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(71) Applicant: TOKYO KOGAKU KIKAI KABUSHIKI KAISHA
75-1, Hasunuma-cho Itabashi-ku
Tokyo(JP)

(72) Inventor: Hara, Atsushi
No. 1746-4, Kougasaka
Machida-shi Tokyo(JP)
Inventor: Isokawa, Nobuhiro
No. 217, Idanakano-machi Nakahara-ku
Kawasaki-shi Kanagawa-ken(JP)
Inventor: Suzuki, Yasuo
Kuki Skyheights 418 No. 1-15-73, Chuo
Kuki-shi Saitama-ken(JP)
Inventor: Hatano, Yoshiyuki
No. 1-26-12-205, Hasune Itabashi-ku
Tokyo(JP)
Inventor: Oogushi, Hiroaki
No. 2-20-17, Yaguchi Ohta-ku
Tokyo(JP)

(74) Representative: Rost, Jürgen, Dipl.-Ing. et al
Patentanwälte Dipl.-Ing. Olaf Ruschke
Dipl.-Ing. Hans E. Ruschke Dipl.-Ing. Jürgen
Rost Dipl.-Chem. Dr. U. Rotter
Pienzenauerstrasse 2
D-8000 München 80(DE)

(54) **Lens grinding apparatus.**

(57) A lens grinding apparatus having: a carriage including lens rotating shafts for clamping and rotating a lens to be ground, and a grinding wheel for grinding said lens, said grinding apparatus being characterized in that the box of said carriage accommodates lens-configuration measuring means constituted by, at least one of feelers which can be brought into contact with said lens, and detecting means for detecting the magnitude of travel of said feelers.

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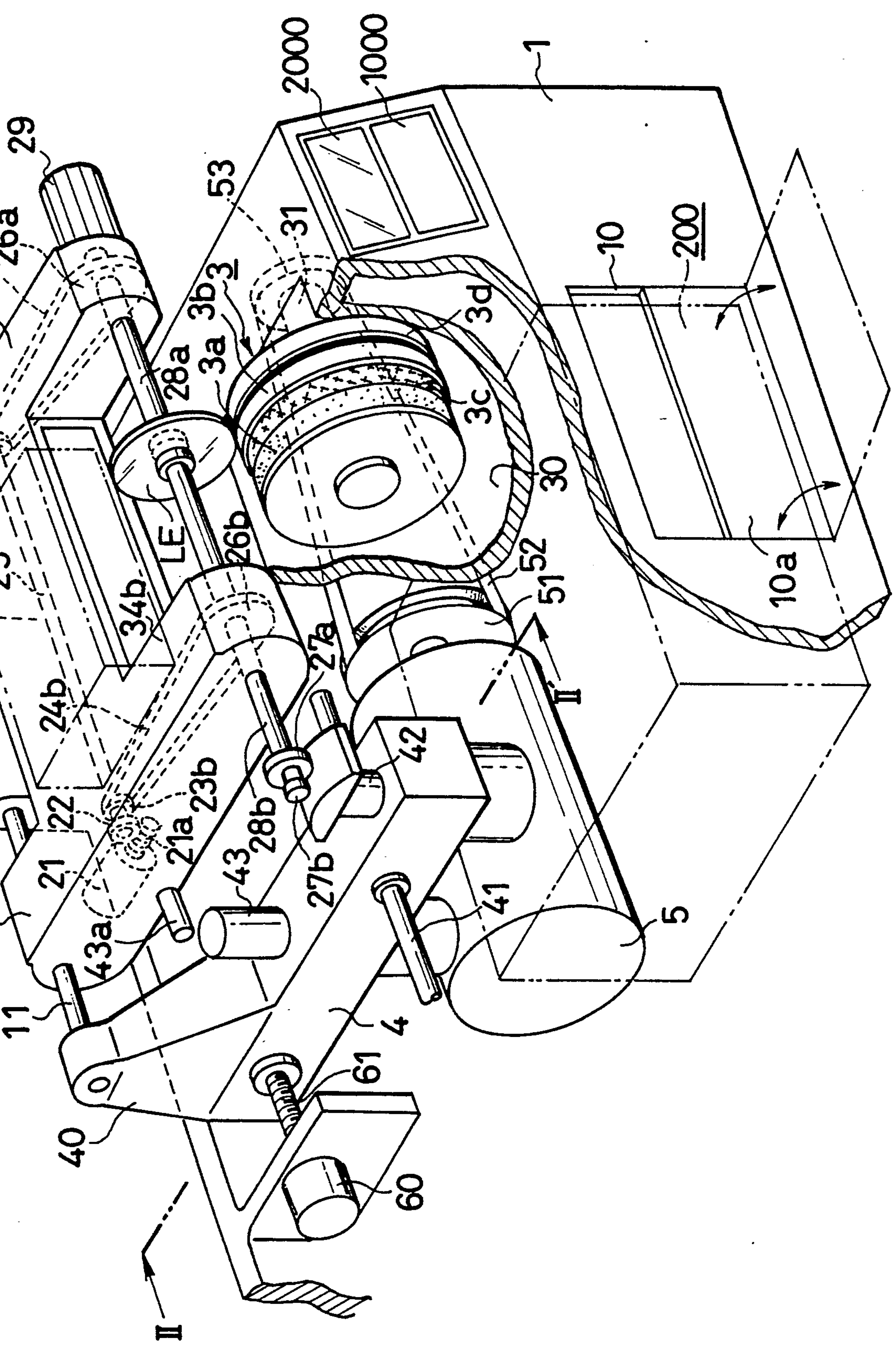
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II

