March 3, 1953 | J. DESENBERG | 2,629,975

ABRADING MACHINE

Filed June 22, 1950 | | 4 Sheets-Sheet 1

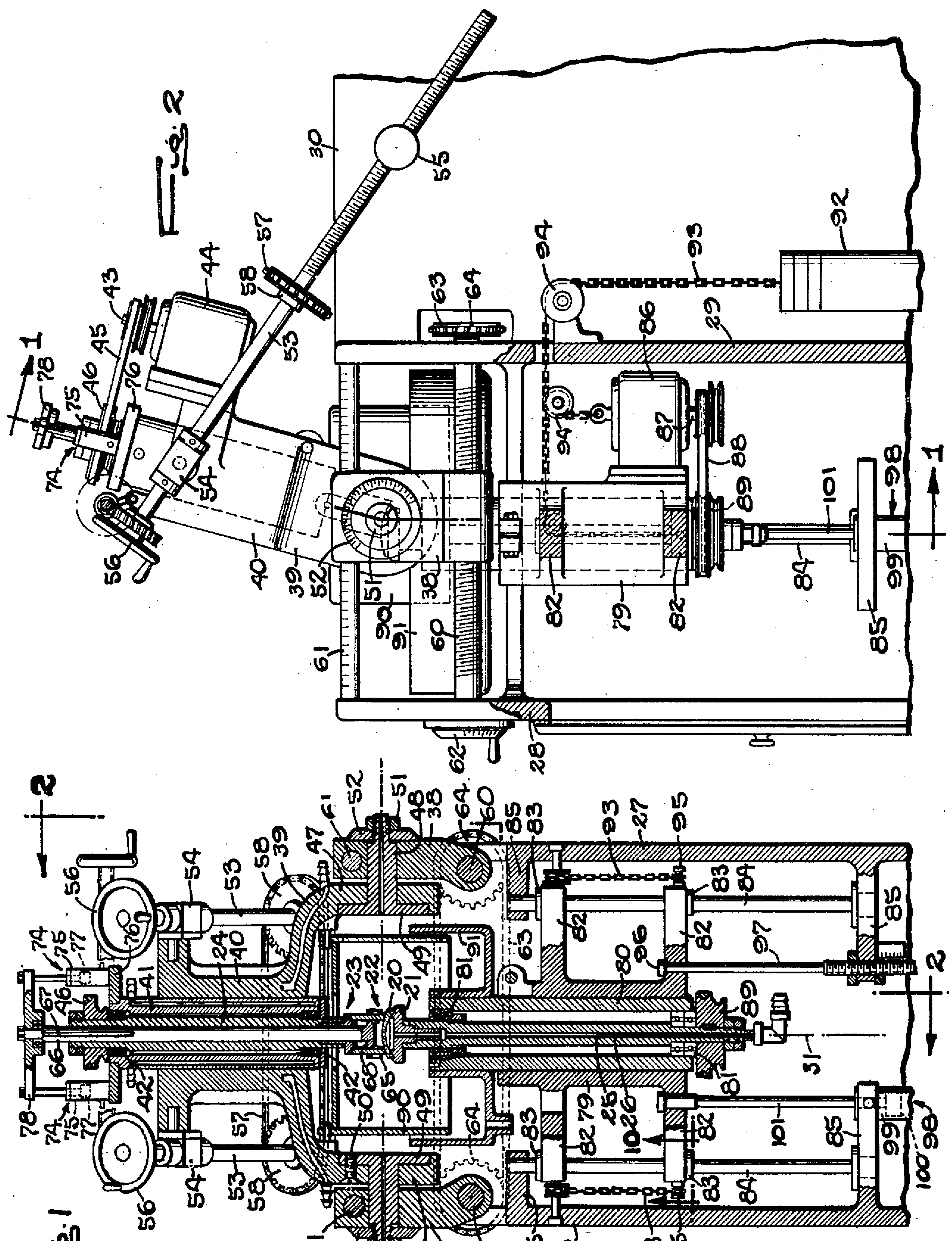

Fig. 2

Fig. 1

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Fig. 3

