E. W. LAISNE.

ART OF FORMING CURVED SURFACES.

APPLICATION FILED NOV. 9, 1915.

1,286,032.

Patented Nov. 26, 1918.

5 SHEETS—SHEET 1.

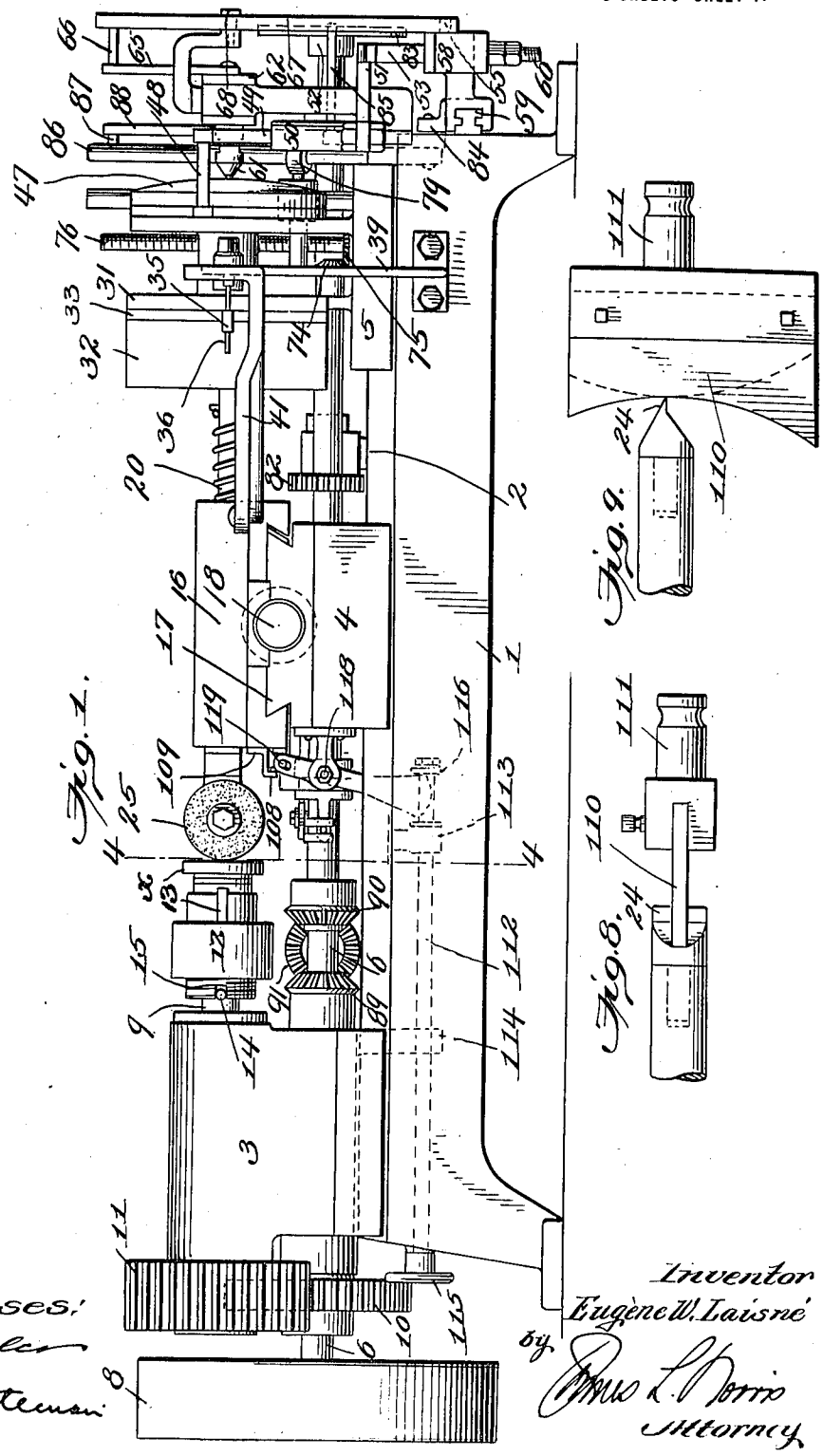


Fig. 1.

Fig. 9.

Fig. 8.

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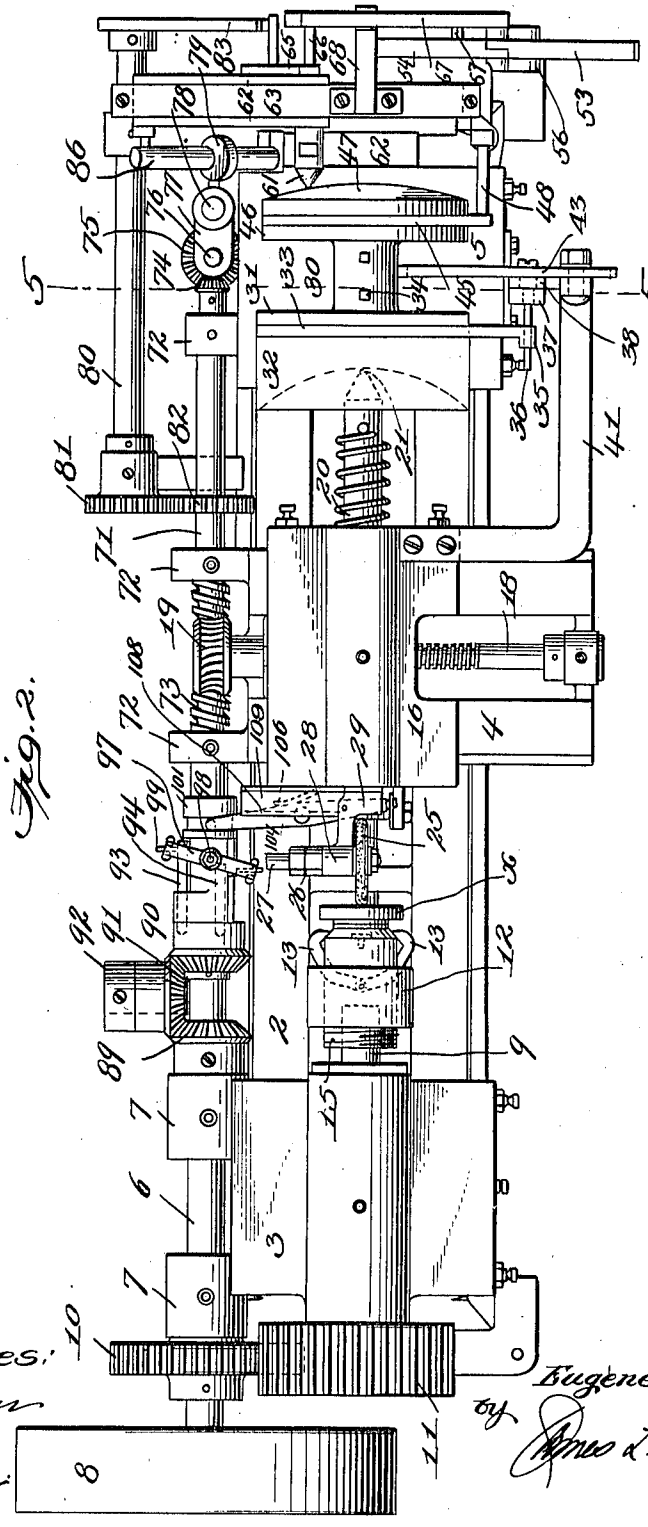


Fig. 2.

