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PROCESS FOR GRINDING BIFOCAL LENSES AND OTHER SPHERICAL SURFACES.

APPLICATION FILED DEC. 18, 1905.

946,571. Patented Jan. 18, 1910.

3 SHEETS—SHEET 1.

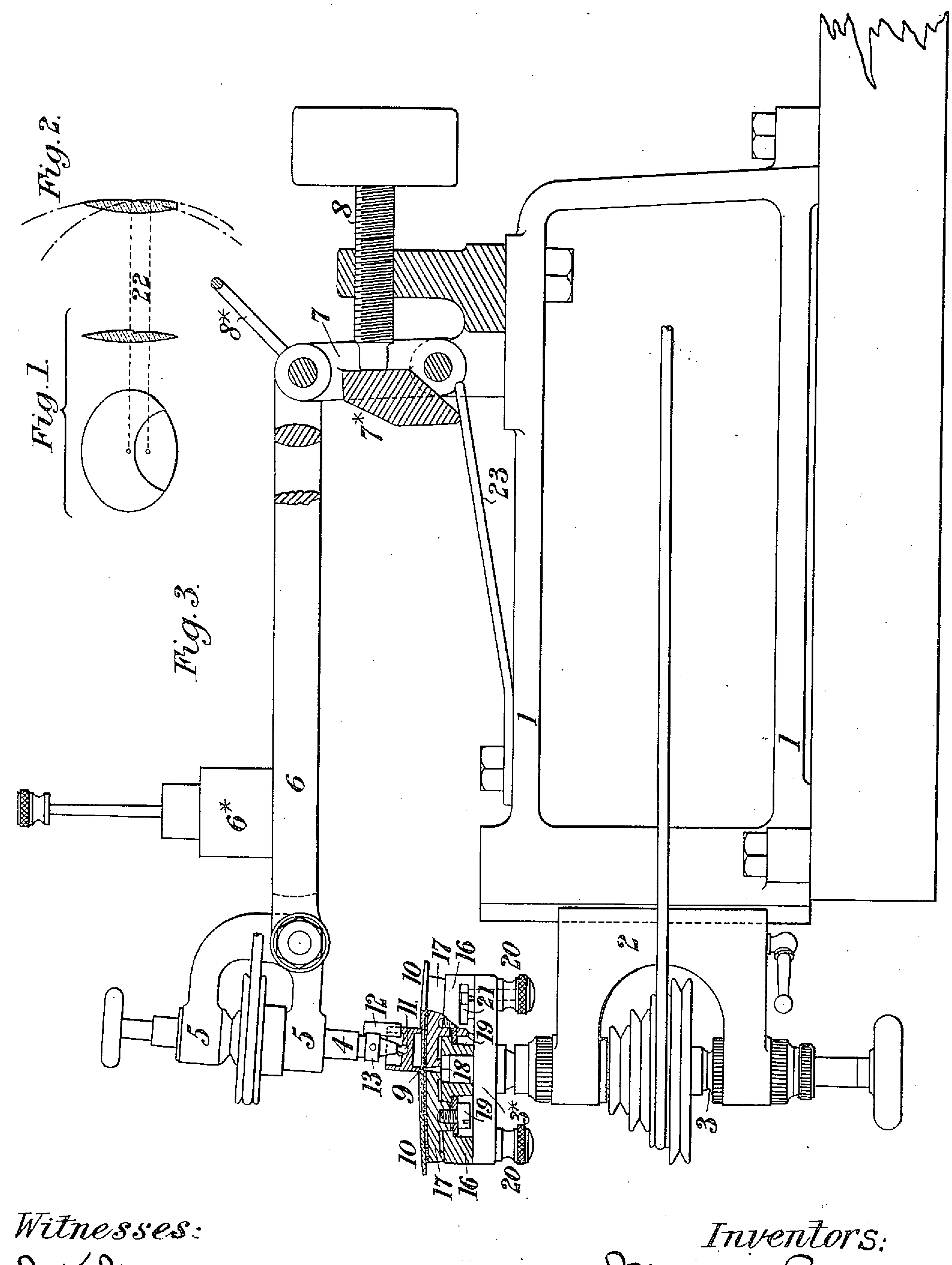

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Fig. 8.

