March 25, 1947. D. E. MULHOLLAND ET AL 2,418,085

SURFACING MACHINE

Filed May 24, 1943 18 Sheets-Sheet 1

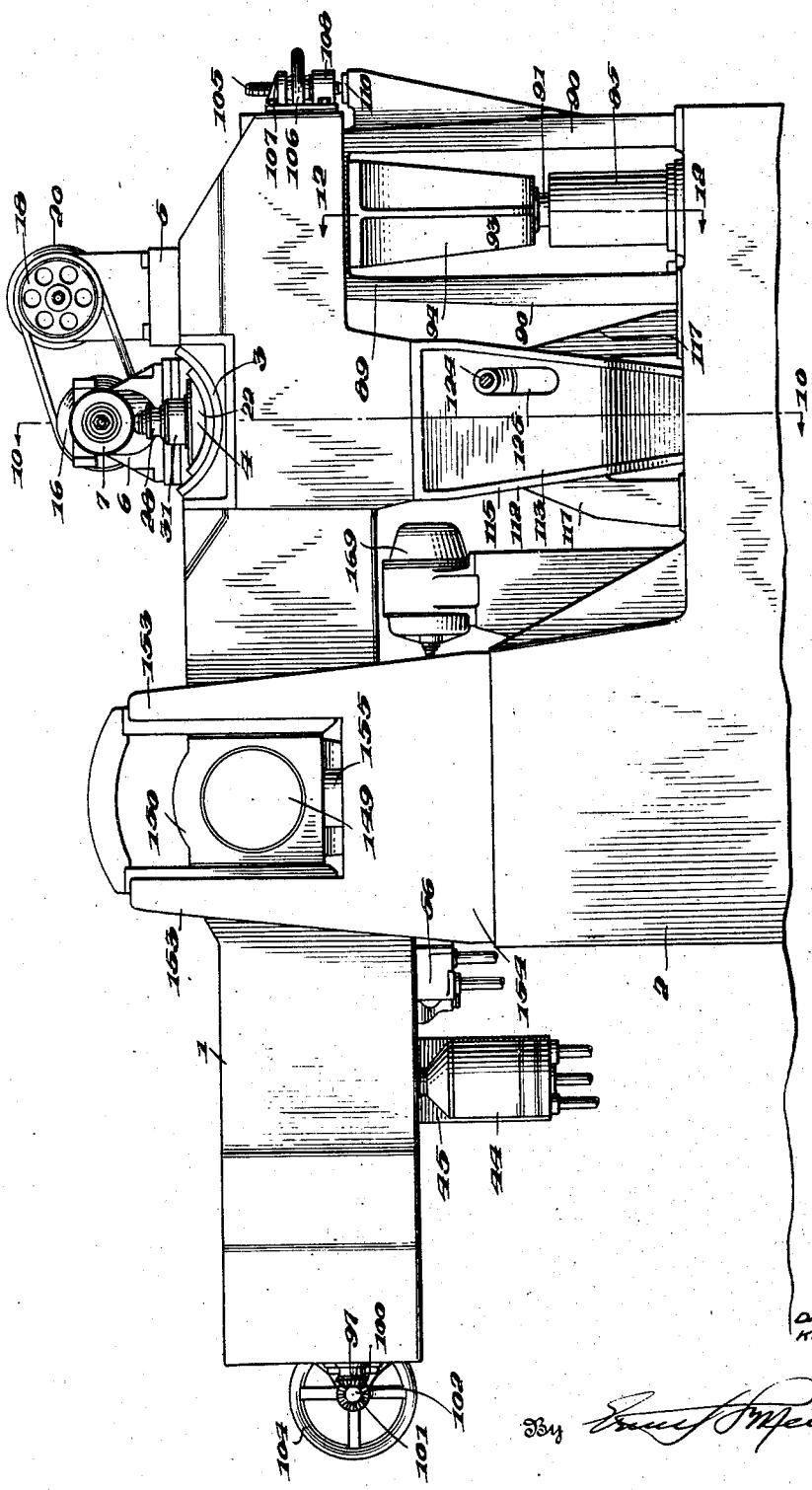

Fig. 1.

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March 25, 1947. D. E. MULHOLLAND ET AL 2,418,085

SURFACING MACHINE

Filed May 24, 1943 18 Sheets-Sheet 2

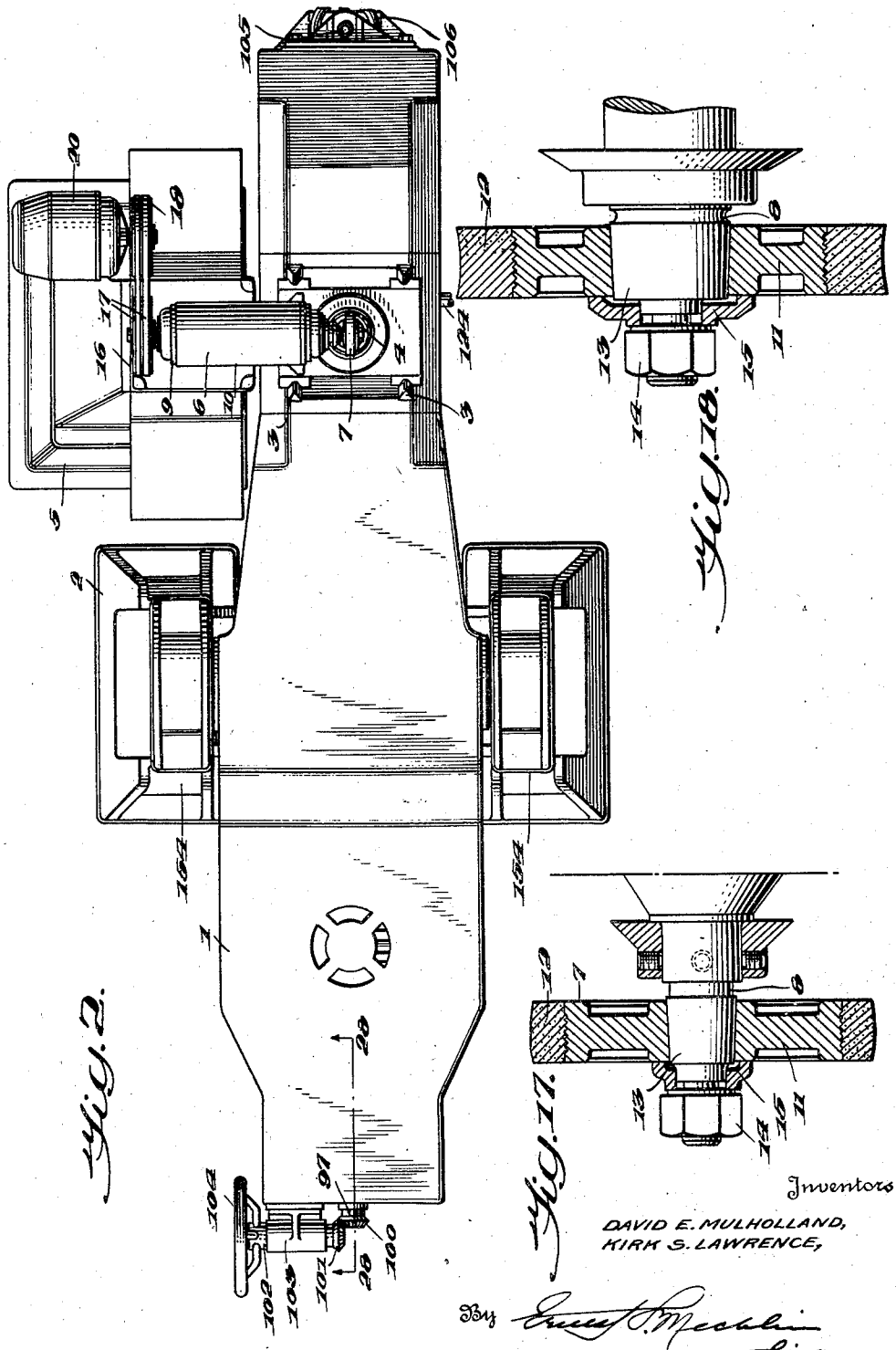

Fig. 2.

Fig. 18.

Fig. 17.

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March 25, 1947. D. E. MULHOLLAND ET AL 2,418,085

SURFACING MACHINE

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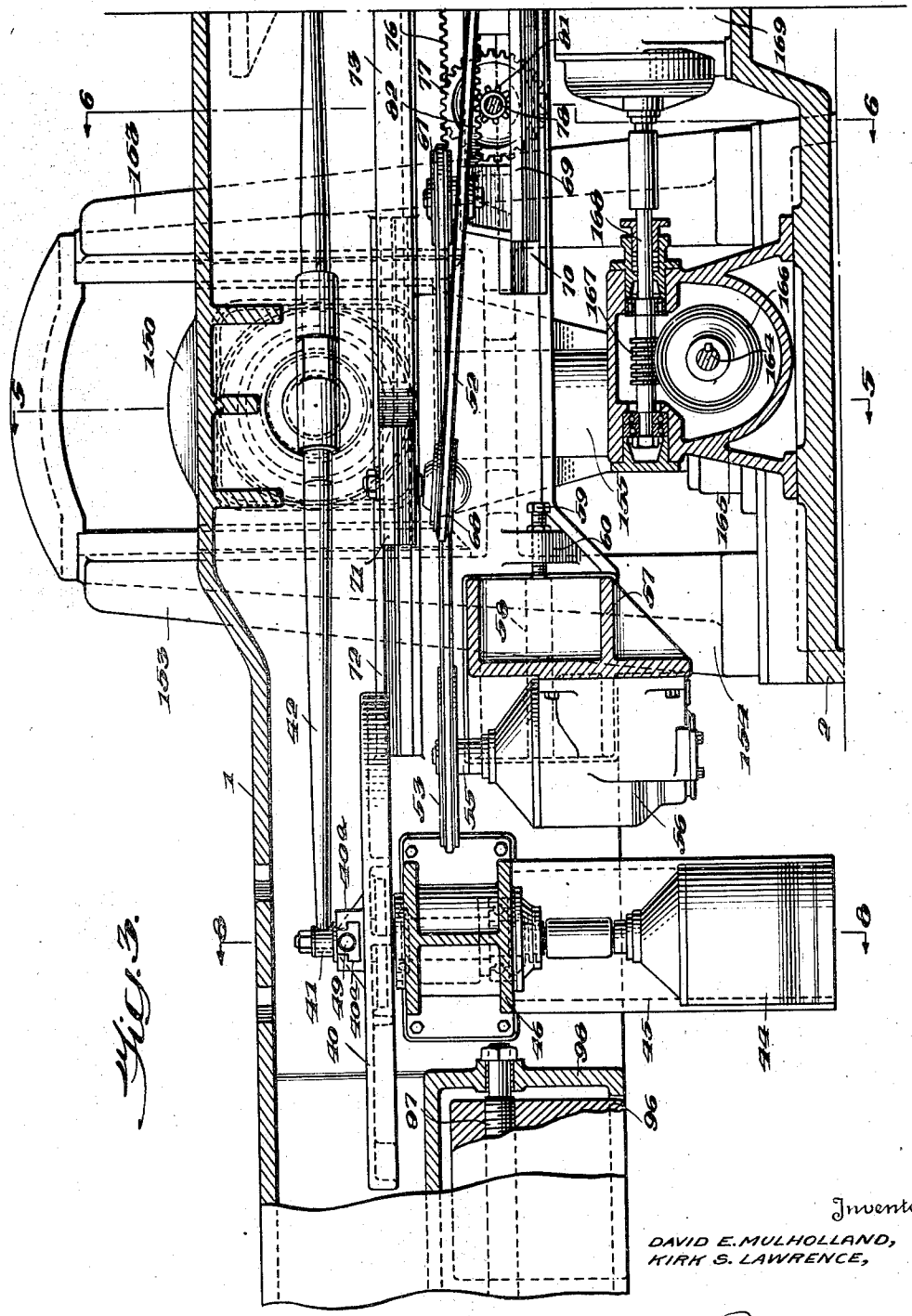

Fig. 3.

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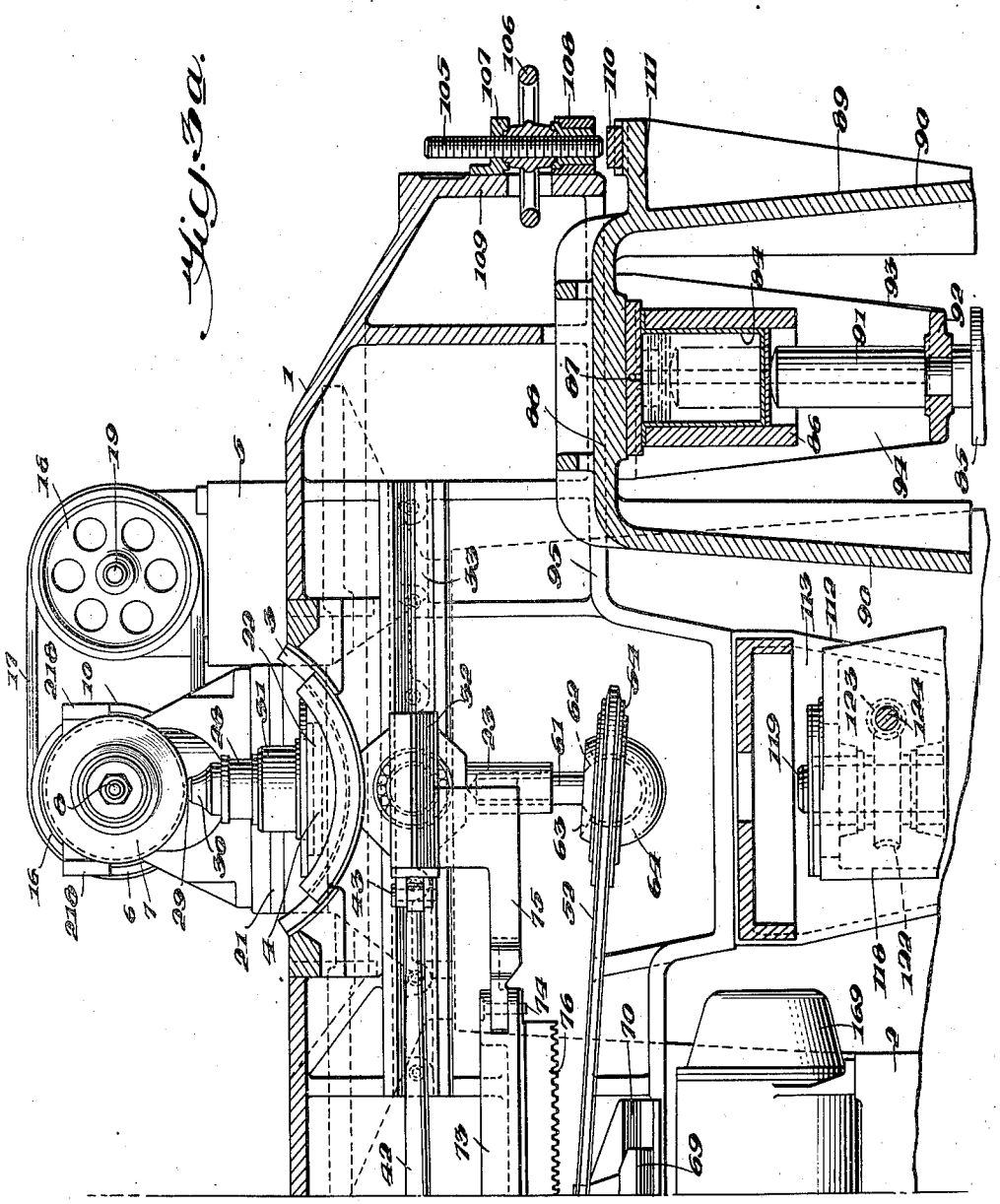
March 25, 1947. D. E. MULHOLLAND ET AL 2,418,085

SURFACING MACHINE

Filed May 24, 1943 18 Sheets-Sheet 4

Fig. 3a.