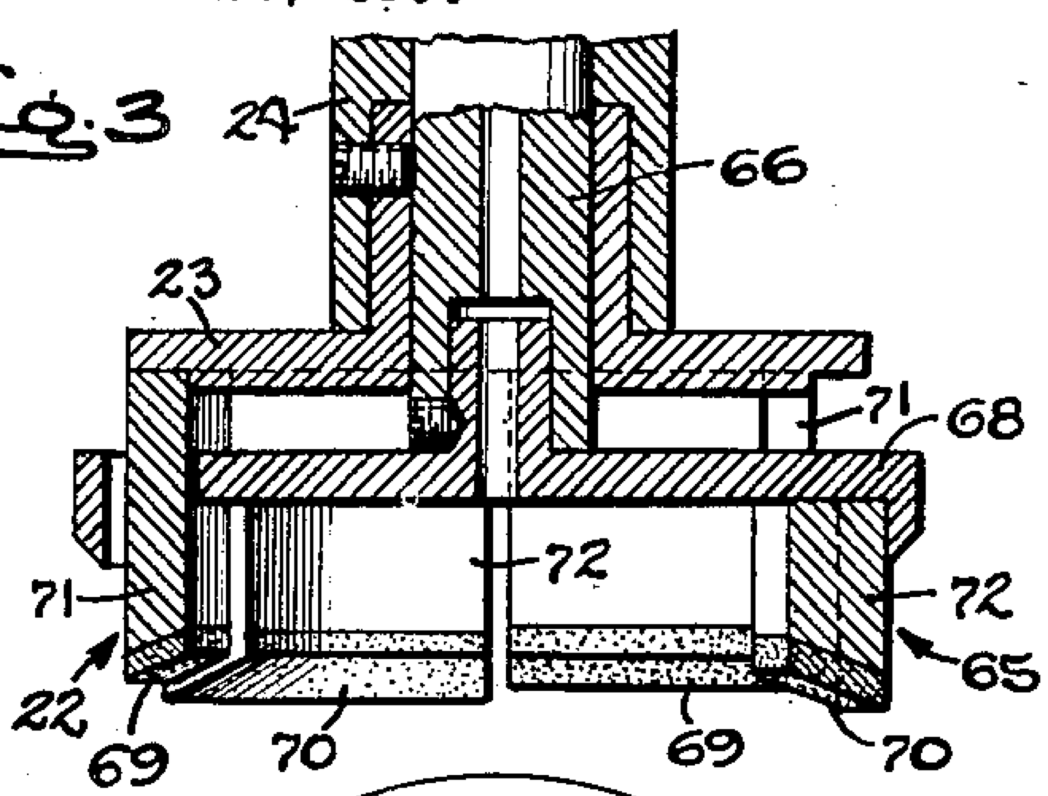


Fig. 7

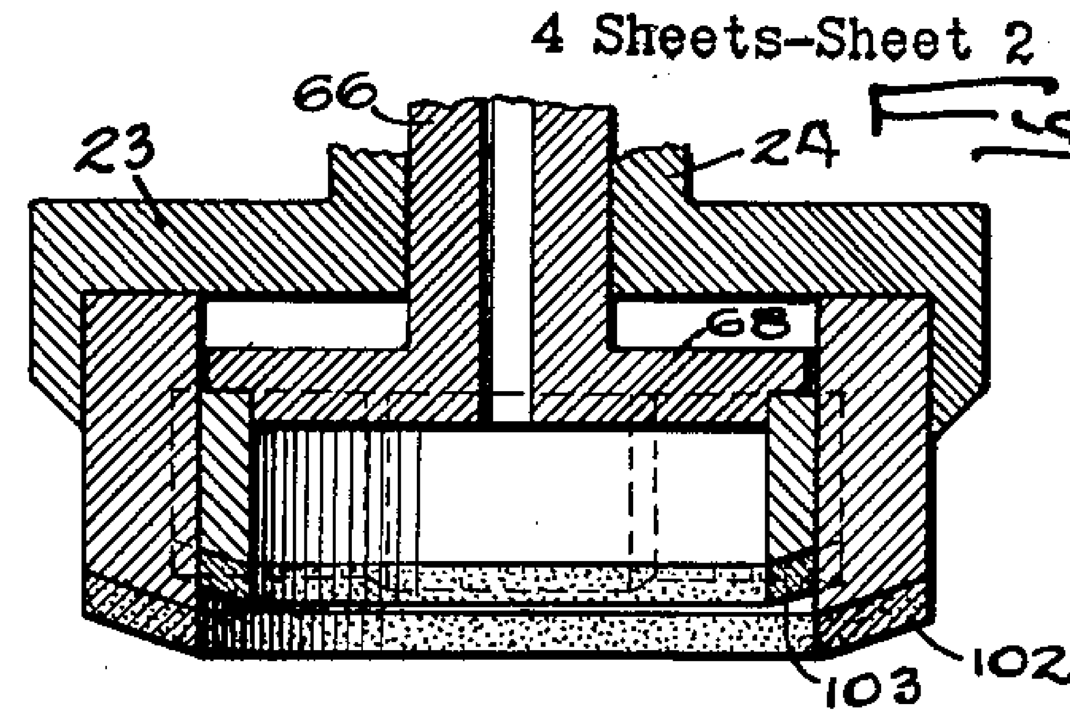


Fig. 4

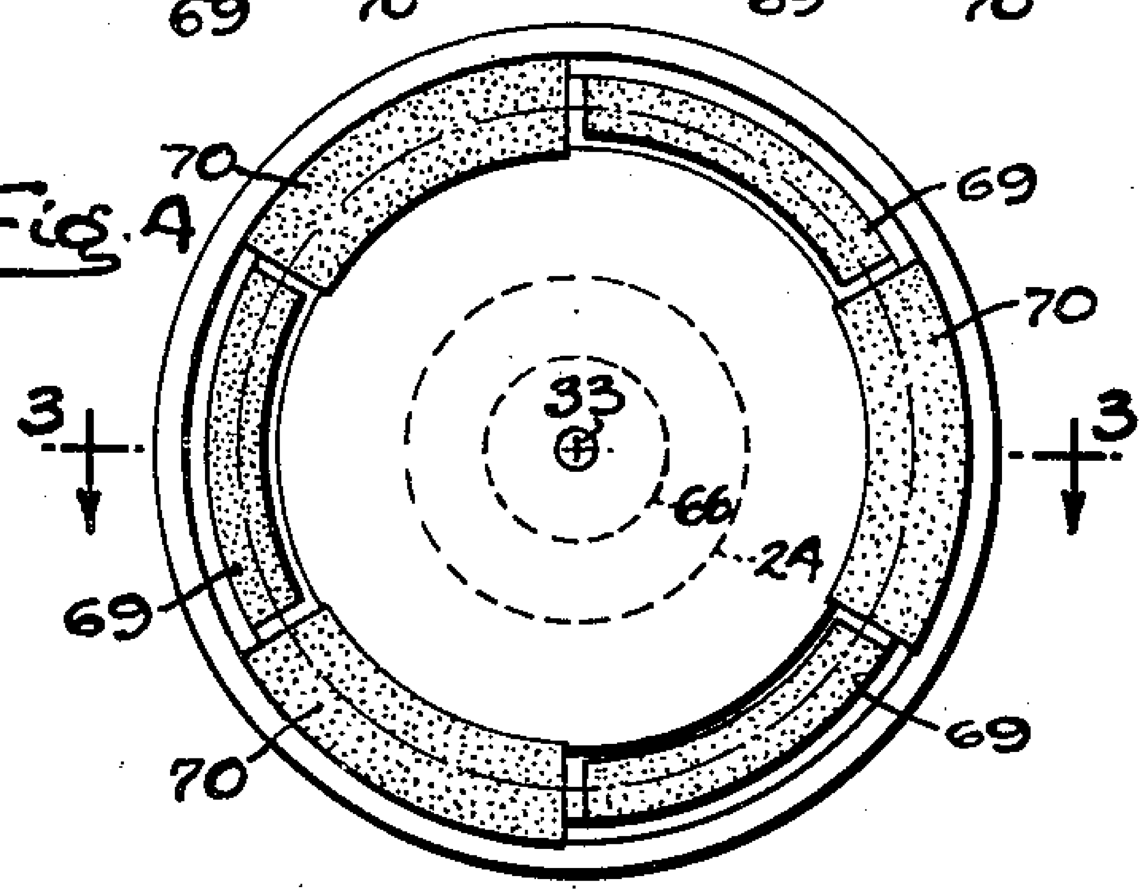


Fig. 8

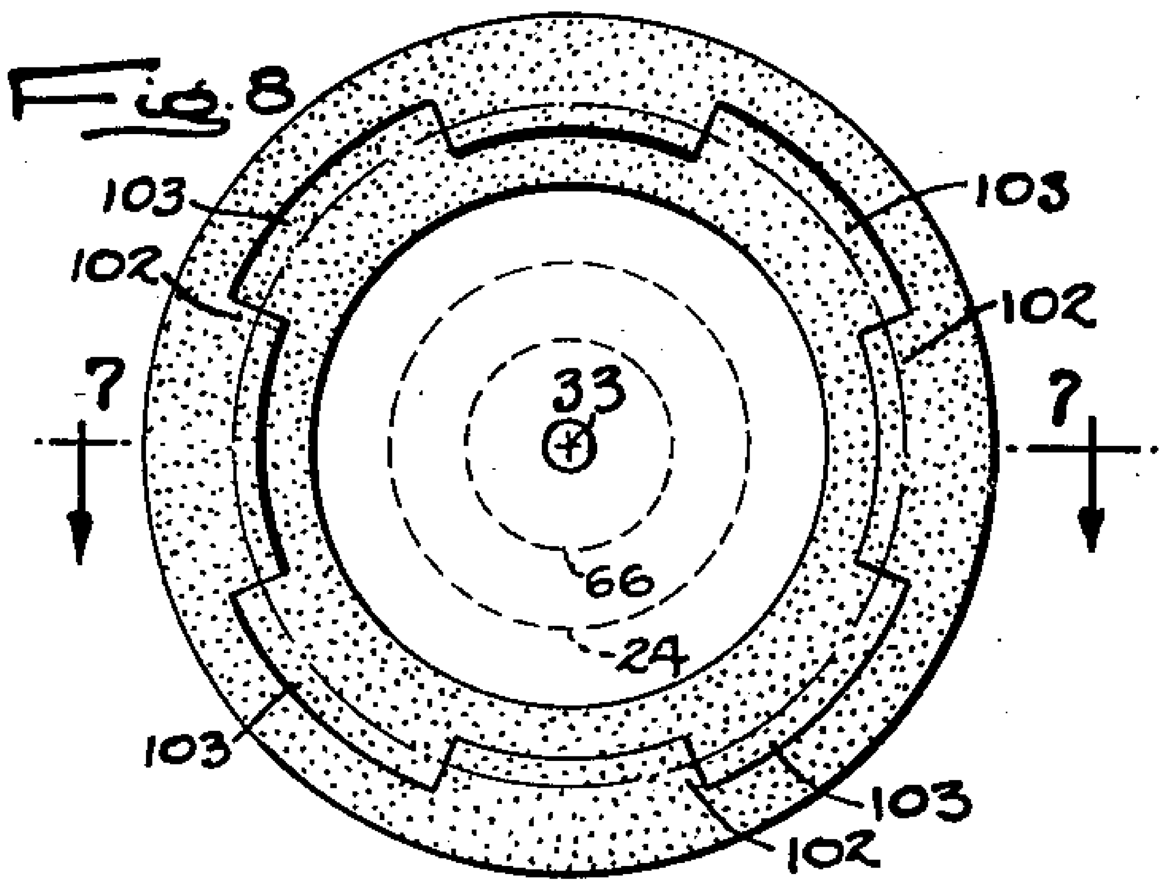