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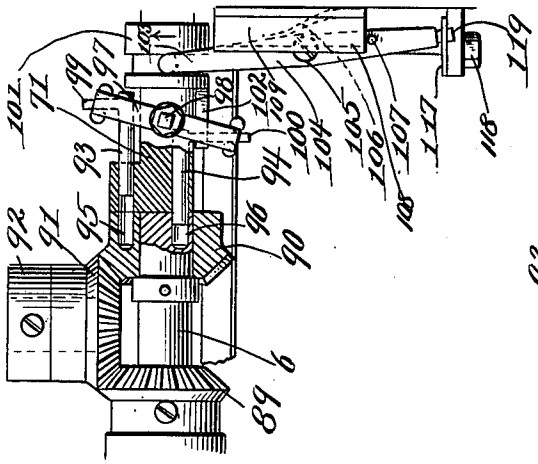


Fig. 6.

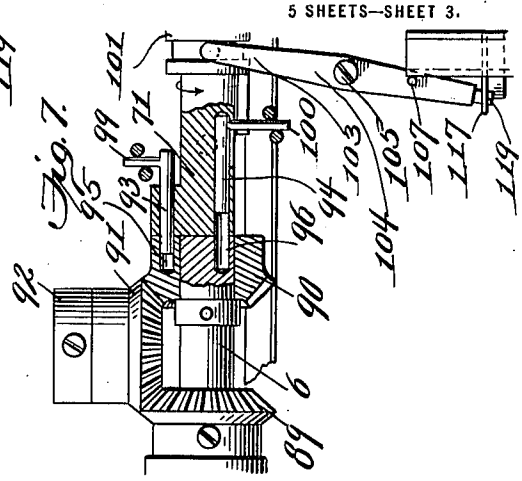


Fig. 7.

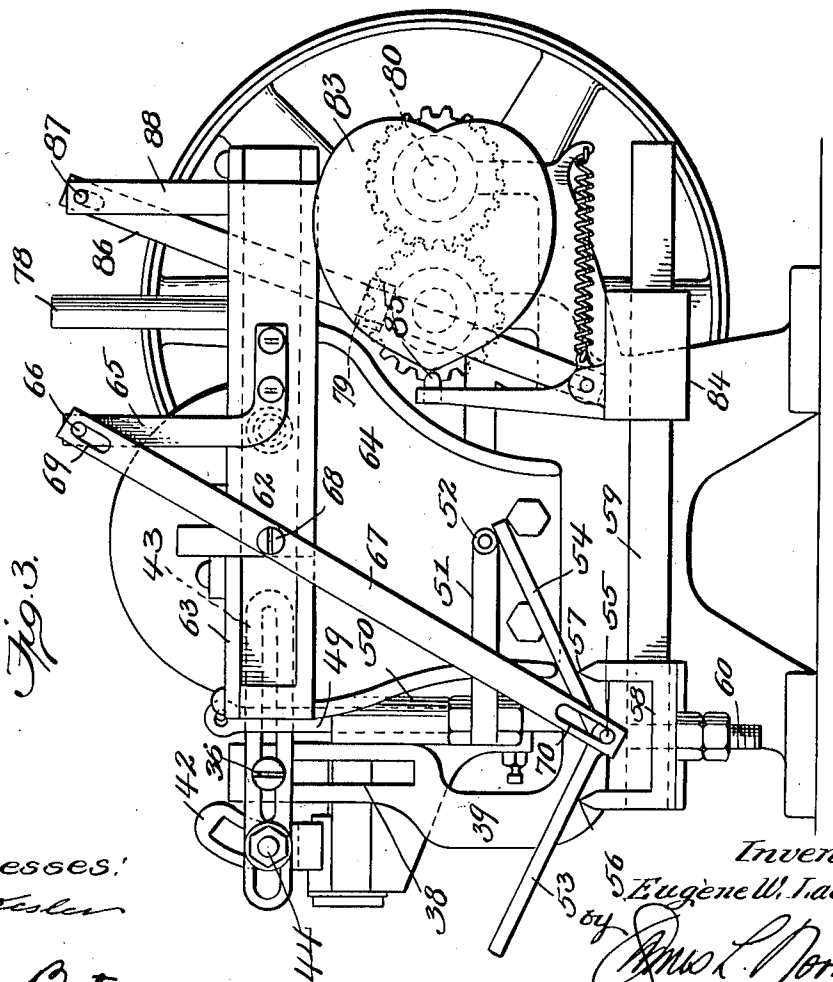


Fig. 3.

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5 SHEETS—SHEET 4.

Fig. 5.