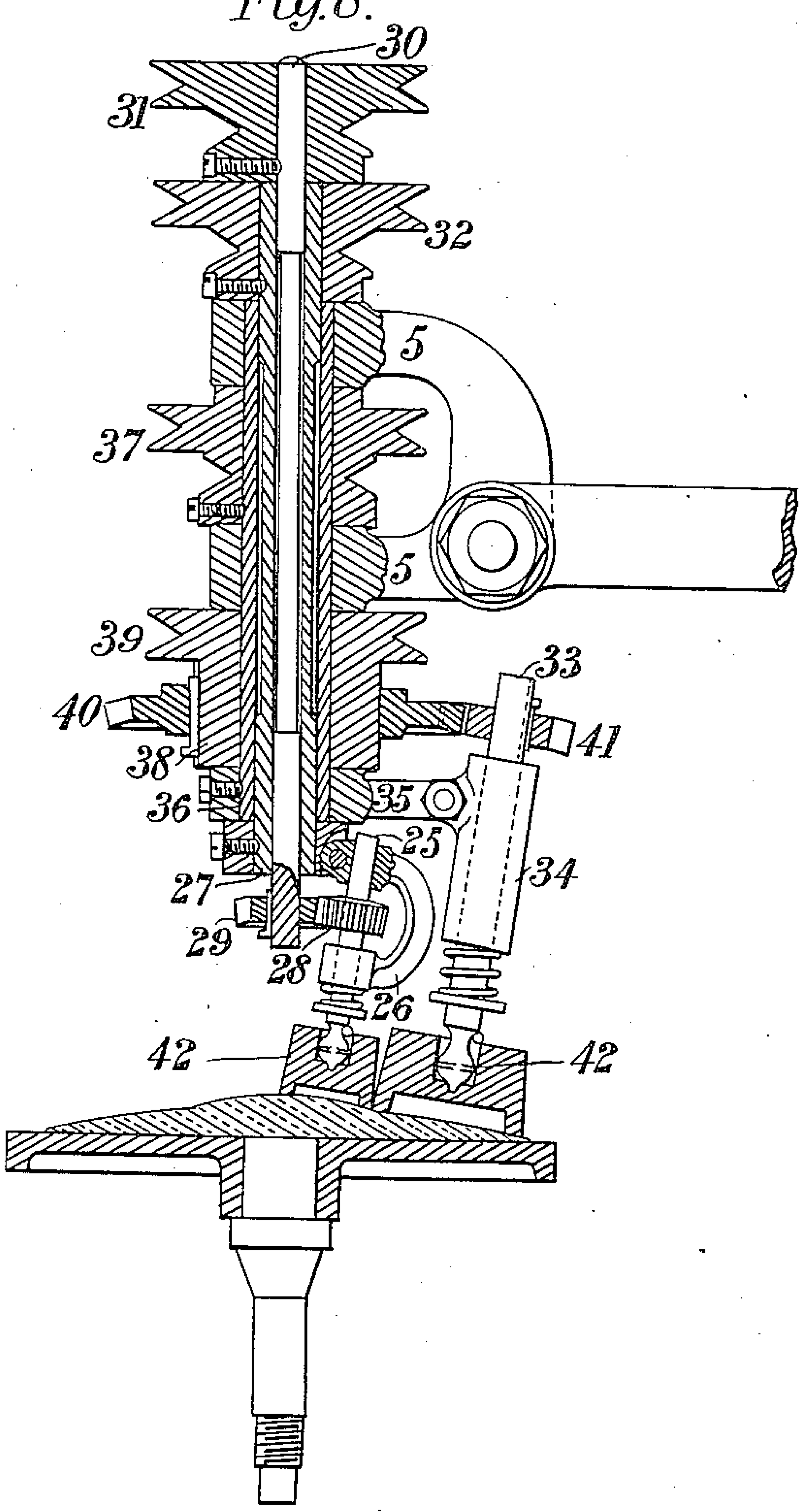


Fig. 5.

