United States Patent

Clark

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[54] **MULTIPLE HEAD LENS PROCESSING MACHINE**

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[52] **U.S. Cl.** .....**51/3,** 51/166 TS, 51/284

[51] **Int. Cl.** **B24b 5/00**

[58] **Field of Search**.....51/3, 131, 166 TS, 166 FB, 51/166 T, 284

[56] **References Cited**

UNITED STATES PATENTS

441,570	11/1890	Leighton	51/131 UX
886,212	4/1908	Hoffman	51/131
1,084,529	1/1914	Bentzon et al.	51/131
1,347,766	7/1920	Tillyer et al.	51/284 X
1,427,787	9/1922	De Wille	51/166.9 UX
2,214,361	9/1940	Burroughs	51/131
3,128,580	4/1964	Davis	51/131

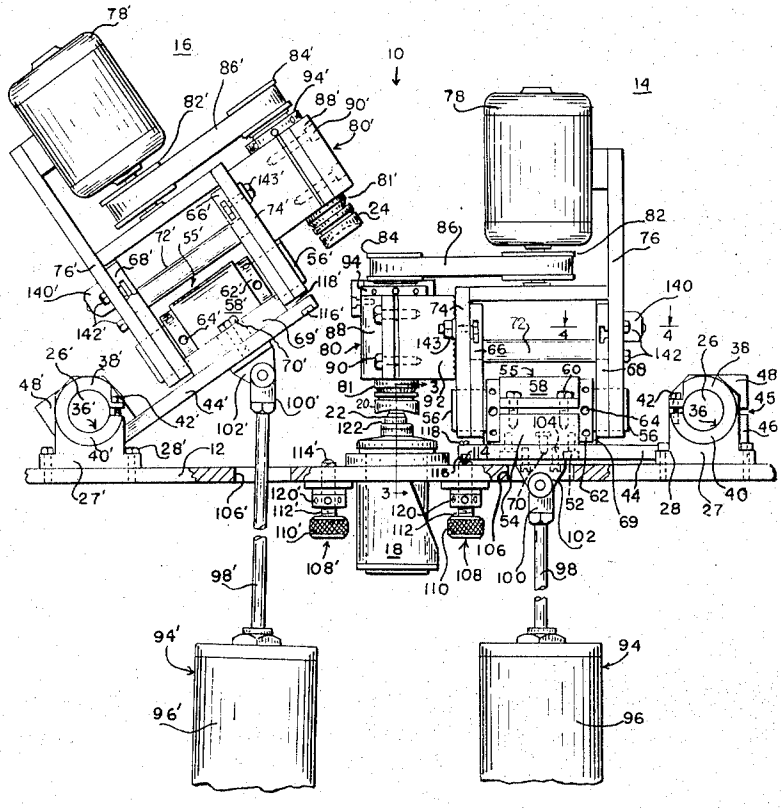
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[57] **ABSTRACT**

A machine for performing multiple operations upon a lens material for forming a lens at a common mounting block has a plurality of spindleheads pivotally carried by a single base support thereby eliminating the need for mounting, dismounting and remounting the lens at each operational stage. The spindles carry tools, for example, for generating, lapping, edging and/or polishing a lens. The lens is mounted on a rotatable lens holder which is disposed in fixed axial relationship to the base mounts of the operational heads. A control system is provided for sequentially operating hydraulic actuators coupled for pivoting the head assemblies and for engaging the tools with the lens material for performing the sequenced operations.

22 Claims, 6 Drawing Figures



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SHEET 1 OF 3

FIG. 1

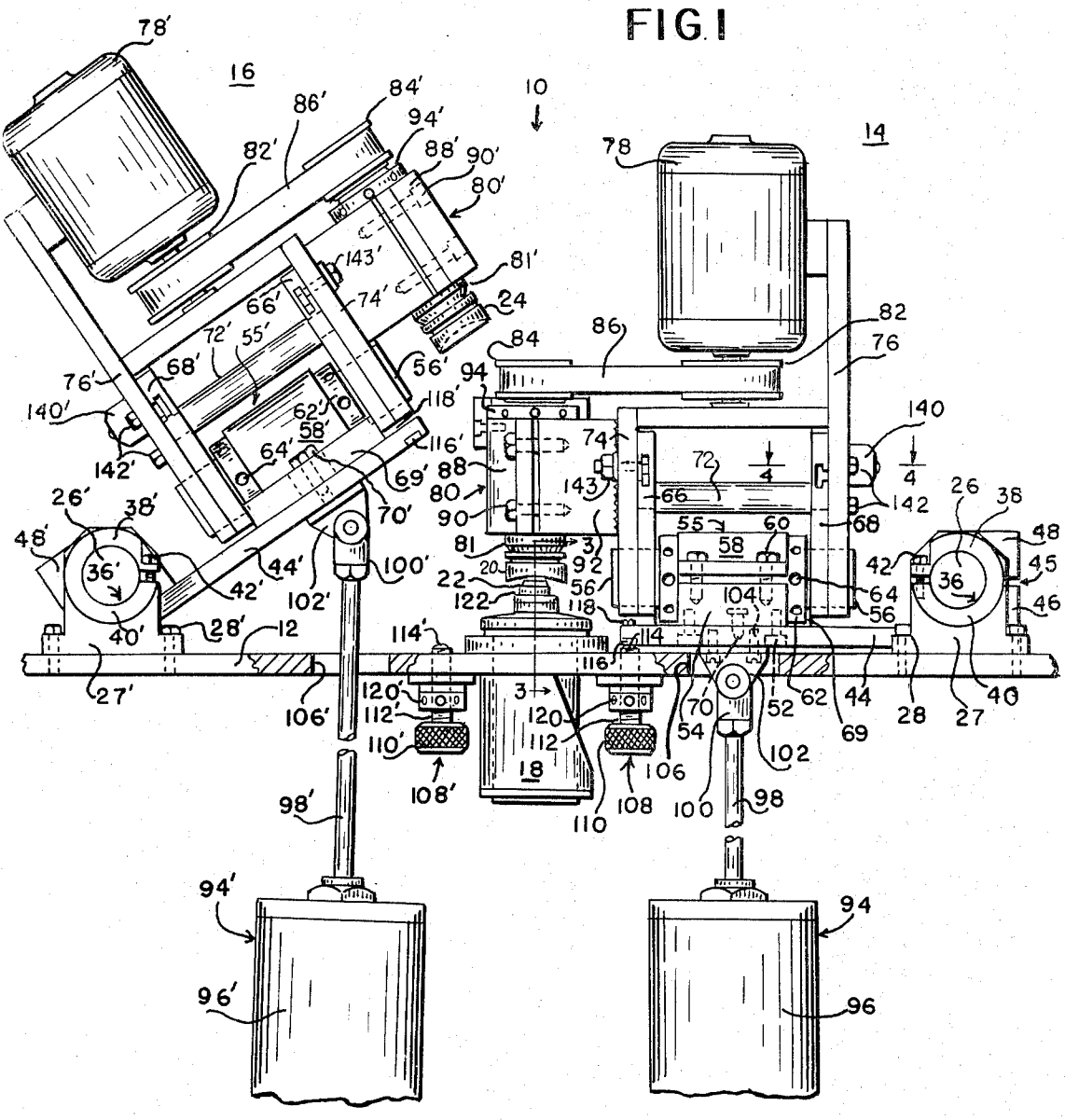
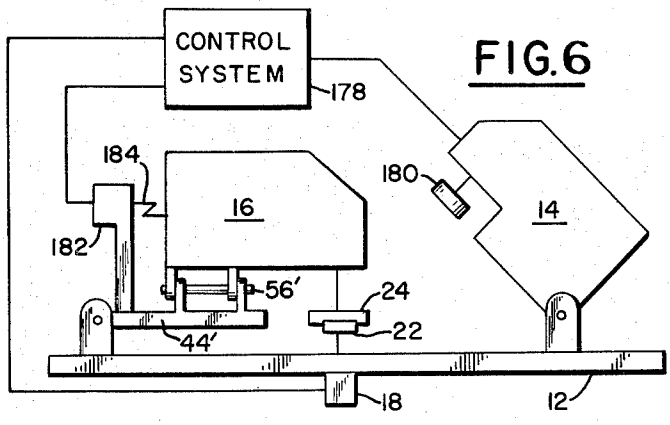