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March 25, 1947. D. E. MULHOLLAND ET AL 2,418,085

SURFACING MACHINE

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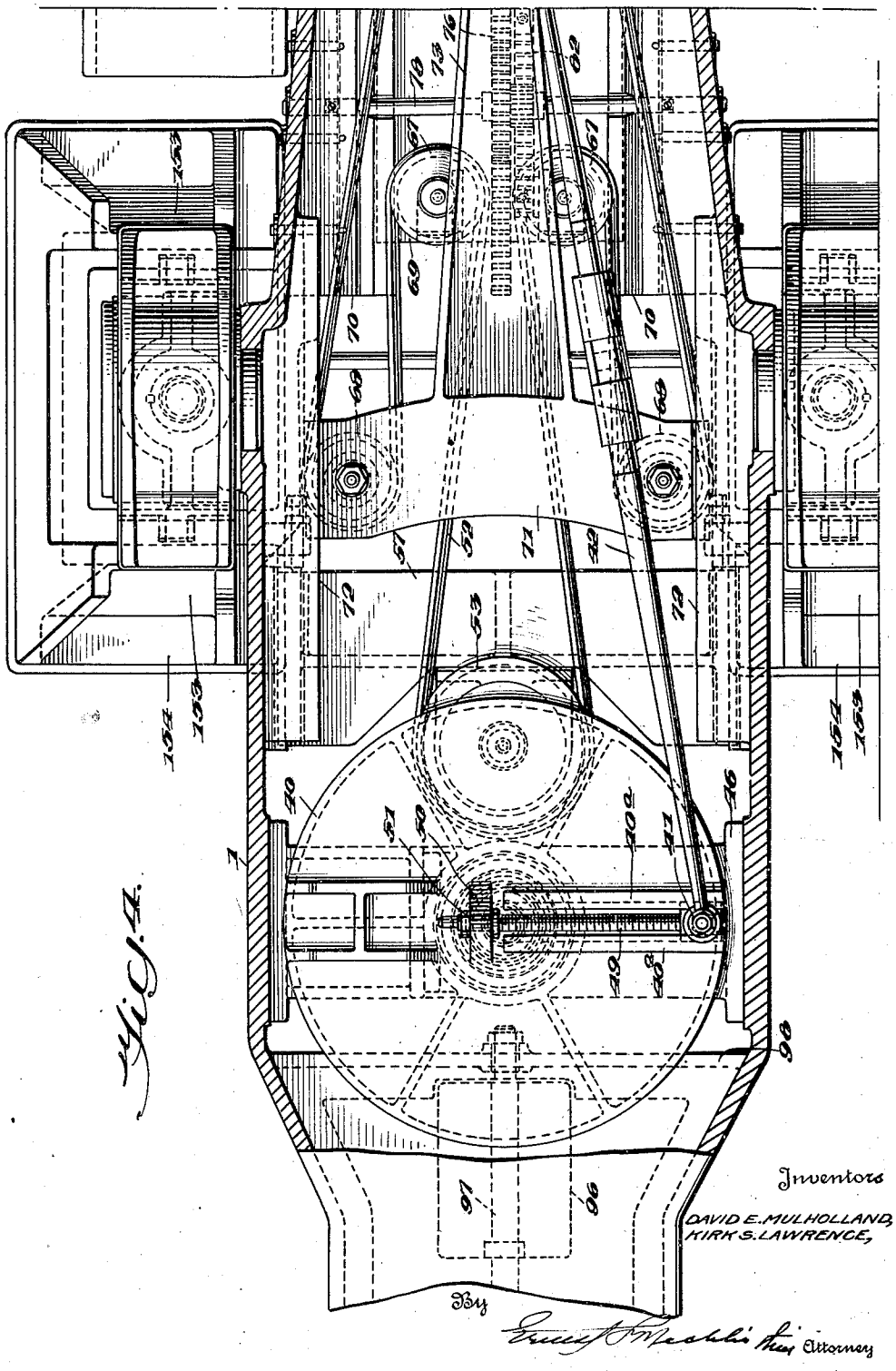

Inventors
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March 25, 1947. D. E. MULHOLLAND ET AL 2,418,085

SURFACING MACHINE

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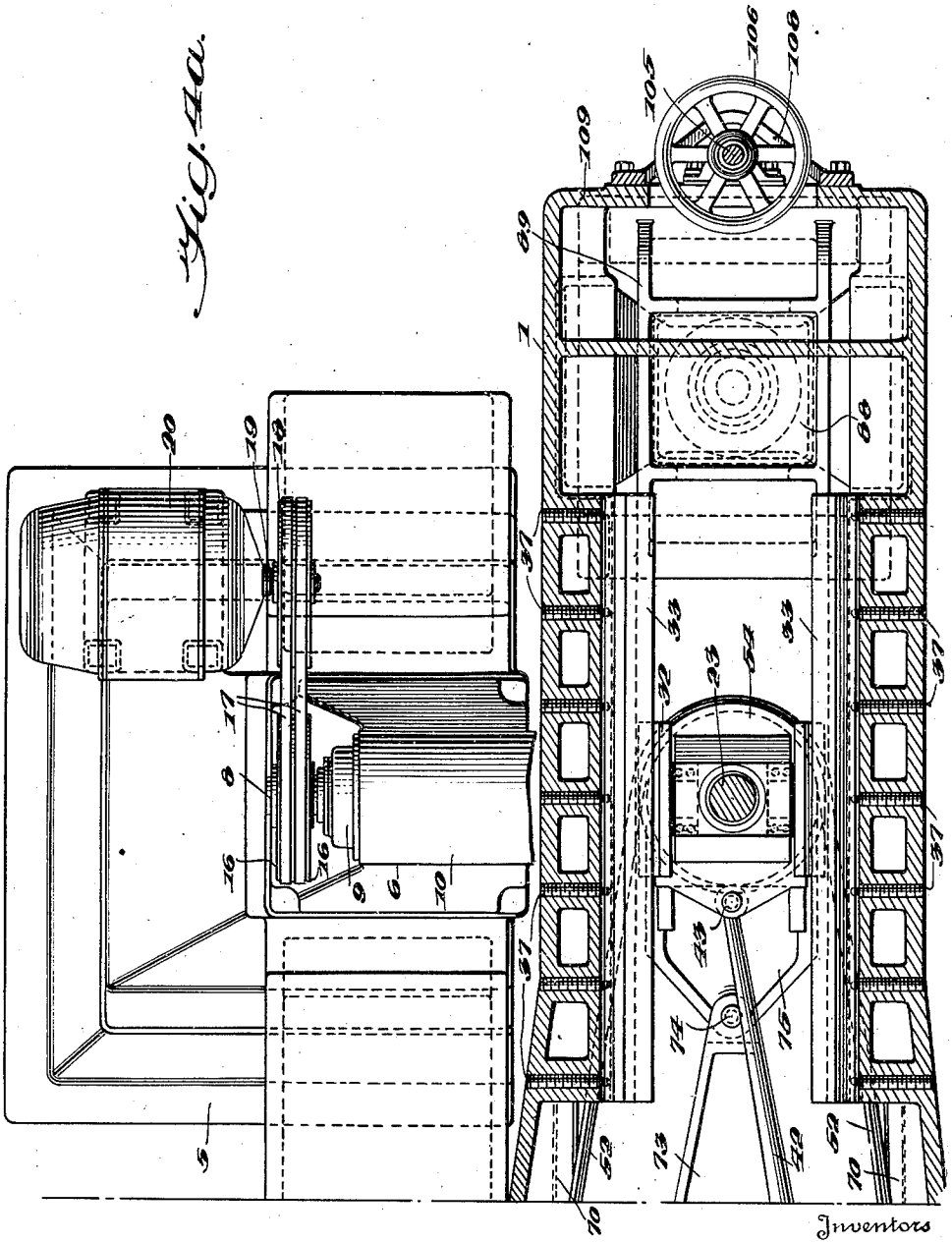
Fig. 4a.



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SURFACING MACHINE

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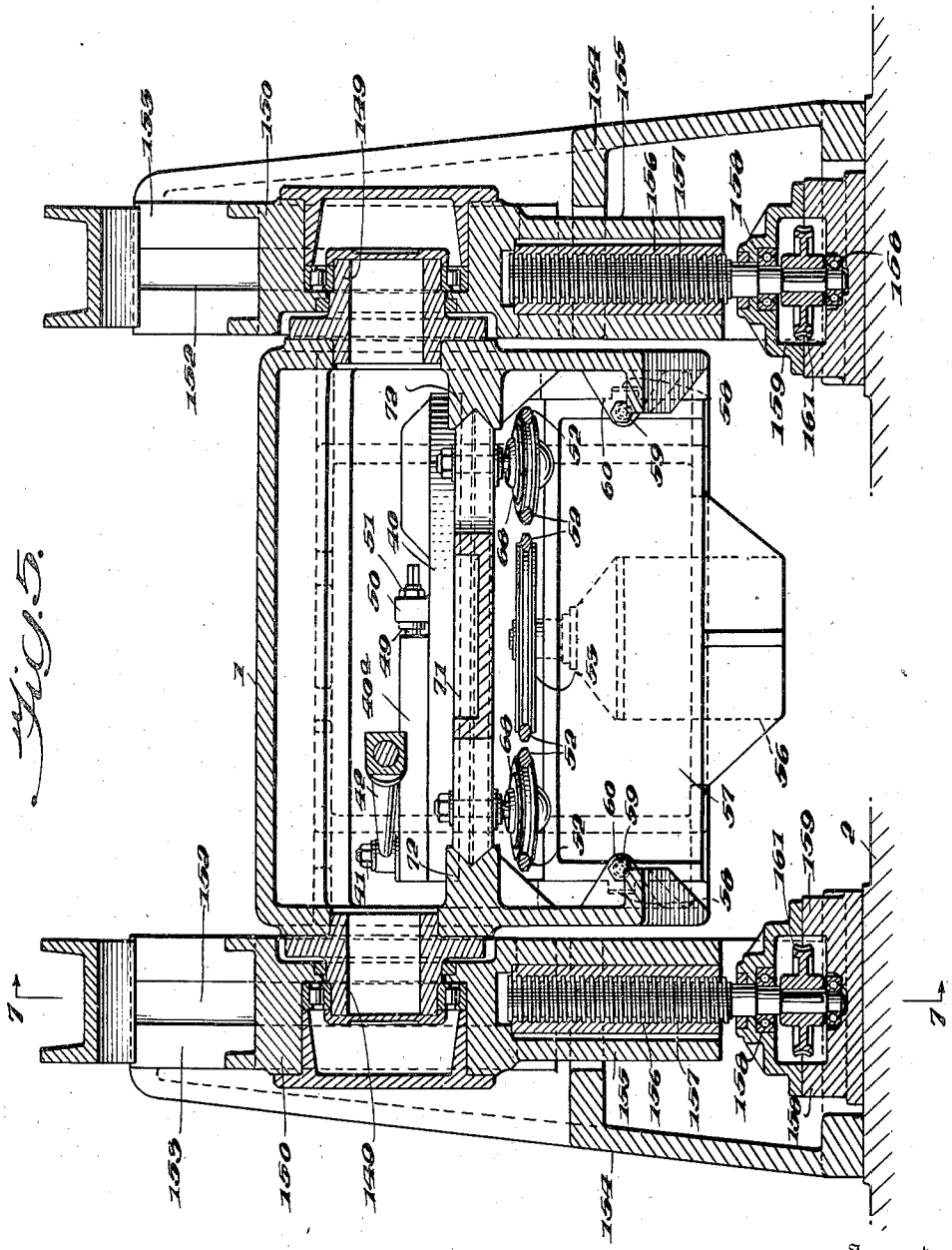

Fig. 5.

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March 25, 1947. D. E. MULHOLLAND ET AL 2,418,085

SURFACING MACHINE

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Fig. 6.

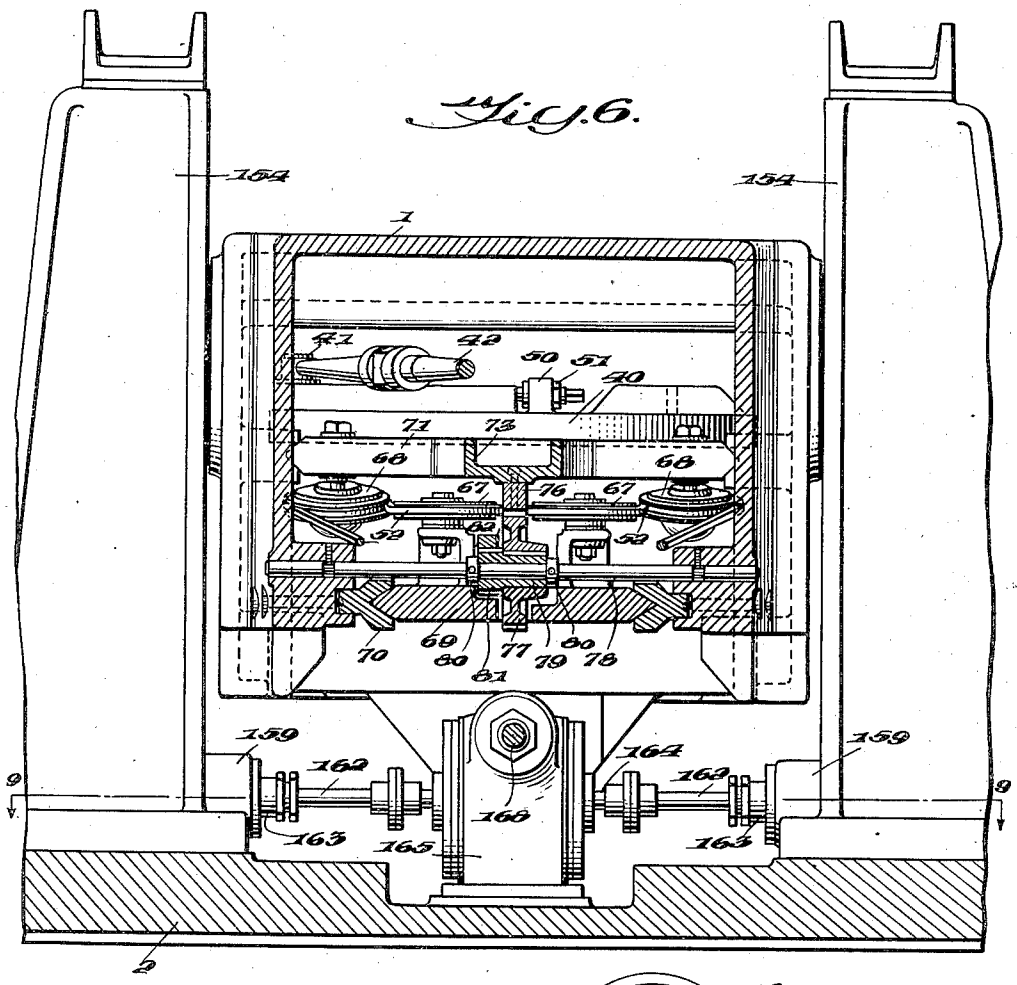
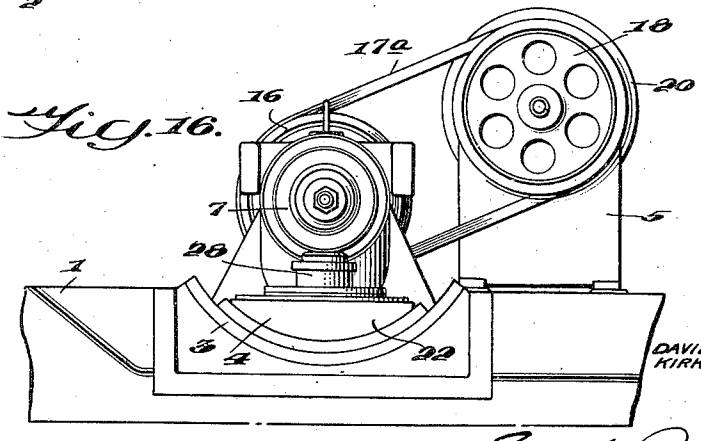


Fig. 16.



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March 25, 1947. D. E. MULHOLLAND ET AL 2,418,085

SURFACING MACHINE

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Fig. 6.