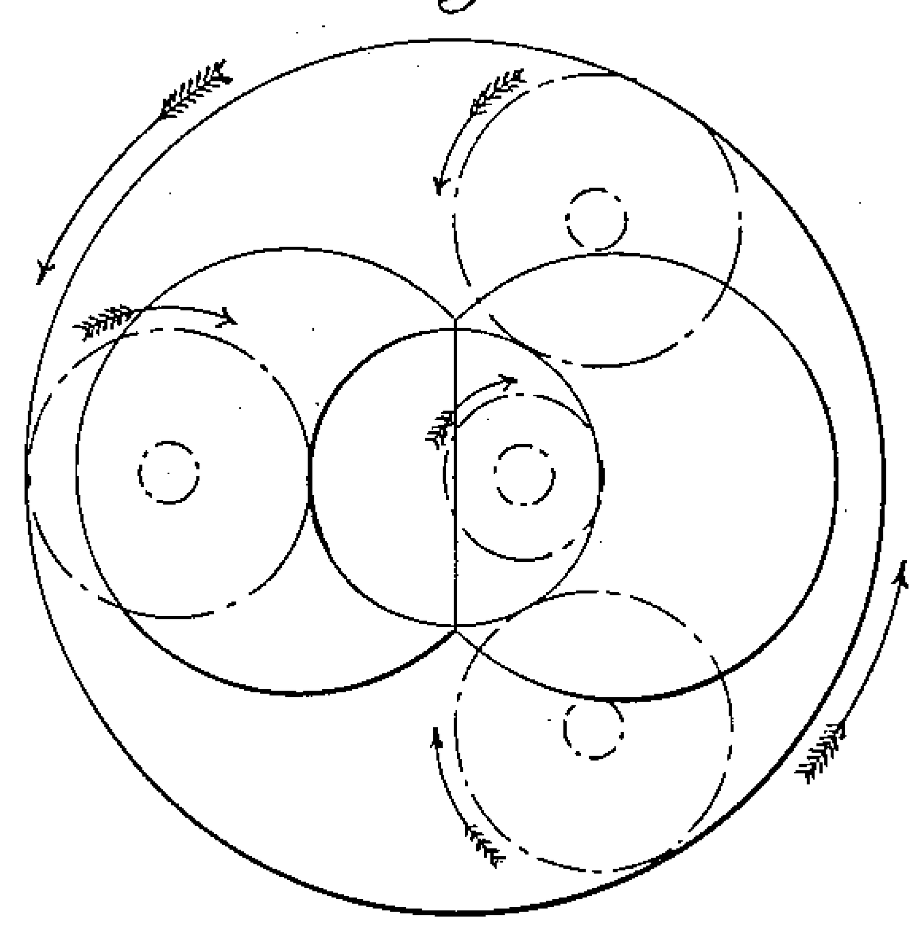
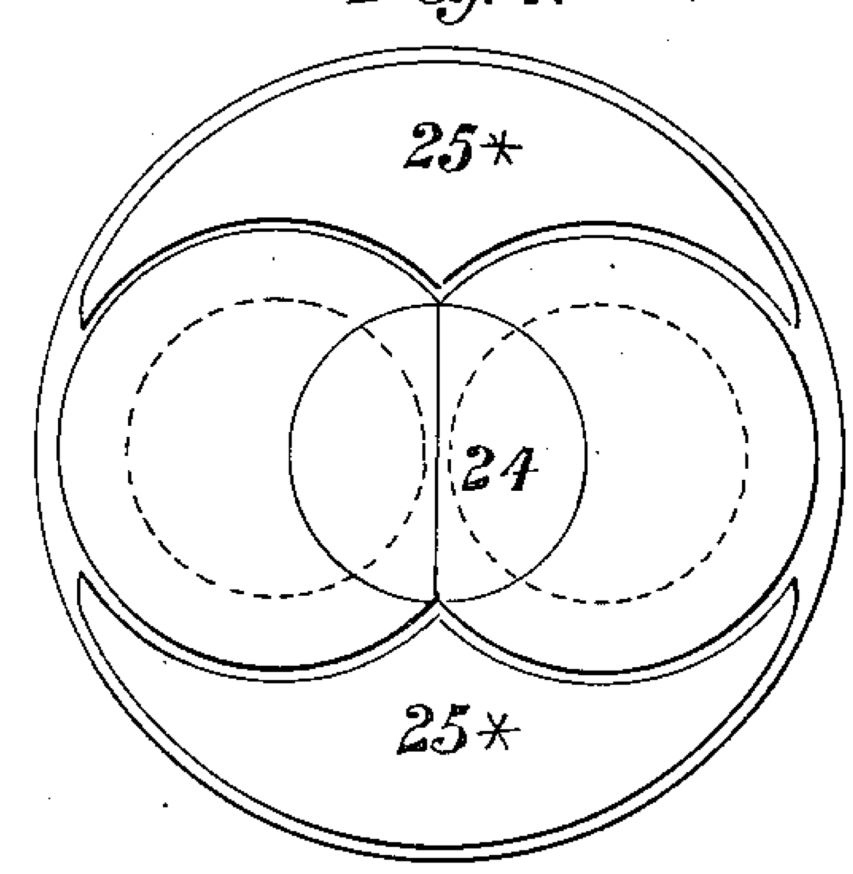


Fig. 7.



