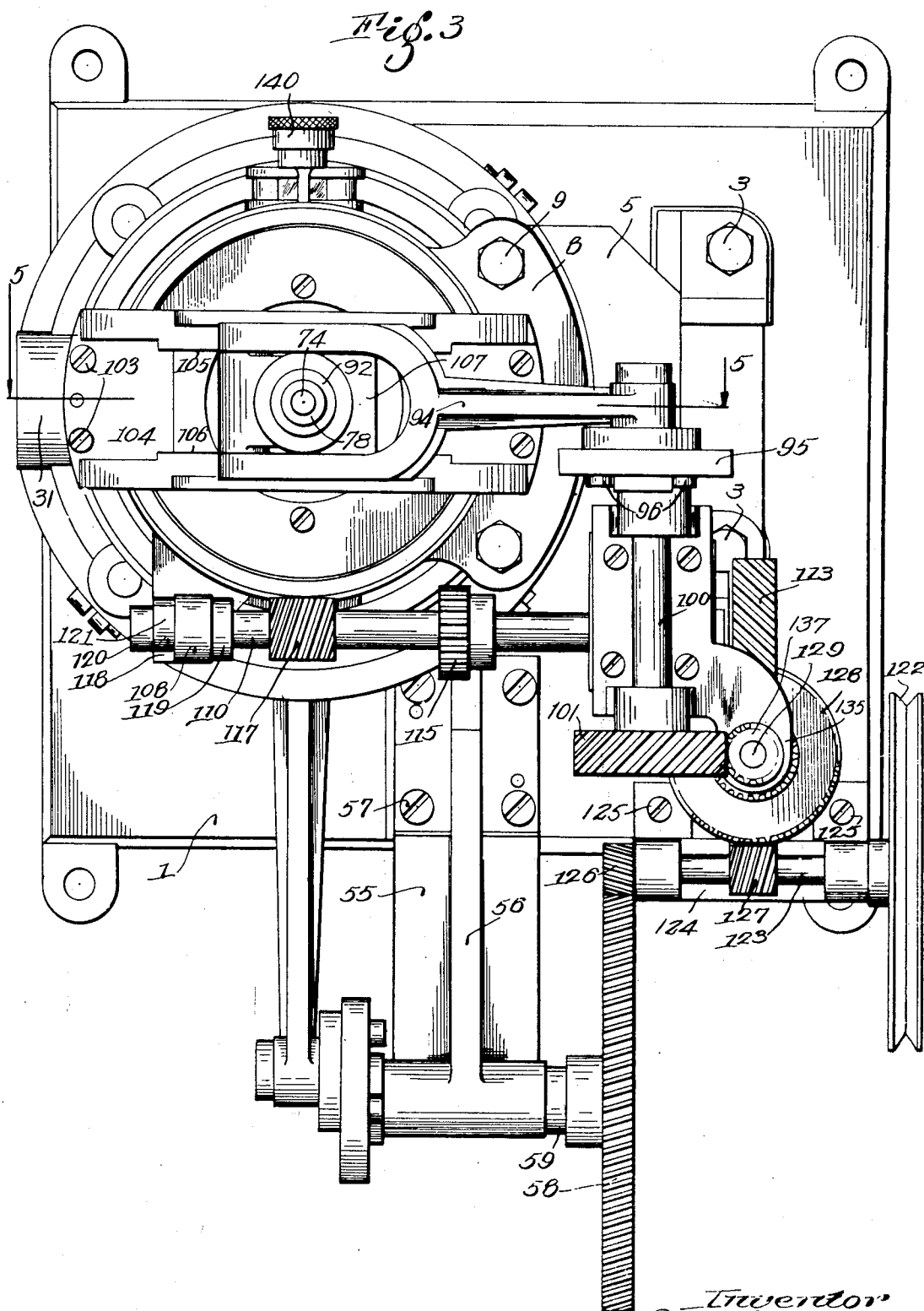
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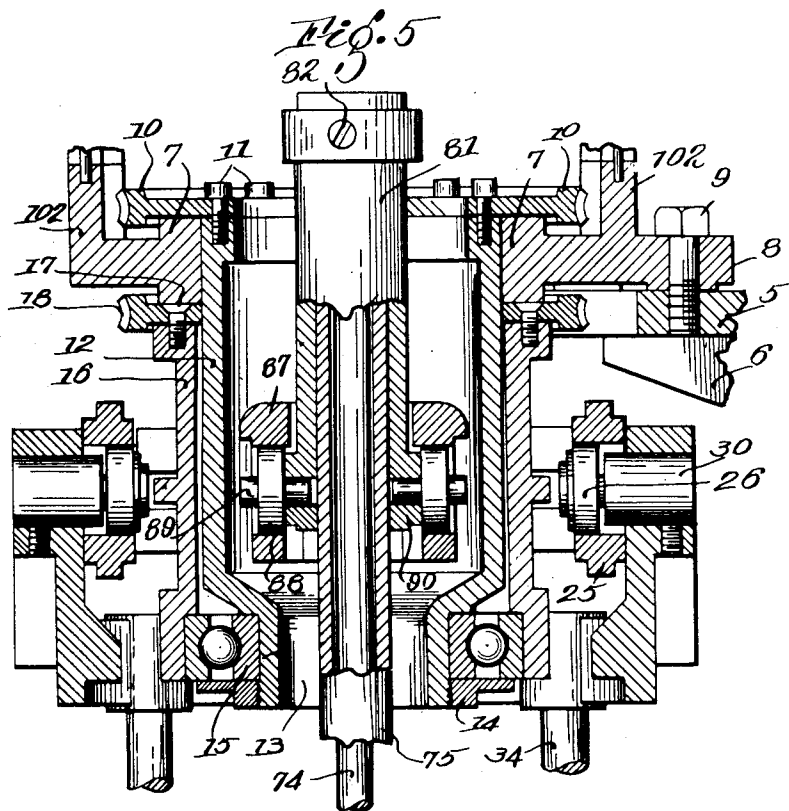
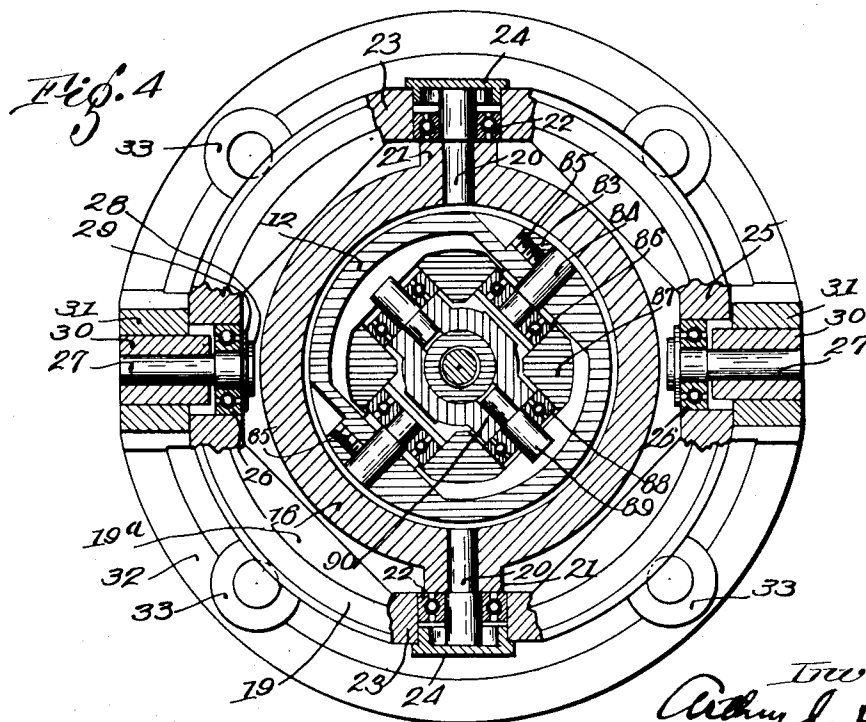
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4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