Fig. 5

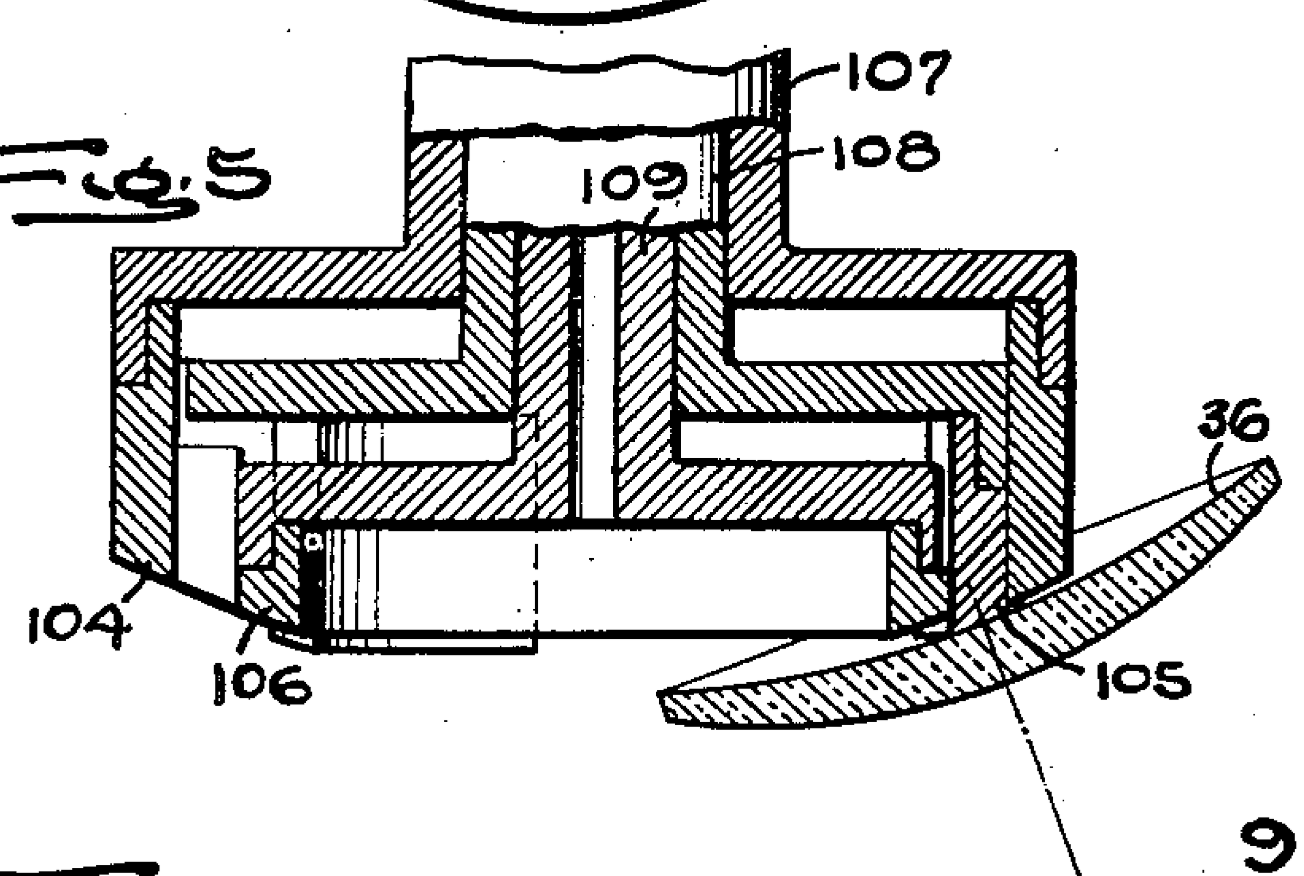


Fig. 9

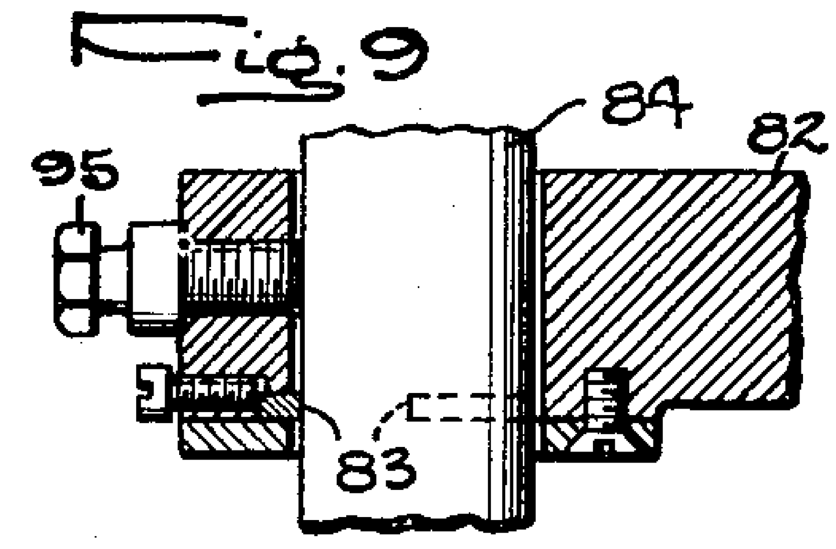


Fig. 10

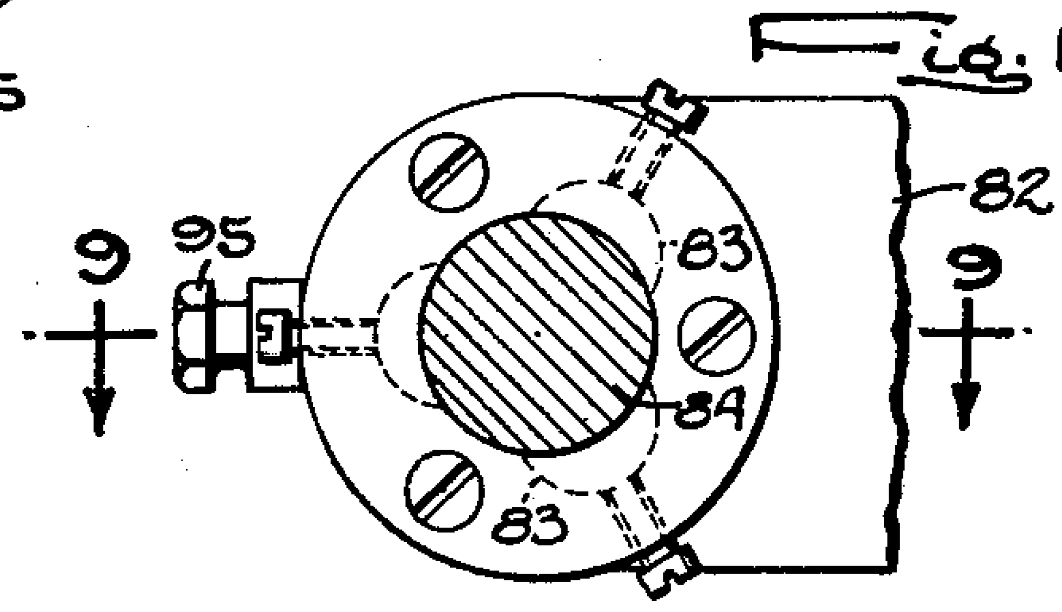
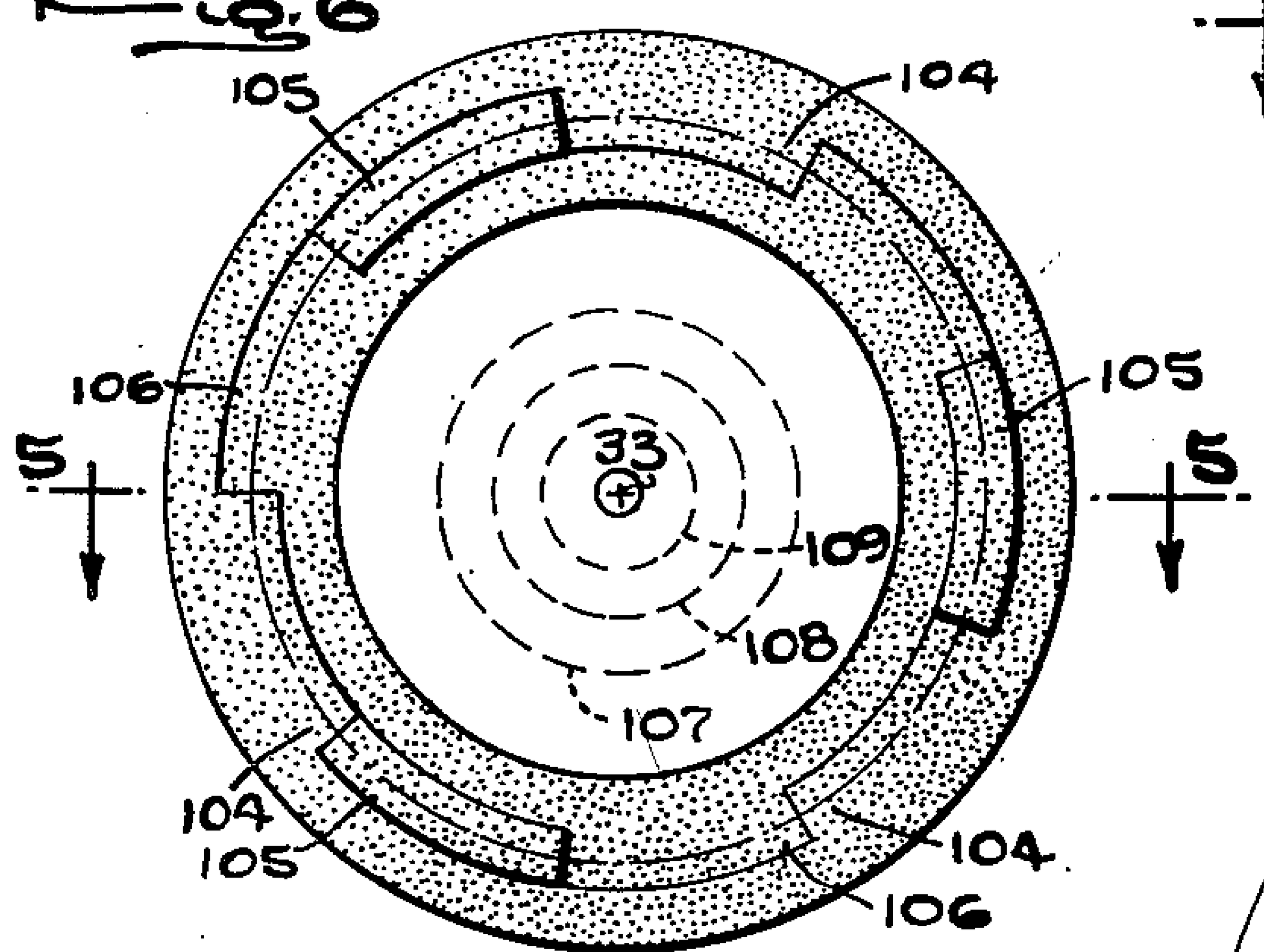