FIG. 6



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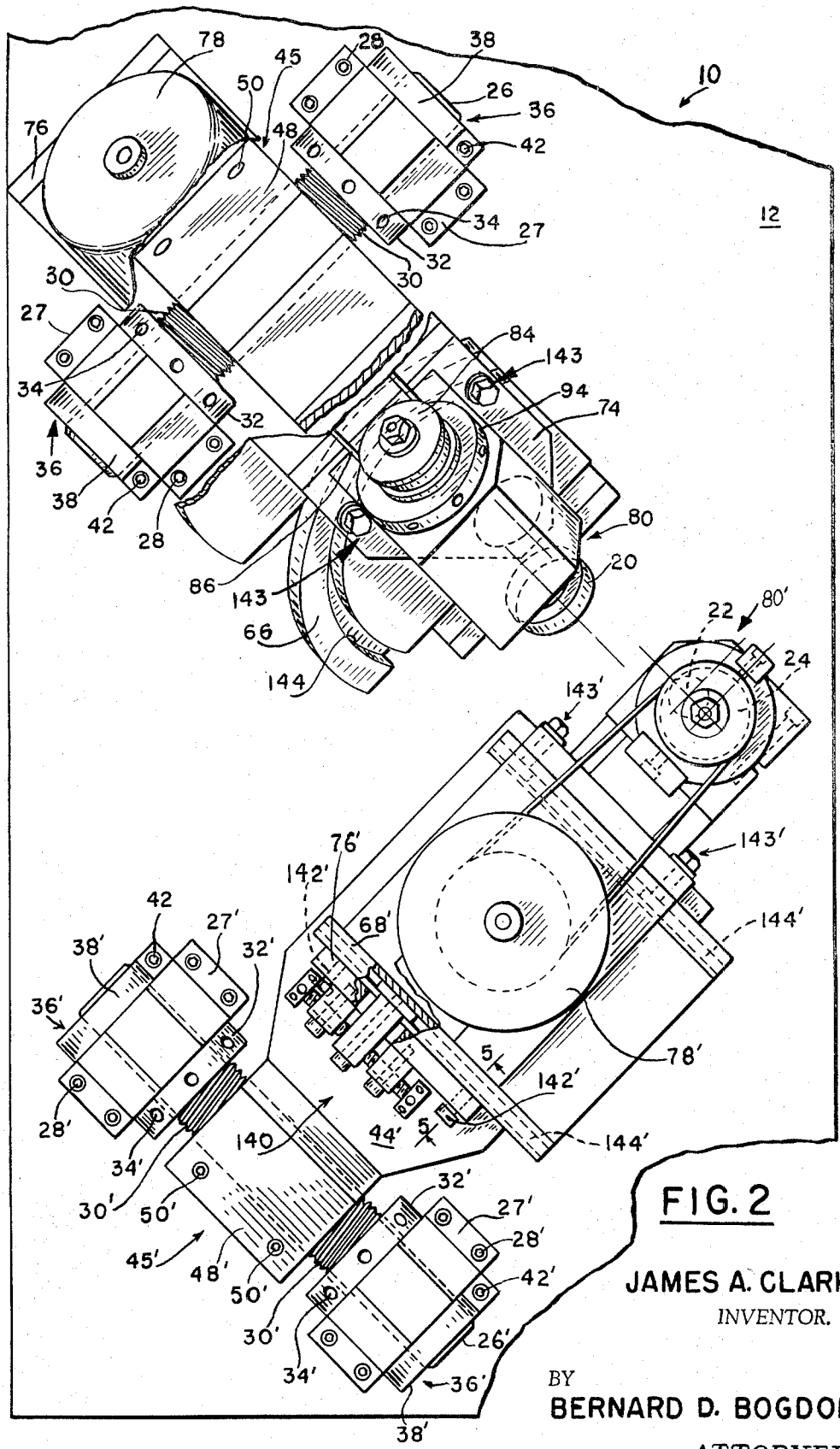