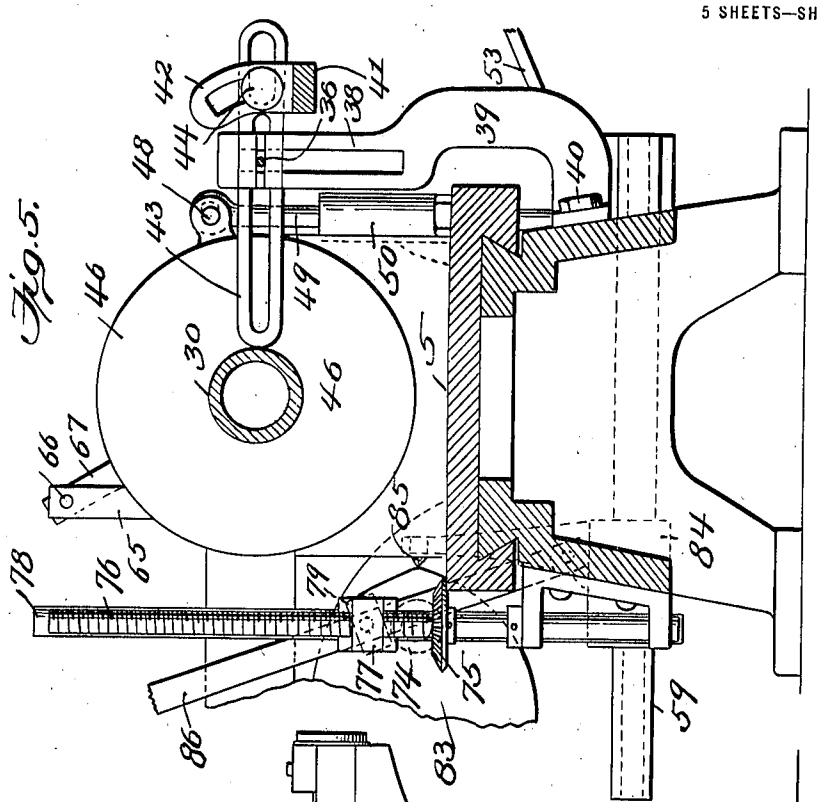
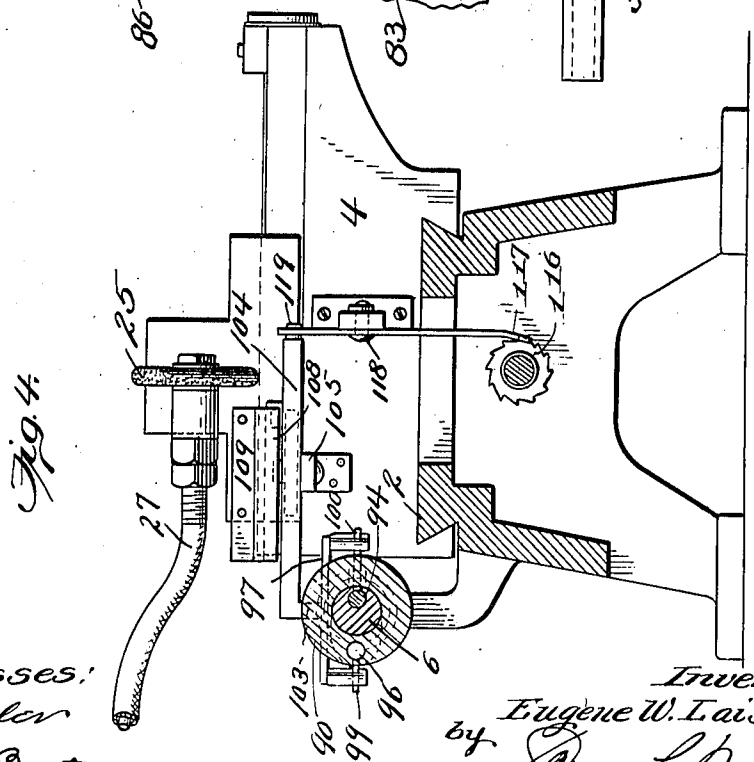


Fig. 4.



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5 SHEETS—SHEET 5.

Fig. 10.

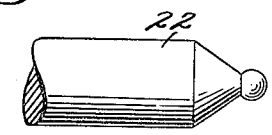


Fig. 11.

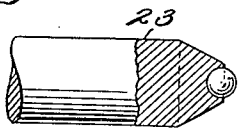


Fig. 12.

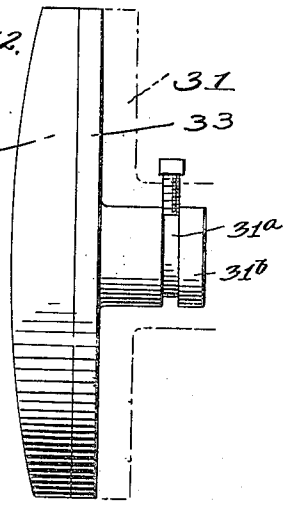


Fig. 15.

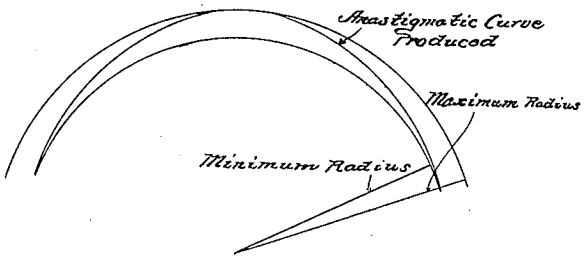


Fig. 13.

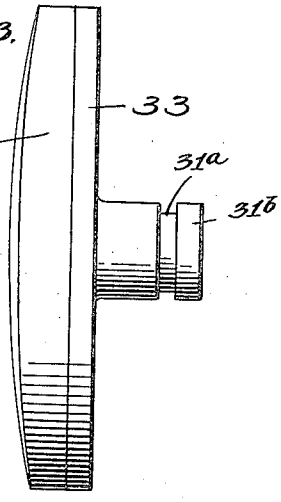
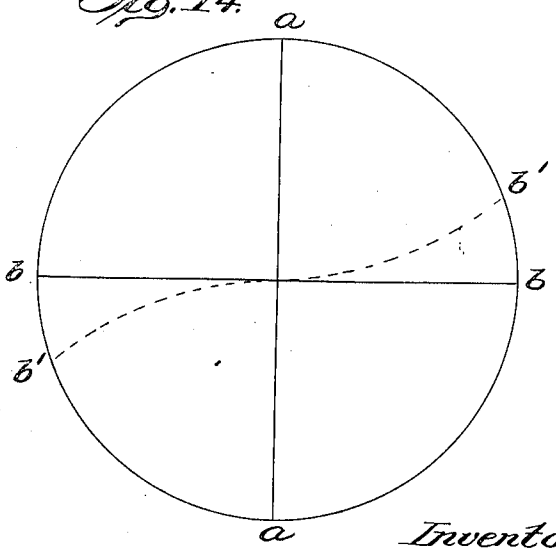


Fig. 14.



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UNITED STATES PATENT OFFICE.

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ART OF FORMING CURVED SURFACES.

1,286,032. Specification of Letters Patent. Patented Nov. 26, 1918.

Application filed November 9, 1915. Serial No. 60,571.

To all whom it may concern:

Be it known that I, EUGÉNE W. LAISNÉ, a citizen of the United States, residing at Fresno, in the county of Fresno and State of California, have invented new and useful Improvements in the Art of Forming Curved Surfaces, of which the following is a specification.

My present invention relates to improvements in the art of grinding lenses or forming curved surfaces.

According to the present invention, the practice of grinding curved surfaces, such as those possessed by lenses, by the use of grinding stones having surfaces conforming in curvatures to those of the surfaces to be ground, and the attendant expense, expenditure of time, and inaccuracies in the ground surfaces due to wear and change in curvature of the grinding stone, are dispensed with and, instead, the curves, whether simple or compound, or of a constant or varying degree of curvature are developed or generated by positioning the working or cutting tool relatively to the work, according to the configuration the surface is to have at each point in its area, the positioning of the working or cutting tool being effected by the aid of one or more appropriately selected and positioned pattern surfaces.

The accompanying drawings show one form of apparatus adapted to be used in carrying the invention into practice.

In the drawings:—

Figure 1 is a side elevation of the machine.

Fig. 2 is a top plan view thereof.

Fig. 3 represents an end elevation of the right-hand end of the machine as shown in Figs. 1 and 2.

Fig. 4 represents a transverse section on the line 4—4 of Fig. 1 looking toward the right.

Fig. 5 represents a transverse section on the line 5—5 of Fig. 2, looking toward the right.

Figs. 6 and 7 are detail views, partly in section, showing the reversing mechanism for the machine.