Fig. 6



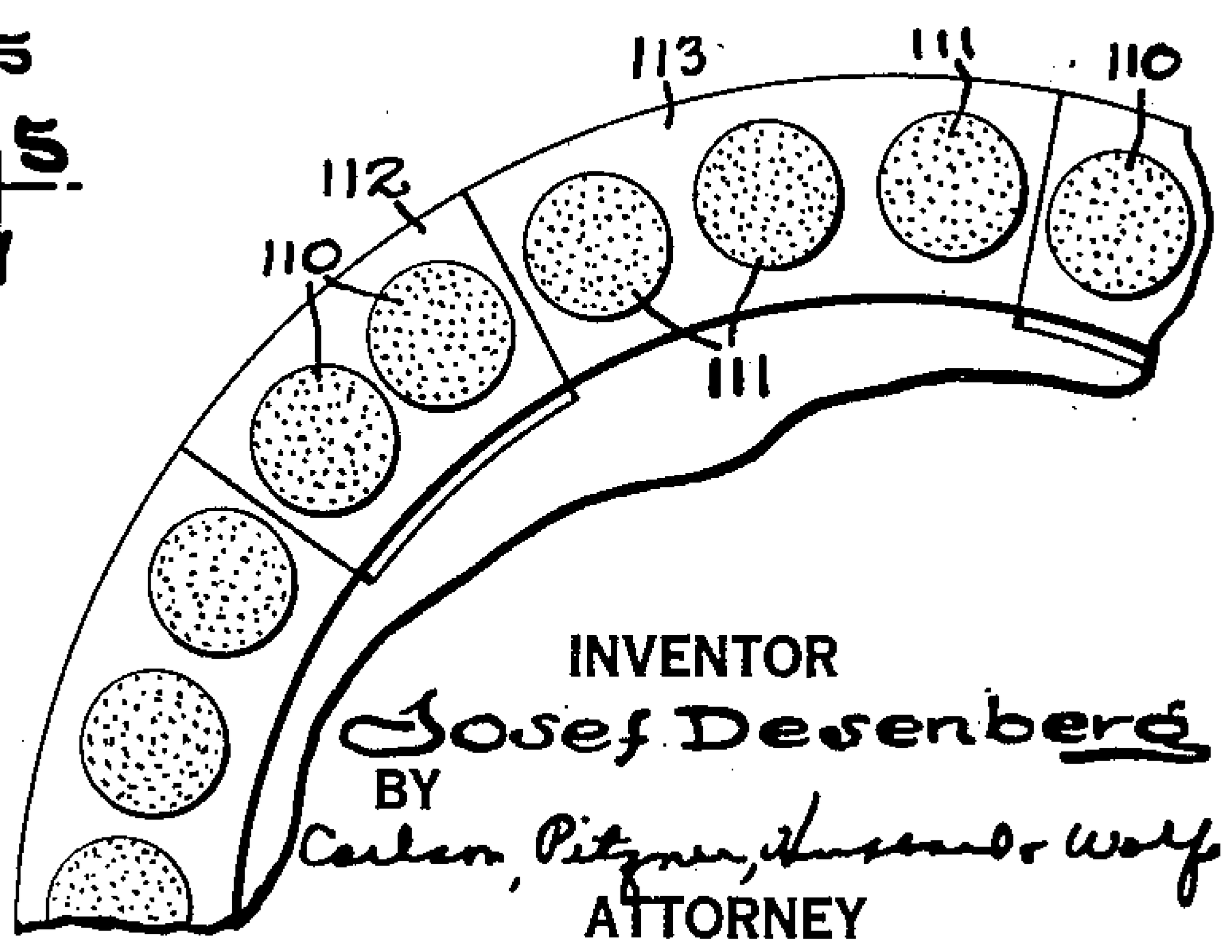


Fig. 11

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Fig. 12

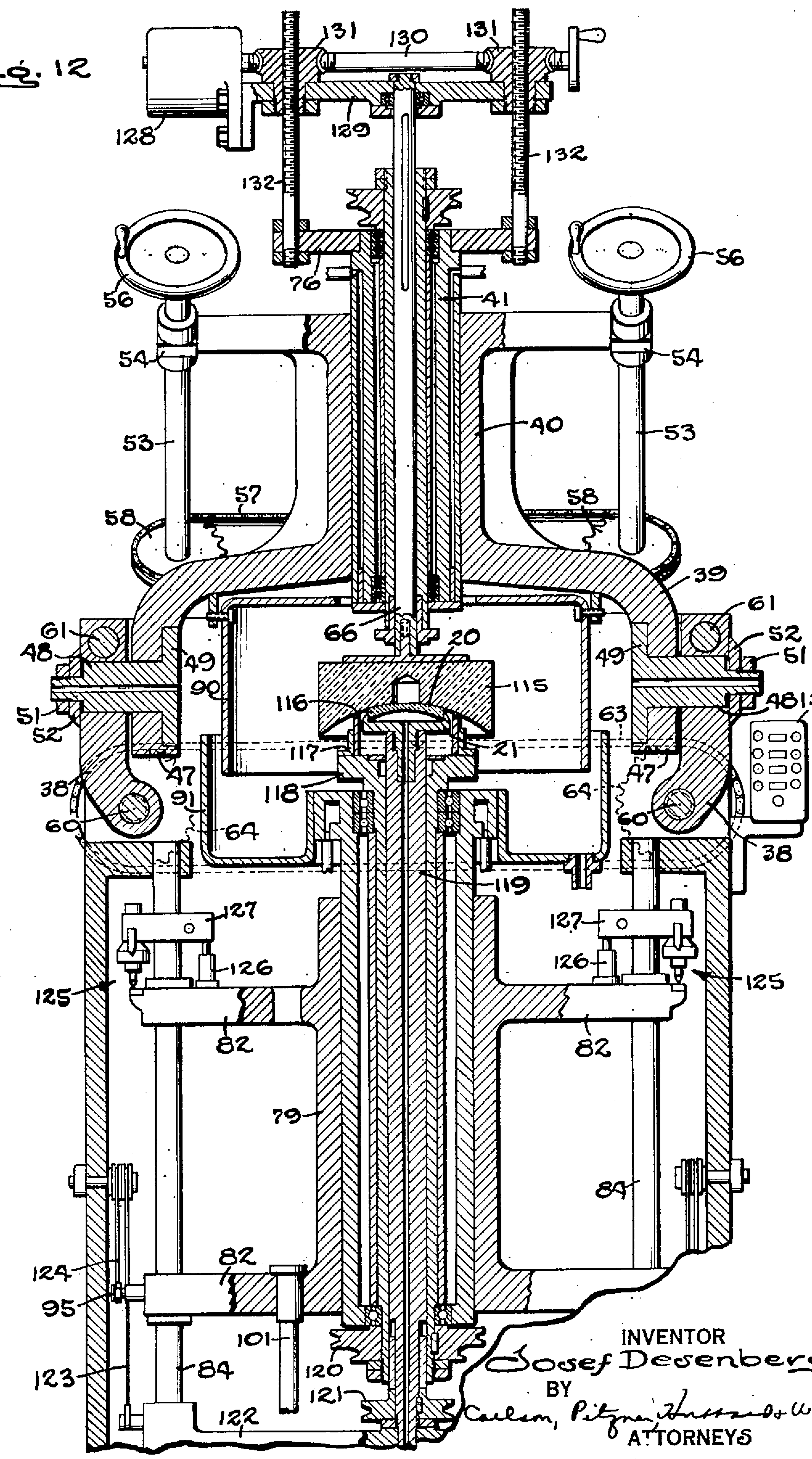

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Fig. 14

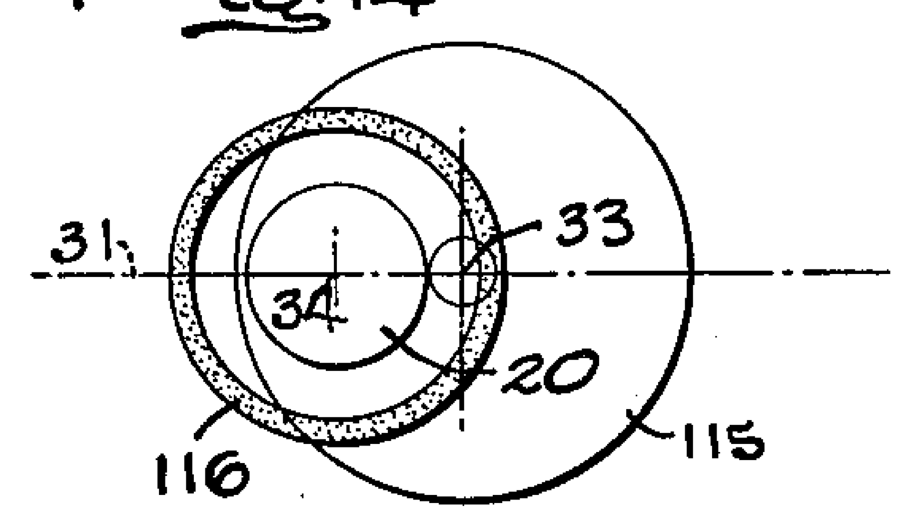
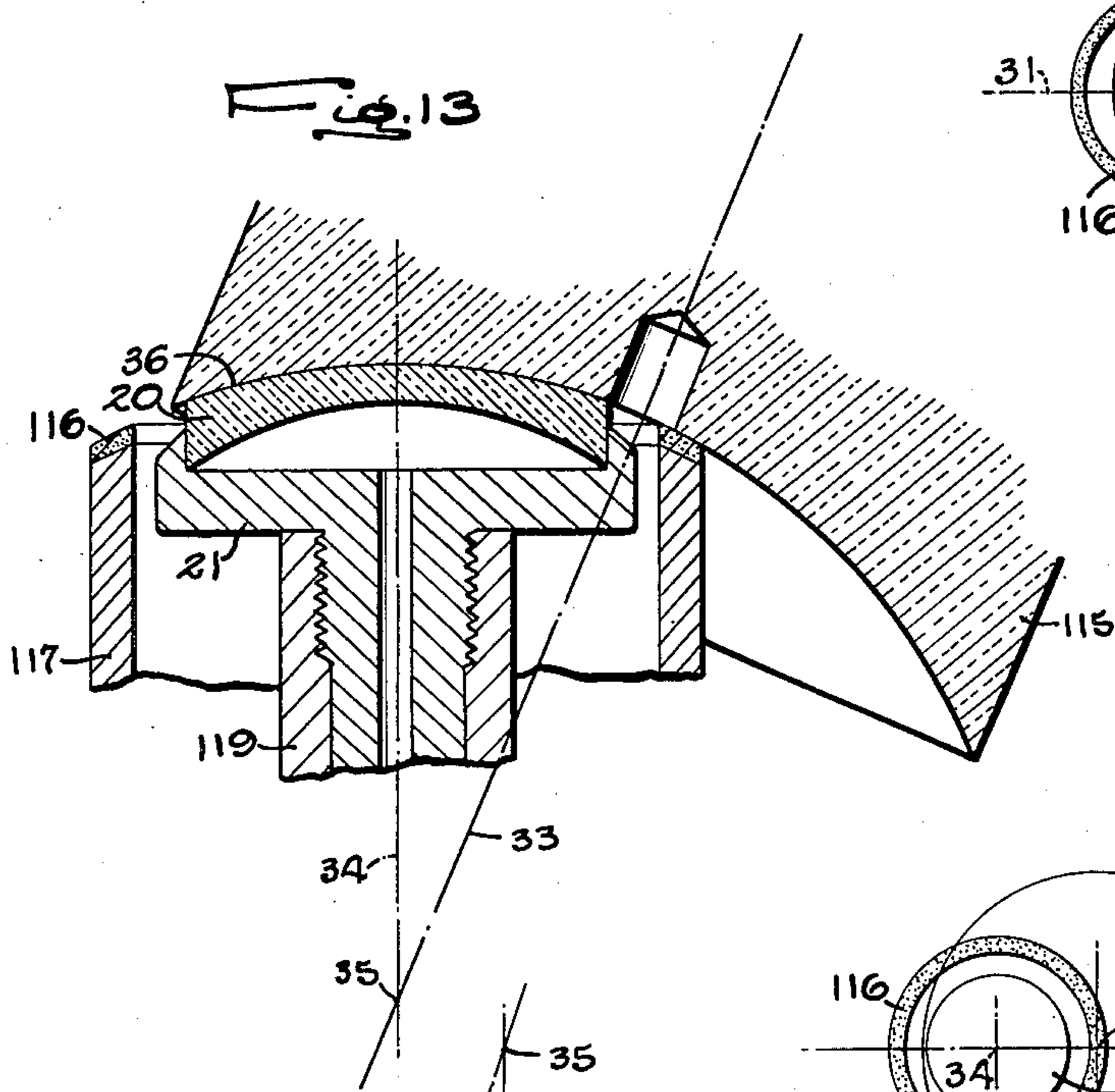


Fig. 13



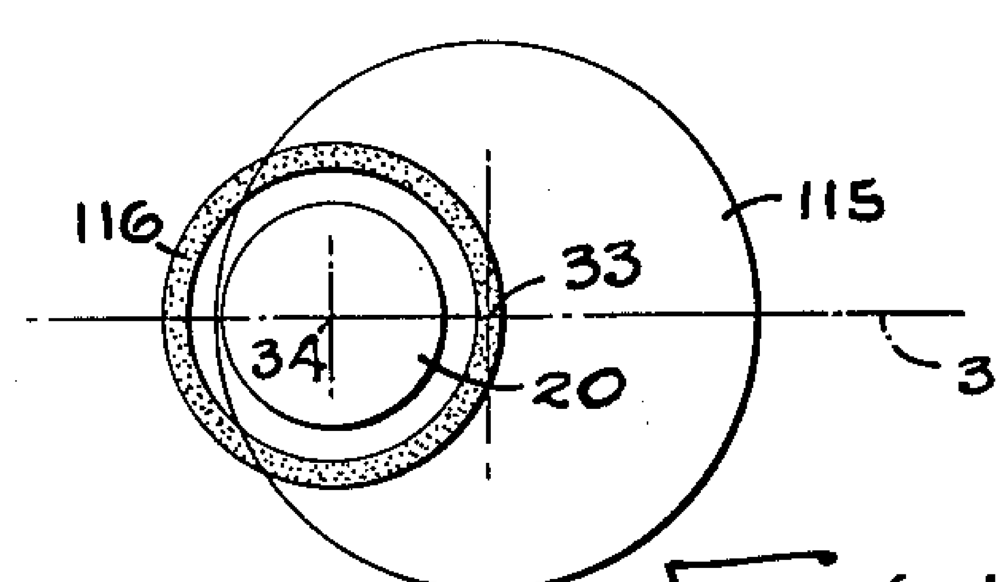


Fig. 16

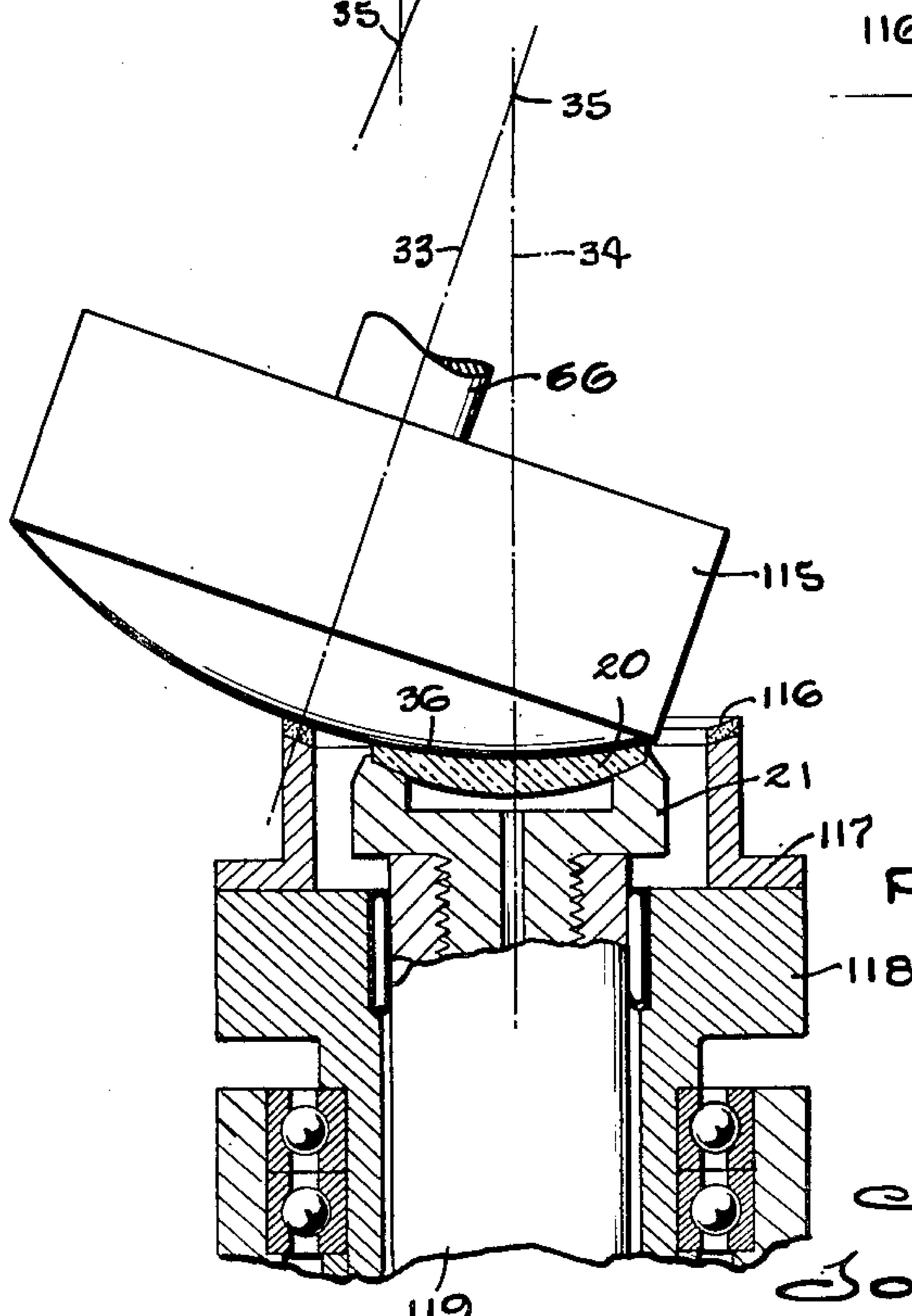


Fig. 15

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2,629,975

ABRADING MACHINE

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Application June 22, 1950, Serial No. 169,742

11 Claims. (Cl. 51—131)

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This invention relates to an abrading machine which is adapted to generate a flat or curved surface on a workpiece such as a lens and in which the work and an abrading or grinding element rotate about axes lying in a common plane and intersecting at the center of curvature of the surface being generated with the axis of rotation of the work intersecting the area or zone of engagement between the work and the abrading element. My prior Patent No. 2,352,146 shows a machine of the above character over which the present invention is an improvement.