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APPARATUS FOR GRINDING AND POLISHING SPHERICAL LENSES

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My invention relates to apparatus for making optical lenses, and it has been the special object of my invention to make a spherical lens grinder and polisher which shall be capable of producing automatically precision work without the employment of highly skilled labor. In the art as commonly practiced the lens blank is brought into grinding or polishing contact with a lap having a spherical surface. The lap spins rapidly in fixed position about an axis of the sphere and consequently the zones of cutting surface more remote from the axis of rotation travel more rapidly than more central zones and have a more rapid cutting action. This results in unequal wearing of the lap so as shortly to destroy the true spherical contour of its surface. A very skilled operator when applying the lens blank to the lap can by highly developed sense of touch determine when and to what extent he should change his cross-stroke so as to equalize the wear on the lap and produce an accurate result in his grinding operation. I have sought to avoid this difficulty and avoid the necessity of skilled operation by so organizing my device that cutting action between the lap and the lens blank is not the result of spinning the lap about an axis of the sphere but is rather the result of oscillating the lap about the center of its spherical surface and at the same time oscillating the lens blank in a plane at right angles to the plane of oscillation of the lap and about the same center as that upon which the lap oscillates. In order to further equalize wearing influence I have also provided a comparatively slow relative rotation of the lap and lens blank, and a constantly varying phase angle between the oscillation of the lap and the oscillation of the lens blank.