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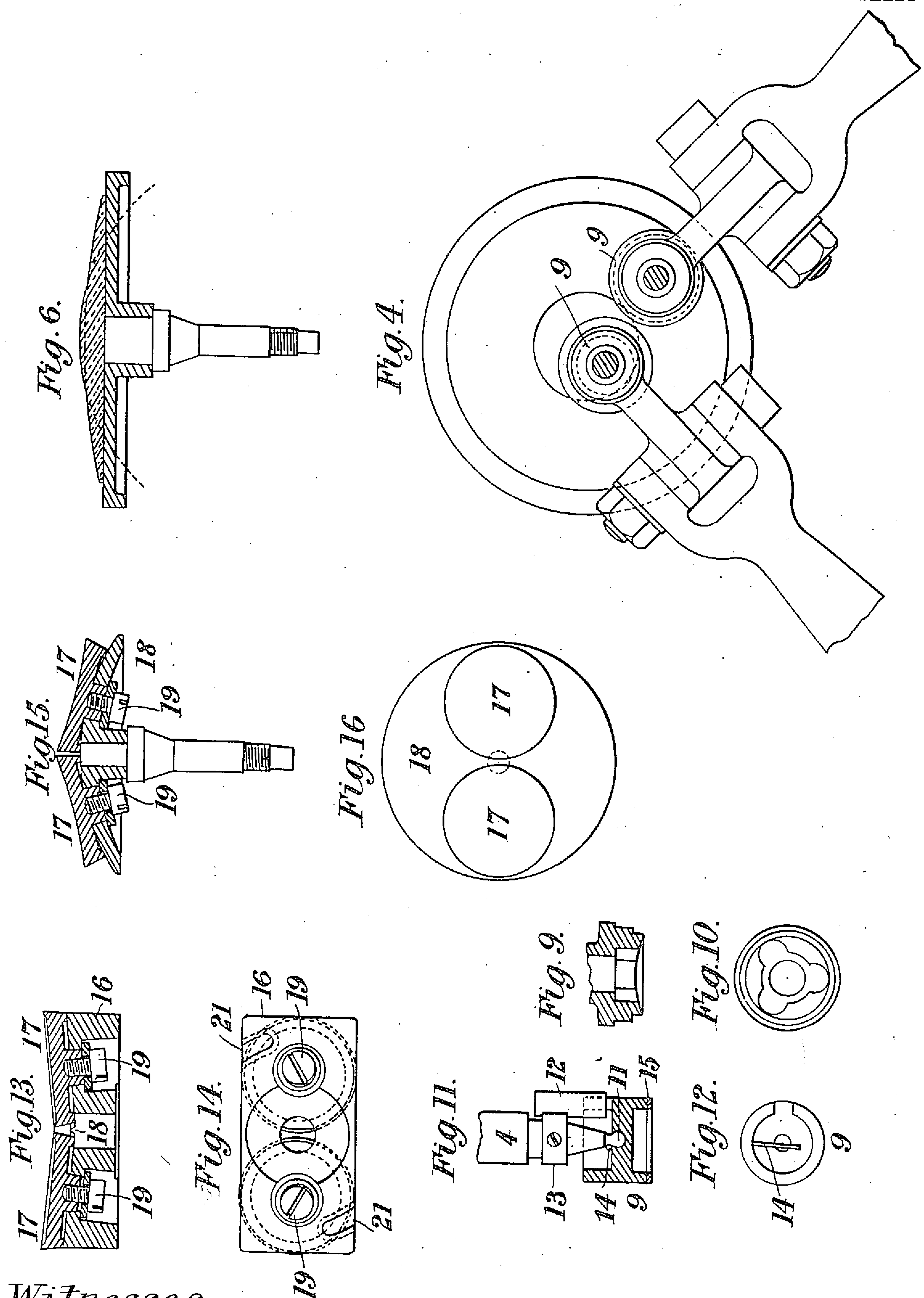

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UNITED STATES PATENT OFFICE.

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PROCESS FOR GRINDING BIFOCAL LENSES AND OTHER SPHERICAL SURFACES.

946,571. Specification of Letters Patent. **Patented Jan. 18, 1910.**

Application filed December 18, 1905. Serial No. 292,393.