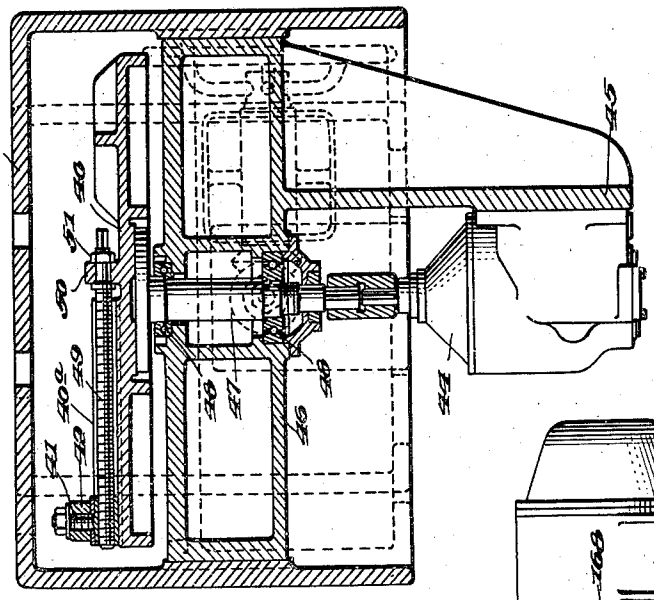
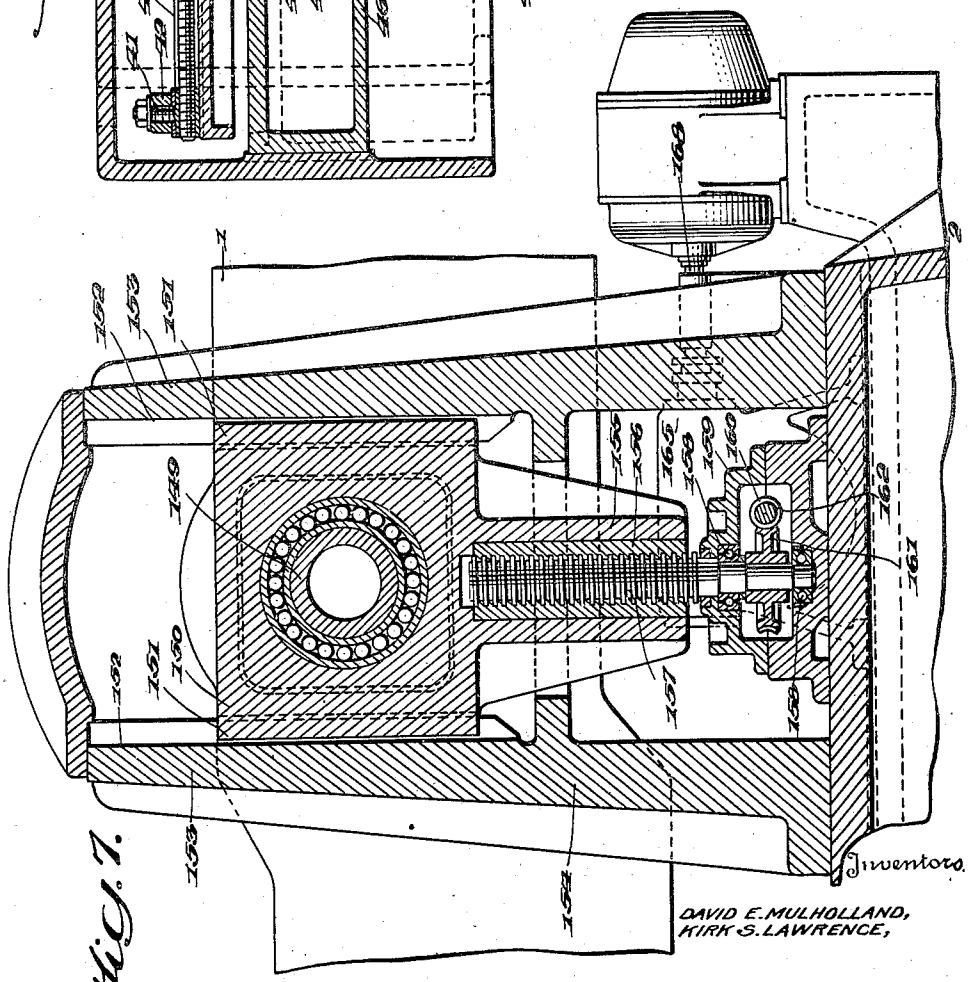


Fig. 7.



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By Ernest J. Mecklenburg Attorney

March 25, 1947. D. E. MULHOLLAND ET AL 2,418,085

SURFACING MACHINE

Filed May 24, 1943 18 Sheets-Sheet 10

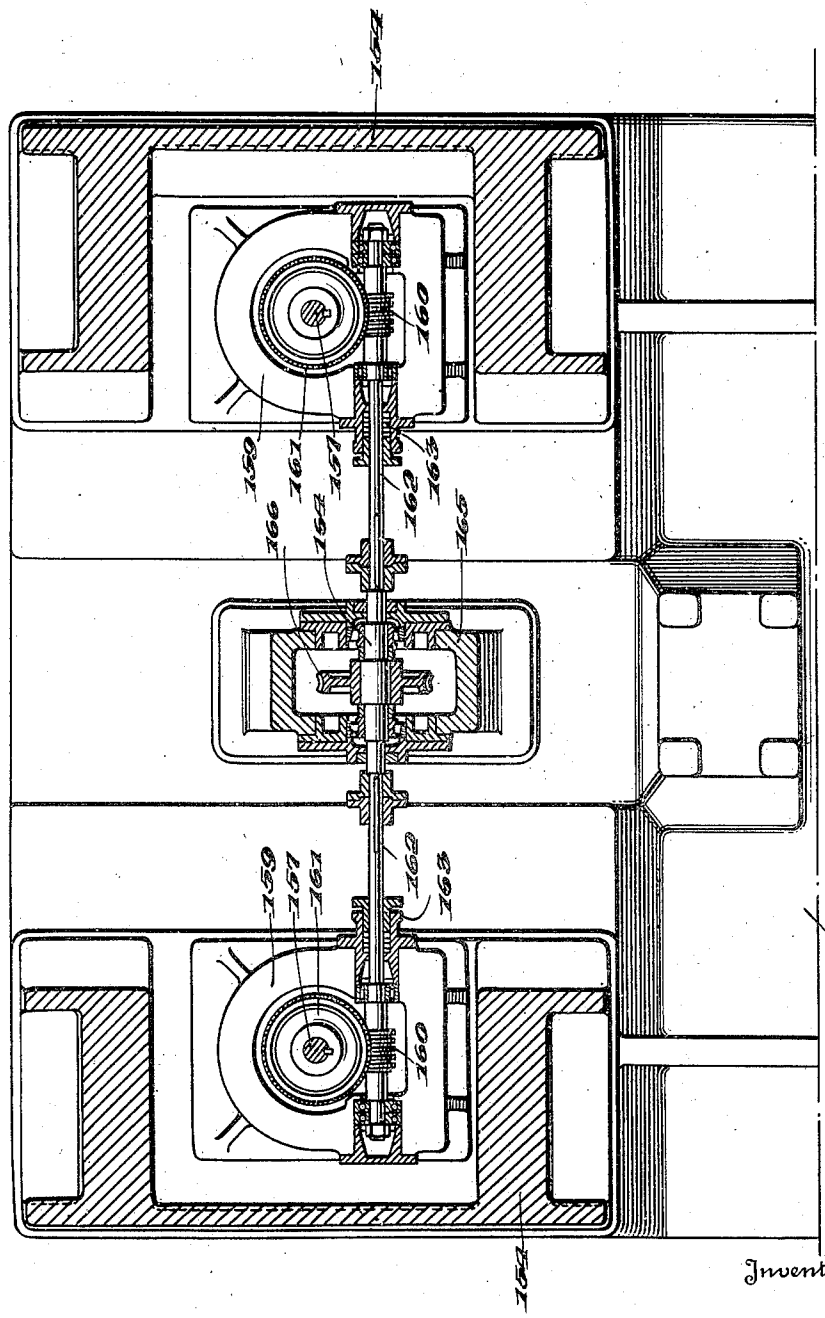

Fig. 9.

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March 25, 1947. D. E. MULHOLLAND ET AL 2,418,085

SURFACING MACHINE

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Fig. 10.

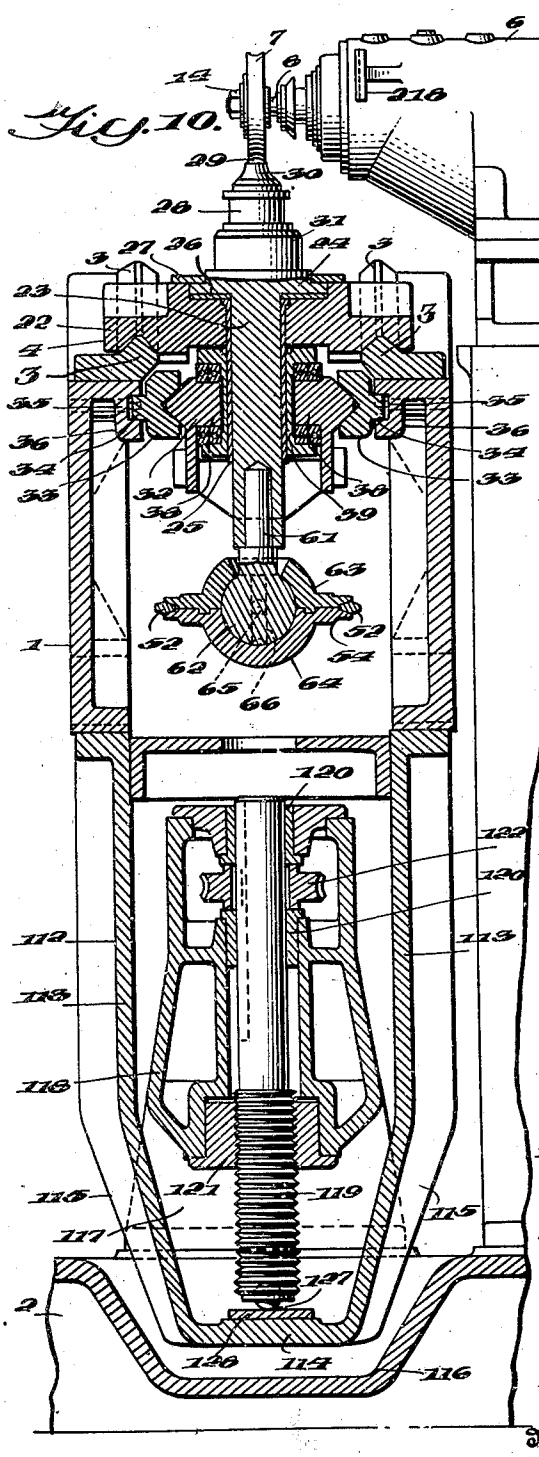
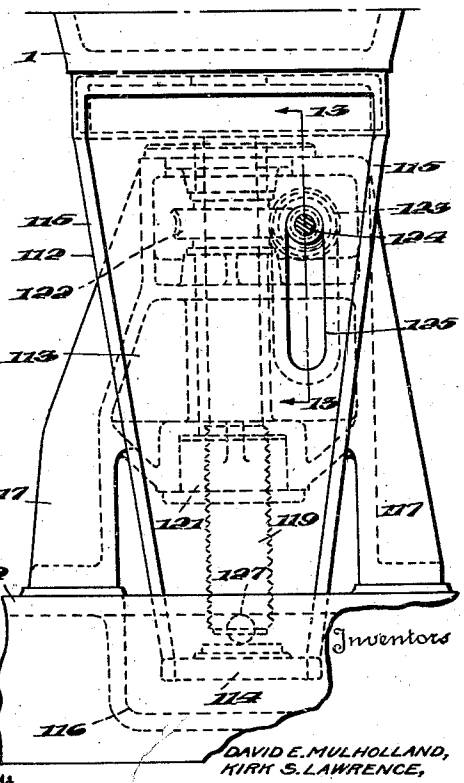


Fig. 11.



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March 25, 1947. D. E. MULHOLLAND ET AL 2,418,085

SURFACING MACHINE

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Fig. 13.

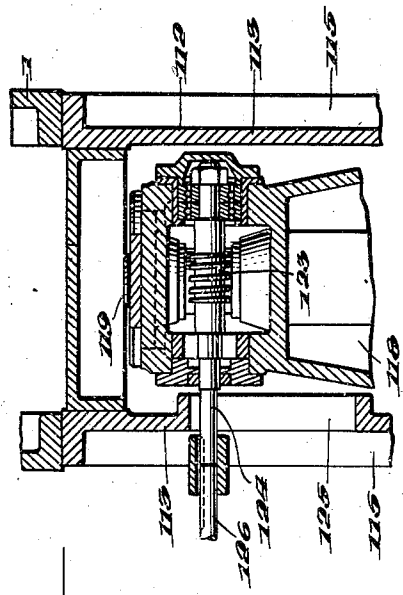


Fig. 15.

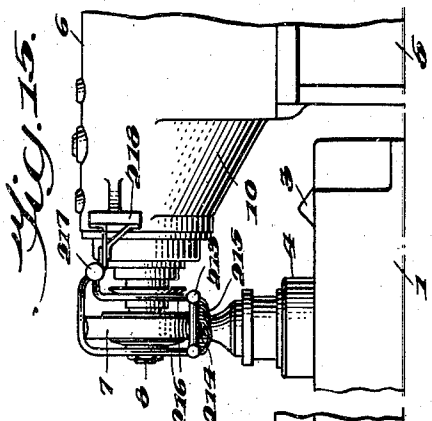


Fig. 14.

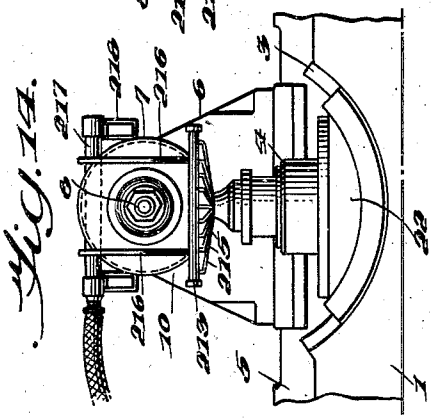
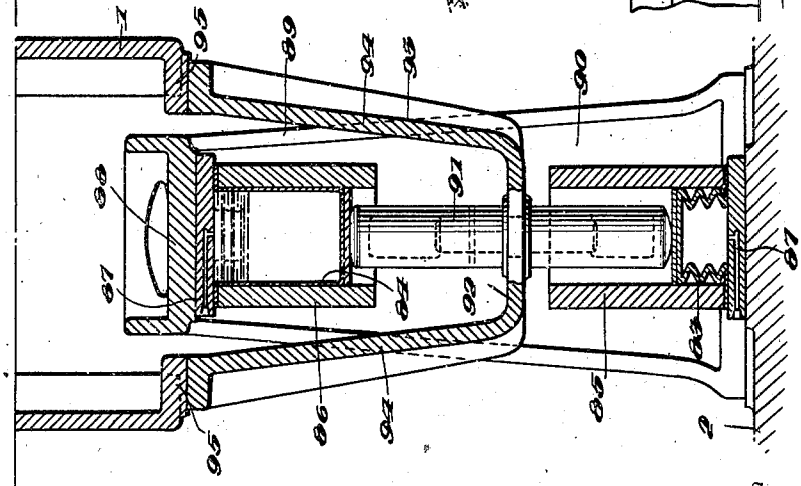


Fig. 12.



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Their Attorney

March 25, 1947. D. E. MULHOLLAND ET AL 2,418,085

SURFACING MACHINE

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Fig. 19.

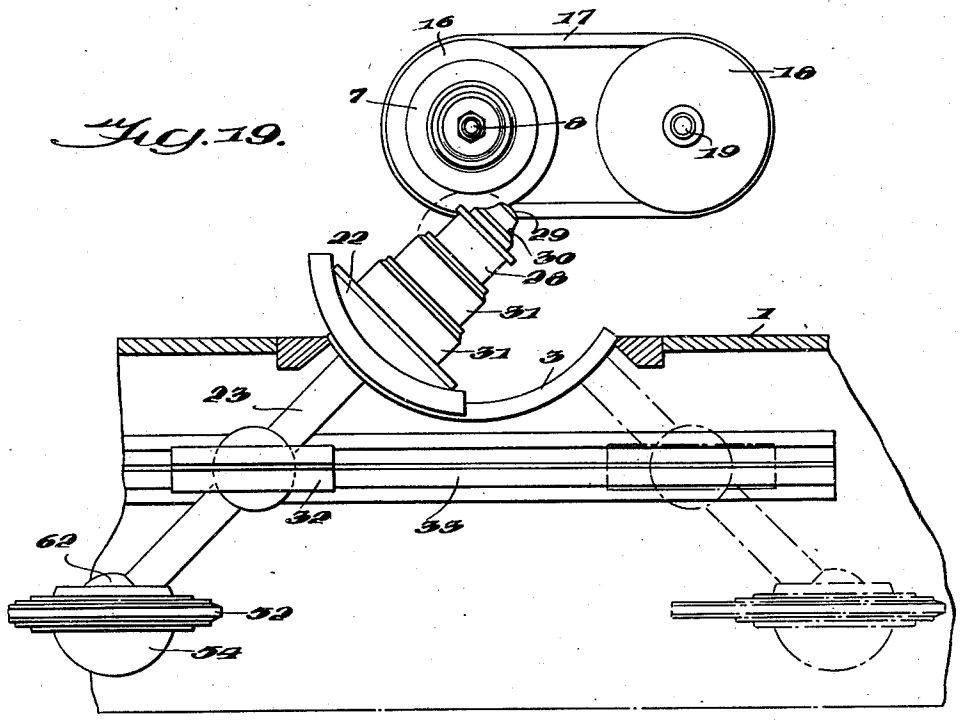
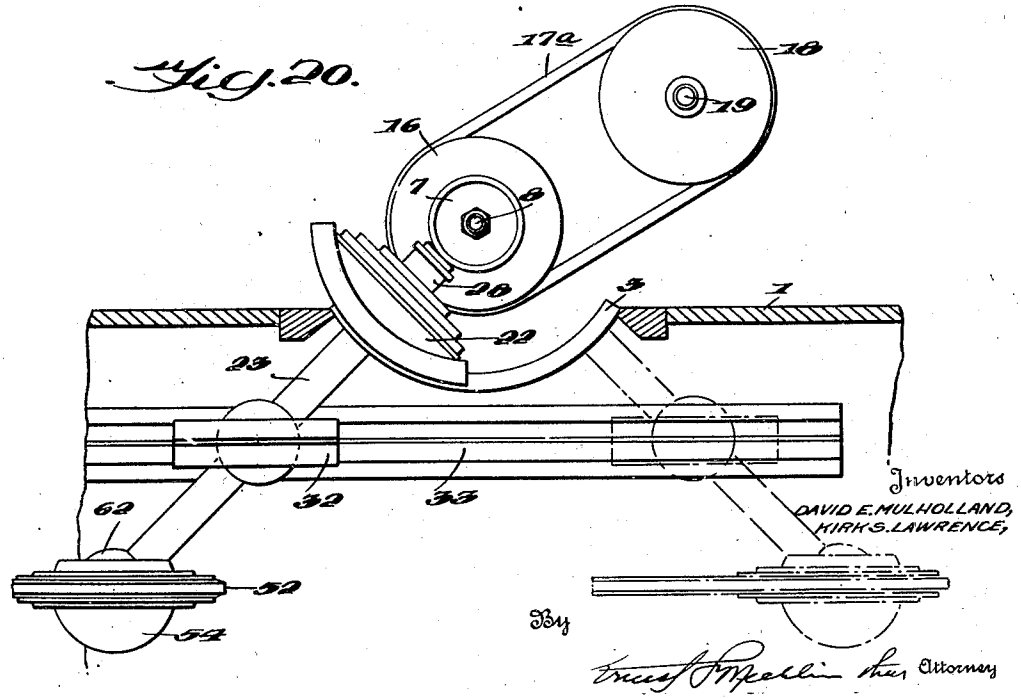


Fig. 20.