Figs. 8 and 9 show, in elevation and top plan, respectively, a tool and pattern for approximately forming the surfaces upon the work.

Figs. 10 and 11 are detail views showing, respectively, a spherical and a ball point adapted to be used upon the pattern surfaces.

Fig. 12 shows a plane cylinder surface adapted to be used as a pattern.

Figs. 13 and 14 are diagrammatic views of a surface having a compound curve or curvatures of different degrees on its primary and secondary axes, respectively.

Fig. 15 is a diagrammatic view showing the variation in the degree of curvature of a surface, having varying radii in a direction from its center toward its periphery, such, for example, as that suitable for use on any anastigmatic lens.

Similar parts are designated by the same reference characters in the several views.

The present invention is applicable generally to the development or generation of curved surfaces, such as those employed on lenses for eyeglasses or other purposes, and for forming curved surfaces upon other objects where such surfaces are desired or necessary. One form of apparatus is shown in the accompanying drawings which may be used advantageously in carrying the invention into practice, but it is to be understood that the invention is not restricted to the particular apparatus shown, as any equivalent apparatus may be used, if desired, within the scope of the claims.

The apparatus shown is particularly adapted to the grinding of lenses, the present embodiment being capable of grinding either concave or convex surfaces in the form of a simple sphere, a plane cylinder, a sphere having varying radii in a direction from its center toward its periphery, a cylinder having varying radii, a sphere having different radii on different meridians thereof, and a sphere the radius of which varies in a direction from its center toward its periphery and having different radii on different meridians thereof, the present invention facilitating the production of such surfaces having any desired degree of curvature. The apparatus shown in the drawings will be described as applied to the grinding of these different types of lenses.

As shown, the apparatus embodies a bed 1 which, preferably, is in the general form of a lathe bed, it having a gib 2 at the top on which the different relatively movable elements of the machine are supported and guided. A head stock 3 is slidably mounted on the gib at one end of the machine, a slide rest 4 is movably mounted on the gib at an

intermediate point in the length of the bed, and a tail stock 5 is movably mounted and guided on the gib toward the opposite end of the machine. A main driving shaft 6 is mounted in bearings 7 forming part of the base or bed, this main shaft being driven by a belt pulley or equivalent power transmitting means 8, and a spindle 9 is journaled in the head stock 3, the spindle and the main driving shaft 6 being caused to revolve at equal speeds by the equal diameter gears 10 and 11 fixed to the main driving shaft 6 and the spindle, respectively. The spindle is adapted to receive a work-holding chuck 12, that shown having jaws 13 adapted to grip the work x, such, for example, as a piece of glass to form the lens, or a body of metal, if metal is to be worked, and means is provided for maintaining a predetermined relation between the meridians of the work x and the spindle. As shown, the spindle is provided with a pin 14 which is arranged diametrically therein, and the chuck is formed with recesses 15 to receive the pin 14, the pin 14 representing, for example, the primary meridian of the work, and a diameter perpendicular to the pin 14 will represent the secondary meridian. While the chuck is definitely positioned as stated with relation to the meridians of the spindle, the chuck itself is preferably of a type which is capable of being easily manipulated to firmly grip or to release the work as may be necessary.

The slide rest 4 extends transversely of the bed and has a slide 16 mounted thereon, the slide being preferably guided on and secured to the slide rest by a gib 17, as shown. The feed of the slide 16 in a direction transversely of the machine is effected preferably by a feed screw 18 which is appropriately journaled in the slide rest 4 and has a thread connection with the slide 16, the rear end of the feed screw having a worm wheel 19 fixed thereon by means of which the feed screw is rotated. The transversely movable slide 16 carries a motion transfer bar or member 20 which is slidable in the slide 16 in a direction longitudinally of the machine or in a direction transversely of the direction of movement of the slide 16. This transfer bar is provided at one end with a tracer which may be in the form of a point 21 (Fig. 2) or in the form of a spherical head 22, as shown in Fig. 10, or it may be a ball point 23, as shown in Fig. 11, where the work is to be polished or the material is removed from the work at a relatively slow rate, or, where a roughing cut is to be made to remove a considerable amount of material from the work to approximately form the curve, a relatively broad point 24 is preferably used, as shown in Figs. 8 and 9. The opposite end of the transfer bar or member 20 carries a suitable tool to operate upon the work. Ordinarily, a grinding tool is used, such a tool being shown in Figs. 1, 2 and 4, it comprising a grinding wheel 25 of suitable material, such, for example, as corundum or carborundum having a convexed working periphery, the wheel being fixed to a spindle 26 connected to a flexible shaft 27 whereby the grinding wheel may be revolved at a suitable speed from an appropriate source of power. The spindle 26 carrying the grinding wheel is journaled in a bearing 28, which bearing is fixed by a bracket 29 to the respective end of the transfer bar or member 20.

The tail stock 5 carries a mounting 30 adapted to position and support curve patterns, one pattern serving to generate spherical surfaces, and the other pattern to generate cylindrical surfaces, the two patterns working conjointly to generate a compound surface, that is, one having different curvatures on different meridians. As shown, the mounting 30 has a head 31 arranged to removably or interchangeably receive any one of a number of curve-determining patterns 32, that shown in Fig. 2 being a concave cylinder or a concave curved surface having varying radii on different meridians thereof. In developing and grinding the surfaces of lenses, having varying radii from their centers toward their peripheries, the curve pattern applied to the member 31 has a curve the radius of which varies on different meridians thereof and it receives a rotary motion which, as will hereinafter appear, brings meridians of different curvatures of the pattern into operative position and thereby varies the degree of curvature of the lens surface in a direction from the center and toward its periphery. For this purpose, a rotary pattern holder 33 is provided on the member 31 of the mounting, and the pattern 32 is fixed to this rotary holder. A set-screw 34 or equivalent device is adapted to engage in a circumferential groove 31^a in an axial extension 31^b of the pattern holder 33 to retain the pattern in proper axial position on the mounting 30, although permitting rotation of the pattern holder relatively to such mounting. Rotation of the pattern holder 33 when such motion is used occurs in predetermined relation to the transverse feed of the slide 16, the slide 16 moving the working tool from the center and toward the periphery of the lens under process of making, and during this motion of the slide 16, the pattern holder 33 is rotated to vary the degree of curvature of the lens surface. In the construction shown, the rotatable pattern holder 33 is provided with an operating arm 35 which is fixed to the periphery of the pattern holder and coöperates with an operating pin 36. This operating pin is connected to a cross-head member 37 which is slidable vertically in a guide 38, the latter being formed as part of a bracket 39, which

latter is fixed, at 40, to the base or bed of the machine. A rigid arm 41 is fixed to the slide 16 and is movable therewith in a direction transversely of the machine. This arm 41 is formed with a slotted sector 42 to which a slotted link 43 is attached by a clamp screw 44. The slotted link 43 is shown in Figs. 3 and 5 as parallel with the plane of motion of the slide 16, and, in consequence, no rotation of the pattern holder 33 will occur. However, by clamping the slotted link 43 at different points on the sector 42, it will be positioned at varying angles to the plane of motion of the slide 16 and, in consequence, reciprocation of the slide 16 will cause the angularly positioned link 43 to operate upon the pin 36, causing rotation of the pattern holder 33 in synchronism with the feed motion of the slide 16 and to a degree proportional to the extent of feed motion of the slide 16.