My device may be best understood by reference to the accompanying drawings in which

Fig. 1 is a front view of my device.

Fig. 2 is a side view with the lap cage rotated forty-five degrees from the position shown in Fig. 1.

Fig. 3 is a top view.

Fig. 4 is a section on line 4—4 of Fig. 2.

Fig. 5 is a section on line 5—5 of Fig. 3, with top broken off.

Fig. 6 is a cross-section on line 6—6 of Fig. 2.

Fig. 7 is a cross-section on line 7—7 of Fig. 1.

Referring now more specifically to the drawings, 1 is a base of cast metal provided with integral feet 2. Attached to the base 1 by bolts 3 is an upright frame 4 which carries a bracket 5 (Figs. 3 and 5) braced by the webs 6 (Figs. 2 and 5). An annular supporting frame 7, provided with an offset portion 8 is thereby attached to the bracket 5 by the bolts 9. Mounted on the top of the annular supporting frame 7 is a worm gear 10 which is attached by screws 11 to the upper end of an inner cylindrical sleeve 12, which has a lower end portion 13 of reduced diameter. The sleeve 12 may rotate freely within the supporting frame 7. The lower end portion 13 of the inner sleeve 12 is threaded externally to receive a flanged nut 14 which retains in position a ball bearing 15, the outer periphery of which is press fitted into the lower end of the outer sleeve 16 which has attached to its top by means of screws 17 a worm gear 18. The heads of screws 17 are counter sunk so that the gear 18 may be butted closely against the under surface of the supporting frame 7. The gear 18 is bored to provide a running fit on the inner sleeve 12.

A tilting ring 19 is hingedly supported on the outer sleeve 16 in the following described manner: a pair of diametrically opposite pins 20 are press fitted into holes in bosses 21 of the outer sleeve 16. The outer ends of pins 20 are press fitted into ball bearings 22 which in turn are press fitted within holes in bosses 23 on the tilting ring 19. Dust caps 24 are press fitted into the holes in bosses 23.

On a diameter at right angles to the diameter through the centers of the bosses 23 are a pair of bosses 25 on ring 19. Within holes in the bosses 25 are press fitted ball bearings 26 within which are press fitted pins 27, the enlarged heads 28 of which retain washer caps 29. Between the bosses 23 and bosses 25 the ring 19 is stiffened by the webs 19^a. The pins 27 extend with pressed fit into bush-

ings 30 which in turn are press fitted in holes in lugs 31. The lugs 31 project upwardly from an annular member 32 provided with four equally spaced bosses 33, into holes within which are press fitted rods 34 the lower ends of which are press fitted into holes within bosses 35 which are integral with a frame 36.

A boss 37 on the lower middle part of frame 36, and centrally located with respect to the bosses 35 thereon, is provided with a hole into which is press fitted sleeve 38 upon which is rotatably mounted a second sleeve 39 having a rectangular boss 40 near its lower end, which boss 40 fits slidably between guides 41 and 42 integral with the base 1. The sleeve 39 is retained in position by a collar 43 attached to the lower end of the sleeve 38.

The sleeve 39 is provided with a boss 44 through a hole in which passes a pin 45 which attaches thereto the forked end 46 of a connecting rod 47. The connecting rod 47 is attached to the crank-pin 48 which is integral with the adjustably mounted block 49 (Fig. 7) attached to the crank 50 by means of screws 51 which pass through slots 52 in the crank 50. The connecting rod 47 is retained on the crank-pin 48 by the collar 53 which is set-screwed to the crank-pin 48.

The crank 50 is fast mounted on the shaft 54 journaled in a bracket 55 provided with a stiffening rib 56. The bracket 55 is attached by screws 57 to the base 1. The shaft 54 has fast thereto a helical gear 58, there being a thrust bearing 59 between the gear 58 and the bracket 55.