FIG.1

LENS GRINDING APPARATUS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a lens grinding apparatus for grinding an unworked spectacle lens so that the lens may be fitted into the lens frame of the spectacle frame.

Conventional types of lens grinding apparatuses are constituted in the form of a single unit by a carriage having a lens rotating shaft for clamping and rotating a lens to be ground and a grinding wheel for grinding said lens to be ground.

However, such prior-art lens grinding apparatus do not have any means for measuring the configuration of a lens to be ground. Therefore, it has been impossible to accurately estimate the shape of a bevel, a bevel curve and so forth which are obtained after completion of grinding.

Object of the Invention

Accordingly, it is an object of the present invention to provide a lens grinding apparatus having a lens-configuration measuring device, in which the lens-configuration measuring device is accommodated by the carriage, the accuracy of measurement is high, and in addition, the size of this apparatus is substantially the same as that of the prior-art apparatus having a carriage and a grinding wheel formed as one unit.

SUMMARY OF THE INVENTION

According to the present invention, the above and other objects can be accomplished by a lens grinding apparatus having: a carriage including lens rotating shafts for clamping and rotating a lens to be ground; and a grinding wheel for grinding said lens, said grinding apparatus being characterized in that the box of said carriage accommodates lens-configuration measuring means constituted by: at least one of feelers which can be brought into contact with said lens LE; and detecting means for detecting the magnitude of travel of said feelers.

According to a specific aspect of the present invention, there is provided a lens grinding apparatus in which said lens-configuration measuring means comprises: a first feeler which is brought into contact with an edge surface of said lens to be ground or a bevel apex of said bevel-ground lens; a first detecting means for detecting the magnitude of travel of said first feeler; a second feeler which can be brought into contact with the front refractive surface of said lens to be ground; a second detecting means for detecting the magnitude of travel of said second feeler; a third feeler which can be brought into contact with the back refractive surface of said lens to be ground; and a third detecting means for detecting the magnitude of travel of said third feeler

In one aspect of the present invention, said carriage comprises: an opening through which said feelers can pass; and an intercepting member for closing said opening as required.

According to another aspect of the present invention, said intercepting member comprises; an intercepting plate for covering said opening; and an arm portion which has said intercepting plate at one end and, at the other end, is rotatably mounted on said lens rotating shaft under a predetermined frictional force, being characterized in that limiting members for limiting the magnitude of travel of said intercepting plate is formed in the vicinity of said opening.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view, partially cut away, of the appearance of the mechanism of a lens grinding apparatus in accordance with the present invention;

Fig. 2 is a sectional view, taken along the line II -II' shown in Fig. 1.;

Fig. 3 is a perspective view of the appearance of the frame-configuration measuring device incorporated in the present invention;

Fig. 4(A) is a perspective view of the frame holder, and Figs. 4(B) and 4(C) respectively show the operation of the frame holder;

Fig. 5 is a longitudinal sectional view of the frame holder, in which the center section of the holder is shown as viewed from the front side thereof;

Fig. 6 is a longitudinal sectional view of the structure of the spring member, in which the center section of the spring is shown as viewed from the front side thereof;