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By

Attorney

March 25, 1947. D. E. MULHOLLAND ET AL 2,418,085

SURFACING MACHINE

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Fig. 21.

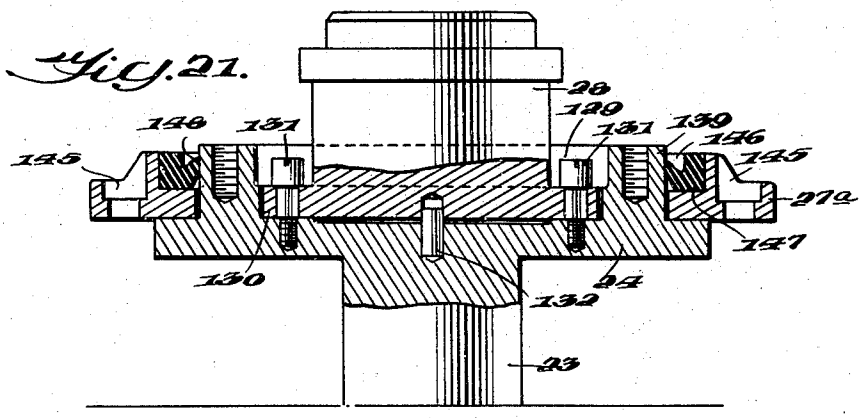


Fig. 22.

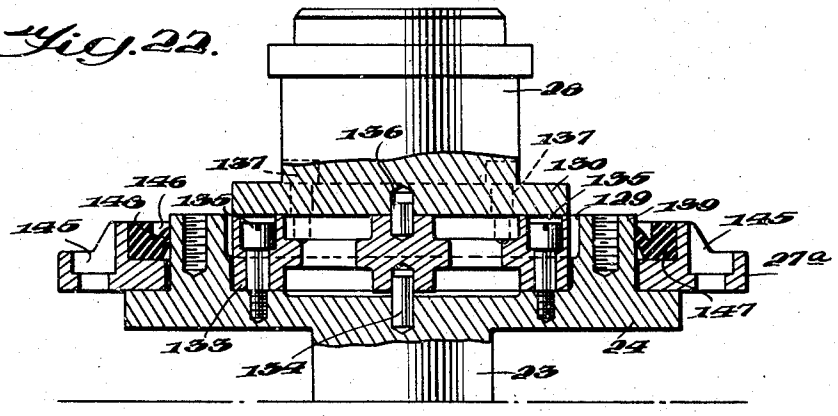
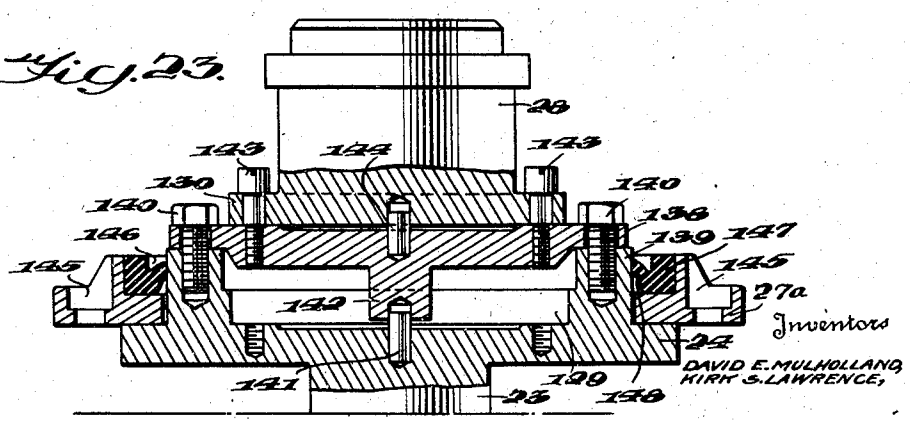


Fig. 23.



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SURFACING MACHINE

Filed May 24, 1943 18 Sheets-Sheet 15

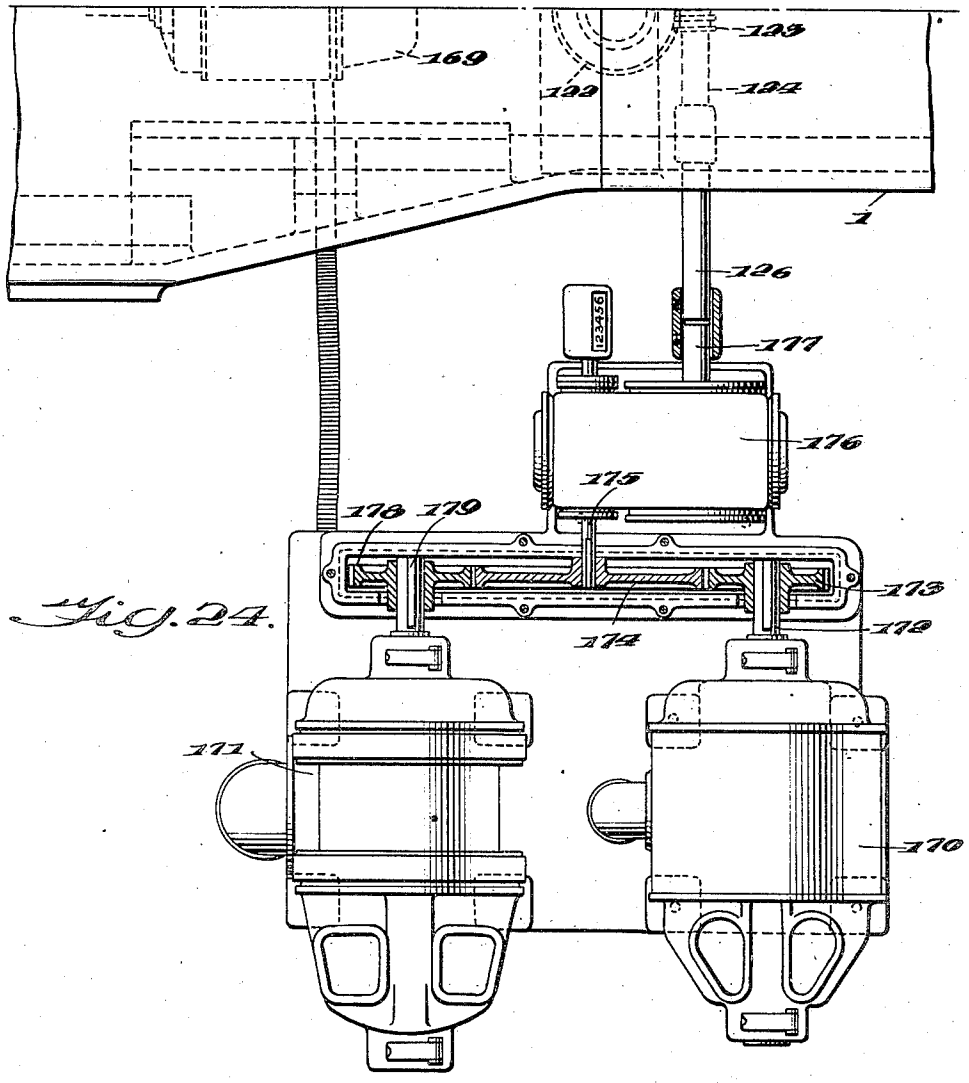

Fig. 24.

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March 25, 1947. D. E. MULHOLLAND ET AL 2,418,085

SURFACING MACHINE

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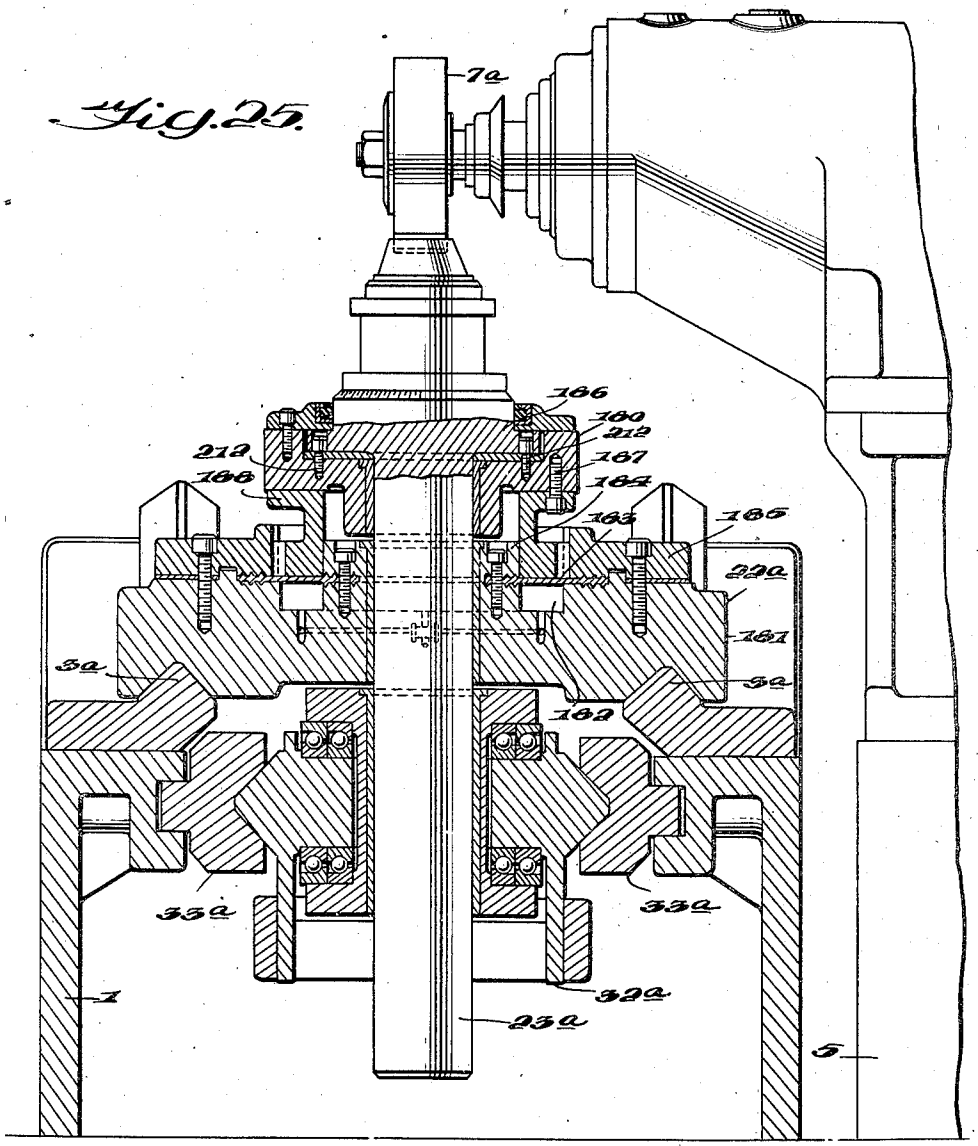
Fig. 25.



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SURFACING MACHINE

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Fig. 26.

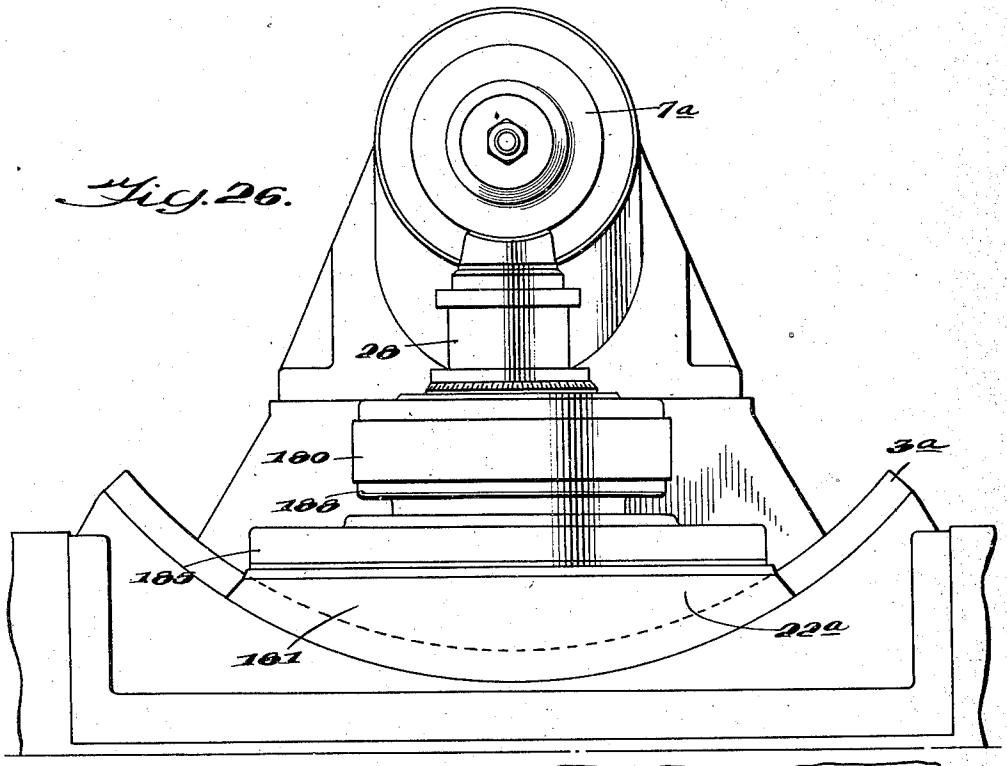
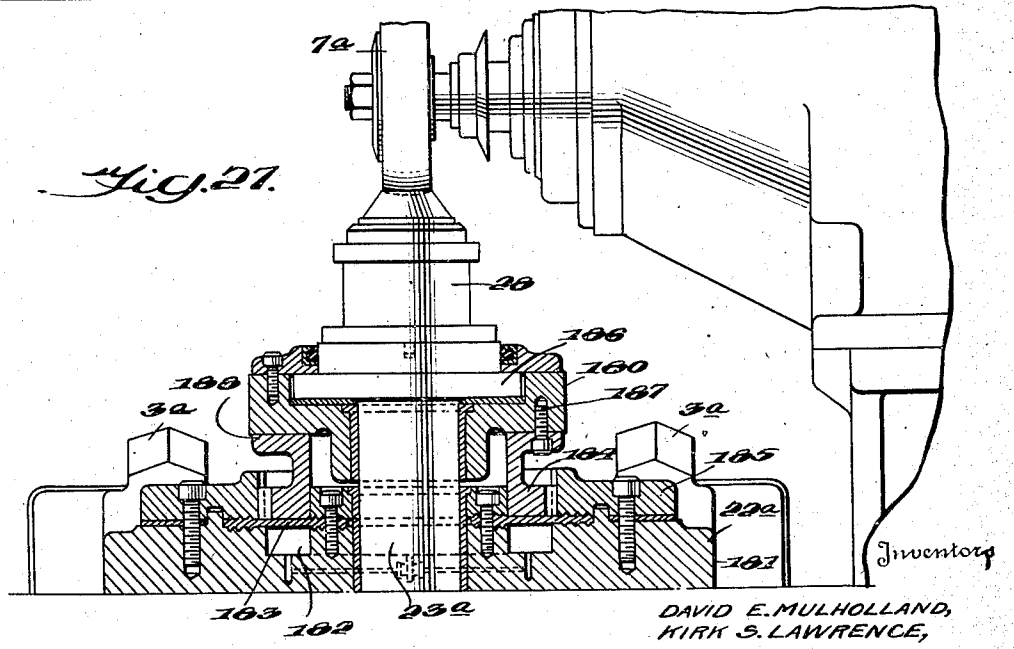


Fig. 27.