The annular member 32 and the frame 36, together with the rods 34, form a cage which may be oscillated by the crank 50 and the connecting rod 47. Within the cage so formed is adjustably mounted a lap 60 which is supported in the following manner: a spider 61 has four split clamps 62 arranged to embrace the rods 34 and adapted to be clamped in various positions thereon by clamp screws 63. The spider 61 has a central hub 64 into which is press fitted the sleeve 65 which projects upward and into the hub 66 of the lap 60 which is secured thereon by set-screw 67.

A rod 68 slidably mounted in the sleeve 38 projects upwardly from the frame 36 and enters with a snug sliding fit the sleeve 65. The rod 68, when my device is used for lens grinding, serves to assist in positioning the lap 60 centrally within the cage. It is to be noted, however, that the rod 68 is provided with a pin 69 which, when my device is fitted up for polishing, in the manner hereinafter described, will enter the slot 70 in the sleeve 65.

The lens blank 71 is secured by pitch, in the usual manner, to the chuck 72 having a hub 73 within which is set-screwed the shaft 74 to which is imparted a rotative and oscillating movement by the sleeve 75 within which the shaft 74 is slidably mounted. The sleeve 75

is provided at each end with bushings 76 in order to properly center the shaft 74 and provide a minimum sliding friction. On the top of the shaft 74 there is fast mounted by the set-screw 77 the collar 78 which is provided with integral dependent keys 79 which enter slots 80 in the top of sleeve 75 thus providing driving engagement of the sleeve 75 with the shaft 74.

To support the sleeve 75 and to permit it to oscillate it is clamped within a sleeve 81 by means of set-screws 82. The sleeve 81 is supported by a universal joint within the rotatable sleeve 12 in the following manner: the sleeve 12 is provided in its interior with diametrically opposite bosses 83 having radially opposite holes in which are fitted pins 84 retained by set-screws 85. The pins 84 are press fitted into ball bearings 86 which in turn are press fitted into the tilting ring 87. Within holes in the ring 87 and on a diameter at right angles to the axes of the bearings 86 are press fitted bearings 88 into which are press fitted pins 89 which project and are press fitted into holes in bosses 90 in sleeve 81.

Mounted above and resting upon sleeve 81 is a sleeve 91 retained in position by collar 92 which is attached to sleeve 75 by set-screw 93. A connecting rod 94 is attached to the sleeve 91 in the same manner as that described in the case of sleeve 39 and connecting rod 47. The sleeve 75 is rotatable within the sleeve 91. The connecting rod 94 is adjustably attached to the crank 95 by screws 96 and structures similar to those described in the case of crank 50.

Integral with and projecting above the frame 4 is an extension 97 upon the top of which is secured by screws 98 the bearing bracket 99 within which is rotatably mounted the crank-shaft 100 to which is fixed at one end the crank 95. Upon the other end of crank-shaft 100 is press fitted the helical gear 101.

The annular frame 7 is provided with integral upward extensions 102 upon which are mounted, and secured by screws 103, the cross frame 104 which has sides 105 and 106 forming a guideway for a rectangular integral boss 107 on sleeve 91.

A lug 108 on the annular frame 7 (Fig. 2) provides bearings at one end for parallel shafts 109 and 110. The other ends of these shafts are journaled in the bearing bracket 111 attached by screw 112 to the frame extension 97. Press fitted on the end of shaft 109 is the helical gear 113. Also fast mounted on shaft 109 is the spur gear 114 which meshes with spur gear 115 fast on shaft 110. Shafts 109 and 110 also carry fast mounted thereon respectively the worms 116 and 117 which mesh respectively with worm gears 118 and 119. Thrust bearings 118 and 119 are provided for shafts 109 and 110 respectively and

collars 120 and 121 retain said shafts respectively in position.

Power to operate my device is applied to pulley 122 which is fixed on shaft 123 which is journaled in bearing bracket 124 (Fig. 2) which is attached to base 1 by screws 125 (Fig. 3). The shaft 123 has fixed thereon the helical gear 126 which meshes with helical gear 58 on crank shaft 54. A helical gear 127 also fixed on shaft 123 meshes with helical gear 128 on the lower end of vertical shaft 129.

The shaft 129 is journaled within bearing brackets 130 and 131, attached to lugs 132 and 133 respectively on frame 4, and also within boss 134 on bearing bracket 111 and boss 135 on bearing bracket 99.

A helical gear 136 fixed on shaft 129 meshes with helical gear 113 on shaft 109. A helical gear 137 also fixed on shaft 129 meshes with helical gear 101 on crank shaft 100. A thrust bearing 138 located between helical gear 136 and boss 134 carries the weight of shaft 129, and a thrust bearing 139 located between bearing bracket 130 and helical gear 128 takes the upward thrust of shaft 129.