FIG. 2

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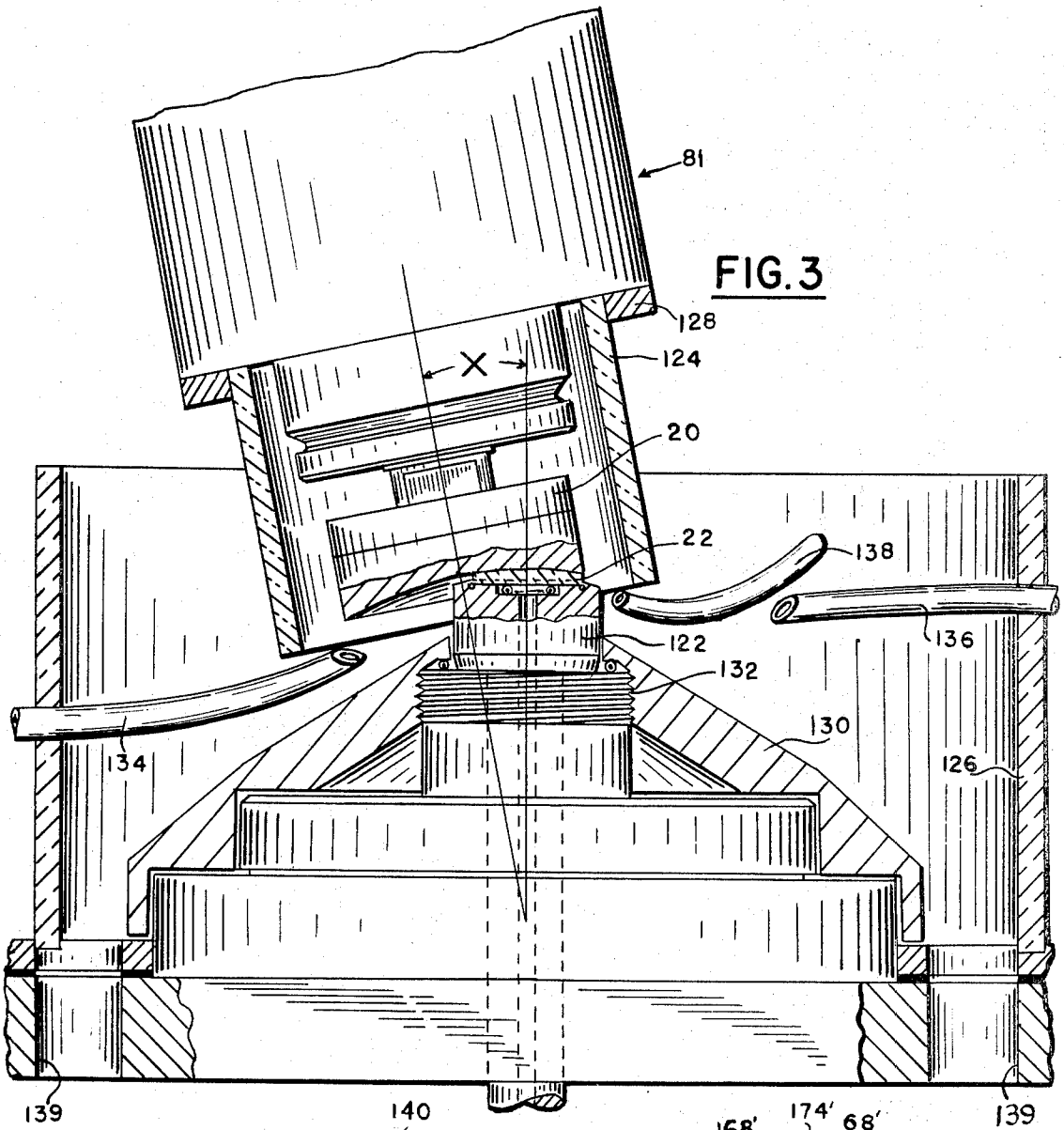


FIG. 3

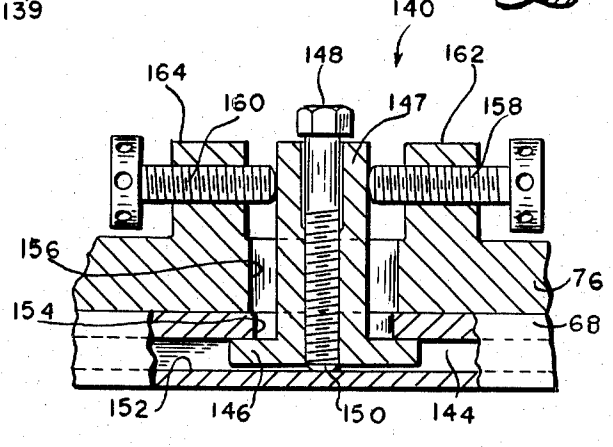


FIG. 4

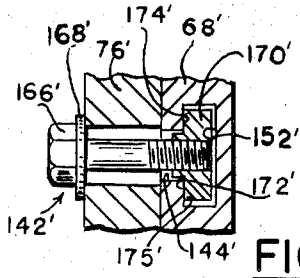


FIG. 5

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MULTIPLE HEAD LENS PROCESSING MACHINE

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

This invention relates to a lens processing machine and more particularly, to a lens processing machine having a single workpiece holder and pivotally mounted spindleheads, for performing more than one process operation, upon a lens material for manufacturing a single lens or a block of lenses.

2. Description of the Prior Art

In the optical lens manufacturing industry, considerable time, material and accompanying expense is being expended in creating a finished lens. The majority of the machinery and devices available are equipped to carry out only one step in the multi-step operation of lens manufacturing. For example, presently a separate machine is utilized for each of the steps of rough grinding, fine grinding, edging and polishing. These machines cannot be modified to carry out more than one of these functions without extensive costly change. Some machinery has been adapted to simultaneously provide essentially the same process steps at different areas of a single lens, for example, grinding a singlet lens having different focal length surfaces such as bifocal ophthalmic lens, but these machines likewise must be extensively altered to carry out more than one process.