The mounting 30 on the tail stock also supports a rotatable pattern holder 45 which is mounted against the head 46 of the mounting, and this holder 45 is adapted to receive any one of a number of spherical patterns 47. Rotation of the pattern holder 45 is effected where anastigmatic cylindrical surfaces or surfaces the radii of which vary on different meridians are to be produced, and, in such cases, owing to the curvature of such a surface varying on different meridians of the lens, it is necessary that this rotation of the pattern holder 45 should occur in synchronism with the rotation of the object or work x. The means shown for oscillating the pattern holder 45 comprises an arm 48 which is fixed to the rotatable pattern holder and is connected to a vertically movable plunger 49 which is guided in a suitable bearing 50 on the main frame of the machine, the lower end of the plunger having an arm 51 fixed thereon and carrying a roller or projection 52 adapted to ride upon a pair of oppositely inclined tracks 53 and 54. These tracks are connected at their adjacent ends by a pivot 55, and they rest at opposite sides of the pivot upon knife edges or fulcrums 56 and 57 formed on a slide 58, this slide being reciprocable along a horizontal guide 59. The vertical position of the pivot 55 determines the degree of inclination of the tracks 53 and 54 and consequently the extent of the vertical strokes of the plunger 49. In order to vary the extent of reciprocation of the plunger 49, the pivot 55 is connected to an adjustable screw 60 secured to the slide 58.

The pattern 47 is used to determine the curvature of a cylinder lens, or to determine the curvature on the secondary meridian of a lens whose curvature varies on different meridians thereof. This requires mechanism coöperative with the pattern 47 which will operate in synchronism or predetermined timed relation with the rotation of the object or work x in order that the curvature of the pattern 47 will determine the curvature of the object or work on one meridian but will have no effect upon the curvature of the surface on the other meridian at a right angle thereto. As shown, the mechanism which cooperates with the pattern 47 comprises a tracer 61 embodying, preferably, a ball center pin, such as that shown in Fig. 11, to roll upon the surface of the pattern 47, and this tracer is carried by a cross-head or slide 62 which is guided to reciprocate horizontally on a guide 63, the latter being rigidly supported by the bracket 64 on the base of the machine. As the plunger 49, as previously stated, reciprocates in predetermined timed relation to the rotation of the object or work, and as the tracer 61 also operates relatively to the pattern 47 in predetermined timed relation to the rotation of the object or work, it is convenient to operate the plunger 49 from the reciprocating cross-head or slide 62. As shown in the present instance, an arm 65 is fixed to the cross-head or slide 62, its upper end carrying a pin or projection 66, and a lever 67 is fulcrumed on a pin 68 fixed to the bed or stationary base of the machine, the upper end of this lever being slotted, at 69, to receive the pin 66, and the lower end of this lever is slotted, at 70, to receive the pivot pin 55 connecting the inclined tracks 53 and 54. Reciprocation of the slide or cross-head 62 will cause oscillation or rocking of the lever 67 about its pivot or fulcrum 68, the to-and-fro swing of the lower end of this lever causing reciprocation of the slide 58 during which the roller or projection 52 will ride alternately upon the tracks 53 and 54. Owing to the reverse inclination of these tracks, the plunger 49 will, in consequence, be reciprocated. It is to be observed, however, that the plunger 49 will reciprocate twice for each complete reciprocation of the cross-head or slide 62, for a purpose to be hereinafter explained.

Suitable mechanism is provided for reversibly operating the feed screw 18 for the feed slide 16, and for reciprocating the cross-head or slide 62 and operating its connected mechanisms. The mechanism shown comprises a secondary shaft 71 mounted in suitable bearings 72 on the base or bed of the machine, this shaft having a worm 73 coöperative with the worm wheel 19 on the feed screw 18. The secondary shaft 71 also carries a bevel pinion 74 which coöperates with a bevel gear 75, the bevel gear 75 being double the diameter of its driving pinion 74, for a purpose that will hereinafter appear. The bevel gear 75 is fixed to a vertical feed screw 76, this feed screw being threaded in a slide 77 which moves vertically on a guide 78 and carries a swiveled fulcrum or pivot member 79. A

countershaft 80 is also provided, it being connected to the secondary shaft 71 by the gears 81 and 82 of equal diameters to secure equal speed of the countershaft 80 and the secondary shaft 71, and the countershaft 80 has a cam 83 fixed thereon which has substantially the outline shown in Fig. 3. A cross-head or slide 84 is mounted to reciprocate on the guide 59, and it has a projection 85 which coöperates with the periphery of the cam 83, causing reciprocation of the cross-head 84 corresponding to the variations in the form of the cam. A lever 86 is operatively connected at its lower end to the cross-head 84, and the upper end of this lever is operatively connected by the pin 87 to an arm 88, which latter is rigid with the cross-head or slide 62. The swiveled fulcrum or pivot member 79 on the vertically movable slide 77 coöperates with an intermediate portion of the lever 86, variation of the vertical position of the fulcrum or pivot member 79 by rotation of the screw 76 causing a corresponding variation in the degree of reciprocation of the cross-head or slide 62.