A grease cup 140 mounted in the annular frame 7 supplies a lubricant to the bore and upper and lower faces of the annular frame 7.

The gear ratios in my device are such as to cause crank 50 to revolve at a slightly different rate of speed than the crank 95, while the worm wheels 10 and 18 revolve at a relatively low rate of speed as compared with the cranks 50 and 95.

It is to be noted that the cage bearing lap 60 and the shaft 74 whereon the lens chuck 72 is mounted have a common center of oscillation which is the common center of the universal joints whereon they are suspended from the outer sleeve 16 and the inner sleeve 12 respectively, and that said sleeves are rotated in opposite directions by the worm wheels 18 and 10 under the influence of the gear train. While the cage bearing the lap 60 and the shaft 74 bearing the lens chuck 72 are oscillated rapidly in planes at right angles and are at the same revolved slowly in opposite directions these simultaneous compound movements are permitted by the pair of universal joints whereon these parts are supported.

The design and arrangement of the inner and outer sleeves and the universal joints is of particular significance as all the mechanism controlling the accuracy of the work done by the machine is centralized in these parts. In the first place, the center of a universal joint of the type used in my device is located at the intersection of the axes of the hinge pins forming the joint and this center is the pivot joint for all movements of the mechanism carried by the joint. Secondly, rotation of the outer and inner sleeves causes the univer-

sal joints to rotate, thereby producing rotation of both lap and lens chuck which are carried on the universal joints. Moreover, the pair of sleeves together with the universal joints comprise a unit which is removed from the proximity of the grinding surfaces. As this unit is enclosed and provided with ball bearings, the precise mechanism, on which depends entirely the accuracy of the work produced, is not subject to any appreciable wear and, consequently, will produce precision lenses over a long operating period. It is to be noted in particular in the use of my device that the surface being formed in the grinding operation is really generated about the center of the universal joints. It is also true that the lap surface is being constantly regenerated and, therefore, it must of necessity always remain true to curve.

The device as shown in the drawings is set up to grind a convex lens in a lap having a curvature of grinding surface the radius of which is equal to the distance from the center of the grinding surface of the lap to the center of oscillation of the lap cage. The adjustment of the position of the lap to obtain this condition is effected by adjusting the position of the spider 61 on the rods 34. After the desired position is obtained the spider may be clamped in place by tightening clamp screws 63.

The lens blank 71 is pressed against the grinding surface of the lap under the weight of shaft 74 and as the lap and the lens blank are oscillated about the center of curvature of the grinding surface of the lap it is obvious that the wear on the lap surface due to cross wiping action will be uniform at all points and consequently the lap will retain its true spherical surface and impart a true spherical surface to the lens blank. As the cross wiping action above described is produced at relatively high speed compared with the speed of rotation of lap and lens blank in opposite directions, the uneven wearing action of relative rotation of lap and lens blank which is the fault of common practice is reduced to a negligible minimum and further compensated by the combination thereof with cross wiping action as such and more particularly by the peculiar cross wiping action produced by the varying phase angle of the cranks 50 and 95. Such slow relative rotation of lap and lens blank as I have provided is designed to be merely sufficient to effect an even distribution of the abrasive compound used in the grinding process, the effective grinding action being produced by the cross wiping action above described.

To properly regulate the amplitude of oscillation of the lap and lens blank to conform to various dimensions of lens diameter and radius of curvature, I have provided the adjustable crank throws for connecting rods 47 and 94.

To grind a concave lens on my device it will of course be necessary to interchange the positions of the lap and lens blank—using a lap of convex grinding surface. To do this the shaft 74 is withdrawn from sleeve 75 and a lap having the required grinding surface is attached to the end of sleeve 75. The lap 60 is removed from the upper end of sleeve 65 and, after adjusting the position of the convex lap by loosening screws 82 and sliding sleeve 75 up or down until the center of curvature of the lap coincides with the center of oscillation, and again setting up screws 82, the shaft 68 may slide upward till its upper end projects beyond the top of sleeve 65 and a lens chuck with lens blank mounted thereon may be attached to the top of said shaft 68. To retain the lens blank in grinding contact with the lap a suitable spring may be inserted between the top of the frame 36 and the pin 69 in shaft 68. The pin 69 will enter the slot 70 in sleeve 65 thereby locking the shaft 68 in rotative engagement with the sleeve 65 which rotates with the cage.