Another multiple operation method involves modifying conventional machines for operating multipurpose tools adapted, for example, for initially rough grinding and subsequentially fine grinding for lens generation. Tools of this type are relatively expensive and require a rather extensive operational control system which further adds to the cost of the operation.

The industry has for many years successfully and competitively manufactured quality lens following the conventional methods using standard machinery. As labor costs rise in the United States and as particular foreign manufacturers improve their quality and use relatively low cost labor, it is increasingly difficult to maintain a competitive position using standard well-established methods. The additional time that is required to set up a lens for any second or following process operation is becoming increasingly noticeably expensive. In addition, in the process of dismounting and remounting a lens for further processing, it is extremely difficult, if not impossible, in reasonable manufacturing time to axially align the lens in an attempt to maintain its optical axis in order to conduct the subsequent processes with reference to the lenses' established axis. Because of the alignment difficulty, each following operation must be adapted to remove sufficient material to establish a new concentric axis in addition to being adapted to carry out its specific designated operation, such as polishing. It is difficult to ascertain the reduction-in-quality machined into the lens each time it is remounted and its center of curvature is reestablished. There is little doubt, however, that as spindle rotates faster and as stock removal becomes less, as for example during polishing, that lens quality decreases in terms of regularity and conformance since the inertia of a polishing tool causes uneven loads on a fast turning eccentrically disposed lens.

SUMMARY OF THE INVENTION

This invention provides a machine for generating a lens rough milling, and finishing a lens by fine milling and polishing while the lens is affixed to a single lens holder. The necessity of dismounting and remounting a lens for progressive processing has been eliminated. The lens and the lens holder rotate about an axis disposed in fixed relationship to base mounts of spindleheads carrying tools adapted to sequentially engage the work to manufacture a lens. The tool passes over the center of the lens under construction and the respective axis of each tool for each spindlehead passes through the center of curvature of the lens after completion of the operation of the tool upon the lens material and before the spindlehead is disengaged. Since a lens is manufactured without dismounting and remounting of the lens considerable time and labor expense is saved in the manufacturing process. In addition, since the lens is found to be of high quality, because it is made about one optical axis which does not change during the manufacturing, less inspection time is required and an additional cost reduction is realized there. The savings from less handling and storage of lenses between operations in terms of space, labor and breakage is also substantial.

This invention provides a machine which is economical to manufacture and which is adapted to produce high quality lenses at drastically reduce manufacturing costs.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a fragmentary front elevational view of a multiple head lens processing machine according to the principles of the present invention, shown with one head in an operational position and with another head in a standby position.

FIG. 2 is a fragmentary plan view of the machine in FIG. 1 with the illustrated heads disposed in reversed operational and standby positions.

FIG. 3 is a fragmentary cross-sectional view along the plane of line 3—3 of FIG. 1 illustrating the grinding worktool spindle and workpiece spindle including plumbing for slurry and coolant fluids.

FIG. 4 is a typical fragmentary cross-sectional view of a worktool spindle angle adjustment and clamping assembly along the plane of line 4—4 of FIG. 1.

FIG. 5 is a typical fragmentary cross-sectional view of a worktool spindle angle clamping device along the plane of line 5—5 of FIG. 2.

FIG. 6 is a schematic diagram according to the principles of the present invention including, in part, the embodiment according to FIG. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

In FIG. 1, a multiple head lens processing machine 10 is shown as having a base 12 for carrying a plurality, and more specifically, as shown, two pivotable and rotatable worktool heads 14 and 16 disposed about a generally centrally located workpiece mounting assembly 18 carried by the base 12. The worktool head 14 is carrying a generating tool 20 and is in an operational position in engagement with a lens material 22. The worktool head 16 is shown at a rest or non-opera-

tional position and is pivoted away from the workpiece mounting assembly **18**.

In FIG. **2**, the worktool head **16** which comprises, for example, a lens polishing tool **24** is in an operational position in engagement with the lens material **22** and shows the worktool head **14** at an elevated or non-operational rest position. For clarity, the elements of FIG. **1** are shown as normal to the drawing surface and not in perspective as would be necessary considering the skewed disposition illustrated in FIG. **2**.

As will be clear from the illustrations and as hereinafter disclosed, the worktool heads **14** and **16** are identical in most aspects and an illustration of one, for the most part, constitutes a typical illustration suitable for both. Like parts of the worktool head **16** respectively, will be identified by like reference characters of the worktool head **14** with a prime designation.

Pivotable operation of the worktool head **14** is provided for about a base shaft **26** journalled within and passing through two spaced apart bearing clad mounting blocks **27** affixed to the base **12** by standard means, for example, by bolts **28** fastened in a conventional manner. As best seen in FIG. **2**, the base shaft **26** is partially threaded at shaft areas **30** generally disposed immediately inside each of the mounting blocks **27** for engagement with nuts **32** for providing for minute lateral movement of the base shaft **26** during fine adjustment. The nuts **32** are generally circular having a convenient number of radially extending holes **34** for engaging a positioning tool (not shown) used in laterally moving the base shaft **26** for fine adjustment.

Two generally C-shaped mounting clamps **36**, each comprising an upper jaw section **38** and a lower jaw section **40**, are disposed, one each, at each end of the base shaft **26**, as best seen in FIGS. **1** and **2**. The mounting clamps **36** are threadingly engaged with the end portions of the base shaft **26**. After the base shaft **26** is positioned by means of the nuts **32**, the mounting clamps **36** are rotated about the base shaft **26** to snug up to the outside surface of each respective mounting block **27**. The upper and lower jaw sections **38** and **40** of each mounting clamp **36**, respectively, are secured, for example, by means of a bolt **42** passing through a clearance hole in the upper jaw section **38** and threadingly engaged with the lower jaw section **40** to thereby secure the position of the base shaft **26**.