Fig. 7(A) schematically shows the relationship between the support device and the sensor section, and Fig. 7(B) is a sectional view of the relationship shown in Fig. 7(A);

Fig. 8 is a side elevational view, partially cut away, of the sensor section;

Fig. 9(A) schematically shows the relationship in which the geometrical center and the optical axis of the lens frame is obtained from the measured value of the frame; Fig. 9(B) schematically shows the relationship between a frame PD (FPD) and PD;

and Fig. 9(C) schematically shows the relationship between data on the right lens frame and data on the left lens frame;

Figs. 10(A) and (B) respectively show the automatic detector for the template operation;

Fig. 11 is a plan view of the lens measuring device;

Fig. 12 is a sectional view taken along the line XII -XII' of Fig. 11;

Figs. 13(A), 13(B) and 13(C) show the construction and the operation of the front end of the lens radius-vector sensor section;

Fig. 14 is a block diagram of the electric system in accordance with the present invention;

Fig. 15 is a block diagram of the electric system incorporated in the frame-configuration measuring device;

Figs. 16(A) and 16(B) are a view of the display device and the input device and a view of another example of data displayed on the display device, respectively;

Fig. 17 is a flow chart of the operational sequence of the apparatus of this invention;

Figs. 18(A), 18(B), 21(A), 21(B), 23(A) and 23-(B) schematically show the operation of the lens measuring device;

Figs. 19(A) and 19(B) schematically show the relationship between lens curvature and edge thickness; and

Figs. 20 and 22 show the relationship between the carriage and the stopper.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Overall Construction of Apparatus

Fig. 1 is a perspective view, partially cut away and in section, of the overall construction of one embodiment of the lens grinding apparatus in accordance with the present invention.

In the Figure, a box 1, in its lower front portion, has a frame-configuration measuring device 200 described later, and an opening 10 through which a frame holder passes is formed in the front wall of the box 1. A flap 10a is mounted on the lower portion of the opening 10, and a key board 1000 and a display device 2000 as described later are disposed in parallel with each other at the upper right portion of the front wall as viewed in the Figure.

The box 1 has a grinding-wheel chamber 30 which accomodates a grinding wheel 3 constituted by a rough grinding wheel 3a for a glass lenses, a rough grinding wheel 3c for plastic lenses, a bevel grinding wheel 3b, and an accurate plane grinding wheel 3d, and the grinding wheel 3 is secured to a rotating shaft 31. The rotating shaft 31 is rotatably supported by the wall of the grinding-wheel chamber 30, and the shaft 31 at its one end has a pulley 53. The pulley 53 is coupled with a pulley 51 through a belt 52, and the pulley 51 is mounted on the rotating shaft of a grinding-wheel rotating motor 5 consisting of an ac drive motor. This construction allows the motor 5 to cause the rotation of the grinding wheel 3. This construction causes the rotation of the motor 5,. thereby turning the grinding wheel 3.

The box 1 has a bearing 12, and a shaft 11 is slideably supported on the bearing 12 such as to be capable of sliding in the direction of the axis of the shaft 11 itself, and the shaft 11 is rotatably supported by the rear arms 33a and 33b of the carriage 2. The carriage 2 further has front arms 34a and 34b, and lens rotating shafts 28a and 28b are coaxially and rotatably supported by the arms 34a and 34b, respectively. The lens rotating shaft 28a and 28b are rotatably and coaxially supported on the right side as viewed in the Figure has a lens chucking mechanism constituted by known means, and the rotation of the chucking handle 29 causes the shaft 28a, 28b to move back and forth in the axial direction. A lens to be ground LE can be clamped between the rotating shafts 28a and 28b as a result of this movement.

A disk 27a and a template support 27b are mounted on the outer end of the left-hand lens rotating shaft 28b, and the disk 27a is kept in contact with a stopper 42 described later and the template support 27b holds a template.

The respective lens rotating shaft 28a and 28b have pulleys 26a and 26b, and the carriage 2 has a built-in drive shaft 25 which at both ends has pulleys 23a and 23b. A worm wheel 22 is mounted on one end of the drive shaft 25, and the worm wheel 22 is meshed with a worm gear 21a mounted on the rotating shaft of a lens shaft rotating motor 21 constituted by a pulse motor. Timing belts 24a and 24b are respectively passed over between the pulleys 23a and 23b and between the pulleys 26a and 26b. This construction converts the rotation of the motor 21 to that of each lens rotating shaft 28a and 28b, thus causing the rotation os the lens LE to be ground. The carriage 2 further includes a lens measuring device 600 described later.