To all whom it may concern:

Be it known that we, MALCOLM BENTZON, residing at 188 Strand, and ALFRED HENRY EMERSON, residing at 26 Eyre Street Hill, Clerkenwell, both of London, England, subjects of the King of Great Britain, have invented new and useful Improvements in Processes for Grinding Bifocal Lenses and other Spherical Surfaces, of which the following is a specification, reference being had to the accompanying drawings, in which—

Figure 1 shows in elevation and section the ordinary form of bi-focal lens. Fig. 2 is a section illustrating the new form of bi-focal lens according to this invention. Fig. 3 is a sectional side elevation of a machine constructed according to this invention for grinding bi-focal lenses. Fig. 4 is a plan illustrating the simultaneous operation of two of the said machines. Fig. 5 is a plan illustrating a modified arrangement of the operating tools. Figs. 6 and 7 are respectively a sectional elevation and a plan illustrating a form of glass disk from which the lenses may be produced. Fig. 8 is a vertical section illustrating a machine provided with two tool spindles for the simultaneous grinding of two surfaces. Figs. 9 and 10 are respectively a vertical section and an underside view of one form of grinding tool to be used in carrying out the invention. Figs. 11 and 12 are respectively a sectional elevation and a plan of the lower part of another form of grinding tool. Figs. 13 and 14 are respectively a sectional elevation and an underside view of a holder for two lenses, while being ground. Figs. 15 and 16 are respectively a sectional elevation and a plan illustrating a modified form of lens holder.

The present invention refers to a process for grinding spherical surfaces, specially intended for the production of bi-focal lenses, which allows, in this latter case, of the working of the two parts of the lens in such a way that any desired centering of these portions may be attained with the utmost exactitude.

The process makes use of hollow grinding tools, with annular faces, turned by a tool-spindle, and executing a movement of rotation relatively to the work simultaneously with the tool-spindle.

In contrast to an already known process of grinding, in which a hollow tool cutting only on its outer edge is made use of, but in which the tool is fixed at a certain angle to the axis of the work, which axis remains constant throughout the grinding process, and the work, as the grinding process goes on, is gradually advanced to meet the tool, there is given to the tool in the process, which forms the subject of the present application, complete freedom of movement, so that the latter is able to execute an oscillatory movement on its driving spindle, and can thus apply itself to the work constantly, whatever curvature the latter may happen to have. The tools, which have a suitable diameter, are set on the work between the center and the limiting line of the surface to be worked, or, in grinding the zones of lenses, between the outer and inner edges of the surface to be worked, and, in consequence of their movable connection with their driving spindle, constantly apply themselves during the grinding process to the curvature which is being worked. While in the known process the curvature developed is determined by the angular relation of the axis of the tool spindle to the axis of rotation of the work, in the present process the desired curvature is produced entirely by the regulation of the velocity of grinding and of the relative directions of the tool and the work, and the regulation of these two is effected by corresponding variations of the velocity and the direction of rotation of the tool spindle around its axis as well as relatively to the work. When the exact curvature has been attained, the tool for rough grinding is replaced by similar smooth grinding and polishing tools, which complete the process by smoothing and polishing the spherical surface. During the smoothing and polishing the speed of grinding must be so regulated that no further change of the curvature of the work shall occur, and the proportion of velocity required for this purpose is determined by empirical methods.

The new process furnishes perfectly regular spherical surfaces, and is adapted for use in fine optical work. The new process is of special value for the production of bi-focal lenses, since it affords the means of production of optically correct lenses, and that with any desired centering of the two portions of the lens.

The production of bi-focal lenses upon the lines of the present process may be effected either by grinding both curves simultaneously by the use of two or more tools in a single operation, or a second curve may be ground on lenses already having one curve. When two curves are ground simultaneously, the tools are so arranged with reference to the work, (which may consist of one or of several lenses) that the circumference of each tool touches the border line of the work, at which one of the two curves commences and the other of the two ceases, the one tool is placed between a known line of separation and the middle point on which the rotation of the work relatively to the tools takes place, and the other tool between the line of separation of the two curves and the periphery of the work-holder. Instead of a single tool two or more tools may under some circumstances be used for the production of each curve, and especially for the production of the outer curvature it will often be convenient to use several tools. In this mode of manufacture of the two curves the middle points or centers of the latter necessarily lie upon the axis on which the rotation of the work with reference to the tool takes place. The lines of separation for the two curves must therefore lie in parallel planes (vertical to this latter axis) and can be brought to coincide exactly in a single plane. From this results the possibility of producing glasses with two convex curvatures without ridge, in which the curvatures meet exactly in one and the same plane, so that the line of separation is practically invisible and does not disturb vision, and as is shown hereafter, the production of optically correct lenses with any desired centering of the two portions of the lens. A ridge which arises from the fact that the part for distant vision is more ground away than that for near vision or conversely, can be removed by simply grinding away the portion which is too high. After the flat glass, by the method described above, has been provided with the two curvatures, it is cut into two or more pieces, which may be of the same or of different sizes, so that evidently the whole or any desired part of the internal curvature may be included in a portion so cut off; the under surfaces of the cut portions are then ground and polished in the usual way.