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March 25, 1947. D. E. MULHOLLAND ET AL 2,418,085

SURFACING MACHINE

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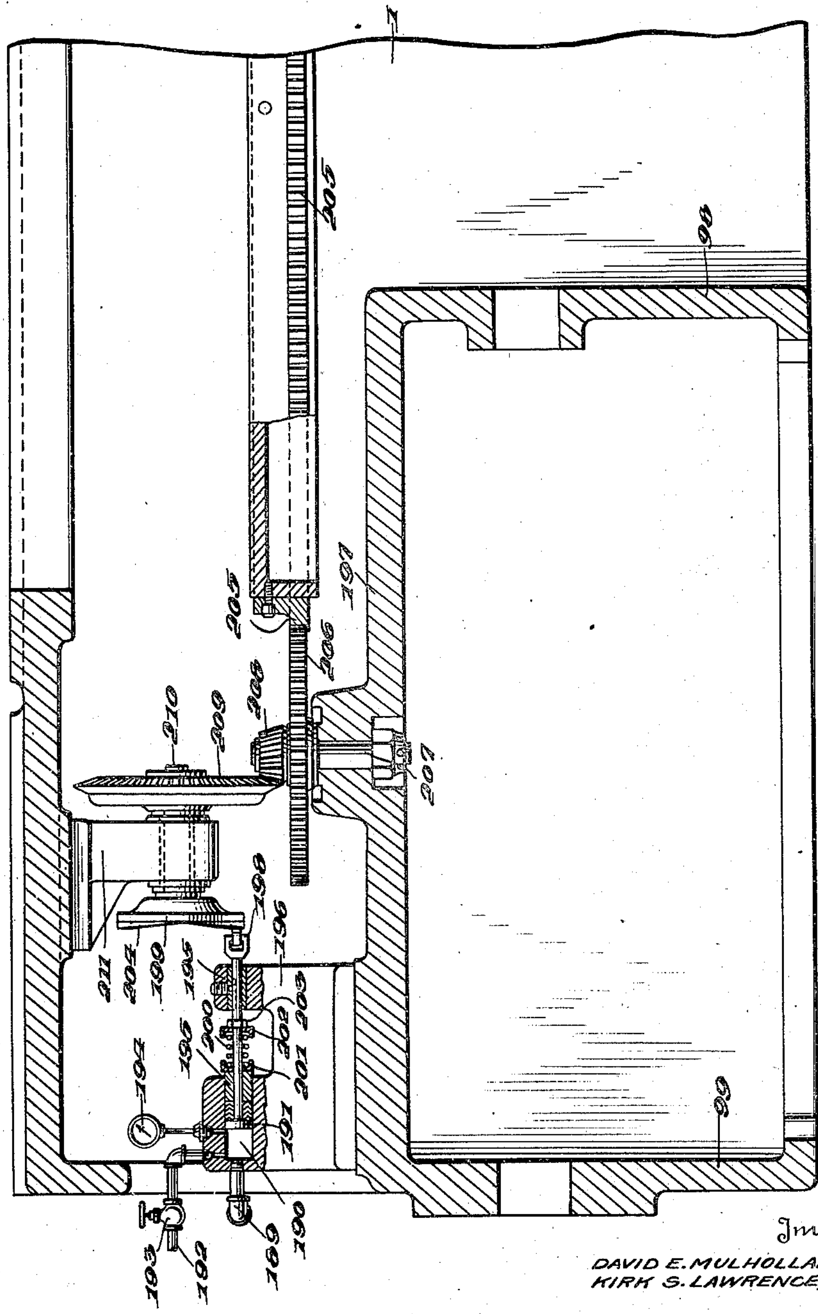
Fig. 28.



Inventors

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By [signature]
their Attorney

Patented Mar. 25, 1947 2,418,085

UNITED STATES PATENT OFFICE

2,418,085

SURFACING MACHINE

David E. Mulholland, Fort Myers, Fla., and Kirk S. Lawrence, West Reading, Pa.; said David E. Mulholland assignor to Walter S. Mulholland, Reading, Pa.

Application May 24, 1943, Serial No. 488,256

44 Claims. (Cl. 51—97)

1

This invention relates to grinding or polishing machines and, while being especially advantageous in the surfacing of lens blanks, it is generally useful in forming curved surfaces wherever precision is required.

The principal object of the invention is to provide a machine for forming curved surfaces whose degree of curvature is independent of the curvature of the surfacing means employed and is thus uneffected by wear of the surfacing means.

Another object of the invention is to provide a surfacing machine which by simple adjustment is selectively capable of producing any one of a great variety of curved surfaces, such, for example, as concave or convex cylindrical surfaces of either circular or non-circular sections, concave or convex spherical surfaces, and concave or convex aspherical surfaces.

A further object of the invention is to provide a surfacing machine which may be successfully operated by comparatively unskilled workmen for rapidly surfacing lens blanks with extreme precision, it being possible by the present invention to surface a succession of lenses at a rate much faster than any machine now in use and with a variation of less than .001 of an inch between any two of them.

A primary feature of the invention consists in providing a surfacing machine having a rotatable surfacing means and a work holding means with mechanism for moving the holding means and the work to and fro in a curved path transversely of the axis of rotation of the surfacing means while maintaining the work in engagement with the surfacing means.

Another feature of the invention consists in providing a surfacing machine with a curved guideway along which the work to be surfaced is moved to and fro while in engagement with the work surfacing means.

A further feature of the invention consists in providing a work surfacing machine with means for moving the work to and fro in a predetermined curved path in engagement with suitable surfacing means and in associating therewith means for rotating the work as it moves to and fro in engagement with the surfacing means.

A still further feature of the invention consists in providing a work holding means which is movable to and fro along a curved guideway for causing the work to move in a curved path in engagement with rotatable surfacing means, and in also providing means whereby the holding means may be selectively positioned at different distances from the guideway so that the degree of curvature imparted to the work may be varied.

2

A still further feature of the invention resides in providing a work surfacing machine with an arcuate guideway along which the work is movable to and fro in engagement with a rotatable surfacing wheel and with means whereby the center of curvature of the arcuate guideway may be selectively positioned on either side of the face of the work in engagement with the surfacing means so that, as desired, either a convex surface or a concave surface may be formed on the work.

Still another feature of the invention consists in mounting the work holding means which causes the work to move to and fro in a curved path upon a pivotally mounted beam which is capable of being rocked to maintain the work in engagement with the surfacing means, the pivotal mounting for the beam being vertically adjustable to enable the beam to move as a whole toward and away from the surfacing means.

Yet another feature of the invention consists in mounting a work holding member on a base which is adapted to swing to and fro in a curved path and in associating therewith means for moving the work holding means toward and away from the base as the latter swings to and fro in engagement with suitable surfacing means.

Other and more specific features of the invention, residing in advantageous forms, combinations and relations of parts will hereinafter appear and be pointed out in the claims.

In the drawings:

Figure 1 is a side elevational view of a machine embodying the invention.

Figure 2 is a plan view of the machine illustrated in Figure 1.

Figures 3 and 3*a* are enlarged complementary longitudinal vertical sectional views of the machine, Figure 3 illustrating the left half thereof as viewed in Figure 1 and Figure 3*a* illustrating the right half.

Figures 4 and 4*a* are enlarged complementary longitudinal horizontal sectional views of the machine, Figure 4 illustrating the left half thereof and Figure 4*a* the right half.

Figures 5 and 6 are transverse vertical sectional views taken on lines 5—5 and 6—6 respectively of Figure 3.

Figure 7 is a vertical sectional view taken on line 7—7 of Figure 5.

Figure 8 is a vertical sectional view taken on line 8—8 of Figure 3.

Figure 9 is a horizontal sectional view taken on line 9—9 of Figure 6.

Figure 10 is a view partly in section and partly in elevation taken on a line corresponding to line 10—10 of Figure 1.

Figure 11 is a side elevational view of the construction illustrated in the lower half of Figure 10 and is viewed from the left hand side thereof.

Figure 12 is a sectional view taken on line 12—12 of Figure 1.

Figure 13 is a detail sectional view taken on line 13—13 of Figure 11.

Figure 14 is a side elevational view of portions of the machine adjacent the work holding and surfacing means showing a device for supplying coolant to the work being surfaced.

Figure 15 is an end elevational view of the construction illustrated in Figure 14.

Figure 16 is a side elevational view of portions of the machine adjacent the work surfacing and work holding means, the particular relationship of the parts there illustrated being such as to produce a concave surface on the work.

Figure 17 is a transverse vertical sectional view of a form of grinding or polishing wheel suitable for forming a concave surface.

Figure 18 is a transverse vertical sectional view of a form of grinding or polishing wheel suitable for forming convex surfaces.

Figure 19 is substantially a diagrammatic view illustrating the relative position of various parts of the machine when set up to form a convex surface.

Figure 20 is substantially a diagrammatic view illustrating the relative position of various parts of the machine when set up to form a concave surface.

Figure 21 is a view partly in vertical section and partly in elevation of a slightly modified form of work holding unit.

Figures 22 and 23 are views partly in horizontal section and partly in elevation of the work holding unit shown in Figure 21 equipped with different sized filler members.

Figure 24 is a plan view of one of the control units of the machine.

Figure 25 is an enlarged transverse vertical sectional view, parts thereof being shown in elevation, of a modified form of the invention.

Figure 26 is a side elevational view of the form of the invention illustrated in Figure 25.

Figure 27 is a view similar to Figure 25 of another slightly modified form of the invention.

Figure 28 is a vertical sectional view taken on a line corresponding to line 28—28 of Figure 2 illustrating a modified form of the invention capable of use with the modifications illustrated in Figures 25 to 27, inclusive.

Referring more particularly to the drawings wherein the invention is shown as embodied in a machine particularly suitable for surfacing lens blanks, 1 indicates a beam which is mounted for limited pivotal movement upon a suitable base 2. The beam may be advantageously formed as a single casting and adjacent one end thereof it is provided with curved guideways 3 along which a work holding unit or device 4 is movable back and forth. Mounted above the work holding unit upon a suitable support 5 to one side of the beam is a work surfacing means 6 consisting of a rotatable work engaging wheel 7 carried on the outer end of the shaft 8 which is effectively restrained from the slightest vibration by being journaled within an elongated bearing 9 housed within a suitable bracket 10.

While the work engaging wheel 7 may be of any preferred construction, very satisfactory results have been obtained in the surfacing of lens blanks by using a wheel consisting of a hub portion 11 and a peripheral portion 12 composed of abrasive grains bonded in a resilient or elastic medium such as rubber or shellac. The wheel may be easily made rigid with the shaft and yet be adapted to be quickly removed therefrom by forming its hub with a central tapered opening for fitting over a correspondingly tapered extension 13 of the shaft and in providing the reduced outer end of the shaft with a screw threaded nut 14 which is adapted to coact with a thrust collar or washer 15 for forcing the wheel axially of the shaft.

On the inner end of shaft 8 are a pair of pulleys or sheaves 16 around which pass a pair of endless belts 17 adapted to be driven by pulleys 18 mounted on a shaft 19 of an electric motor 20. The electric motor is mounted on the same supporting base 5 as the work surfacing means 6. For a purpose which will hereinafter appear, the work surfacing means is vertically adjustable with respect to the beam 1 and consequently with respect to the motor 20. This adjustment may be accomplished by merely employing a removable block or member 21 which, when interposed between the supporting base 5 and the work surfacing means, maintains the latter in an elevated position as shown in Figures 3a and 10. When the block is removed however, the work surfacing means rests directly on the supporting base 5 and is thus supported at a lower elevation, as seen in Figures 16 and 20 of the drawings.

The work holding unit or device 4 comprises a base 22 and a spindle 23 which extends through an opening in the base and is provided at its upper end with a head or circular flange 24. The base 22 is adapted to move back and forth along the curved guideways 3 which are preferably arcuate in shape and it is formed on its under side with correspondingly shaped grooves into which the guideways extend.

As it is intended that the spindle shall be rotatable with respect to the base, the upper portion thereof is encased within a sleeve 25 formed of suitable anti-friction material and a washer 26 of the same material may advantageously be interposed between the head 24 of the spindle and the bottom of the circular recess in the base 22 in which the head is arranged. To maintain the spindle in operative association with the base, a suitable locking ring 27 may be employed which is arranged in overlapping relation with both the head of the spindle and the adjacent portion of the base, being rigidly secured to the latter by any suitable means such as machine screws (not shown). Mounted on the head of the spindle is a work holding member 28 on which a lens blank 29 is mounted in plaster of Paris or other suitable material 30. Depending on the distance at which it is desired to support the lens blank above the beam, the work holding member 28 may be detachably secured directly to the head 24 of the spindle or one or more filler blocks 31 may be interposed between the work holding member and the spindle head as shown in Figures 3a and 19.

Arranged within the beam 1 is mechanism for moving the work holding unit 4 to and fro along the curved guideways 3, as well as mechanism for simultaneously rotating the spindle. The mechanism for moving the work holding unit to and fro may advantageously consist of a rectilinearly movable carriage or the like 32 which is

slidably mounted in a pair of opposed guideways 33 having rearwardly projecting ribs 34 fitting within grooves 35 formed by channel-shaped members 36 rigid with the side walls of the beam 1. The guideways are maintained in place and at the proper distance apart by a plurality of set screws or the like 37.

The carriage 32 has a pair of inwardly projecting horizontally arranged trunnions 38 on which are rotatably mounted a sleeve 39 which encircles the spindle 23 and is slidable longitudinally thereof. So that the sleeve 39 will freely swing with respect to the trunnions 38, ball bearings are preferably interposed between these parts. With the sleeve 39 being swingable with respect to the carriage and slidable longitudinally of the spindle, it is evident that, when the carriage is reciprocated rectilinearly, the spindle and the base 22 which is movable along the curved guideways 3 will move or swing to and fro in a curved path.

The means for moving the carriage back and forth consists of a rotatable member 40 which may be advantageously in the form of a circular disk and be provided on its upper surface with radially arranged guideways 40a between which is movably mounted a crank arm 41. Pivotally secured to the crank arm is one end of a connecting rod 42 whose other end is pivotally secured by a suitable bolt or the like 43 to the carriage 32. Rotary motion may be imported to the disk 40 in any suitable manner, such, for example, as by a fluid motor 44 which may be mounted upon a bracket 45 depending from a transversely extending member 46 which is rigidly secured to the side walls of the beam 1 and affords a support for the disk 40. The motor 44 is coupled to a shaft 47 which is journaled in suitable thrust bearings 48 and is connected at its upper end to the under side of the disk 40.

The distance the carriage 32 is caused to move back and forth by the disk 40 and the connecting rod 42 may be controlled and adjusted by changing the location of the crank arm 41 with respect to the center of rotation of the disk. For this purpose, the crank arm is preferably mounted upon a screw threaded rod 49 which is rotatably mounted at its inner end in a bracket 50 formed upon the top of the disk. By rotating the screw threaded rod 49, the crank arm 41 may be readily moved either toward or away from the axis of rotation of the disk to vary the distance the carriage 32 will be displaced. A lock nut 51 may, of course, be used for locking the rod 49 against rotation.

The mechanism for rotating the spindle 23 as it is swung to and fro by the carriage 32 involves an endless belt 52, a driving pulley 53 and a driven pulley 54. The driving pulley 53 is mounted on a shaft 55 of a fluid motor 56 which may be conveniently supported upon a transversely extending member 57 which is adjustable longitudinally of the beam 1 and has laterally projecting ribs 58 fitting within grooves formed in the inner side of the adjacent portion of the side walls of the beam. The member 57, and consequently the motor 56, may be secured in a desired position of adjustment by a pair of set screws 59 which may be respectively threaded in brackets 60 integral with the side walls of the beam.

The driven pulley 54 is mounted on the lower end of a rigid extension 61 of the spindle 23. To enable the driven pulley to angle with respect to the spindle as it swings to and fro, the lower end 62 of the extension 61 is preferably of spherical shape and the pulley has a spherically

shaped cavity into which the portion 62 fits. The pulley is preferably made in two parts, an upper part 63 and a lower part 64, which are secured together in any suitable manner, and projecting inwardly from one or both of the parts is a boss or lug 65 which extends into a vertically extending groove 66 in the spherical lower end of the extension 61 whereby the pulley and spindle are keyed together to rotate as one and yet are free to angle with respect to each other.

To compensate for the relative movement between the driving and driven pulleys 53 and 54 respectively and to at all times maintain the endless belt 52 under sufficient tension to transmit motion from the driving pulley to the driven pulley, two pairs of relatively movable pulleys 67 and 68 are provided. Pulleys 67 are mounted relatively close together on the upper side of a member 69 which is slidable longitudinally of the beam 1 in guideways 70 suitably secured to the side walls of the beam. Pulleys 68 are mounted adjacent the side walls of the beam on the under side of a member 71 which like member 69 is movable longitudinally of the beam in guideways 72 rigid with the side walls of the beam.