When my device is used as a lens polisher for convex lenses it is necessary to establish the arc of oscillation of the lens blank on shaft 74 by means other than the lap as the lap is replaced by a plastic element which may wear or otherwise yield considerably during the polishing operation. The position of the lens blank may be fixed with respect to the center of oscillation by locking the shaft 74 within the sleeve 75 by a set screw or other suitable means. The polishing element is then mounted on the shaft 68 in the same manner as that described for mounting the lens chuck when a concave lens is to be ground, the polishing element being pressed by spring action against the lens surface being polished.

To polish a concave lens blank the shaft 68 on which the lens blank was mounted for grinding should be fixed within the sleeve 65, by a suitable set screw or otherwise, in such a position that the center of curvature of the concave surface coincides with the center of oscillation. The polishing element is then mounted on the shaft 74 and is pressed by the weight thereof against the concave surface being polished. If additional pressure is desirable it may be secured by loading the top of shaft 74.

It will be readily apparent from the foregoing that all grinding and polishing movements produced by my device are positively controlled and directed, and consist of sweeping action wherein the radius of oscillation is always equal to that of the designed curvature of the surface to be obtained. No point on the lap surface, notwithstanding its various movements, ever departs from the surface of an imaginary sphere having a radius equal to the radius of curvature desired to be pro-

duced upon the lens surface and a center coinciding with the center of curvature of the lap.

Although I have described my device as organized so as to produce true spherical lens surfaces, nevertheless the structures described may be slightly modified so as to enable them to produce lenses which are aspheric in character, the surface being symmetrical about the center, the curvature diminishing or increasing in proportion to the departure from the center. The nature and magnitude of departure from the true sphere may be regulated by an appropriate displacement of the centers of oscillation of the cage and sleeve 75.

Having thus fully described my invention, what I claim is,—

1. In a device of the character specified the combination of a lap, a rotatable universal joint supporting said lap, means for simultaneously rotating said universal joint, thereby imparting rotation to said lap, and oscillating said lap in a manner whereby no point on the lap surface may during its travel deviate from an extended spherical surface coincident with its own spherical contour, a lens chuck, and means for retaining a lens carried by said chuck in grinding contact with said lap.

2. In a device of the character specified, the combination of a lap, a rotatable universal joint supporting said lap in a manner whereby said lap may oscillate about the center of said universal joint, said center of said universal joint occupying a fixed position in close proximity to the center of curvature of said lap, means for oscillating said lap and rotating said universal joint, and means for supporting a lens blank in grinding contact with said lap.

3. In a device of the character specified the combination of a lap, a rotatable universal joint supporting said lap in a manner whereby said lap may oscillate about the center of curvature of its spherical surface, means for supporting a lens blank in grinding contact with said lap, and means for simultaneously oscillating said lap and rotating said universal joint thereby imparting rotation to said lap simultaneously with the oscillation thereof.

4. In a device of the character specified, the combination of a chuck adapted to support a lens blank, a rotatable universal joint supporting said chuck in a manner whereby said chuck may oscillate about the center of said universal joint, a lap so mounted as to have grinding engagement with a lens blank mounted on said chuck, the center of curvature of said lap being in close proximity to the fixed center of said universal joint, and means for oscillating said chuck and rotating said universal joint thereby imparting rotation to said chuck simultaneously with the oscillation thereof.

5. In a device of the character specified the combination of a chuck adapted to support a lens blank, a rotatable universal joint supporting said chuck in a manner whereby said chuck may oscillate about the center of said universal joint, a lap so mounted as to have grinding engagement with a lens blank mounted on said chuck, the center of curvature of said lap being positioned to coincide with the center of said universal joint, and independent means for oscillating said chuck and rotating said universal joint thereby imparting rotation to said chuck simultaneously with the oscillation thereof.

6. In a device of the character specified the combination of a lap, a rotatable universal joint supporting said lap in a manner whereby said lap may oscillate about the center of said universal joint, means for oscillating said lap, a chuck adapted to support a lens blank, means for mounting said chuck in a manner whereby it may oscillate about a fixed center, means for oscillating said chuck, means for supporting a lens blank mounted on said chuck in grinding contact with said lap, and means for rotating said universal joint thereby imparting rotation to said lap simultaneously with the oscillation thereof.

7. In a device of the character specified the combination of a lap, a rotatable universal joint supporting said lap in a manner whereby said lap may oscillate about the center of said universal joint, means for oscillating said lap, a chuck adapted to support a lens blank, means for mounting said chuck in a manner whereby it may oscillate about a fixed center, means for oscillating said chuck in a plane other than the plane of oscillation of said lap, means for supporting a lens blank mounted on said chuck in grinding contact with said lap, and means for rotating said universal joint thereby imparting rotation to said lap simultaneously with the oscillation thereof.