The two portions of each lens may be centered in any desired way, with absolute exactitude. The desired centering (*i. e.* the position of the centers of the two portions of the lens) is obtained by fixing correspondingly the diameter of the line of separation of the two curves when grinding the two curves on the upper surface of the lens, and this diameter must be greater the greater the power of the lens and the distance between the optical centers of the two portions of the lens. The diameter required for any given combination can be obtained by a simple trigonometrical calculation, observing always that the middle points for the two front curves must lie, on the one hand on the axis on which in grinding these curves the lens lies relatively to the tools, and on the other side with the optical center of the particular portion of the lens and the middle point of the under curvature of the lens, in one line.

The new form of lens which can be produced by the above process of grinding, with two convex curves produced at a single operation, having no ridge, and absolutely correctly centered in both portions, is shown in Fig. 2 in the drawing.

Fig. 1 in the drawing shows the ordinary form of lens with a ridge, which results from the grinding of a second curve on a lens already having a single one (*i. e.* a finished spectacle lens). In this case too, any desired centering of the two portions of the lens can be obtained with absolute exactitude. This is done by inclining the lens holder at a certain angle to the axis of relative rotation of the lens with reference to the tool when the second curve is being ground. The degree of the angle of inclination required for any combination can be found by a simple calculation, observing always that the middle point of the second curvature must lie in one straight line on the one hand with the axis of rotation between the lens and the tool relatively, and on the other hand with the optical center of the second portion of the lens and the middle point of the rear curvature of the latter.

A method of constructing a machine for grinding bi-focal lenses in accordance with the grinding process just described is shown in Fig. 3 in side elevation, and partly in section. The frame 1 carries a bed 2, capable of adjustment in a vertical direction, and of fixation, and in this rotates the spindle 3 on which is fixed a disk $3^{\times}$, for carrying the lens holder. The tool spindle 4 is carried in a carrier head 5 on an arm 6, and this has a weight $6^{\times}$, by which the pressure on the work can be regulated. The arm 6 is pivoted at the end to a lever 7. The lever 7 is in one piece with the block $7^{\times}$, and the whole rests upon a spring 23, and can be adjusted by a screw 8, so that the other end of the arm 6 with the carrier head 5 can be moved in any required direction, so as to allow the tool 9 carried by the spindle 4 to be placed in any desired position over the glass or glasses 10. The arm 6 is held up by a support $8^{\times}$ when it is turned back. The tool 9 is so attached to the spindle as to be on the one hand easily secured to or removed from it, and on the other hand to take up automatically the proper position upon the glass, and to retain it while the latter is being ground. In the example shown, this is attained by a joint consisting of a ball-point 11 on the end of the spindle 4, which enters a corresponding hollow in the axis of the tool. A tongue 12 lies in slots in the collar 13 on the spindle 4, and at the upper part of the tool 9, and thus transmits the motion of the spindle to the tool. The spindles 3 and 4 are provided with pulleys, which allow of the alteration of the proportional velocities, so that by controlling the relative velocities of grinding between the work and the tool, any desired curvature can be obtained.

In Fig. 3 the tool is so set that the middle line of the acting surface passes through, on the periphery of the tool, the axis of rotation of the spindle 3, and so through the geometrical center of the surface which is being worked. If now it be desired to increase the curvature of a convex surface, or to diminish that of a concave one, the lower spindle must rotate rapidly, while the tool revolves slowly, and, most suitably, in the opposite direction. If for instance the work be set rotating at 400 revolutions per minute in one direction, and the tool executes 100 in the contrary direction, there will evidently be more friction at the periphery of the surface of the work than at its center. The edge will consequently be ground down faster than the center, and a convex surface will become more convex, while a concave one will become less concave, and indeed convex if the grinding be continued long enough. If, on the other hand, the curvature of a concave surface is to be increased, the direction of rotation of either the work or the tool is changed, so that both revolve in the same direction. If now, for instance, the tool have 400 revolutions and the work 100 per minute, it is clear that the resultant velocity of grinding at the edge of the surface operated upon will come out very small, while in the center the tool will move rapidly over the surface, and will in consequence grind the glass away quickly at this point. The exact curvature can be determined by spherometers. As soon as the desired curve is attained, the tool for rough grinding is substituted by the tools for smoothing and polishing, and the glass is smoothed and polished without further alteration of the curve. The proportion of velocity which must be arranged so that no change in the curve shall occur, will soon be found by trial.

In Fig. 3 the grinding machine is shown in action as arranged for grinding a second curve on a lens already possessing one curve *i. e.*, on a finished spectacle lens, and there are attached to the lower spindle, by an arrangement to be described later, two lenses 10, for exact centering of the two sections of the lens, these meeting in the axis of rotation of the work spindle, so that both lenses can be ground and provided with a second curvature at the same time.