One end of the shaft 11 is fitted into an arm portion 40 of a frame 4 for moving the carriage 2. The frame 4 is slideably supported by a shaft 41 mounted on the box 1, and a feed screw 61 is screwed into the frame 4. The feed screw 61 is secured to the rotating shaft of a carriage drive motor 60 which is constituted by a pulse motor. This construction converts the rotation of the motor 60 to the leftward and rightward movement of the frame 4, and the carriage 2 in turn travels rightwardly and leftwardly through the shaft 11. The frame 4 further has the stopper 42 and a grinding pressure control device 43 which are described later. The grinding pressure control device 43 is brought into contact with a pin 43a which is secured to the carriage 2 in such a manner as to project toward the grinding pressure control device 43.

FIG. 2 is a sectional view of the frame 4, taken along the line II -II' shown in Fig. 1. The stopper 42 is essentially constituted by: a motor 420 which consists of a pulse motor for moving the stopper member up and down disposed on the underside of the frame 4; a support pillar 421; and a stopper member 422. A feed screw 423 is secured to the rotating shaft of the motor 420, and the feed screw 423 is screwed into an internally-threaded portion 424 of the support pillar 421. A key 425 is protrusively fixed to the outer periphery of the pillar 421, and the key 425 is slideably fitted into a key groove 44 formed in the frame 4.

A photosensor unit 427 is mounted on a table portion 426 formed on the upper end of the pillar 421. A shaft 428 is rotatably fitted into one side of the table portion 426, and the stopper member 422 is mounted on the table portion 426 such as to be capable of swinging about the axis of the shaft 428. A spring 470 is inserted between the stopper member 422 and the table portion 426, and the action of the spring 470 consistently pushes the stopper member 422 upwardly as indicated by a two-dot chain line.

A light intercepting bar 429 is mounted in the interior of the stopper member 422, and when the stopper member 422 is pushed down, the bar 429 is inserted into the gap between the photosensor units 427 so as to intercept the light rays running between the units 427. An eccentric cam 471 is mounted in the interior of the stopper member 422, and the eccentric cam 471 is rotated to change the distance between the cam surface and the table portion 426, thereby enabling fine adjustment of the position in which the stopper member 422 stops. A horizontal cut surface 422b and a curved portion 422a having the same curvature as that of the rough grinding wheel 3a are formed on the top of the stopper member 422.

While grinding is being performed using a template, a template SP mounted on the carriage 2 is kept in contact with the curved portion 422a. While grinding is being performed using the data obtained from the measurement of the configuration of a lens frame, a disk 27a is kept in contact with the horizontal cut surface 422b. This preferred embodiment is arranged such that the template is detected by bringing the stopper member 422 into contact with the template. However, the present invention is not limited to this mechanism. As an example, it is possible to adopt the method in which the movement of the template, namely, the process of grinding the lens may be checked by detecting whether or not the edge of the template is positioned in the gap between the photosensor units 427.

The grinding pressure control device 43 is constituted by: a pulse motor 432 having a feed screw 431; a piston 434 having an internally-threaded portion 433 screwed onto the feed screw 431; a cylinder 435 which is slideably fitted onto the outer periphery of the piston 434; and a spring 436 which is disposed between the cylinder 435 and the piston 434. A key 437 is protrusively provided on the flange of the piston 434, and the key 437 is fitted into a key groove 45 formed in the frame 4. A top surface 435a of the cylinder 435 is brought into contact with the lower periphery of the pin 43a which is protrusively secured to the carriage 2, so that the weight of the carriage 2 is supported by the virtue of the resiliency of the spring 436. When the piston 434 is caused to travel upwardly and downwardly by the rotation of the screw 433 driven by the motor 432, the compressive amount of the spring 436 is correspondingly varied and a force generated when the spring support of the carriage 2 is changed, wherby it is possible to vary the grinding pressure applied to the grinding wheel 3 for grinding the lens <u>LE</u>.

Lens-frame Configuration Measuring Device

The construction of a lens-frame configuration measuring device 200 will be described with reference to Figs. 3 through 10.