8. In a device of the character specified the combination of a lap, a rotatable universal joint supporting said lap in a manner whereby said lap may oscillate about the center of said universal joint, means for oscillating said lap, a chuck adapted to support a lens blank, means for mounting said chuck in a manner whereby it may oscillate about a fixed center, means for oscillating said chuck in a plane other than the plane of oscillation of said lap, at a frequency different from that of the oscillation of said lap, means for supporting a lens blank mounted on said chuck in grinding contact with said lap, and means for rotating said universal joint thereby imparting rotation to said lap simultaneously with the oscillation thereof.

9. In a device of the character specified the combination of a lap, a rotatable universal joint supporting said lap in a manner whereby said lap may oscillate about its center of

curvature, means for oscillating said lap, a chuck adapted to support a lens blank, means for mounting said chuck in a manner whereby it may oscillate about the center of curvature of said lap, means for oscillating said chuck in a plane other than the plane of oscillation of said lap at a frequency different from that of the oscillation of said lap, means for supporting a lens blank mounted on said chuck in grinding contact with said lap, and means for rotating said universal joint thereby imparting rotation to said lap simultaneously with the oscillation thereof.

10. In a device of the character specified the combination of a chuck adapted to support a lens blank, a rotatable universal joint supporting said chuck in a manner whereby said chuck may oscillate about the center of said universal joint, a lap, means for mounting said lap in a manner whereby it may oscillate about a fixed center and be retained in grinding engagement with a lens blank mounted on said chuck, means for oscillating said lap, and means for oscillating said chuck and rotating said universal joint thereby imparting rotation to said chuck simultaneously with the oscillation thereof.

11. In a device of the character specified the combination of a chuck adapted to support a lens blank, a rotatable universal joint supporting said chuck in a manner whereby said chuck may oscillate about the center of said universal joint, a lap, means for mounting said lap in a manner whereby it may oscillate about a fixed center and be retained in grinding engagement with a lens blank mounted on said chuck, means for oscillating said lap in a plane other than the plane of oscillation of said chuck, and means for oscillating said chuck and rotating said universal joint thereby imparting rotation to said chuck simultaneously with the oscillation thereof.

12. In a device of the character specified the combination of a chuck adapted to support a lens blank, a rotatable universal joint supporting said chuck in a manner whereby said chuck may oscillate about the center of said universal joint, a lap, means for mounting said lap in a manner whereby it may oscillate about a fixed center and be retained in grinding engagement with a lens blank mounted on said chuck, means for oscillating said lap in a plane other than the plane of oscillation of said chuck at a frequency different from that of the oscillation of said chuck, and means for oscillating said chuck and rotating said universal joint thereby imparting rotation to said chuck simultaneously with the oscillation thereof.

13. In a device of the character specified the combination of a chuck adapted to support a lens blank, a rotatable universal joint supporting said chuck in a manner whereby said chuck may oscillate about the center of

said universal joint, a lap, means for mounting said lap in a manner whereby it may oscillate about its center of curvature and be retained in grinding engagement with a lens blank mounted on said chuck, the center of curvature of said lap being positioned at the center of said universal joint, means for oscillating said lap in a plane other than the plane of oscillation of said chuck at a frequency different from that of the oscillation of said chuck, and means for oscillating said chuck and rotating said universal joint thereby imparting rotation to said chuck simultaneously with the oscillation thereof.

14. In a device of the character specified the combination of a lap, a rotatable universal joint supporting said lap in a manner whereby said lap may oscillate about the center of said universal joint, a chuck adapted to support a lens blank, a second rotatable universal joint supporting said chuck in a manner whereby said chuck may oscillate about the center of said second universal joint, and independent means for oscillating said lap and said chuck.

15. In a device of the character specified the combination of a lap, means for mounting said lap in a manner whereby it may oscillate about a fixed center, means for oscillating said lap, a chuck adapted to support a lens blank, means for mounting said chuck in a manner whereby it may oscillate about a fixed center, means for oscillating said chuck in a plane other than the plane of oscillation of said lap, means for supporting a lens blank mounted on said chuck in grinding contact with said lap, and means for rotating said lap and said chuck simultaneously with the oscillations thereof.