As best seen in FIG. **1**, worktool heads **14** and **16** comprise a frame structure having frame bases **44** and **44'** for pivotable movement about the base shafts **26** and **26'**, respectively. As illustrated in FIG. **2**, the frame base **44'** is secured to a non-threaded portion of the shaft **26'** between the shaft's threaded areas **30'** by a base shaft clamp **45'** of generally similar construction as the mounting clamps **36** and comprises a lower jaw portion **46'** integrally formed with the frame base **44'** and threadingly engaged with an upper jaw portion **48'** by, for example, two spaced apart bolts **50'**.

The inner surfaces of the upper jaw sections **38** and the lower jaw sections **40** of the mounting clamps **36** and the inner surfaces of the upper jaw portion **48** and the lower jaw portion **46** of the base shaft clamp **45** differ in that the mounting clamps **36** are formed to fixedly engage the base shaft **26** at threaded surfaces of the base shaft **26**, whereas the base shaft clamp **45** engages the base shaft **26** at a non-threaded outer surface of the base shaft **26**.

Affixed to the frame base **44**, in any conventional manner, for example, by bolts **52** in FIG. **1** is a lower jaw section **54** of a C-shaped support clamp **55** for securing a support shaft **56** having an axis extending generally parallel to the frame base **44** and transversely to the base shaft **26**. A jaw section **58** comprises the upper part of the support clamp **55** and carries within two spaced apart clearance holes, two bolts **60** threadingly engaged with the lower jaw section **54**. The C-shaped support clamp **55** is similar in configuration to the base shaft clamp **45** and engages at its inner surface, a non-threaded section of the support shaft **56**. When the support clamp **55** is in tight engagement with the support shaft **56**, nuts **62**, disposed at opposite ends of the support clamp **55** to threadingly engage the support shaft **56**, are moved in opposite directions along the support shaft **56** to be tightened against the support clamp **55** by means of a tool inserted into one or more of radially extending apertures **64** in the nuts **62**.

As hereinbefore mentioned, worktool head **14** is rotatable, as will be appreciated, about the support shaft **56** and secured, at other times when in operation, by the support shaft clamp **55** affixed to the frame base **44**. For providing additional stability and for including structure for fine angular adjustment of the worktool head **14** with respect to the workpiece mounting assembly **18**, there is provided spaced apart lateral frame sides **66** and **68** affixed to a mounting plate **69**, best seen typically in FIG. **1**, adjustably held fast to the frame base **44** by, for example, a bolt **70** passing through an elongated clearance hole in the mounting plate **69** to threadingly engage the frame base **44**. The lateral frame sides **66** and **68** extend generally transversely to the frame base **44** to maintain a generally uniform distance therebetween and are secured in this relationship by a support rod **72** fixedly secured to each of the lateral frame sides **66** and **68** at a point remote from their attachment to the mounting plate **69**. The support shaft **56** journals within bearing clad apertures provided in the lateral frame sides **66** and **68** and extends outwardly therefrom to fixedly engage rotational frame sides **74** and **76** which comprise a portion of the worktool head **14** which is rotatable about the support shaft **56**.

The rotational portion of the worktool head **14**, further, comprises a power source for driving the tools and generally includes, for example, an electrical induction drive motor **78**, of, for example, **1** horsepower, fixedly mounted to an extended portion of the rotational frame side **76**; a worktool spindle clamp **80** is fixedly secured to the rotational frame side **74** for rotatably carrying a worktool spindle **81** for driving the generating tool **20**. A pulley system including an electrical motor pulley **82**, a worktool spindle pulley **84** and an endless timing belt **86** matingly engaged with the respective pulleys, provides for delivering the power to the worktool spindle **81** for driving the generating tool **20** when the drive motor **78** is energized.

The worktool spindle clamp **80** is similar in configuration to the support shaft clamp **55** and the base shaft clamp **45**. The worktool spindle clamp **80** is of C-shaped configuration and comprises a front jaw portion **88** having two spaced apart clearance holes for carrying two bolts **90** threadingly engaged with a back jaw portion **92** affixed to the rotational frame side **74**.

As will be appreciated, the worktool spindle clamp 80 is made secure to the worktool spindle 81 after the worktool spindle 81 is adjusted for height by a circular nut 94 threadingly engaged with the worktool spindle 81 for raising and lowering the combination of the worktool spindle 81 and the attached generating tool 20 relative to the lens material 22. The worktool spindle 81 comprises, for example, a Whitnon spindle having ball bearings. The generating tool 20 may, for example, be either a diamond impregnated continuous lap tool or a pellet lap tool.

Pivotal operation of the worktool heads 14 and 16 about their respective base shafts 26 and 26' is provided for by, for example, hydraulically controlled air cylinders 94 and 94', respectively, as best seen in FIG. 1. Suitable air cylinders are available from, for example, Electro-Mechano Company of Milwaukee, Wis. The air cylinder 94 generally comprises an air and hydraulic control cylinder body 96 and a movable piston rod 98 having an end fitting 100 adjustable in length attached to a clevis 102 affixed in any suitable manner, for example, by means of bolts 104 to the frame base 44. An aperture 106 is provided in the base 12 for passage therethrough of the piston rod 98 and its related connected parts. The air and hydraulic control cylinder body 96 internally comprises a mechanism for metering the the flow of hydraulic oil from one side of its piston to the other, which metering effectively occurs during the operational action of the worktool heads 14 and 16.

A stop assembly 108 is provided for limiting the down travel of the worktool head 14. The stop assembly 108 comprises an adjustable knurled knob 110 having a shaft 112 extending therefrom to threadingly engage with the base 12 and to pass therethrough to provide at its shaft tip 114 a bearing surface for a stop material 116 inlaid in the frame base 44 and held thereto by means of a bolt and nut assembly 118. The amount of the protrusion of the shaft tip 114 above the top surface of the base 12 is adjustable by turning the knurled knob 110 in an appropriate direction. To fixedly maintain the amount of the protrusion of the shaft tip 114 after any setting, a nut assembly 120 is provided for tightening against the bottom most surface of the base 12.