The portions of the endless belt 52 leading to and going from the driving pulley 53 pass around the pulleys 67, while the portions of the endless belt leading to and going from the driven pulley 54 pass around the pulleys 68. So that the idle pulleys 67 and 68 will function to maintain the endless belt 52 under the desired substantially uniform tension as the driven pulley 54 swings to and fro, member 71 is provided with an extension 73 which is directly connected by a bolt or any suitable means 74 to a downwardly offset forwardly projecting portion 75 of the carriage 32. Pulleys 68 thus move to and fro with the carriage and to the same extent. However, since the driven pulley on the lower end of the spindle 23 is also moved by the carriage but yet travels in an arc, it moves at a greater rate and is displaced a greater distance longitudinally of the beam than the carriage. To compensate for this differential in movement between the carriage 32 and the pulley 54 on the lower end of spindle 23, pulleys 67 are caused to move longitudinally of the beam at a different rate than pulleys 68. This is accomplished by providing the under side of the extension 73 with a rack 76 which meshes with a gear 77 rotatably mounted upon a transversely extending shaft or axle 78 whose outer ends are suitably suported in the side walls of the beam 1. The gear 77 is keyed to a sleeve 79 which is freely rotatable with respect to the shaft and is held against longitudinal movement thereof by a pair of collars 80 adjustably secured to the shaft. Sleeve 79 extends beyond one side of the gear 77 and is there in the form of a gear wheel 81 to mesh with an overlying rack 82 which is rigidly connected to the member 69 on which idle pulleys 67 are mounted. The ratio between gears 77 and 81 is such that the difference in the rates of movement of the two pairs of idle pulleys 67 and 68 is sufficient to compensate for the difference in horizontal displacement between the carriage 32 and the driven pulley 54 on the lower end of spindle 23 and thereby maintain the endless belt 52 under substantially uniform tension at all times.

It is evident that, as the work holding unit swings to and fro in a curved path, the work itself is also caused to move to and fro in a curved path. While the work is thus moving, it is main-

tained in engagement with the rotatable surfacing wheel 7 by applying a force to the beam 1 which will cause it to rotate in a counter-clockwise direction as viewed in Figure 1. Hydraulic means is preferably employed for rotating the beam in this direction as well as in the opposite direction and such means may advantageously consist of two opposed flexible diaphragms 83 and 84 which are respectively mounted within otherwise open-ended cylinders 85 and 86. Each of the cylinders 85 and 86 has a passageway 87 communicating at one end with the interior of the associated diaphragm and communicating at its other end with a common source of fluid pressure (not shown). The lower cylinder 85 may be conveniently supported on the base 2 of the machine, while the inverted upper cylinder 86 is rigidly connected to the web portion 88 of a yoke-shaped member 89, the legs or arms 90 of which straddle the lower cylinder 85 and are rigid with the base 2.

Interposed between the flexible diaphragms 83 and 84 is a strut or post 91 which is rigidly connected to the web 92 of a yoke 93 whose arms or legs 94 extend upwardly on opposite sides of the upper cylinder 86 and are rigidly connected at their upper ends to inturned rigidifying flanges 95 formed integrally with the lower edges of the adjacent portion of the side walls of the beam 1. It will thus be seen that, when fluid under pressure is admitted to the diaphragm 83 in the lower cylinder 85 and released from diaphragm 84 in the upper cylinder 86, the beam is caused to move in a direction to maintain the work in engagement with the surfacing wheel 7, while, if fluid under pressure is admitted to diaphragm 84 in the upper cylinder 86 and released from diaphragm 83 in the lower cylinder 85, the beam will be caused to pivot in the opposite direction to move the work away from the surfacing wheel.

The beam is preferably balanced so that it will immediately respond to changes in the forces to which it is adapted to be subjected by the fluid pressure operated diaphragms 83 and 84. A condition of approximate balance may be readily maintained by providing the beam with a longitudinally adjustable counterweight 96. Adjustment of the counterweight may be easily effected by mounting it on a rotatable screw threaded shaft 97 whose inner end may be supported in a transverse partition wall 98 of the beam and whose outer end may be supported in the end wall 99 of the beam. The outer end of shaft 97 is formed with a bevel gear 100 which meshes with a bevel gear 101 on the inner end of a transversely extending shaft 102 rotatably mounted in a suitable bracket 103 secured to the end wall of the beam. The outer end of shaft 102 has a hand wheel 104 whereby it may be easily rotated to effect rotation of shaft 97 and thus cause longitudinal adjustment of the counterweight 96.

Pivoted movement of the beam in a direction causing the work to move away from the surfacing wheel 7 is limited by an adjustable stop means which is preferably mounted on the end of the beam opposite the counterweight 96 and it may conveniently consist of a vertically adjustable stop member 105 which is screw threaded into the hub of a rotatable hand wheel 106 suitably journaled in brackets 107 and 108 respectively secured to the end wall 109 of the beam. The lower end of the stop member 105 is adapted to abut against a pad or block 110 mounted on a flange 111 projecting laterally from the upper portion of the yoke 89 which is rigidly secured to the base 2 of the machine. It will thus be seen that the extent to which the beam may be moved in a direction to move the work away from the surfacing wheel may be readily adjusted by merely rotating the hand wheel 106.

Movement of the beam in the opposite direction is also limited by suitable stop means for controlling the amount of material which the surfacing wheel 7 will remove from the face of the work being surfaced. This means preferably comprises a yoke member 112 which extends downwardly from the beam and comprises laterally spaced legs or arms 113 integrally connected at their lower ends by a substantially horizontal web portion 114. The arms of the yoke may be suitably reinforced by marginal ribs or flanges 115 and the lower end of the yoke preferably extends down into a well or recess 116 formed in the base of the machine.

Arranged within the yoke 112 and supported on legs 117 straddling the yoke is a housing or casing 118 in which is mounted a verically adjustable stop member 119. The upper end of the stop member is journaled in vertically spaced bushings 120 while its lower end is screw threaded into a collar or the like 121 rigidly secured to the housing 118.

To rotate the stop member and thus cause it to move axially, a gear 122 may be conveniently splined to the upper end of the stop member between the two bushings 120. The connection between the gear and the stop member is such that rotation of the gear will impart corresponding movements to the stop member but yet the latter is free to move axially with respect to the gear. For rotating the gear 122, a worm 123 is preferably mounted upon a horizontally arranged shaft 124 which is suitably journaled in the housing 118. One end of the shaft 124 projects through a slot 125 in the upper portion of one of the arms 113 of the yoke 112 where it may be conveniently coupled to a shaft 126 of mechanism, to be hereinafter described, which is preferably employed for rotating the worm 123 for raising and lowering the stop member from its illustrated position.

Mounted in the lower end of the stop member is a ball 127 which, when the beam is rotated in a direction to move the work upwardly, is engageable by a pad or bearing block 128 carried on the web 114 of the yoke 112. The stop member thus functions to arrest and limit movement of the beam in a direction causing movement of the work toward the surfacing wheel, but instead of setting it at the beginning of each grinding operation so that it will not coact with the beam until after the desired amount of material has been removed from the work, it is preferred that the stop member be continuously operated so that it constantly coacts with the beam to control and restrain movement thereof throughout the grinding operation. This is accomplished by setting the stop member so that it will be engaged by the bearing block 128 on the yoke 112 of the beam just before the beam assumes a position which would enable the work to engage the surfacing wheel and then continuously rotating the stop at such a rate that the beam cannot move upwardly beyond a predetermined point, that is the distance separating the stop member from the pad 128 on the yoke member 112. In this manner the beam will remain in substantially the same position even when the work, as illustrated in Figure 19, moves out of contact with the surface of the grinding wheel, and thus will prevent damage to the work which might be caused if the upward

movement of the beam is restrained only by the engagement of the work with the surface of the wheel.

When the stop is operated in the manner described to continuously restrict the movement of the beam, the surfacing wheel will continue to remove material from the face of the work with which it is in engagement as long as the stop member rotates, but as soon as rotation thereof ceases, movement of the beam in a direction causing upward movement of the work is immediately arrested and the surfacing wheel is thereby prevented from removing further material from the work. The mechanism hereinafter described for effecting rotation of the stop member is preferably of such construction that rotation of the stop member will be automatically stopped after being raised to a predetermined point.

The contour or shape of the surface formed on the work by the wheel is controlled by the movement imparted to the work. In the forms of the invention illustrated in Figures 1 to 24, inclusive, the guideways 3 are of arcuate shape and consequently as the work holding unit 4 moves to and fro along the guideways, the work is caused to move to and fro in an arcuate path. If, as shown in Figure 19, for example, the work is spaced a distance from the guideways greater than the radius thereof, it will trace an arc forming the upper portion of a circle concentric with the guideways, but if the work is arranged as shown in Figure 20, for example, so that it is spaced from the guideways a distance less than the radius thereof it will trace an arc forming the lower portion of a circle concentric with the guideways. With the work arranged as shown in Figure 19 and maintained in engagement with the surfacing wheel 7 it will be appreciated that a convex surface will be imparted to the upper surface thereof, and with the work arranged as shown in Figure 20 and maintained in engagement with the surfacing wheel a concave surface will be generated thereon. In the arrangement shown in Figure 19 the work is positioned so far above its axis of swing, which is the same point as the center of curvature of the guideways, that it swings into and out of engagement with the surfacing wheel, but the limit stop 119 arrests upward movement of the beam when the work moves from engagement with the wheel and the source of fluid pressure supplied to the lower diaphragm 83 for swinging the beam in a direction to cause the work to move upwardly is such that as the work swings back into engagement with the surfacing wheel, the beam is held in such position that the engagement between the work and the wheel will be substantially tangent to the surface.

The degree of curvature to be imparted to the face of the work to be surfaced may be varied simply by changing the position of the work with respect to the center of curvature of the guideways 3. This may be accomplished in the structure shown in Figure 19 by removing one or more of the filler blocks 31 or by employing filler blocks of different thickness. It is to be particularly noted that the diameter of the surfacing wheel will have no influence whatever upon the degree of curvature imparted to the work as this is controlled entirely by the path of movement of the work.

In the form of the invention illustrated in Figures 1 to 24, inclusive, the work, as has been explained, is rotated while it is being moved to and fro in a curved path. The effect of simultaneously rotating the work and moving it to and fro is to produce a spherical surface on the face thereof which is in engagement with the surfacing wheel. Thus such compound motion when imparted to the work arranged as shown in Figure 19 will result in a convex spherical surface being formed thereon, and when imparted to the work as shown in Figure 20 will result in the generation of a concave spherical surface.

In forming concave surfaces, it is necessary for the center of curvature of the guideways to be positioned above the axis of rotation of the surfacing wheel if a concave surface of greater radius than the radius of the wheel is to be formed. To permit of this relationship between the centers of curvature of the guideways and of rotation of the surfacing wheel, the beam may be moved bodily upward or, as is preferred the surfacing wheel may be lowered into the position shown in Figures 16 and 20 by removing the removable block or filler 21. In lowering the grinding wheel, the endless belt 17 must be removed from the pulleys 16 and 18 and a longer belt 17a substituted therefor.

To generate a concave surface of smaller radius than shown in Figure 20, the grinding wheel shown in that figure will have to be replaced by a smaller one. Using a wheel of smaller diameter will, of course, necessitate moving the work nearer the axis of rotation of the wheel in order to have it engage the periphery thereof. This shifting of the position of the work is preferably accomplished by interposing filler blocks of various thicknesses between the head 24 of the spindle 23 and the work holding member 28 instead of moving the beam with respect to the axis of the wheel.

As is shown in detail in Figure 21, the head 24 of the spindle 23 is formed with a circular recess 129 in which the work holding member 28 is seated. The base of the work holding member is provided with a peripheral flange 130 for receiving a plurality of cap screws 131 whereby it may be rigidly connected to the spindle, the work holder being initially centered with respect to the spindle by a pin 132.

One form of filler which may be advantageously interposed between the spindle head 24 and the work holding member 28 to elevate the work itself is shown in Figure 22. As there illustrated, the filler may comprise a substantially circular casting 133 positioned within the recess 129 of the spindle head, it being centered with respect to the spindle by a pin 134 and being made rigid therewith by a plurality of cap screws 135. The work holding member 28 is centered with respect to the filler, and consequently with respect to the spindle, by a pin 136 and it is made rigid with the filler by cap screws 137.

To position the work holder still closer to the axis of the finishing wheel, a filler member 138 of the character illustrated in Figure 23 may be advantageously employed. Here the filler is mounted on an annular flange 139 on the spindle head 24 which defines the circular recess 129, it being secured to the flange by bolts 140 and being centered with respect to the spindle by a pin 141 which fits within a recess formed in the under side of a depending boss 142. As in the structure illustrated in Figure 22, the work holding member is connected to the filler 138 of Figure 23 by cap screws 143 and it is centered with respect thereto by a pin 144.

In each of Figures 21, 22 and 23 there is shown a slightly modified form of locking ring 27a for

securing the spindle 23 to the base 22 of the work holding unit. This locking ring has suitably shaped apertures 145 for receiving cap screws (not shown) to rigidly connect it to the base 22 and it is formed on its inner side with an annular recess 146 in which is arranged a gasket or sealing ring 147 of rubber or other suitable material. The gasket has an inwardly extending deformable portion 148 which bears firmly against the outer surface of the upstanding flange 139 of the spindle head and thus effectively prevents water or other liquid which may be sprayed on the face of the work being surfaced, as well as the ground material, from seeping down around the spindle on to the reciprocating carriage 32.

When one or more of the filler blocks 31 illustrated in Figure 19 are removed or replaced by filler blocks of different thickness to lower the position of the work with respect to the beam and thus enable a convex surface of smaller radius than that shown to be generated, the work holding unit is moved upwardly to cause the work to engage the surfacing wheel. Upward movement of the holding means to compensate for lowering the work with respect to the beam is preferably accomplished by moving the beam bodily upward, rather than by rotating it about its pivotal axis, since such bodily movement of the beam makes it possible for the beam to be so adjusted that it will assume the same angular position with respect to its pivotal axis at the conclusion of each surfacing operation irrespective of the character or radius of the surface generated and the wear of the surfacing wheel. This function of the machine enables each surface to be generated in the same relative position as to a predetermined point on the work holder and is particularly advantageous in forming on the lens blank either an aspherical or a cylindrical surface of non-circular section. If aspherical surfaces are so formed it will be obvious that subsequent edge grinding about the same point as a center will bring the geometrical center of the blank into coincidence with the main optical axis of the blank.

All surfaces formed by rotation of the spindle and simultaneous rocking of the beam will be symmetrical on the axis of rotation of the spindle. The ability of the machine by which the center of rotation of the beam can be moved to correspond with the movement of the stop enables the beam to be so positioned at the conclusion of the grinding operation that a line perpendicular to the tangent at the mid-point of the curved path traversed by the work intersects the axis of rotation of the surfacing wheel. This position of the beam will be indicated by the precision instruments used in connection therewith and thus render unnecessary independent supplemetary mathematical calculations which are essential if the final orientation of the beam is at any other angle.

Not only does vertical movement of the beam as a whole enable it to be adjusted so that, irrespective of the degree of curvature imparted to the work, it will assume the same angular position with respect to its pivotal axis at the conclusion of each surfacing operation, but such adjustment of the beam also makes it possible to compensate for wear of the surfacing wheel and still have the beam assume the desired angular position a the conclusion of each surfacing operation.

The ability of the machine to maintain at the conclusion of each grinding operation a definite angular position of the beam with reference to a vertical line passing through the axis of rotation of the grinding wheel is, as pointed out above, advantageous. It is possible, however, with the machine to produce on each of a series of lens blanks identical spherical lens surfaces without regard to the angular position or orientation of the beam so long as the center of curvature of the ways are maintained at a constant radial distance from the surface of the grinding wheel.

Due to the manner of forming a spherical surface on a lens blank by the present invention, subsequent centering of the lens may be easily and most expeditiously effected by merely removing from the machine the lens blank and the holding member therefor without disconnecting these parts and mounting and centering them as a unit on a rotatable chuck so that the axis about which the lens and holder were rotated in the machine coincides with the axis of rotation of the chuck. The blank may then be quickly edge ground to bring the mechanical axis thereof into coincidence with the optical axis of the lens.

The vertical adjustment of the beam is preferably accomplished by providing the beam with outwardly projecting trunnions 149 which are suitably journaled within vertically movable bearings 150. Each of the bearings has oppositely extending ribs 151 which respectively fit within vertically arranged guideways or grooves 152 formed in the inner faces of the upright arms 153 of the side frame members 154 of the machine. Depending downwardly from each of the bearings 150 and preferably formed integrally therewith is a tubular-like portion 155 in which is arranged an interiorly threaded sleeve 156 for receiving an exteriorly threaded vertically disposed shaft 157 which may be conveniently mounted adjacent its lower end in a pair of vertically spaced bearings 158 of suitable construction. The bearings 158 are mounted in the upper and lower walls respectively of a two-part housing 159 carried upon the base 2 of the machine.