The direction of rotation of the secondary shaft 71 and all the mechanism driven therefrom, which includes the entire mechanism, excepting the main driving shaft 6 and the work spindle 9, is periodically reversed. Means is provided in the machine shown for automatically reversing this secondary shaft at appropriate intervals. As shown, a pair of equal size and reversely arranged bevel gears 89 and 90 are mounted on the main driving shaft 6, the gear 89 being fixed to the shaft 6, and the gear 90 being loosely mounted thereon. An idler bevel gear 91 coöperates with the gears 89 and 90, this gear being supported by a shaft mounted in a stationary bracket 92. From this arrangement, the gear 90 will revolve loosely on the main driving shaft 6, but in a reverse direction to the rotation of the main driving shaft 6. The secondary shaft 71 carries a pair of clutch pins 93 and 94 which are rotatable with this shaft and are guided to slide axially thereon. The pin 93 is adapted to enter a notch or recess 95 in the gear 90, while the pin 94 is adapted to enter a notch or recess 96 formed in the end of the main driving shaft 6, the engagement of these pins with the respective notches or recesses, however, being alternate, that is to say, while one pin is in engagement with its respective notch or recess, the other pin is in disengaged relation to its notch or recess. To effect such an operation of the clutch pins, they are preferably connected operatively to the opposite ends of a lever 97, the latter being pivoted by the pin 98 to the secondary shaft 71, while the opposite ends of this lever coöperate with studs 99 and 100 which project from the clutch pins 93 and 94, respectively. Obviously, rocking of the lever 97 about its center will cause reciprocation of the clutch pins in reverse directions, causing one of them to engage its notch or recess the moment the other pin disengages from its notch or recess. To enable the lever 97 to be rocked to reverse the direction of rotation of the secondary shaft 71 during the operation of the machine, a clutch-shifting collar 101 is mounted to slide longitudinally on the secondary shaft 71, and it is connected to the lever 97 or to the clutch pin 94 by an extension 102. The clutch-shifting collar receives the fork 103 of a lever 104, the latter being fulcrumed, at 105, on the slide rest 4. A spring 106 is attached to the transversely movable slide 16, and by the movement of this slide is carried alternately to opposite sides of the pivotal center 105, the spring 106 acting on the lever 104 to shift the reversing clutch in one direction or another, according to the position it occupies relatively to the pivotal center 105. In order to cause shifting of the clutch quickly and at the correct moment, the clutch-shifting lever is provided with a pin 107 arranged to coöperate with the flange 108 of a rail 109 attached to the transversely movable slide 16, the pin 107 coöperating with the flange 108 to prevent reversal of the clutch until the slide 16 has moved to an extent which will carry the flange 108 of the rail clear of the pin 107, whereupon the spring 106 will be permitted to act, causing shifting of the clutch and consequent reversal in the direction of rotation of the secondary shaft. Rotation of the secondary shaft in a reverse direction causes the feed screw 18 to reverse the direction of travel of the feed slide 16, the pin 107 on the clutch-shifting lever 103 re-engaging with the retaining flange 108 and preventing reversal of the clutch until the feed slide 16 has reached a predetermined point in its reverse travel. The range of feed of the slide 16 is controlled by applying rails 109 having retaining flanges 108 of appropriate lengths.

In making a rough cut to approximate the desired curved surface of a lens, or in operating upon metal, a curved pattern 110 (Figs. 8 and 9) may be applied to the bearing member 31 with its stud 111 secured by the set-screw 34. The curve pattern 110 and the tracer 24 then present a line contact which is able to sustain the thrust of the tool against the work with a minimum wear of the parts. In making a finishing cut, a concave or convex spherical pattern or a cylinder pattern, such as shown in Fig. 12, may be applied to the bearing member 31.

Means is provided in the present instance for automatically feeding the work to the tool as the grinding operation proceeds. In the present instance, the head stock 3 carrying the work-supporting spindle 9 is ad-

vanced along the gibbed bed in a direction toward the slide 16 by a feed screw 112 which is supported in suitable bearings 113 on the bed and is threaded in the extension 114 connected to the head stock. This feed screw is provided with a hand-wheel 115 at the exterior of the bed whereby the head stock may be positioned by manual adjustment of the feed screw, preparatory to the commencement of the grinding operation, and thereafter the feed of the work to the tool is effected automatically by a ratchet 116 on the feed screw which is engaged and rotated step-by-step by a pawl 117. The pawl 117 is pivoted to the slide rest 4, at 118, and its upper end has a slot connection with a projection 119 on the clutch-shifting lever 104 whereby each reversal in the position of the clutch-shifting lever will effect a stroke of the pawl 117 whereby the ratchet 116 is advanced a tooth.

The operation of grinding or forming a curved surface by the aid of a machine constructed as shown in the accompanying drawings may be briefly described as follows:

The lens blank or other piece of work x which is to receive the desired curved surface is fixed in the chuck 12. Power is applied to the machine through the medium of the driving wheel 8, causing the main driving shaft 6 and the work spindle 9 to revolve continuously and at the same speed. The grinding or operating tool 25 initially occupies a position with its operating surface in alinement with the axis of rotation of the blank or piece of work x. The work is brought up to the operating tool by turning the wheel 115 attached to the feed screw 112.

The operation of the machine will be described with reference to the grinding of lenses, and it will be understood from this description how similiar curved surfaces may be formed on other objects.

In order to produe a spherical surface on the lens blank x, a pattern is applied to the bearing 31 having an appropriate curve, the pattern having a convex surface, if a concave curved surface is to be formed on the lens blank x, and the pattern having a concave surface, if a convex spherical surface is to be formed on the lens blank x. For example, in order to cut or grind a convex sphere of +10 diopters, a concave curve pattern having different radii on different meridians, such as that shown in Fig. 14, is applied to the bearing 31. For instance, a concave compound curve pattern having a primary meridian a—a of 7.50 diopters and a secondary meridian b—b of 11.25 diopters may be used, the pattern being so set in the bearing 31 that its meridian having a curve of 10 diopters is in a horizontal position or in a line parallel to the plane of motion of the slide 16. The tracer 21 on the transfer bar or member 20 is then brought into contact with the surface of this pattern, it traveling across the horizontal meridian having a curve of 10 diopters as the slide 16 moves transversely. With the operating tool 25 in coöperative relation with the lens blank x, power is transmitted to the operating tool 25 through the flexible shaft 27, imparting continuous motion to the tool. As the machine operates, the motion transmitted to the secondary shaft 71 causes rotation of the feed screw 18, moving the slide 16 transversely to carry the tool from the center of the lens blank x toward the periphery of the blank, and, during this movement of the slide 16, the tracer 21 of the transfer bar or member 20 moves horizontally across the horizontal meridian of the curve pattern applied to the bearing 31, reproducing on the lens blank x a convex spherical surface having a curve of 10 diopters corresponding to the horizontal meridian of the pattern. In producing a surface having the same curvature on every meridian, the pattern applied to the bearing 31 remains stationary and the tracer 61 is in operative relative to the pattern 47. The curvature of the surface produced on the lens blank will be of a uniform degree from the center to the periphery.

In order to produce a spherical surface the radius of which varies in a direction from its center toward its periphery, the machine may be adjusted as previously described but instead of the pattern applied to the bearing 31 remaining motionless by setting the slotted member 43 horizontally or parallel with the direction of motion of the slide 16, this slotted link 43 is adjusted at an inclination which will impart rotation to the curve pattern on the bearing 31 as the slide 16 reciprocates, the degree of rotation of the pattern necessary to secure the desired variation in curvature of the spherical surface depending upon the degree of variation between the curvatures on the primary and secondary meridians of the curve pattern. This rotation of the curve pattern causes the tracer 21 of the transfer bar 20 to follow the line b'—b' (Fig. 14) or a line which deviates from the meridian having the power or curvature which would be reproduced in making an ordinary spherical surface. This deviation of the tracer from the true meridian of the pattern produces in the product a surface, the curvature of which increases or diminishes gradually from the center to the periphery of the lens, the variation in curvature rendering the lens anastigmatic. In forming spherical surfaces, such as those just described, the tail stock 5 is stationary.