16. In a device of the character specified the combination of a lap, means for mounting said lap in a manner whereby it may oscillate about its center of curvature, means for oscillating said lap, a chuck adapted to support a lens blank, means for mounting said chuck in a manner whereby it may oscillate about a fixed center, means for oscillating said chuck in a plane other than the plane of oscillation of said lap, means for supporting a lens blank mounted on said chuck in grinding contact with said lap, and means for rotating said lap and said chuck simultaneously with the oscillations thereof.

17. In a device of the character specified the combination of a lap, means for mounting said lap in a manner whereby it may oscillate about its center of curvature, means for oscillating said lap, a chuck adapted to support a lens blank, means for mounting said chuck in a manner whereby it may oscillate about the center of curvature of said lap, means for oscillating said chuck in a plane other than the plane of oscillation of said lap, means for supporting a lens blank mounted on said chuck in grinding contact with

said lap, and means for rotating either said lap or said chuck simultaneously with the oscillation thereof.

18. In a device of the character specified the combination of a lap, means for mounting said lap in a manner whereby it may oscillate about a fixed center, means for oscillating said lap, a chuck adapted to support a lens blank, means for mounting said chuck in a manner whereby it may oscillate about a fixed center, means for oscillating said chuck in a plane other than the plane of oscillation of said lap at a frequency different from that of the oscillation of said lap, means for supporting a lens blank mounted on said chuck in grinding contact with said lap, and means for rotating said lap and said chuck simultaneously with the oscillations thereof.

19. In a device of the character specified the combination of a lap, means for mounting said lap in a manner whereby it may oscillate about a fixed center which coincides with its center of curvature, means for oscillating said lap, a chuck adapted to support a lens blank, means for mounting said chuck in a manner whereby it may oscillate about said fixed center of oscillation of said lap, means for oscillating said chuck, in a plane other than the plane of oscillation of said lap, means for supporting a lens blank mounted on said chuck in grinding contact with said lap, and means for rotating said lap and said chuck simultaneously with the oscillations thereof.

20. In a device of the character specified the combination of a lap, means for mounting said lap in a manner whereby it may oscillate about a fixed center which coincides with its center of curvature, means for oscillating said lap, a chuck adapted to support a lens blank, means for mounting said chuck in a manner whereby it may oscillate about said fixed center of oscillation of said lap, means for oscillating said chuck in a plane other than the plane of oscillation of said lap at a frequency different from that of the oscillation of said lap, means for supporting a lens blank mounted on said chuck in grinding contact with said lap, and means for rotating said lap and said chuck simultaneously with the oscillations thereof.

21. In a device of the character specified the combination of two universal joints, one of said universal joints being situated within the other, a pair of sleeves supporting said universal joints, a lap supporting means carried by one of said universal joints, a lens chuck supporting means carried by the other of said universal joints, and independent means for oscillating said lap supporting means and said lens chuck supporting means.

22. In a device of the character specified the combination of a pair of concentric universal joints, a pair of rotatably mounted sleeves supporting said universal joints, a lap supporting means carried by one of said uni-

versal joints, a lens chuck supporting means carried by the other of said universal joints, and independent means for oscillating in different planes said lap supporting means and said lens chuck supporting means.

23. In a device of the character specified the combination of a pair of concentric universal joints, a pair of sleeves supporting said universal joints, a lap supporting means carried by one of said universal joints, a lens chuck supporting means carried by the other of said universal joints, independent means for oscillating in different planes said lap supporting means and said lens chuck supporting means, and independent means for rotating said lap supporting means and said lens chuck supporting means simultaneously with the oscillations thereof.

24. In a device of the character specified the combination of an annular supporting frame, an inner sleeve rotatably mounted in said annular supporting frame, a gear fast mounted on the top of said inner sleeve, an outer sleeve concentric with said inner sleeve and rotatably mounted thereon, a second gear mounted on said outer sleeve, a tilting ring concentrically mounted with respect to said sleeves and hinged on a diameter thereof, a lap cage hingedly hung from said tilting ring, a second tilting ring mounted concentrically within said inner sleeve and hinged on a diameter thereof, a third sleeve hingedly supported by and within said second tilting ring, a fourth sleeve slidably and adjustably mounted within said third sleeve, a shaft slidably mounted in said fourth sleeve and locked to rotate therewith, a lens chuck mounted on said shaft, driving gears meshing with said gears attached to said inner and outer sleeves, means for actuating said driving gears so as to rotate said inner and outer sleeves in opposite directions, and means for simultaneously oscillating said lap cage and said lens chuck each in a single plane and at an angle to the other at different frequencies.

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