Each shaft 157 may be advantageously rotated to effect vertical displacement of the bearing 150 associated therewith by means of a worm 160 and a worm gear 161 arranged within the housing 159, the worm gear 161 being keyed to the shaft 157 and the worm 160 being mounted on a shaft 162 which is rotatably supported in suitable bearings in the walls of the housing and projects through the inner wall thereof. Where the shaft extends through the inner wall of the housing, a stuffing box 163 may be conveniently provided for preventing leakage of lubricant from the housing.

The inner ends of both shafts 162 are preferably coupled to an intermediate shaft 164 so that they may be rotated in unison to the same extent. Shaft 164 is rotatably mounted in the side walls of a housing 165 and splined to the shaft within the housing is a worm gear 166 which is adapted to be rotated by a worm 167 carried by a shaft 168 which is journaled in the upper portion of the housing and is connected to a motor 169 which preferably constitutes one of the units of a pair of synchronous devices known in the trade as "Selsyn" devices. Being thus operatively connected to motor 169, shafts 162 are simultaneously rotatable in the same direction to cause bearings 150 to move vertically in unison to adjust the elevation of the beam 1.

The angular position which the beam occupies

at the conclusion of each surfacing operation is determined by the setting of the stop member 119 as well as by the position of the pivotal axis of the beam. Means is, therefore, preferably provided for synchronizing the adjustment of the stop member 119 and of the bearings 150. This means may advantageously consist of an electric motor 170 and two "Selsyn" units 169 and 171 respectively. A "Selsyn" device is a miniature bipolar alternator in which the primary is a single-phase concentrated winding, while the secondary is a three-phase, Y-connected winding. The primaries of the two units are connected to the same single-phase power supply. The three induced voltages in the secondary are also single-phase but they vary in magnitude, depending upon the relative positions of the rotor and stator. When the rotors of the two "Selsyns" are in corresponding positions, the secondary voltages are equal in magnitude, but vectorially opposite in direction and no current flows in the secondary. However, if the rotors are displaced relatively to each other, i. e. if they are not in phase correspondence, the voltages do not balance and current flows through the secondary circuit. This circulating current produces a synchronizing torque.

Motor 170 which actuates "Selsyn" unit 171 is provided with a shaft 172 to which is keyed a gear wheel 173 which meshes with a gear 174 mounted on an imput shaft 175 of a conventional gear reduction unit 176 whose output shaft 177 is directly coupled to shaft 126 for actuating the stop member 119. Also meshing with gear 174 is a gear 178 which is keyed to shaft 179 of "Selsyn" unit 171. The two Selsyn units are electrically connected so that for every revolution of the rotor of unit 171 the rotor of Selsyn unit 169 which controls the adjustment of the bearings 150 of the beam will make a like number of revolutions. By thus operatively connecting the means for actuating the limit stop 119 and the bearings 150, it will be seen that the limit stop and the beam as a whole may be simultaneously shifted vertically exactly the same distance but those skilled in the art will appreciate that the Selsyn units may be operated so that separate adjustment of the stop and beam may be effected, should that be desired.

Figures 25 to 28, inclusive, illustrate forms of the invention wherein surfaces other than convex and concave spherical surfaces may be generated. In these embodiments, means is provided for moving the spindle 23*a* axially as it is swung to and fro by a reciprocating carriage 32*a* which is of the same construction as the carriage 32 and in like manner is slidably mounted in guideways 33*a*. By moving the spindle axially as it swings to and fro, the work can be caused to traverse a curved path of practically any desired shape, either symmetrical or otherwise, and since the particular path in which the work moves determines the contour of the surface which will be imparted to it by the surfacing wheel, it will be appreciated that surfaces of practically any shape and contour may be generated.

Axial movement may be conveniently imparted to the spindle 23*a* by forming the base 22*a* in which it is mounted into two relatively movable parts, an upper part 180 and a lower part 181. Like the base 22, the lower part 181 of the base 22*a* has recesses on its under side for fitting the curved guideways 3*a* along which it is movable to and fro. The upper face of the lower part 181 of the base is formed with an annular recess or chamber 182 having a plurality of inlet ports for communicating with a source of fluid. The chamber is closed by a flexible diaphragm 183 whose inner edge is rigidly clamped to the lower part of the base by a ring or collar 184 and whose outer edge is similarly clamped by an annular plate 185.

The upper part 180 of the base 22*a* is formed with a recess in its upper portion in which the head 186 of the spindle 23*a* is seated. Depending from the under side of the upper part 180 of the base and rigidly secured thereto as by cap screws 187 is a sleeve or collar 188 which extends down into the space between the diaphragm clamping members 184 and 185 into engagement with the diaphragm. The collar 188 is splined to the clamping member 185 so that the upper and lower parts of the base will be locked against rotation but it is free to move vertically with respect to the lower part of the base in response to movement of the diaphragm 183. Changes in the volume of the fluid under pressure contained within the chamber 182 will actuate the diaphragm 183 and it in turn will move the upper part 180 of the base with respect to the lower part 181 thereof and thus cause the spindle 23*a* to move axially.

To control the extent of axial movement of the spindle 23*a* and consequently the character of the curve imparted to the work, the inlet ports of chamber 182 are connected by a pipe 189 to a chamber 190 in which a piston 191 is movably mounted. The two chambers 182 and 190 and the connecting pipe 189 constitute a closed system to which fluid under pressure may be supplied through a pipe 192 having a valve 193. The pressure of the fluid within the closed system, which may be conveniently indicated on a gauge 194, is preferably maintained sufficiently high to balance the weight of the spindle 23*a* and of the parts carried thereby to which the diaphragm is subjected, so that any movement of the piston 191 will effect a change in volume of the fluid in chamber 190 which, in turn, will immediately cause a corresponding change in the volume of the fluid in chamber 182 and thus, through movement of the diaphragm 183, induce a raising or lowering of the spindle 23*a* depending upon whether the volume of the fluid in chamber 182 is increased or decreased.

The spindle 190 may be conveniently supported in spaced bearings 195 suitably mounted in a casting or the like 196 in which the chamber 190 may be formed and which as a whole may be carried on a horizontal wall 197 of the beam 1 which, with the transverse walls 98 and 99, forms a housing for the counterweight 96. At its inner end, the piston 191 is provided with a roller 198 adapted to bear against a rotatable disk or plate 199, it being maintained in engagement with the plate by a coiled expansion spring 200 interposed between spring caps 201 and 202 respectively. Spring cap 201 seats against one of the bearings 195 and the piston is freely movable with respect thereto but spring cap 202 backs up against a nut 203 which is threaded on the piston rod and consequently serves as a movable abutment with which the spring coacts to maintain the inner end of the piston in engagement with the rotating disk 199.

On the outer face of disk 199 along the portion thereof traversed by roller 198 of the piston 191 is arranged a cam surface 204 which, upon rotation of the disk, is adapted to move the piston outwardly and by means heretofore explained effect an upward movement of spindle 23*a*.

Spring 200 by causing the inner end of the piston to track with the cam will move the piston inwardly at suitable intervals during the rotation of disk 199 and, when this occurs, the active grinding pressure, that is the pressure between the work and the surfacing wheel, will force fluid from chamber 182 into chamber 190 and thus enable the spindle 23a to move downwardly. Any desired form of cam surface may be used on the disk 199 and consequently the curved path through which the work is moved by the spindle may be greatly varied, whereby any one of many different curved surfaces may be imparted to the work.

Disk 199 is preferably rotated in timed relation with the swinging movement imparted to the spindle 23a by driving it through a train of gears from a ring gear 205 mounted on the crank disk 40 which by means heretofore described actuates the reciprocating carriage 32 which causes the spindle to swing to and fro. The train of gears for rotating disk 199 consists of a gear wheel 206 which meshes with the ring gear 205 and is mounted upon a shaft 207 journaled in the horizontal wall 197 of the beam 1. On the upper end of shaft 207 is a bevel gear 208 which meshes with a larger bevel gear 209 carried on one end of a shaft 210 on the opposite end of which the disk 199 is mounted, shaft 210 being conveniently supported by a bracket 211 secured to the top wall of the beam 1.

In the form of the invention illustrated in Figures 25 and 26, the spindle 23a is locked against rotation by cap screws 212 so the lower end of the spindle is unprovided with a driving pulley as shown in the form of the invention illustrated in Figures 1 to 24, inclusive. If the only motion imparted to the spindle and work illustrated in Figures 25 and 26 is a swinging motion, the work will move in an arcuate path because the guideways 3a are in the form of an arc. Consequently, the surface imparted to the work by the surfacing wheel 7a will be a cylindrical surface of circular section. However, by moving the spindle axially the proper extent at the proper times by use of the mechanism heretofore described in conjunction with a suitable cam surface on the rotatable disk 199 a cylindrical surface of non-circular cross section may be generated.

In the form of the invention illustrated in Figure 27, the spindle 23a is not locked against rotation with respect to any part of the base 22a and it is intended to be rotated with respect to the base by the means heretofore described in the embodiment of the invention illustrated in Figures 1 to 24, inclusive. By simultaneously rotating the spindle and moving it axially while swinging to and fro, an aspherical surface of revolution may be generated on the work, that is a surface of revolution in which the radius of curvature of the contour of a polar section varies from point to point, symmetrically with respect to the polar axis. Of course, either a convex or concave aspherical surface may be formed depending upon, as heretofore explained, whether the center of curvature of the guideways is above or below the lowest point on the periphery of the surfacing wheel.

The curved guideways 3 and 3a of each of the embodiments of the invention are preferably removably mounted so that guideways of any desired curvature may be applied to the machine. They may be arcuate as shown, or otherwise just as desired.

In the surfacing of lens blanks, it is desirable to maintain the blank at a predetermined temperature and, for this purpose, means is preferably provided for supplying a coolant to the work and to the surfacing wheel as shown in Figures 14 and 15. This means may advantageously comprise a pair of longitudinal headers 213 connected by a pair of transverse headers 214, each of which is provided with a plurality of jets or nozzles 215 arranged to discharge coolant on to the surfacing wheel and the work. Pipes 216 may conveniently connect the longitudinal headers 213 to a main supply pipe 217 for the coolant which is supported by suitable brackets 218 on the housing 10 for the bearing of the shaft 8 of the surfacing wheel 7.

While the drawings only illustrate forms of the invention particularly suitable for the surfacing of lens blanks, it will be apparent to those skilled in the grinding and polishing arts that the invention is readily adaptable to machines for forming curved surfaces on substances other than glass, such, for example, as turbine blades, tubine nozzles and other articles irrespective of the material of which they are made. Various modifications may, of course, be made in the structural features of the machine illustrated without departing from the spirit and scope of the appended claims and it is to be understood that the term "lens blank" appearing in the claims is used not by way of limitation but merely by way of exemplification.

What we claim is:

1. A machine for surfacing a lens blank involving rotatable surfacing means, movable lens blank holding means having a rotatable spindle on which the blank is adapted to be mounted, a curved guideway along which said holding means is movable, rectilinearly movable means beneath said guideway for sliding said holding means to and fro along said guideway to swing said spindle as a pendulum whereby the lens blank is caused to move in a curved path, means for causing the lens blank to engage the surfacing means during movement thereof in said curved path, and means for rotating said spindle as said holding means moves to and fro.

2. A machine for surfacing a lens blank involving rotatable surfacing means, movable lens blank holding means, a curved guideway along which said holding means is movable, means for moving said holding means to and fro along said guideway whereby the lens blank is caused to move in a curved path, means for rotating said holding means and the lens blank carried thereby, and fluid pressure operated means for holding said lens blank under substantially constant pressure in engagement with the surfacing means as the lens blank is rotated and moved to and fro.

3. A machine for surfacing a lens blank involving rotatable surfacing means, a curved guideway beneath the surfacing means, movable means slidably mounted on said guideway having a substantially upright spindle journaled therein adapted to support a lens blank at its upper end, means for sliding said movable means back and forth along said guideway to swing said spindle as a pendulum and cause the lens blank mounted thereon to move to and fro in a curved path, means for rotating said spindle, and means for maintaining the lens in engagement with the surfacing means as it is being rotated and moved to and fro.

4. A machine for surfacing a lens blank involving rotatable surfacing means, movable lens blank holding means, a curved guideway along which

said holding means is movable, means for moving said holding means back and forth along said guideway for causing said lens blank to move to and fro in a curved path, means for selectively positioning the lens blank at different distances from said guideway, and means for causing the lens blank to engage said surfacing means during movement thereof in said curved path.

5. A machine for surfacing a lens blank involving rotatable surfacing means, lens blank holding means having a rotatable spindle adapted to support a lens blank at its upper end, a curved guideway on which said holding means is supported, means for sliding said lens blank holding means back and forth along the guideway to swing the spindle as a pendulum and cause the lens blank to move to and fro in a curved path, means adapted to be interposed between the lens and said end of the spindle whereby the lens may be selectively positioned at different distances from the guideway, means for rotating said spindle, and means for causing the lens blank to engage the surfacing means.

6. A machine for surfacing a lens blank involving rotatable surfacing means, movable lens blank holding means, an arcuate guideway along which said holding means is movable, means for moving said holding means back and forth along said guideway for causing the lens blank to move to and fro in a curved path, means for causing the lens blank to engage the surfacing means during movement thereof in said curved path, the center of curvature of said guideway and the axis of rotation of said surfacing means being disposed on the same side of the face of the lens blank in engagement with the surfacing means whereby a concave surface is generated on said face.

7. A machine for surfacing a lens blank involving rotatable surfacing means, movable lens blank holding means, an arcuate guideway along which said holding means is movable, means for moving said holding means back and forth along said guideway for causing the lens to move to and fro in a curved path, means for causing the lens blank to engage the surfacing means during movement thereof in said curved path, the center of curvature of said guideway and the axis of rotation of said surfacing means being on opposite sides of the face of the lens blank in engagement with said surfacing means whereby a convex surface is generated on said face.

8. A machine for surfacing a lens blank involving a movable lens blank holding means, an arcuate guideway along which said holding means is movable, means for moving said holding means back and forth along said guideway for causing the lens to move to and fro in a curved path, rotatable surfacing means, and means for causing the lens blank to engage the surfacing means during movement thereof in said curved path, said surfacing means being adjustably mounted whereby the axis of rotation thereof may be moved from a position on one side of the center of curvature of said guideway to a position on the opposite side of said center.

9. A machine for surfacing a lens blank involving rotatable surfacing means, a curved guideway beneath the surfacing means, a lens blank holding device slidably mounted on said guideway and movable back and forth thereon for moving the lens blank in a curved path beneath the surfacing means, and means for causing the lens blank to engage the surfacing means during movement thereof in said curved path, said lens blank holding device including a base member slidable back and forth on said guideway, a rotatable spindle journaled in said base and extending upwardly therefrom for supporting the lens blank on its upper end, and means for actuating said base.

10. A machine for surfacing a lens blank involving rotatable surfacing means, a lens blank holding device for simultaneously rotating the lens blank and moving it to and fro in a curved path, a guideway beneath the surfacing means on which said lens blank holding means is slidable back and forth, and means for causing the lens blank to engage said surfacing means while it is rotating and moving in said curved path, said lens blank holding device including a base member slidably mounted on said guideway, a spindle rotatably journaled in said base member and extending upwardly therefrom for supporting the lens blank on its upper end, means for rotating said spindle, and means for actuating said base member.

11. A machine for surfacing a lens blank involving rotatable surfacing means, a curved guideway, a lens blank holding device movable back and forth on said guideway for causing the lens blank to move back and forth in a curved path beneath said surfacing means, and means for causing the lens blank to engage the surfacing means during movement thereof in said curved path, said lens blank holding device including a base member slidable to and fro on said guideway, a spindle carried by the base member on which the lens blank is adapted to be mounted, said spindle having a portion projecting below the base member, and reciprocating means cooperable with said portion of the spindle for moving said base member.

12. A machine for surfacing a lens blank involving rotatable surfacing means, a lens blank holding device for simultaneously rotating the lens blank and moving it to and fro in a curved path, a guideway on which said holding means is movable back and forth and means for causing the lens blank to engage said surfacing means while it is rotating and moving in said curved path, said holding device including a base member movable to and fro on said guideway, a spindle rotatably journaled in said base member and having a portion projecting below the latter, said spindle being adapted to support the lens blank at its upper end, means for rotating the spindle cooperable with said projecting portion thereof, and reciprocating means also cooperable with said projecting portion of the spindle for moving said base member to and fro.