One object of the invention is to provide a machine of the above character in which the abrading element is supported in a novel manner on opposite sides of the common plane of the axes of the work and the abrading element so as to provide a rugged and stable mounting which may be adjusted easily and accurately for concave as well as convex work surfaces.

Another object is to perform both rough and finish grinding operations on a workpiece in successive steps in a single machine without stopping the machine or readjusting the same.

A more detailed object is to effect the foregoing object by mounting a plurality of rough and finish grinding tools for rotation along a common circular path about a common axis with portions of the tools alternating each other along the path and movable selectively into engagement with the work.

A further object is to provide a machine of the above character in which truing of the abrading element is effected during a lens grinding operation by a truing element mounted concentrically with respect to the lens so as to simplify the machine and facilitate accurate adjustment thereof.

Other objects and advantages of the invention will become apparent from the following detailed description taken in connection with the accompanying drawings, in which

Figure 1 is a fragmentary sectional view of a machine embodying the novel features of the present invention taken along the line 1—1 of Fig. 2.

Fig. 2 is a fragmentary sectional view taken along the line 2—2 of Fig. 1.

Fig. 3 is an enlarged sectional view taken along the line 3—3 of Fig. 4.

Figure 4 is a plan view of one form of the grinding elements.

Figs. 5 and 6 are views similar to Figs. 3 and 4 and showing a modified form of the grinding elements, Fig. 5 being a section taken along the line 5—5 of Fig. 6.

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Figs. 7 and 8 are views similar to Figs. 3 and 4 showing another modification, Fig. 7 being a section taken along the line 7—7 of Fig. 8.

Fig. 9 is a sectional view taken along the line 9—9 of Fig. 10.

Fig. 10 is a sectional view taken along the line 10—10 of Fig. 1.

Fig. 11 is a fragmentary view similar to Fig. 4 showing still another modification of the grinding elements.

Fig. 12 is an enlarged view showing a modification of the machine shown in Fig. 1.

Fig. 13 is a fragmentary sectional view showing the relation of the parts of the machine shown in Fig. 12 with a convex lens.

Fig. 14 is a schematic plan view of the parts shown in Fig. 13.

Fig. 15 is a view similar to Fig. 13 showing the relation of the parts with a concave lens.

Fig. 16 is a schematic plan view of the parts shown in Fig. 15.

While the invention is susceptible of various modifications and alternative constructions, it is shown in the drawings and described in the specification in a machine especially adapted for high precision and high production grinding of lenses. It is to be understood, however, that I do not intend to limit the invention by such disclosure but aim to cover all modifications and alternative constructions falling within the spirit and scope of the invention as expressed in the appended claims. Grinding as used in the specification and claims contemplates abrading of any degree of fineness including polishing.

In the improved machine shown in Figs. 1 and 2, a lens blank **20** is mounted in a holder **21** and is ground by the action of a tool **22** mounted in another holder **23**. The tool holder **23** is fixed on a spindle **24** and the work holder **21** on a second spindle **25**, the work being held on its holder by suction derived from a pump (not shown) which communicates with a passage **26** extending axially through the second spindle. Herein, all of the movable parts of the machine are mounted on a frame comprising generally a base (not shown) adapted to rest on a supporting surface and having parallel upstanding side walls **27** connected by parallel front and rear walls **28** and **29** with an upright column **30** projecting rearwardly from the intermediate portion of the rear wall.

The tool and work spindles **24** and **25** are mounted on the frame for rotation about axes **33** and **34** which lie in a common plane **31** (Fig. 1) and intersect each other at the center **35** of curvature (Figs. 13 and 15) of the lens surface

36 being ground with the work axis 34 passing through the zone of engagement between the lens 20 and the tool. To adapt the machine for grinding both concave and convex lens surfaces of widely varying radii of curvature, the spindles are mounted for selective pivotal adjustment of one of the spindles about an axis 32 (Fig. 1) normal to the plane and also for bodily adjustment of one of the spindles in the plane in a direction normal to the pivotal axis. Thus, when the work surface 36 is convex as shown in Figs. 1, 2, 12, and 13, the spindle axes intersect on one side of the work surface, herein below. where the center 35 of curvature is located. However, when the work surface is concave (Fig. 15), the intersection of the axes at the center of curvature is on the other side or above the work surface.

The present invention contemplates the provision of an extremely rugged and accurate mounting for at least one of the spindles 24 and 25 while still permitting the pivotal and bodily adjustments of the spindles above referred to. This is accomplished by supporting the spindles at widely spaced points located on opposite sides of the plane 31 so as to reduce substantially any deflection of the spindle axes 33 and 34 resulting from a deflection of the spindle supports. Such support of the spindles makes it possible to achieve a very high degree of accuracy in the precision grinding of lenses. Preferably, though not necessarily, both the pivotal and bodily adjustments are effected by moving only the tool spindle 24, the axis of the work spindle 25 being fixed.

In this instance, the common plane 31 of the axes 33 and 34 is disposed between and parallel to the frame side walls 27 and the mounting for the work spindle 24 includes widely spaced adjustable supports 38 located on opposite sides of the plane and at opposite ends of an elongated crosspiece 39 which is secured to and extends transversely across an elongated hollow upright member 40. The latter lies in the plane of the axes and carries a sleeve 41 having bearings 42 at opposite ends to rotatably support the tool spindle 24. The shaft 43 of an electric motor 44 secured to and movable with the hollow member is connected through a belt 45 to a pulley 46 fast on the upper end of the tool spindle for rotating the latter. Herein, the crosspiece 39 is U-shaped and formed integral with the hollow member 40 so that the two form a bifurcated yoke having legs 47 at its lower end disposed generally parallel to the member at widely spaced points on opposite sides of the plane.

The swinging adjustment of the tool spindle 24 above referred to is effected by pivotally connecting the yoke legs 47 and the supports 38 which herein are in the form of parallel upright arms lying along the yoke legs on the outer sides of the latter. To pivotally connect the yoke legs and the arms, trunnions 48 having heads 49 clamped to the yoke legs as by screws 50, project outwardly from the legs in a direction normal to the plane of the axes and are journaled in the support arms 38. Nuts 51 acting against washers 52 on the trunnions are threaded on the outer ends of the latter to secure the yoke against movement along the trunnion axis. If desired, the washers may be keyed to the trunnions and formed with a scale to indicate the angular position of the tool spindle 24 about the trunnion axis 32.

Disposed on opposite sides of the hollow member 40 and extending transversely of the trunnion axis are elongated parallel shafts 53 which, adjacent one of their ends, are journaled in and secured against axial movement relative to bearing blocks 54 pivoted on the hollow member 40 adjacent the upper end of the latter. At their other ends, the shafts are threaded into a shaft 55 disposed parallel to and rearwardly of the trunnion axis 32 and journaled intermediate its ends in the upright column 30. By turning handwheels 56 secured to the parallel shafts, the upper ends of the hollow member and the tool spindle are swung about the trunnion axis 32 in the plane 31 of the axes of the tool and the work. Preferably, to enable the shafts to be turned in unison and thereby facilitate accurate adjustment of the tool spindle, a chain 57 is stretched taut between sprockets 58 fast on the shafts.

The bodily adjustment of the tool spindle 24 in a plane of the axes of the latter and the work spindle 25 is effected in the present instance by two parallel screws 60 which extend along the frame side walls 27 parallel to the latter and are journaled at opposite ends in the front and intermediate frame walls 28 and 29. The lower ends of the yoke supporting arms 38 are threaded onto the screws while the upper ends of the arms slidably receive and are guided by rods 61 disposed parallel to the frame side walls 27 and secured at opposite ends to the front and intermediate walls. By turning handwheels 62 fast on the front ends of the screws, the supporting arms 38 are adjusted along the screws and the tool spindle 24 is thereby adjusted bodily in the plane 31 in a direction normal to the work axis 34. Preferably, the screws 60 are connected as by a chain 63 stretched taut between sprockets 64 on the rear ends of the screws so that the supporting arms 38 may be adjusted simultaneously along the respective screws.