If two curves are to be ground at one operation, two machines of the kind shown in Fig. 3 can be used, their tools 9 being applied to the surface under treatment in the manner shown in Fig. 4. The tool of the one machine is so set that its periphery passes through the axis of rotation of the revolving work, and touches the line of separation between the two curves, while the other tool is set between the line of separation and the periphery of the surface of the work. Instead of two machines there may be used a single one having on the frame 1 two arms with two tool spindles 4.

Instead of allowing the work carrier to rotate, it may be fixed, and the tool alone allowed to rotate, in which case the tool or tools rotate upon their spindles, and at the same time execute a motion in a circle around the center of the surface being worked, as shown in outline in Fig. 5.

The two curves may be worked upon a single flat disk, which is cut into several pieces, from which, by grinding the under surfaces, the complete lenses are produced. Such a glass disk, with the two curves on the upper surface is shown with its holder in Fig. 6. Instead of this however, as shown in Fig. 7, the two glasses or lenses might be cut first so as to meet along a straight line, the spaces between them being filled up by fish-tail pieces 25×, so that a coherent surface for grinding is obtained. In some cases it is advisable to use an ordinary tool before rough grinding, this tool being rigidly connected to a vertical upper spindle, in order to remove the projecting surfaces of the lenses along their line of contact.

A machine with two tool spindles for the simultaneous grinding of two surfaces, in which the work carrier is stationary and only the tools revolve, is shown in Fig. 8. The inner tool is carried by a spindle 25 in bearings on an arm 26 which is attached to the sleeve 27. The spindle is driven by means of the toothed wheels 28, 29, of which the latter is fixed to the axle 30, and is driven by a belt passing around the pulley 31. The sleeve 27 is provided with driving pulleys 32. The outer tool is carried by the spindle 33, which has its bearing 34 on an arm 35. The arm 35 is removably attached to the sleeve 36, which is borne by the head 5 of the machine, and is provided with driving pulleys 37. A sleeve 38 with a pulley 39 carries a toothed wheel 40, which engages with a toothed wheel 41 on the spindle 33. In this way each tool has imparted to it a rotation upon its own axis and a planetary motion. The arm 35 which carries the bearing 34 for the outer tool may, according to the size of the glass, be replaced by longer or shorter arms.

In the drawing only one tool is shown at work upon the outer surface. Two or more tools may, however, be made use of, while a single tool may be appropriately used for the inner surface. (See Fig. 5.)

In producing bi-focal lenses by grinding a second curve on a lens already having a single curve (a finished spectacle lens) any desired position of the optical center of the lens may be attained by the following arrangement. The lens holders are secured to a block 16 of metal or other suitable material, Figs. 3, 13, 15, which is carried by a chuck or work spindle. This block is best made of such a size that it will carry two lens holders 17, and is so shaped from the center toward the two ends that an angle is formed at the middle line 18, this angle corresponding to the curve of the lenses to be ground, the curves to be ground, *i. e.*, superadded and the desired position of the optical center. By a calculation familiar to experts the correct angles for lenses of all curvatures can be readily determined.

According to Fig. 3, which shows an apparatus for grinding two convex lenses, the legs of the angle run outward and downward, while Figs. 13 and 14 show a block for grinding concave lenses, in which the legs run outward and upward. Fig. 13 is a vertical section, and Fig. 14 a view from beneath.

The block 16 has an aperture in each of the two inclined faces, in which the stem of a lens holder 17 is secured by means of screws 19. The position of the holes naturally depends upon the magnitude of the angle under which the surfaces which carry the lens holders are inclined to each other. The block 16 is secured to the chuck 3^{x} at the top of spindle 3 by screw bolts, which are screwed down by nuts 20, so that the heads of the screw bolts rest against the undercut part of the slots 21, which, when the nuts 20 are slackened, allow the block 16 to be removed. Before the lenses (after being cemented to the lens holders) are secured to the block 16, they must be exactly centered upon the lens holders. A portion of each lens is cut away, so that both lenses can be brought under a single grinding or polishing tool and operated upon by it, as is shown in Fig. 3. The block 16 may have three or more surfaces instead of two, these being inclined to the axis of rotation of the work under the same angle, and having each an aperture for the reception of a lens holder. In this case three or more lenses can be worked simultaneously, and these again are to be so cut, that the portions of the lenses upon which the tool is to operate abut upon each other.