13. A machine for surfacing a lens blank involving rotatable surfacing means, a lens blank holding device having a base member and a rotatable spindle projecting on opposite sides thereof, the upper end of said spindle being adapted to receive a lens blank, a curved guideway along which said base is movable back and forth with the axis of the spindle disposed substantially radially thereof whereby the lens blank on the upper end of said spindle is caused to move to and fro in a curved path, means slidably mounted beneath said guideway for moving said base back and forth, means for maintaining the lens blank in engagement with the surfacing means, and means cooperable with the lower portion of said spindle for rotating it during movement of the base member back and forth.

14. A machine for surfacing a lens blank involving rotatable surfacing means, a lens blank holding device having a base member and a ro-

tatable spindle projecting on opposite sides thereof, the upper end of said spindle being adapted to receive a lens blank, a curved guideway along which said base is movable back and forth with the axis of the spindle disposed substantially radially thereof so that the lens blank on the upper end of said spindle is caused to move to and fro in a curved path, means slidably mounted beneath said guideway and cooperable with the lower portion of said spindle for moving the base back and forth, and mechanism for rotating said spindle during back and forth movement of the base member including means mounted on the spindle adjacent the lower end thereof.

15. In a machine for holding lens blanks to be surfaced by rotatable surfacing means, movable means having a rotatable spindle for supporting a lens blank to coact with the surfacing means, a curved guide-way along which said movable means is slidable back and forth, the axis of rotation of the spindle being substantially radial to said guideway in all positions said means occupies during movement thereof, and a rectilinearly movable element for sliding said means back and forth on said guideways to move the lens blank to and fro in a curved path.

16. In a machine for holding lens blanks to be surfaced by rotatable surfacing means, movable means having a rotatable spindle for supporting a lens blank to coact with the surfacing means, a curved guideway along which said movable means is slidable back and forth, the axis of rotation of the spindle being substantially radial to said guideway in all positions said means occupies during movement thereof on said guideway, and a rectilinearly slidable member mounted beneath said guideway and cooperable with said means for sliding it back and forth on said guideway to move the lens blank to and fro in a curved path.

17. In a machine for holding lens blanks to be surfaced by rotatable surfacing means, movable means having a rotatable spindle for surfacing a lens blank to coact with the surfacing means, a curved guideway along which said movable means is slidable back and forth, the axis of rotation of the spindle being substantially radial to said guideway in all positions said means occupies during movement thereof on said guideway, a straight guideway beneath said curved guideway, and reciprocating means slidably mounted in the straight guideway cooperable with said movable means for sliding the latter back and forth on said curved guideway to move the lens blank to and fro in a curved path.

18. In a machine for holding lens blanks to be surfaced by rotatable surfacing means, movable means having a rotatable spindle for supporting a lens blank to coact with the surfacing means, laterally spaced curved guides along which said movable means is slidable back and forth, the axis of rotation of the spindle being substantially radial with respect to said curved guideways in all positions said means occupies during movement thereof along the guideways, and movable means for sliding said first named movable means back and forth on said guideways to move the lens blank to and fro in a curved path.

19. In a machine for holding lens blanks to be surfaced by rotatable surfacing means, movable means having a rotatable spindle for supporting a lens blank to coact with the surfacing means, laterally spaced curved guideways along which said movable member is slidable back and forth, a reciprocating element beneath said movable means having laterally spaced slidably supported portions, said movable means having a portion extending downwardly between said laterally spaced portions, and means operatively connecting said reciprocating element and said movable means for sliding said means back and forth on said curved guideways to move the lens blank to and fro in a curved path.

20. A machine for surfacing a lens blank involving rotatable surfacing means, a lens blank holding means, a movable base on which said holding means is mounted, a curved guideway along which said base is movable back and forth, reciprocating means coacting with said holding means for causing said base to move back and forth along said guideway and for causing the lens blank carried by the holding means to move to and fro in a curved path.

21. A machine for surfacing a lens blank involving rotatable surfacing means, a lens blank holding means, a movable base on which said holding means is mounted, a curved guideway along which the base is movable back and forth to cause the lens blank carried by said holding means to move in a curved path, and a reciprocating device below the guideway for moving the holding means and base back and forth, said device including a rectilinearly movable member provided with pivotally mounted means slidably engageable with said holding means.

22. A machine for surfacing a lens blank involving rotatable surfacing means, a lens blank holding means, a movable base in which said holding means is journaled, curved guideways along which said base is movable back and forth to cause the lens blank carried by the holding means to move in a curved path, and a reciprocating device below the guideways for moving said holding means back and forth, said device including pivotally mounted means slidably engageable with said holding means, and means for rotating said holding means while it is moving back and forth.

23. A machine for surfacing a lens blank involving rotatable surfacing means, a lens blank holding means, a movable base on which said holding means is mounted, a curved guideway along which the base is movable back and forth to cause the lens blank carried by said holding means to move in a curved path, a sleeve slidably mounted on said holding means, and reciprocating means pivotally connected to said sleeve for actuating said holding means so as to cause the lens blank carried thereby to move back and forth in a curved path.

24. A machine for surfacing a lens blank involving rotatable surfacing means, a curved guideway, a lens blank holding means slidably mounted on said guideway including a rotatable spindle on which the lens blank is adapted to be mounted, slidably mounted means for moving said holding means and lens blank back and forth in a curved path, to swing said spindle as a pendulum and cause the lens blank to move to and fro in a curved path and belt drive means for rotating said spindle during movement of the lens blank in said curved path, said belt drive means including a pulley pivotally mounted on said spindle so as to angle with respect to the axis of rotation thereof.

25. A machine for surfacing a lens blank involving rotatable surfacing means, a rotatable lens blank holding means for rotating the lens blank, means for swinging said holding means

back and forth to cause the lens blank to move to and fro in a curved path, belt drive means for rotating said holding means during swinging movement thereof, said belt drive means including a driving pulley, a driven pulley mounted on the holding means and movable back and forth therewith relatively to the driving pulley, a belt operatively connecting said pulleys, and slidable idle pulleys operatively interposed between the driving and driven pulleys and cooperable with said belt to compensate for the relative movement of the driving and driven pulleys caused by the swinging movement of said holding means, and means for moving said idle pulleys in timed relation with movement of the driven pulley.

26. A machine for surfacing a lens blank involving rotatable surfacing means, a lens blank holding means, means for moving said holding means back and forth to cause the lens blank carried thereby to move to and fro in a curved path, and belt drive means for rotating said holding means and the lens blank while the latter is moving to and fro in said curved path, said belt drive means including a driving pulley, a driven pulley mounted on the holding means and movable therewith relatively to the driving pulley, a belt operatively connecting said pulleys, and two pairs of idle pulleys operatively interposed between the driving and driven pulleys and cooperable with said belt to compensate for the relative movement of the driving and driven pulleys, said pairs of idle pulleys being simultaneously movable.

27. A machine for surfacing a lens blank involving rotatable surfacing means, a lens blank holding means, means for moving said holding means and the lens blank carried thereby to and fro in a curved path, and belt drive means for rotating said holding means and lens blank while the latter is moving to and fro in said curved path, said belt drive means including a relatively immovable driving pulley, a driven pulley mounted on the holding means and movable therewith relatively to the driving pulley, a belt operatively connecting said pulleys, two pairs of idle pulleys cooperable with said belt for compensating for relative movement of the driving and driven pulleys caused by movement of said holding means, a reciprocating carriage for each pair of idle pulleys, means operatively interposed between said carriages whereby movement of one carriage in one direction will cause movement of the other carriage in the same direction at a different rate, and means movable with said holding means for actuating one of said carriages.

28. A machine for surfacing a lens blank involving rotatable surfacing means, lens blank holding means, means for rotating said holding means and the lens blank, reciprocating means for oscillating said holding means to cause the lens blank to swing to and fro in a curved path while it is rotating, and belt drive means for rotating said holding means including a driving pulley, a driven pulley mounted on the holding means and movable therewith relatively to the driving pulley, a belt operatively connecting said pulleys, two pairs of relatively movable idle pulleys operatively interposed between the driven and driving pulleys and cooperable with said belt to compensate for relative movement of the driving and driven pulleys, and means actuated by said holding means for moving said idle pulleys.

29. A machine for surfacing a lens blank involving a horizontally pivoted beam, vertically adjustable bearings in which said beam is journaled,

rotatable surfacing means mounted above the beam, a lens blank holding means movably mounted on said beam beneath said surfacing means, means for moving said holding means back and forth relatively to said beam to cause the lens blank carried by the holding means to move to and fro in a curved path, means for moving said beam about its pivot to cause the lens blank to engage the surfacing means during movement of the blank in said curved path, and means for vertically adjusting said bearings.

30. A machine for surfacing a lens blank involving a horizontally pivoted beam, vertically adjustable bearings affording a pivotal mounting for said beam, rotatable surfacing means above said beam, rotatable lens holding means mounted on said beam beneath the surfacing means, means for rotating said holding means and the lens blank, means for moving said holding means back and forth relatively to the beam for causing the lens blank carried by the holding means to move in a curved path, means for moving the beam about its pivot to cause the lens blank to engage said surfacing means while being rotated and moved in said curved path, and means for vertically adjusting said bearings.

31. A machine for surfacing a lens blank involving a horizontally pivoted beam, vertically adjustable bearings affording a pivotal mounting for said beam, a surfacing wheel mounted above the beam, a lens blank holding means movably mounted on the beam beneath the surfacing wheel, said lens blank holding means being movable relatively to the beam for causing the lens blank carried thereby to move to and fro in a curved path, means for pivoting said beam in a direction to cause the lens blank carried by the holding means to engage said surfacing means during movement in said curved path, and adjustable stop means for limiting pivotal movement of the beam in said direction.

32. A machine for surfacing a lens blank involving rotatable surfacing means, a beam pivotally movable with respect to said surfacing means, vertically adjustable bearings affording a pivotal mounting for said beam, a lens blank holding means movably mounted on the beam, means for moving said beam about its pivot in a direction to cause the lens blank carried by the holding means to engage said surfacing means, adjustable stop means for limiting pivotal movement of the beam in said direction, movable means for adjusting said stop means, and means whereby adjustment of said stop means will also effect adjustment of said bearings.

33. A machine for surfacing a lens blank involving rotatable surfacing means, a lens blank holding means, a curved guideway along which the holding means is movable back and forth, means for causing the lens blank carried by said holding means to move in a direction substantially radial to the guideway as the holding means moves back and forth along said guideway, and means for maintaining the lens blank in engagement with the surfacing means during movement of the holding means along said guideway.

34. A machine for surfacing a lens blank involving rotatable surfacing means, a lens blank holding and supporting device for causing the lens blank to move back and forth in a curved path with respect to the surfacing means, and means for causing the lens blank to engage the surfacing means during movement thereof in said curved path, said holding and supporting device including a base member movable back and forth,

a lens blank holding means mounted on said base member, and means cooperable with said holding means for causing the lens blank carried thereby to move toward and away from said base as the latter moves back and forth.

35. A machine for surfacing a lens blank involving rotatable surfacing means, a base member movable to and fro beneath said surfacing means, a lens blank holding means mounted on said base member and movable therewith, means for moving said holding means and lens blank up and down with respect to said base as the latter moves back and forth, and means for causing the lens blank to engage said surfacing means as it moves back and forth with the holding means.

36. A machine for surfacing a lens blank involving rotatable surfacing means, a base member movable to and fro in a curved path beneath the surfacing means, a lens blank holding means mounted on said base member and movable therewith, means for moving said holding means relatively to said base member for causing the lens blank carried by the holding means to move toward and away from said base during movement of the latter to and fro in said curved path whereby the lens blank is caused to move in a curved path having a different degree of curvature than the curved path in which said base is movable, and means for causing the lens blank to engage said surfacing means during movement thereof in said curved path.

37. A machine for surfacing a lens blank involving rotatable surfacing means, a lens blank holding means, a curved guideway along which said holding means is movable to and fro, means for causing the lens blank carried by the holding means to move toward and away from said guideway as the holding means moves to and fro along said guideway whereby the lens blank is caused to move in a curved path having a different degree of curvature than the guideway, and means for causing the lens blank to engage said surfacing means during movement thereof in said curved path.

38. A machine for surfacing a lens blank by rotatable surfacing means involving a pivoted beam, a curved guideway on the beam, a lens blank holding means slidably mounted on said guideway beneath the surfacing means, means for moving said holding means back and forth to cause a lens blank carried thereby to move in a curved path, fluid pressure operated means for moving said beam about its pivot to cause the lens blank to move upwardly into engagement with said surfacing means, and movable means engageable with said beam acting in opposition to the force delivered to the beam by said fluid pressure operated means for controlling the rate of movement of the beam by the fluid pressure operated means.

39. A machine for surfacing a lens blank involving a pivoted beam, rotatable surfacing means mounted above the beam, a lens blank holding means movably mounted on said beam beneath said surfacing means, fluid pressure operated means for moving said beam about its pivot to cause the lens blank to move upwardly into engagement with said surfacing means, and movable abutment means opposing movement of said beam by said fluid pressure operated means, said abutment means including a movable member engageable with said beam, and means for actuating said member while the beam is in engagement therewith and is subjected to the action of said fluid pressure means whereby said abutment means is operable to control the rate of movement of the beam by said fluid pressure operated means.

40. A machine for surfacing a lens blank involving a pivoted beam, rotatable surfacing means mounted above the beam, a lens blank holding means movably mounted on said beam beneath said surfacing means, fluid pressure operated means for moving said beam about its pivot to cause the lens blank to move upwardly into engagement with said surfacing means, and movable abutment means cooperable with said beam, said abutment means being operable to control the rate of movement of the beam by said fluid pressure means and being adapted when brought to rest to prevent movement of the beam by the fluid pressure operated means.

41. A machine for surfacing a lens blank involving a pivoted beam, adjustable means for laterally shifting the pivotal axis of the beam, rotatable surfacing means mounted above said beam, a lens holding means movably mounted on said beam beneath the surfacing means, fluid pressure operated means for moving the beam about its pivotal axis in a direction to cause the lens blank carried by the holding means to engage said surfacing means, additional adjustable means acting in opposition to said fluid pressure operated means for controlling the rate of movement of said means by the fluid pressure operated means, and means operatively connected to each of said adjustable means for controlling the movement thereof.

42. A machine for surfacing a lens blank involving a pivoted beam, adjustable means for vertically shifting the pivotal axis of the beam, rotatable surfacing means mounted above said beam, a lens holding means movably mounted on said beam beneath the surfacing means, fluid pressure operated means for moving said beam about its pivot to cause a lens blank carried by the holding means to move upwardly into engagement with the surfacing means, a vertically movable abutment cooperable with said beam to control the rate of movement thereof by the fluid pressure operated means, and means for simultaneously operating said adjustable means and said abutment means.

43. A machine for surfacing a lens blank by rotatable surfacing means including a pivoted beam adapted to be associated with the surfacing means, a curved guideway on the beam, movable means slidably mounted on said curved guideway having a rotatable spindle for supporting a lens blank to coact with the surfacing means, said movable means being slidable back and forth on said guideway and the axis of rotation of the spindle being disposed substantially radially of said guideway in all positions said movable means occupies during movement thereof on the guideway, and reciprocating means slidably mounted on said beam for sliding the movable means back and forth on said guideway to move the lens blank to and fro in a curved path.

44. A machine for surfacing a lens blank by rotatable surfacing means including a pivoted beam adapted to be associated with the surfacing means, laterally spaced curved guideways on the beam, movable means slidably mounted on said guideways having a rotatable spindle for supporting a lens blank to coact with the surfacing means, said movable means being slidable back and forth on said guideways and the axis of rotation of the spindle being disposed substantially radially of said guideways in all positions

said movable means occupies during movement thereof on the guideways, and reciprocating means slidably mounted on said beam for sliding the movable means back and forth on said laterally spaced curved guideways to move the lens blank to and fro in a curved path.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,264,929	Heim	May 7, 1918
1,599,405	Bugbee	Sept. 14, 1926
1,869,461	Bugbee	Aug. 2, 1932
1,624,658	Devine	Apr. 12, 1927
1,643,978	Bugbee	Oct. 4, 1927
2,291,000	Simpson	July 28, 1942
1,639,012	Tillyer et al.	Aug. 16, 1927
1,287,091	Pearsen	Dec. 10, 1918
2,212,179	Martin	Aug. 20, 1940
521,002	Roberts	June 5, 1894
2,320,672	Stein	June 1, 1943
441,570	Leighton	Nov. 25, 1890
1,331,037	Sullivan	Feb. 17, 1920
1,023,513	Gonard	Apr. 16, 1912
1,503,497	Glancy	Aug. 5, 1924
2,187,462	Mulholland	Jan. 16, 1940
1,337,139	Kimmel	Apr. 13, 1920
1,343,522	Robertson et al.	June 15, 1920
Re. 14,751	Brockbank	Nov. 18, 1919
1,186,616	Strecker	June 13, 1916
1,708,680	Patrick	Apr. 9, 1929
1,982,141	Nault	Nov. 27, 1934
640,191	Gaither	Jan. 2, 1900

FOREIGN PATENTS

Number	Country	Date
38,606	Switzerland	Dec. 26, 1906