To simplify the grinding operations performed on each workpiece 20 and adapt the machine for high production grinding operations, the invention contemplates the provision of a second grinding tool 65 (see Figs. 1 and 3 through 8) which is of a different coarseness than the tool 22 above described and is arranged in a novel manner with respect to the latter so that the tools may be brought selectively into engagement with a common zone of the workpiece including the center of the work surface 36 without stopping the machine or changing the settings of the work and tool axes 33 and 34. For this purpose, the tools 22 and 65 are both mounted for rotation about the tool axis 33 with a portion of each tool spaced angularly from the other tool around a circular path concentric with the tool axis and with each tool movable selectively along the tool axis and into engagement with the work. Preferably, each tool comprises a plurality of angularly spaced arcuate abrading elements which intervene between the spaced elements of the other tool.

Such an arrangement of the tools 22 and 65 is shown in Figs. 1, 3, and 4 in which the tool spindle 24 is made hollow to receive an inner spindle 66 splined as at 67 (Fig. 1) to the hollow spindle so as to rotate therewith but to move axially relative thereto and having an inner tool holder 68 secured to its inner end. The arcuate abrading elements 69 of the tool 22 on the hollow spindle are coarser than the elements 70 of the second tool 65 and are secured to the outer ends of angularly spaced projections 71 which extend along the tool axis 33 and form a part of the outer holder 23. The arcuate elements 70 of the second tool 65 are secured to the outer ends of similar projections 72 forming a part of the inner tool holder and intervening between the outer holder projections 71 which are longer than the inner projections 72 so that, with the inner spindle retracted, only the rough grinding elements 69 engage the surface 36 being ground.

While the inner spindle may be moved in various ways to project the finish grinding elements 70 axially beyond the rough elements 69 and into engagement with the work, this is effected hydraulically in the present instance by two servos 74 (Figs. 1 and 2) each including an air cylinder 75 mounted on a plate 76 secured to the upper end of the sleeve 41 in the hollow member 40 of the yoke. Slidable in each cylinder is a piston 77 whose rod is connected to a cross bar 78 secured to the outer end of the inner tool spindle 66.

To facilitate rapid loading and unloading of lenses from the work holder 21, the work spindle 25 which in this instance rotates about a fixed vertical axis is mounted on a vertically slidable carriage 79. The latter includes an upright hollow body surrounding a sleeve 80 having bearings 81 therein rotatably receiving the work spindle with the work holder secured to the top of the spindle. Projecting outwardly in opposite directions from the top and bottom of the hollow body are horizontal arms 82 carrying bearings 83 which slide along vertical guides 84 secured at opposite ends to vertically spaced horizontal flanges 85 projecting inwardly from the frame side walls 27. Secured to and movable with the carriage is an electric motor 86 whose shaft 87 is connected by a belt 88 to a pulley 89 keyed to the lower end of the work spindle 25 for rotating the latter. If desired, the lens 20 and the tools 22 and 65 may be enclosed during wet grinding operations in a casing comprising two telescoping parts 90 and 91 respectively secured to the yoke and to the sleeve 80.

In this instance, the carriage 79 is yieldably urged upwardly into a grinding position by weights 92 secured to chains 93 extending around rotatable pulleys 94 on the side and rear frame walls 27 and 29 and connected to the motor 86 and studs 95 projecting outwardly from the lower carriage arms 82. Upward movement of the carriage is limited by the engagement of one of the lower carriage arms with an enlarged upper end 96 of a vertical rod 97 slidable in the arm and threaded at its lower end in one of the lower flanges 85.

While retraction of the work carriage 79 downwardly may be effected manually, it is preferred to use a hydraulic servo 98 (Figs. 1 and 2) having a cylinder 99 secured to one of the frame flanges 85 and having a piston 100 therein. The rod 101 of the piston extends through the adjacent lower carriage arm 82 and at its outer end is enlarged to engage the arm and pull the carriage downwardly when the servo is energized.

In operation, let it be assumed that a lens blank 20 has been placed in the work holder 21 with the carriage 79 retracted downwardly and that the yoke has been adjusted so that the tool axis 33 of rotation intersects the work spindle axis 34 at a point corresponding to the center 35 of curvature of the work surface 36 when the carriage is against the stop 96 and the grinding operation is finished. With the finish grinding elements 70 retracted, the motors 44 and 86 are energized to rotate the work and the tool spindles 24, 25, and 66 and the servo 98 is deenergized to permit feeding of the lens blank 20 under the action of the weights 92 into engagement with the rough grinding elements 69. The lens continues to feed into the rough grinding elements until the carriage engages the stop 96 and the rough grinding elements are no longer effectual to grind the lens, an action corresponding to "sparking out" in metal grinding operations. At this time, air is admitted to the rod ends of the cylinders 75 to advance the finish grinding elements 70 under light air pressure axially beyond the rough elements 69 and into engagement with the work. Since the rough and finish grinding elements are disposed along a circle concentric with the tool axis 33, the finish elements engage a zone of the lens surface traversed by the rough elements. After a short time determined from experience and depending on the type of lens being ground, air is admitted to the head ends of the cylinders 75 to retract the finish elements and the carriage servo 98 is energized to retract the carriage for removal of the finished lens and the insertion of another lens blank.

The angularly spaced rough and finish grinding elements may take various forms. One modification is shown in Figs. 7 and 8 in which each of the elements 102 and 103 are continuous so as to form an annulus with projections and notches on the inner periphery of the outer or rough element 102 alternating with each other and mating with complementary projections and notches on the outer periphery of the inner or finish element 103.

Another modified form is shown in Figs. 5 and 6 in which three sets of grinding elements, a rough element 104, a semi-finish element 105, and a finish element 106, lie along a common circular path and are arranged on the inner ends of three concentric spindles 107, 108 and 109 which are movable axially relative to each other. If desired, the finish element 106 may be impregnated with a material fine enough to effect a polishing operation after rough and finish grinding by the other two elements 104 and 105.

In the modification shown in Fig. 11, rough elements 110 and finish elements 111 are formed as circular blocks of abrading material which are embedded in angularly spaced portions of two tool holders 112 and 113. These portions are arcuate in cross section and movable axially relative to each other in a manner similar to the holders 23 and 68 above referred to.

The machine described above may, merely by the substitution of a few parts, be used for performing very fine grinding or polishing operations in which it is desirable to effect a truing operation on the polishing tool during the polishing operation. Such a modified machine is shown in Figs. 12 through 16 in which parts corresponding to the parts above described are indicated with corresponding reference numbers. The simultaneous polishing and truing operations are effected by rotating a polishing tool 115, a truing element 116, and the lens blank 20 about axes which intersect at the center 35 of curvature of the surface 36 being ground and feeding the polishing tool axially into engagement with the truing element and the lens blank axially into engagement with the polishing tool. In the form shown in Figs. 12, 13, and 14, the polishing tool 115 is concave and the work surface is convex whereas, in the form shown in Figs. 15, and 16, a convex polishing tool is arranged to engage a concave lens surface.

To simplify the construction of a polishing machine of the above character and to facilitate accurate positioning of the truing element 116, the polishing tool 115, and the lens 20 for precision finishing of the latter, the invention contemplates mounting the truing element concentrically with respect to the lens so that the axes of the truing element and the work coincide. Thus, all three axes of the tool, the truing element, and the work may be brought into the proper relation of intersection at the center 35 of curvature of the work surface 36 merely by adjusting the positions of the tool and the work axes 33 and 34. In the present instance, the truing element 116 is mounted in a holder 117 on a vertical hollow spindle spindle 118 journaled in the work carriage 79. The work holder 21 is concentric with the truing element holder and is secured to the inner end of an inner work spindle 119 journaled in and movable axially relative to the hollow spindle 118. The motor 86 (not shown in Fig. 12) mounted on the carriage 79 rotates the hollow spindle 118 through a belt (not shown in Fig. 12) and a pulley 120 keyed to the outer end of the spindle and secured thereon as by nuts. At the same time, the motor rotates the inner spindle independently of the truing element and at a different speed through another belt (not shown) and another pulley 121 keyed to the inner spindle.

To feed the lens 20 axially of the truing element, the inner work spindle 119 is secured to a slide 122 (Fig. 12) which is mounted on the vertical guides 84 and is movable relative to the carriage 79 along the guides. The slide is yieldably urged upwardly by weights (not shown) acting through cables 123 connected to the slide. Similar cables 124 connect the carriage studs 95 and the weights 92 (not shown in Fig. 12) to urge the carriage upwardly. Upward movement of the carriage is limited in this instance by two individually adjustable stops 125 which are rigid with brackets 127 secured to the guides 84 and are located at widely spaced points on opposite sides of the plane 31 to engage the outer ends of the upper carriage arms 82. By using two stops which are adjustable individually and engage the carriage 79 at widely spaced points, it is possible to locate the work axis 34 precisely in the plane 31 and thereby secure accurate positioning of the lens 20 regardless of any deflection in the parts caused by temperature changes. Shock absorbing devices 126 of suitable construction may be mounted on the upper carriage arms to engage the brackets 127 and reduce the rate of upward movement of the upper carriage arms 82 just before engagement of the latter with the stops.