In producing a simple cylindrical surface, the pattern having a simple cylindrical surface, such as that shown in Fig. 12, is

applied to the bearing 31. In a pattern of this character, the primary meridian has zero curvature, while the secondary meridian or the meridian perpendicular to the primary meridian has the maximum curvature. A pattern is applied to the bearing 46 which has a surface having curvatures of different radii on different meridians thereof, that is, one having a greater curvature on its secondary meridian than the curvature on its primary meridian. The pattern applied to the bearing 46 is so set rotatively in said bearing as to bring the meridian having the desired degree of curvature into a horizontal position or into a position parallel with the line of reciprocation of the cross-head or slide 62. In producing the simple cylindrical surface, the slotted member 43 is set horizontally or parallel with the plane of motion of the slide 16, but the tracer 61 is set in operation, it coöperating with the pattern applied to the bearing 46. The tracer 61 is set into operation by turning the screw 76 in a direction to lower the swivel pivot 79, the projection 85 being thus brought into coöperation with the actuating cam 83 and the tracer is rendered inoperative by turning the screw 76 to raise the swivel pivot 79 until the projection 85 is retracted out of range of the cam 83. The tracer 61 starts at the center of the pattern 47 in the bearing 46 and moves horizontally toward the periphery of the pattern, increasing the extent of its stroke at each reciprocation due to rotation of the screw 76 which shifts the pivot 79, and by the same proportionate amount, the operating tool 25 moves from the center of the lens blank x. As the tracer 61 moves toward the periphery of the pattern 47, it allows the tail stock 5 to recede, together with the plane or straight line pattern applied to the bearing 31, the transfer bar 20 carrying the operating tool 25 receding to the same extent under the influence of the spring 20^a. The tracer 61 always comes to the center of the pattern 47 as the primary meridian of the lens blank x reaches the horizontal position, and the tracer 61 is always at the end of its stroke to either side of the center of the pattern 47 when the secondary meridian of the lens blank x is in a horizontal position. As the tracer 61 is always at the center of the pattern 47 when the primary meridian of the lens blank is presented to the operating tool, this primary meridian on the lens blank will be plane or not curved, and as the tracer 61 is always at the end of its stroke when the secondary meridian of the lens blank is presented to the operating tool 25, the surface ground upon the lens blank will have a curve equal to the horizontal radius of the pattern 47. As the lens blank revolves to present its primary and secondary meridians alternately to the operating tool while the tracer 61 is moving from the center toward the periphery of the pattern 47, and vice versa, the curvature of the surface produced on the lens blank x will vary from a zero curvature on the primary meridian to the maximum curvature on the secondary meridian, with the result that the surface produced on the lens blank will be in the form of a simple cylinder. During this operation, the patterns 32 and 47 applied to the bearings 31 and 46, respectively, are not rotated.

In order to produce a cylindrical surface which has a curvature of varying radii in a direction from its center toward its periphery, the same or similar patterns referred to in the preceding example may be used, but the tracks 53 and 54 are set into operation by setting the screw 60 to adjust the tracks 53 and 54 at appropriate angles, these tracks being set horizontally or in alinement when the pattern 47 is not rotated, as in the preceding instance. This mechanism causes the pattern 47 to rotate in synchronism with the strokes of the tracer 61 to bring the pattern 47 into a position where it will present a meridian of greater curvature to the tracer as the latter moves from the center toward the periphery of the pattern, the pattern being restored to its initial position upon each return of the tracer 61 to the center of the pattern. The degree of rotation of the pattern 47 and consequently the degree of increase of curvature in the product is effected automatically by the increased degree of rotation imparted to the pattern 47 by the tracks 53 and 54, the increase in inclination of these tracks being effected automatically by the increased length of the strokes of the cross-head or slide 62. The result is that a cylinder surface is produced, wherein the curvature of the surface on all meridians, except the one presenting zero curvature, increases or decreases uniformly from the center toward the periphery.

In order to produce a toric curve surface, or one having varying radii on different meridians thereof, a cylindrical pattern or one having varying radii on different meridians thereof is applied to the bearing 31 it being set to present a curvature on its horizontal meridian depending upon the curvature which the lens is to have on its primary meridian, and a cylindrical pattern or one having varying radii on different meridians thereof is applied to the bearing 46 with its meridian set to bring into horizontal position a curve which will determine the curvature of the lens on its secondary meridian. In operating the machine to produce a toric lens or surfaces of this type, the mechanisms which rotate the patterns 32 and 47 are set inoperative, the tracer 21 following

the curve of the pattern 32 set horizontally to produce the curve on the primary meridian of the lens, and the tracer 61 following the curve of the pattern 47 set horizontally to produce the curve on the secondary meridian of the lens, and the curves intermediate between the primary and secondary meridians.

In order to produce an anastigmatic compound or toric surface, patterns, such as those just described, may be used, but the mechanisms which rotate the patterns 32 and 47 are set into operation so as to bring meridians of the patterns 32 and 47 having increased or decreased degrees of curvature into coöperation with the tracers 21 and 61, respectively, as the generation or development of the curves on the surface of the lens blank proceeds from the center and toward the periphery of the lens blank, the curvature of the surface of the lens produced increasing or decreasing gradually toward the periphery of the lens and rendering the lens anastigmatic.

The present invention provides a method of and apparatus for surfacing lenses and other objects which enables a surface of any desired curvature to be produced by the aid of one or more patterns operating singly or in combination to impart to the curved surface the desired characteristics. It obviates the defects found to exist in surfacing lenses and other objects according to the method heretofore used of employing a grinding or surfacing stone individual to each surface to be ground, such method requiring a great number of stones, and involving the expenditure of much time and labor, and, moreover, such method is objectionable in that the grinding surfaces of the stones become worn out of true, introducing inaccuracies into the curvatures produced therefrom.

I claim as my invention:—

1. The method of producing curved surfaces which comprises relatively rotating a tool and an object, moving the tool radially relatively to the object, relatively positioning the tool and object in a direction axially of the object in accordance with a pattern surface having curvatures of varying radii on its different meridians, and relatively moving said pattern surface during the production of the curved surface on the object to cause the production of a curved surface on the object in accordance with the variation in radii of the curvatures on the pattern surface.

2. The method of producing curved surfaces which comprises rotating an object, relatively moving a tool and the object radially of the latter, guiding the tool in accordance with a pattern curve having curvatures of varying radii, and relatively shifting the pattern curve during the production of the curve on the object to vary the degree of curvature of said curve in a direction from the center toward the periphery thereof.

3. The method of producing curved surfaces which comprises relatively rotating and moving radially a tool and an object, and relatively moving the tool and object axially in accordance with the surface of a pattern having curvatures of varying radii to produce on the object a curved surface which is a composite of the components of the curvatures of varying radii on the pattern surface.

4. The method of producing curved surfaces which comprises rotating an object relatively to a tool, relatively moving the tool and object radially of the object, and relatively moving the tool and object in a direction axially of the object under the control of a pattern having curvatures of varying radii, and concurrently moving the pattern to render active the curvatures of various radii thereon to determine the axial movement of the tool relatively to the object, thereby producing on the object a surface having a varying radius of curvature in a direction from the center toward the periphery thereof.