The workpiece mounting assembly 18, generally, also comprises a Whitnon spindle having ball bearings and a vacuum chuck 122 of a type well known in the art, as best seen in FIG. 3, to fixedly hold the lens material 22 during operation of either the worktool head 14 or 16.

As is usual, during operation fluids are introduced to facilitate grinding and polishing. FIG. 3 best illustrates splash shields 124 and 126 surrounding the generating tool 20 and the vacuum chuck 122, respectively, provided for this purpose. The splash shield 124 is affixed to the stationary part of the worktool spindle 81 in any convenient manner, such as, by the mounting ring 128. Likewise the splash shield 126 is fixedly held in place relative to the base 12 in any convenient manner. To preclude undesirable foreign matter, including fluids, from penetrating into the workpiece mounting assembly 18 there is provided an additional splash shield 130 threadingly engaged at area 132 with a non-rotational part of the workpiece mounting assembly 18.

Conveniently disposed about the vacuum chuck 122 is at least one jet tube 134 for introducing, for example, a coolant fluid to the lens material 22 when being operated upon by the generating tool 20. Water jets 136, one of which is shown in FIG. 3, are disposed about the vacuum chuck 122 and pass through the splash shield 126 for introducing a lens flushing fluid, such as water, to the lens material 22 after operation thereon by, for example, the generating tool 20. Likewise a jet tube 138 is provided for introduction of a polishing slurry when a second worktool head, such as the worktool head 16 carrying the polishing tool 24, is brought down for operation upon the lens material 22. The flushed coolant and slurry may be recycled by separately capturing each, after each passes through outlet ports 138, defined by the base 12.

As best illustrated in FIG. 2 at the worktool head 16 lens material 22 is eccentrically disposed to the axis of the polishing tool 24 and the worktool spindle 81'. However, as best seen in FIG. 1 at the worktool head 14, the concentric axes of the workpiece lens material 22 and the workpiece mounting assembly 18 lie in the same plane as the axis of the worktool spindle 81 at such time as the stop material 116 embedded in the base frame 44 is brought to bear against the shaft tip 114. As is appreciated, the same alignment is provided for the axis of the work spindle 81' of the worktool head 16 with the axis of the workpiece mounting assembly 18, as best seen in FIG. 2.

In operation, it will be appreciated, that the worktool head 14 engages the lens material 22 at its generating tool 20 to initially commence generation of a lens of aspherical shape. Generation continues to be aspherical until the stop material 116 is brought to bear against the shaft tip 114 at which location the generating tool 20 has completed its operation to provide a spherically shaped lens surface. Certain latitudes may be taken in the polishing of the spherically shaped lens surface, i.e., the worktool spindle 81' may be allowed to float in the direction of the axis of the tool spindle 81' merely by loosening the bolts 90' engaged in the work spindle clamp 80'.

To provide for a predetermined radius of curvature, angular adjustment of either the worktool head 14 or 16 is accomplished, as best seen in FIG. 3, by changing the amount of an angle X defined between the axis of the lens material 22 and the worktool spindle 81'. The angle X is determinative of the center of radius of the curvature of the lens to be formed from the lens material 22.

As hereinbefore mentioned, rotational frame sides 74 and 76 are rotatably adjustable about the support shaft 56 fixed relative to the base 12. Rotatable adjustment of the rotational frame side 76 is provided for by an adjustment and clamping assembly 140 generally centrally disposed upon the frame side 76, as typically shown in FIGS. 2 and 4, and by two T-shaped clamping devices 142, as typically shown in FIG. 5, disposed for frictionally engaging the rotational frame side 76' and the lateral frame side 68', fixed relative to the frame base 44'. For maximum stability, the clamping devices 142 are generally spaced an equal distance from the generally centrally located adjustment and clamping assembly 140. An additional two T-shaped clamping devices 143 of identical configuration to the T-shaped

clamping devices **142**, are provided for additional stability and are disposed for frictionally engaging the rotational frame side **74** with the relatively fixed lateral frame side **66**.

Defined within each of the lateral frame sides **66** and **68** is a T-shaped slot **144** arcuately extending across the breadth of each of the lateral frame sides **66** and **68**, as best seen in FIGS. **1**, **2** and **5**.

For matingly engaging the T-shaped slot **144**, the adjustment and clamping assembly **140** generally comprises a T-shaped follower **146** having a base extension **147**. The follower **146** has a threaded aperture extending through the base extension **147**, for engaging a hold-down bolt **148** having a bolt tip **150** for engaging a lateral surface **152** of the T-shaped slot **144** for securing the angular orientation of the frame sides **76** and **68** after adjustment. The T-shaped follower **146** extends through apertures **154** and **156** provided in the lateral frame side **68** and the rotational frame side **76**, respectively, to extend outwardly therefrom for engaging on each of two lateral sides of the base extension **147** bolts **158** and **160**. The bolts **158** and **160** are threadingly engaged within flanges **162** and **164** extending outwardly from the rotational frame side **76** and disposed on opposite sides of the aperture **156**. The bolts **158** and **160** are adjustable and are rotatable to bear against the lateral surfaces of the base extension **147** of the T-shaped follower **146**, as hereinbefore mentioned, to provide for fine adjustment of the rotational frame side **76** relative to the lateral frame side **68** after the bolt tip **150** of the bolt **148** is turned down against the lateral surface **152** of the T-shaped slot **144**.

In FIG. **5** there is typically illustrated the T-shaped clamping device **142'** which, as hereinbefore mentioned, is identical to the T-shaped clamping device **143**. In the clamping device **142'**, a bolt **166'** of standard configuration passes through an aperture in a conventional washer **168'** to threadingly engage a T-shaped slug **170'** riding in the T-shaped slot **144'**. A surface **172'** of the T-shaped slug **170'** is brought to bear against lateral surfaces **174'** and **175'** of the T-shaped slot **144'** opposite its lateral surface **152'**, when the bolt **166'** is tightened to cause the washer **168** to tightly engage the outer lateral surface of the rotational frame side **76'**.