Herein, the polishing tool 115 is secured to the inner tool spindle 66 which is fed axially toward the truing element 116 by a reversible electric motor 128. The latter is mounted on a plate 129 secured to the outer end of the inner spindle and acts through a screw 130 to turn worm wheels 131 which are journaled in the plate and are threaded on parallel rods 132 secured as by bolts to the plate 76 at the upper end of the sleeve 41 in the hollow member 40 of the yoke. When the motor is energized, the spindle plate 129 is moved toward or away from the sleeve plate 76 and the polishing tool is moved inwardly or outwardly along its axis depending on the direction of rotation of the motor.

In the operation of the polishing machine, the yoke and the stops 125 are adjusted so that the axis 33 of the polishing tool 115 will intersect the axis 34 of the truing element 116 and the work 20 at the point which coincides with the center 35 of curvature of the work surface and is the center of curvature of the truing surface of the truing element (see Figs. 13 and 14) at the time that the carriage arms 82 are engaging the stops. Then, the carrage is retracted by energizing the servo 98, the lower end of the hollow spindle 118 engaging the pulley 121 on the inner spindle 119 to retract the slide 122 for inserting the lens blank 20 in the work holder 21. The servo 98 is then deenergized to permit the carriage to move upwardly against the stops under the action of the weights 92 and the motors 44 and 86 are energized to rotate the polishing tool, the truing element, and the lens at different speeds. At this time, the motor 128 is energized to feed the polishing tool slowly into engagement with the truing element and the slide 122 is permitted to move upwardly relative to the carriage and project the lens surface into engagement with the polishing tool. Such engagement continues for a predetermined time depending on the type of lens being ground. At the end of this time, the servo 98 is energized to retract the carriage and the slide for the insertion of another lens blank to be polished. If desired, the switches for controlling all of the motors and hydraulic servos may be centralized at a control panel 134 located conveniently on the machine frame.

It will be apparent that the machine above described is especially adapted for high production lens grinding since different degrees of grinding may be performed on a lens in a continuous operation and because the novel mounting of the tool spindles 24 and 66 enables adjustments of the same to be made quickly and easily. By supporting the tool spindles at widely spaced points on opposite sides of the common plane of the work and tool axes 33 and 34, it is possible to avoid inaccuracies in the work caused by vibration and deflection of the machine parts during the grinding operations. Accuracy in finished lenses is further insured by the novel concentric arrangement of the truing element 116 and the work holder 21 so that the machine may be set up for simultaneous truing and grinding operations by positioning only two axes, that of the polishing tool 115 and the common axis 34 of the lens and the truing element.

I claim as my invention:

1. In an abrading machine, the combination of, a frame, an annular truing element, means on said frame rotatably supporting said truing element, a work holder for supporting a workpiece within said truing element and rotatably mounted on said frame to turn the workpiece about the axis of the truing element, a spindle adapted to support an abrading tool on said frame for rotation about an axis lying in a plane including the axis of said truing element and said workpiece, means on said frame for moving said spindle axially to bring said abrading tool into engagement with said truing element, and means on said frame for moving said work holder axially relative to said truing element to bring said workpiece into engagement with said abrading tool.

2. In an abrading machine, the combination of, an annular truing element, means on said frame rotatably supporting said truing element, an abrading tool mounted on said frame for en-

gagement with said truing element, a work holder for supporting a workpiece within said truing element and rotatably mounted on said frame to turn the workpiece about the axis of the truing element, and means on said frame for moving said work holder axially relative to said truing element to project said workpiece axially beyond the truing element and into engagement with said abrading tool.

3. In an abrading machine, the combination of, a frame, a work holder mounted on said frame to rotate about a first axis and adapted to support a workpiece, a hollow spindle mounted on said frame for rotation about a second axis lying in a plane including said first axis, a first abrading tool carried by said hollow spindle and comprising a plurality of arcuate portions angularly spaced around and extending along a circular path concentric with said second axis and disposed at a predetermined radius therefrom to intersect said first axis during rotation of the tool, an inner spindle disposed within and rotatable with said hollow spindle, a second abrading tool carried by said inner spindle and comprising a plurality of arcuate portions extending along and spaced angularly around said path and intervening between the spaced portions of said first tool, and means on said frame mounting one of said spindles for movement axially relative to the other spindle to bring said tools successively into engagement with a common zone of said workpiece intersected by said first axis.

4. In an abrading machine, the combination of, a frame, a pair of abrading tools mounted on said frame for rotation about a common axis and each having a plurality of arcuate portions spaced angularly around and extending along a common circular path having said axis as its center with the arcuate portions of one tool intervening between the arcuate portions of the other tool along said path, and means for selectively moving said tools relative to each other along said axis to bring said arcuate portions of the respective tools alternately into engagement with a common zone of a workpiece supported on said frame.

5. In an abrading machine, the combination of, a frame, an abrading tool rotatably mounted on said frame and comprising a plurality of angularly spaced elements disposed along a circular path, a second abrading tool mounted on said frame to rotate about the axis of said first tool and comprising a plurality of angularly spaced elements disposed along said path and intervening between the elements of said first tool, and means for selectively advancing said tools axially relative to each other into engagement with a common zone of a workpiece supported on said frame.

6. In an abrading machine, the combination of, a frame, a pair of abrading tools mounted on said frame for rotation about a common axis and along a common circular path concentric with said axis, each of said tools having a portion spaced angularly around said path from a portion of the other tool, and means for selectively advancing said portions relative to each other along said axis to bring the respective portions alternately into engagement with a common zone of a workpiece supported on said frame.

7. In an abrading machine, the combination of, a frame, a carriage mounted on said frame for movement along a rectilinear path, a hollow spindle journaled in said carriage for rotation about an axis extending longitudinally of said path, a holder on one end of said spindle for supporting a truing element with the cutting surface of the same disposed radially outwardly from said axis, an inner spindle journaled in and movable axially relative to said hollow spindle, a work holder on said inner spindle adjacent said first holder for supporting a workpiece within the radius of said truing element and turning the workpiece about the axis of the truing element, a third spindle adapted to support an abrading tool and journaled on said frame to rotate about an axis lying in a plane including the axis of said inner and outer spindles, mechanism on said frame for moving said carriage along said path to bring said truing element and said abrading tool into engagement with each other, and mechanism for moving said inner spindle axially relative to said hollow spindle to project said workpiece beyond said truing element and into engagement with the abrading tool.

8. In an abrading machine, the combination of, a frame, a first holder for supporting an annular truing element, a work holder concentric with said first holder for supporting a workpiece within said truing element, an outer hollow spindle journaled on said frame and supporting said first holder to turn the truing element about its axis, an inner spindle journaled in and movable axially relative to said hollow spindle and supporting said work holder to turn the workpiece about the axis of the truing element, a third spindle adapted to support an abrading tool for engagement with said truing element and journaled on said frame to rotate about an axis lying in a plane including the axis of rotation of said inner and outer spindles, means on said frame for rotating said spindles independently of each other, and means for moving said inner and outer spindles axially relative to each other to project the work surface of said workpiece into engagement with said abrading tool.

9. In an abrading machine, the combination of, a frame, an elongated hollow member, a spindle journaled in said member for rotation about an axis lying in a predetermined plane, a crosspiece secured to and extending transversely of said member with opposite ends of the crosspiece disposed on opposite sides of said frame, two supporting members on said frame disposed at opposite ends of said crosspiece and pivotally connected thereto to permit swinging of said spindle in said plane about an axis normal to the latter, a carriage mounted on said frame for movement toward and away from one end of said spindle, a second spindle supported by said carriage for rotation about an axis lying substantially in said plane with one end of the spindle adjacent said one end of the first spindle, and means for tilting said carriage and said second spindle in a second plane perpendicular to said first plane to cause the axes of said spindles to intersect.

10. In an abrading machine, the combination of, a frame, a spindle, a member supporting said spindle for rotation about an axis lying in a predetermined plane, means pivotally mounting said member on said frame to permit swinging of said spindle in said plane about an axis normal to the latter, a carriage mounted on said frame for movement toward and away from one end of said spindle, a second spindle supported by said carriage for rotation about an axis lying substantially in said plane with one end of the spindle adjacent said one of said first spindle, means on

said carriage providing two abutment surfaces disposed at widely spaced points on opposite sides of said plane, a first stop mounted on said frame to be engaged by one of said surfaces as said carriage moves toward said one end of said first spindle, a second stop mounted on said frame and similarly disposed with respect to the other of said surfaces, and means to move at least one of said stops relative to its abutment surface independently of the movement of said carriage thereby to effect tilting of the carriage and intersecting of the axes of said spindles.

11. In a abrading machine, the combination of, a frame, a first spindle rotatably mounted on said frame with its axis lying in a predetermined plane, a carriage mounted on said frame for movement toward and away from one end of said spindle, a second spindle supported by said carriage for rotation about an axis lying substantially in said plane with one end of the spindle adjacent said one end of said first spindle, means on said carriage providing two abutment surfaces disposed at widely spaced points on opposite sides of said plane, a first stop mounted on said frame to be engaged by one of said surfaces as said carriage moves toward said one end of said first spindle, a second stop mounted on said frame and similarly disposed with respect to the other of said surfaces, and means to move at least one of said stops relative to its abutment surface independently of the movement of said carriage thereby to effect tilting of the carriage and intersecting of said axes.

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