5. The method of producing curved surfaces which comprises relatively rotating an object and tool, and moving a pattern having a curve thereon active to move the tool axially of the object and in synchronism with the rotation thereof, thereby producing on the object a surface the degree of curvature of which varies on different meridians thereof.

6. The method of producing curved surfaces which comprises relatively rotating an object and tool, and concurrently moving the tool axially relatively to the object, and moving the pattern curve relatively to the tool in synchronism with the rotation of the object, thereby producing on the object a surface the degree of curvature of which varies on different meridians thereof.

7. The method of producing curved surfaces which comprises relatively rotating an object and a tool, concurrently moving the tool axially relatively to the object and a pattern curve, and simultaneously moving the tool axially relatively to the object by a second pattern curve active in synchronism with the rotation of the object, thereby producing on the object a compound surface the degree of curvature of which varies on different meridians thereof.

8. The method of producing curved surfaces which comprises simultaneously rotating an object relatively to a tool, relatively moving the tool radially of the object under the guidance of a pattern surface having curvatures of different radii on different meridians thereof, rotating such pattern

surface to render active different meridians thereof, and concurrently moving the tool axially relatively to the object in synchronism with the rotation of the object to produce on the object a surface the degree of curvature of which varies on different meridians thereof and the degree of curvature of which varies from the center toward the periphery thereof.

9. The method of producing curved surfaces which comprises rotating an object relatively to a tool, and concurrently moving the tool both axially and radially relatively to the rotating object under control of a plurality of pattern curves to produce on the object a surface which is the resultant of the components of the curvatures of the plurality of pattern surfaces.

10. The method of producing curved surfaces which comprises rotating an object relatively to a tool, and concurrently moving the tool axially relatively to the object in accordance with a curved pattern surface active in synchronism with the rotation of the object to produce on the latter a cylinder or compound curved surface.

11. The method of producing curved surfaces which comprises rotating an object relatively to a tool, and concurrently moving the tool axially relatively to the object under control of a pattern curve active in synchronism with the rotation of the object, thereby producing on the object a surface the curvature of which on one meridian is determined by the synchronously active surface of the pattern curve.

12. The method of producing a curved surface having a varying radius in a direction from its center toward its periphery, which comprises rotating an object while acted upon by a tool, and relatively moving the tool and object axially by causing the tool to move in accordance with the surface of a pattern having curvatures of different radii on different meridians thereof while such pattern is rotated to bring different meridians thereof into operation and while the tool and object relatively move radially.

13. The method of producing a compound curved surface having curvatures of different radii on different meridians thereof, which comprises rotating an object while acted on by a tool, and relatively moving the tool and object axially in accordance with the curved surface of a pattern and in synchronism with the rotation of the object.

14. Apparatus for producing curved surfaces comprising in combination, means for rotating an object, an operating tool therefor, the tool and object being relatively movable radially and axially, a curve-pattern having curvatures of different radii on different meridians thereof, and means for adjusting the pattern during the production of the surface on the object to bring different meridians of the pattern into coöperation with the tool and thereby relatively position the object and tool in a direction axially of the object.

15. Apparatus for producing curved surfaces comprising, in combination, means for rotating an object, an operating tool therefor, the object and tool being relatively movable in directions parallel and transverse to the axis of rotation of the object, a curve-pattern having curvatures of different degrees on different meridians thereof, a tool controlling member engaging the pattern to cause relative axial movement between the object and tool during the relative transverse movement between such elements, and means for shifting the pattern during the relative transverse movement between the object and tool to bring different meridians of the pattern into engagement with the tool controlling member.

16. Apparatus for producing curved surfaces comprising, in combination, means for rotating an object, an operating tool therefor, the object and tool being relatively movable in directions parallel and transverse to the axis of rotation of the object, a curve-pattern having varying degrees of curvature on different meridians thereof, means engaging the pattern to cause relative axial movement between the object and tool during the relatively transverse movement between such elements, and means operatively connected to said object rotating means for adjusting said pattern to bring meridians of different curvatures into action during the relatively transverse movement between the object and tool.

17. Apparatus for producing curved surfaces comprising, in combination, means for rotating an object, an operating tool therefor, the object and tool being relatively movable axially and radially, a curve-pattern, a tracer engaging the pattern and connected to the tool, a second tracer, a second pattern engaging the second tracer, means for operating the second named tracer on its pattern in synchronism with the rotation of the object, and means connected to the tool and movable by said tracers and their patterns for relatively moving the tool and object axially and thus produce on the object a surface having varying degrees of curvature on different meridians thereof.

18. Apparatus for producing curved surfaces comprising, in combination, means for rotating an object, an operating tool therefor, the object and tool being relatively movable axially, a curve-pattern having varying degrees of curvatures on different meridians thereof, a tracer engaging the pattern and having means operatively connecting it to the tool, means for operating the tracer on said pattern in synchronism with the rotation of the object, and means for rotating

the pattern to bring different meridians thereof into engagement with the tracer.

19. Apparatus for producing curved surfaces comprising, in combination, a rotary work holder, a tool, the work holder and tool being relatively movable transversely and axially, a movable pattern, means controlled by the movement of the pattern and operatively connected to the tool to control the said relative axial movement, means to control the movement of the pattern in synchronous relation to the movements of the tool and work, and means to actuate the work holder, tool, and pattern.

20. Apparatus for producing curved surfaces comprising, in combination, means for rotating an object, an operating tool, the object and tool being relatively movable both radially and axially, a pattern having curvatures of different radii on different meridians thereof, and a tool controlling member engaging the pattern, the pattern being adjustable relatively to the tool controlling member to bring different meridians of the pattern into coöperation therewith.

21. Apparatus for producing curved surfaces comprising, in combination, means for rotating an object, an operating tool to cooperate with the object, the object and tool being relatively movable both radially and axially, a pattern having curvatures of different radii on different meridians thereof, a tool controlling member engaging the pattern, and means for adjusting the pattern during rotation of the object and also during relative radial movement between the object and tool to bring different meridians of the pattern into coöperation with the tool controlling member and thus vary the curvature of the surface produced on the object.

22. Apparatus for producing curved surfaces comprising, in combination, means for rotating an object, an operating tool to cooperate with the object, the object and tool being relatively movable both radially and axially, a pattern, a tool controlling member engaging the pattern, and means for adjusting the pattern in synchronism with the rotation of the object.

23. Apparatus for producing curved surfaces comprising, in combination, means for rotating an object, an operating tool coöperative with the object, the object and tool being relatively movable both radially and axially, a pattern having curvatures of different radii, a tool controlling member engaging the pattern, the pattern being shiftable relatively to the tool controlling member to bring different radii of such pattern into engagement therewith, a second pattern, a tool controlling member engaging said second pattern, and means for shifting said second pattern relatively to its tool controlling member in synchronism with the rotation of the object to control relative axial movement between the tool and object.

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

EUGÉNE W. LAISNÉ.

Witnesses:
C. V. LYONS,
C. A. TRUETT.