It will be appreciated from the description, including the illustration of FIG. **6**, that a control system **178** for the multiple head lens processing machine, in its simplest form, would include electrical controls for positioning both worktool heads **14** and **16** at a standby or rest position to provide access for initially mounting the lens material **22** to the workpiece mounting assembly **18**, for lowering each of the worktool heads successively for engagement with the workpiece material **22**, for example, to generate, to polish, or, as illustrated with edging tool **180**, to edge and to, accordingly, introduce the respective coolant and slurry fluids, and to provide for an intermediate flushing to prevent contamination of the reusable fluids and then to cycle the worktool head to the rest position, for example the head **16**, for unloading the polished lens.

As hereinbefore mentioned, to provide a predetermined radius of curvature for the lens desired to be manufactured, adjustment of the angle X is necessary. It will be appreciated that in complex machinery for precision workings of the type herein disclosed, that each machine, eventhough designed to the same standard, will generally require individual final adjustment to provide a predetermined curvature. From experience of those skilled in the subject art, it is most practical for initial machine set-up to be based upon a working experience with the particular machine and art involved after a study has been made of actual statistical results obtained from grinding and polishing lenses and to then preliminarily make a rough estimate of the angle setting necessary to manufacture a lens of the predetermined curvature. Afterwards, initial settings of the equipments are adjusted by trial and error until lenses of desired curvature are consecutively manufactured. Although this procedure may sound out-dated, it is relatively simple and quick to accomplish and is by far the best method of obtaining precision results.

For the illustrated embodiment, according to principles of the present invention, fine angular adjustment is accomplished in the following manner for each of the worktool heads and most specifically for worktool head **14**, as best seen in FIGS. **2**, **4** and **5**. Considering first that the bolts **166** of the T-shaped clamps **142** and **143** and the hold-down bolt **148** of the adjustment and clamping assembly **140** are loose, the worktool head **14** is rotated about the support shaft **56** to a preliminary angular location based upon best judgment of the skilled machine operator and the bolts **166** of the four T-shaped clamps, i.e., clamps **142** and **143**, are tightened. This provides for a preliminary coarse angular setting. Next, the base extension **147** of the T-shaped follower **146** is positioned approximately midway between the flanges **162** and **164** extending from the rotational frame side **76**. Disposing the T-shaped follower **146** midway is accomplished by rotation of either of the bolts **158** or **160**. The hold-down bolt **148** is then tightened. Once the hold-down bolt **148** is tightened and thereby causing the bolt tip **150** to bear against the lateral surface **152** of the T-shaped slot **144**, the T-shaped follower **146** frictionally engages the T-shaped slot lateral surfaces **174** and **175** to fix the dispositional relationship between the T-shaped follower **146** and the lateral frame side **68**.

After centering of the adjustment and clamping assembly **140**, the bolts **166** are loosened and the bolts **158** and **160** of the adjustment and clamping assembly **140** are manipulated for fine adjustment to thereby move the rotational frame side **76** relative to the fixed lateral frame side **68**. After completion of this preliminary final adjustment step the bolts **166** are securely fastened, as hereinbefore mentioned, but this time for a final clamping effort, unless the process needs to be repeated as determined by the end product results. It will be appreciated that the T-shaped clamps **143** are tightened and loosened at the same time as the clamps **142**.

As best seen in FIG. **1**, the tool spindle clamp **80** is provided for adjusting the vertical height of the worktool spindle **81** to control the thickness of the finalized lens, and in the case of the tool spindle clamp **80'** to provide for a free floating worktool spindle **81'** to polish the generated surface of the lens material **22**. Likewise, adjustment of the support shaft clamp **55** provides for fine adjustment of the operational lateral position of the worktool head **14** to maintain planar

alignment of the axes of the worktool spindle 81 and the lens material 22. As illustrated in FIG. 2, fine adjustment of the operational position of the worktool head 16 in the direction of the plane defined by the axis of the lens material 22 and the worktool spindle 81' is provided for by adjustment of the base shaft clamp 45' in the direction of the axis of the base shaft 26'.

For each of the clamps 45, 55 and 80, it will be appreciated that, adjustment is accomplished by loosening of the respective bolts threadingly engaged in each to provide for axial movement of the respective shaft or spindle by rotation of the juxtaposed nuts 32, 62 and 94 for each respective shaft or spindle. The hereinbefore descriptions for the clamps and the steps of fine adjustments are typical and, of course, apply equally as well to the adjustments for either of the worktool heads 14 or 16.

The machine as heretofore described, provides a finished product of exceptionally fine quality. It may be desirable to provide for oscillation of the polisher in manufacturing lenses where quality control is most rigid. In the illustrated embodiment it will be obvious to those skilled in the art that an oscillating polisher disposed to rotate about a crankshaft eccentrically disposed to the worktool spindle 81' may be provided. Additional oscillation devices, for example, might include apparatus for oscillating a polishing head about a vertical axis where the lens acts as a cam to raise the polisher about the center of curvature of the lens. A generally preferred method of oscillation is schematically illustrated in FIG. 6 and involves rotation of, for example, the worktool head 16 about an axis, for example, the axis of the support shaft 56 disposed for extending through the center of curvature of the lens by providing an oscillator assembly 182 cooperating through linkage 184 to provide the desired oscillatory movement, for example, to the worktool head 16.

It will be appreciated that the illustrated practical embodiment of the invention provides a machine for course generation, fine generation, lapping and polishing by methods which include rigidly held and free floating worktools about one single spindle for holding the lens material, and that other practical embodiments are possible to be constructed without departing from the spirit and scope of this invention as defined in the appended claims. As will be appreciated, a myriad of structures are possible without departing from the scope and spirit of the invention.

I claim:

1. A machine for processing lens material to provide a lens having an axis and a center of curvature disposed upon that axis, comprising:

a base;

a lens material holder having an axis, said holder being rotatably carried by said base about the axis of said lens material holder, including means for substantially concentrically disposing the lens material about the axis of said lens material holder;

first processing means for performing a first operation on the less material including means for carrying a first tool in an arcuate path to perform the first operation;

second processing means for separately performing a second operation different than that of the first operation upon the lens material including means for carrying a second tool different than that of the first tool in an arcuate path to perform the second operation; and

means for controlling the operation of said lens material holder including means for coordinating the separate operation of each of said processing means.