If the block 16 be employed for grinding a lens in which the part of it intended for reading exceeds a radius and the glass consequently projects over the lens holder, only one lens holder can be fixed to the block 16. Instead of the block 16 having flat bearing surfaces, it may consist of a curved headpiece, as shown in Fig. 15 in vertical section, and in plan in outline in Fig. 16. The lower sides of the lens holder 17 are then so cut out as to fit the curve of the block 16, and the calculations are made for tangents to the curved surfaces at the central point of the lens holder.

In bi-focal lenses with a prominent dividing line, or a ridge between the two portions (Fig. 1) such as are obtained by consecutive grinding of the two curves, the ridge forms a third reflecting surface, which is very irritating and injurious to the eye of the wearer, and since the edge of the ridge is sharp, the lens is very easily injured, if it comes into contact with a hard surface. This fault can be overcome by darkening or graying the ridge or leaving it unpolished, so that it offers no reflecting surface, and by chamfering the sharp edge off the ridge, so that the lens cannot be injured if it comes into contact with a hard surface. This may be effected in any convenient way, as for instance by holding a copper strip against the ridge while the block 16 carrying the lens holder rotates.

In cases in which the lenses have to be decentered, the lens holder can be tilted by laying packing disks under it to the desired amount.

Various forms of constructing the tools are shown in Figs. 9, 10, 11 and 12. Figs. 9 and 10 show in vertical section and from below the under part of a hollow tool in which the hollow instead of being merely annular is specially shaped so that the part of the grinding surface which grinds most heavily is the strongest, it being at the same time supposed that the tool is to be used for grinding convex lenses, in which case the glass is ground more strongly toward the edge than in the center. The grinding surface may be either flat or curved. Figs. 11 and 12 show in vertical section and in plan another form of hollow tool. Fig. 11 specially shows the method of attaching the tool to the spindle. In the inside of the tool is a spring 14, so arranged that it holds the ball-point 11 at the end of the spindle in the recess of the tool, so that the tool can be removed from or attached to the spindle by pushing on one side the spring of the ball 11. The tool is one for polishing, and carries polishing material 15 on the working edge.

Instead of attaching the tools to the spindle in the way described, they may be secured by other methods, as for example by a square portion at the end of the spindle entering a square hole inside the tool, as shown at 42 in Fig. 8.

The annular form of tool shown in Figs. 11 and 12 is the most suitable for polishing, but can also be used for roughing and smoothing. The tool shown in Figs. 9 and 10 is more suitable for the two latter processes than for the former.

The polishing felt or corresponding material 15 must be made sufficiently hard, so that the surfaces produced upon the lenses may be perfectly polished spherical ones. For this purpose the felt or other material may be boiled in pitch. Rouge or any other suitable material may be used for polishing. The tools for smoothing may suitably be made of a rather softer metal such as brass, than those for the roughing, which may for example be made of steel.

The apparatus herein shown and described for carrying our process into effect is covered by our application for Letters Patent of the United States, Serial No. 528,800, filed Nov. 18, 1909, which is a division of this application.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. The herein described process of grinding spherical surfaces which consists in abrading in an annular path upon the surface to be ground, and simultaneously establishing a relative rotation between the work, and the annular path.

2. The herein described process of grinding spherical surfaces which consists in abrading the surface in an annular path, establishing simultaneously a relative rotation between the work and the annular path of abrasion, the annular path of abrasion being located between the center of said relative rotation and the peripheral portions of the work.

3. The herein described process of grinding spherical surfaces which consists in abrading the surface in an annular path, establishing simultaneously a relative rotation between the work and said annular path, and regulating the speed and direction of relative rotation and annular abrasion, to produce surfaces of desired character.

4. The herein described process of grinding spherical surfaces, which consists in abrading the surface in an annular path, simultaneously establishing a relative rotation of the work with respect to annularly moving the abrading surface, and supporting the surface in a position inclined to the axis of said relative rotation.

5. The herein described process of grinding spherical surfaces to simultaneously produce two abutting spherical surfaces which consists in abrading the surface to be treated in two annular paths on opposite sides of the line of demarcation between said spherical surfaces to be produced, and establishing a relative rotation between the abrading surfaces, and the work, having the center of rotation at one side of one of said annular paths of abrasion and the peripheral portions of the work on the other side of the other of said annular paths of abrasion.

6. The herein described process of grinding surfaces to produce simultaneously two abutting spherical surfaces, which consists in abrading the surface to be treated in two annular paths on opposite sides of the line of demarcation between said abutting surfaces, rotating the surface treated with respect to the annularly moving abrading surfaces, about a center located at one side of one of the said annular paths of abrasion.

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