2. The machine for processing the lens material, as defined in claim 1, wherein:

the means for controlling the operation includes first operational means for disposing an imaginary axis of each tool, respectively, to pass through the axis of the lens material holder at the center of curvature of the lens material and further including second operational means for passing each tool over a center most point of the lens material.

3. The machine for processing the lens material, as defined in claim 1, wherein:

the first processing means is adapted for carrying a first milling tool for milling a surface upon the lens material.

4. The machine for processing the lens material, as defined in claim 3, wherein:

the second processing means is adapted for carrying a second milling tool for fine milling the surface milled by the first milling tool.

5. The machine for processing the lens material, as defined in claim 3, wherein:

the second processing means is adapted for carrying an edging tool for edging the lens material.

6. The machine for processing the lens material, as defined in claim 3, wherein:

the second processing means is adapted for carrying a polishing tool for polishing the surface milled by the first milling tool.

7. The machine for processing the lens material, as defined in claim 6, wherein:

the second processing means is adapted for carrying a polishing tool in fixed relationship relative to a surface of the lens material disposed for polishing.

8. The machine for processing the lens material, as defined in claim 6, wherein:

the second processing means is adapted for carrying a polishing tool to oscillate about the center of curvature of the lens over a surface of the lens material disposed for polishing.

9. A machine for processing lens material to provide a lens having an axis and a center of curvature disposed upon that axis, comprising:

a base;

a lens material holder having an axis, said holder being rotatably carried by said base for substantially concentrically disposing the lens material about the axis of said lens material holder;

first processing means for performing a first operation upon the lens material including means for carrying a first tool in an arcuate path to perform the first operation, said first processing means carried by said base for movement about two transversely disposed axes;

second processing means for performing a second operation different than that of the first operation upon the lens material including means for carrying a second tool different than that of the first tool in an arcuate path to perform the second opera-

tion, said second processing means carried by said base for movement about two transversely disposed axes; and

means for controlling the operation of said lens material holder including means for coordinating the separate operation of each of said processing means.

10. The machine for processing the lens material, as defined in claim **9**, further including:

a tool for the first operation, said tool being a tool for rough milling generation of the lens material and including a tool for the second operation, said last-mentioned tool being a tool for fine milling generation of the lens material.

11. The machine for processing the lens material, as defined in claim **9**, further including:

a tool for the first operation, said tool being a tool for milling of the lens material and having a tool for the second operation, said last-mentioned tool being a tool for polishing the lens material.

12. The machine for processing the lens material, as defined in claim **9**, wherein:

the first and second processing means each individually comprises a tool holder radially extending from a support axis, respectively defining the first of the two transversely disposed axes for each processing means, said tool holder concentrically defining a tool axis for operational rotation of a tool.

13. The machine for processing the lens material, as defined in claim **12**, further including:

means for variably extending said tool holder in the direction of the support axis.

14. The machine for processing the lens material, as defined in claim **12**, wherein:

each radially extending tool holder is pivotable about the support axis at least 180° in a plane transversely disposed to the support axis, the first of the two transversely disposed axes.

15. The machine for processing the lens material, as defined in claim **14**, further including:

means for alternately moving each processing means relative to the base between a standby position and an operative position for processing the lens material.

16. The machine for processing the lens material, as defined in claim **15**, wherein:

said last-mentioned means includes means for pivotally moving each processing means about a base axis transversely disposed to the support axis and thereby defining the second of the two transversely disposed axes.

17. The machine for processing the lens material, as defined in claim **16**, further including:

means for variably extending said tool holder in the direction of the support axis relative to the base axis.

18. The machine for processing the lens material, as defined in claim **16**, wherein:

the pivotal movement about each respective base axis for each processing means is provided for by mechanical actuators.

19. The machine for processing the lens material, as defined in claim **16**, further including:

means for variably extending said tool holder in the direction of the tool axis.

20. The machine for processing the lens material, as defined in claim **16**, further including:

means for variably extending said tool holder in the direction of the base axis relative to a predetermined fixed point along the base axis.

21. A machine for processing lens material to provide a lens having an axis and a center of curvature disposed upon that axis, comprising:

a base;

a lens material holder having an axis, said holder being rotatably carried by said base for substantially concentrically disposing the lens material about the axis of said lens material holder;

first processing means having a tool holder for carrying a lens material milling tool rotatably about a tool axis, wherein said first processing means includes first support means carried by said base for pivotable movement about a first base axis and second support means for rotational movement about a first support axis transversely disposed to the first base axis, said tool holder generally extending radially from the first support axis;

second processing means having a tool holder for carrying a lens material polishing tool rotatably about a tool axis, wherein said second processing means includes third support means carried by said base for pivotable movement about a second base axis and fourth support means for rotational movement about a second support axis transversely disposed to the second base axis, said tool holder generally extending radially from the second support axis;

means for variably extending each tool holder in the direction of its respective tool axis;

means for variably extending each tool holder in the direction of its respective support axis relative to its respective base axis; and

means for variably extending each tool holder in the direction of its respective base axis relative to a respective predetermined fixed point along its respective base axis.

22. A method of generating a lens from lens material mounted upon a lens material holder of a given lens processing machine having a lens generating tool and a lens polishing tool and of subsequently polishing the lens before removal of the lens from the lens material holder of the given lens processing machine, comprising the sequential steps of:

mounting lens material concentrically upon a rotatable lens material holder of a given lens processing machine;

engaging the lens material with a lens generating tool carried by the given lens processing machine;

generating a lens from the lens material in engagement with the lens generating tool;

disengaging the lens material from the lens generating tool;

engaging the lens with a lens polishing tool carried by the given lens processing machine;

polishing the lens in engagement with the lens polishing tool;

disengaging the lens from the lens polishing material; and

removing the lens from the lens material holder of the given lens processing machine.

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