Fig. 3 is a perspective view of the lens-frame configuration measuring device in accordance with the present invention. This device is constituted by three major parts: a lens-frame holder 100 for holding a lens frame; a support member 200A which supports the lens-frame holder 100 and moves the member 100 into the plane of measurement and causes the member 100 in the plane of measurement; and a measurement section 300 for digitally measuring the configuration of the lens frame or the template.

The support member 200A has a casing 201. The casing 201 has feet 253 and 254, and the feet 253 and 254 are slideably laid on rails 251 and 252 mounted on the box 1 of the lens grinding apparatus, respectively. Furthermore, the rails 255 and 256 are mounted on the flap 10a, and, when the flap 10a is opened, the rails 251 and 252 are so located as to correspond to the rails 255 and 256, respectively. This construction enables the operators to draw the casing 201 out of the box 1, as required.

The casing 201 has guide rails 202a and 202b which are disposed on top of the casing 201 in parallel with each other along the ordinate (in the direction of the X axis of the measurement coordinate system), and a movable stage 203 is slideably mounted on the guide rails 202a and 202b. An internally-threaded portion 204 is formed on the underside of the movable stage 203, and an X-axis feed screw 205 is screwed into the internally-threaded portion 204. The X-axis feed screw 205 is turned by an X-axis motor 206 consisting of a pulse motor.

A guide shaft 208 is interposed between opposite flanges 207a and 207b of the movable stage 203 in parallel with the Y axis of the measurement coordinate system. The guide shaft 208 can be rotated by a guide shaft motor 209 mounted on the flange 207a. A single line of guide groove 210 is formed on the outer periphery of the guide shaft 208 and in parallel with the axis thereof. Hands 211 and 212 are slideably supported by the guide shaft 208, and the hands 211 and 212 respectively have bores 213 and 214 into which the guide shaft 208 passes. Projections 213a and 214a are respectively formed on the inner surfaces of the bores 213 and 214, and the projections 213a and 214a are engaged with the guide groove 210 of the guide shaft 208, thereby preventing the hands 211 and 212 from rotating about the guide shaft 208.

The hand 211 has two inclined surfaces 215 and 216 crossing each other, and similarly, the other hand 212 has two inclined surfaces 217 and 218 crossing each other. A combined edge 220 formed by the edges of both inclined surfaces 217 and 218 of the hand 212 is disposed in parallel with and in the same plane as a combined edge 219 formed by the edges of both inclined surfaces 215 and 216 of the hand 211. and the combined angle formed by the inclined surfaces 217 and 218 is equal to that formed by the inclined surfaces 215 and 216. Cutouts 215a and 217a are formed in the inclined surfaces 215 and 217, respectively. Furthermore, as shown in Fig. 7(B), a spring 230 is interposed between both hands 211 and 212.

The hand 212 has an arm 241 which has a contact ring 242 at one end and, at the other end, is rotatably mounted on the hand 212. The arm 241 is consistently maintained in contact with a microswitch 244 by a spring 243. The contact ring 242, the arm 241, the spring 243, and the microswitch 244 constitute a device 240 for judging whether the lens frame to be measured is for the right-hand lens frame or the left-hand lens frame.

A pulley 222 is rotatably supported by one end of a back flange 221 of the moving stage 203, and the Y-axis motor 224 having a pulley 223 and consisting of a pulse motor is mounted on the other end of the back flange 221. A miniature belt 226 is passed over between the pulleys 223 and 224, having a spring 225 at a certain position between the pulleys 223 and 224. Each end of the miniature belt 226 is secured to a pin 27 perpendicularly provided on the upper surface of the hand 211. On the other hand, a flange 228 is formed on the upper surface of the hand 212, and when the hand 212 travels in the direction of the motor 224, the flange 228 is brought into contact with one end of a pin 229 projecting from the back flange 221 of the movable stage 203.

The measurement portion 300 is constituted by: a sensor-arm rotating motor 301 consisting of a pulse motor mounted on the underside of the casing 201; and a sensor arm section 302 which is rotatably supported on the upper surface of the casing 201. A pulley 303 is mounted on the rotating shaft of the motor 301, and a belt 305 is passed over between the pulley 303 and a rotating shaft 304 of the sensor arm section 302, thereby transmitting the rotation of the motor 301 to the sensor arm section 302.

The sensor arm seciton 302 has two rails 311 and 311 which are disposed substantially parallel with each other above a base 310, and a sensor head section 312 is slideably laid on the rails 311 and 311. A magnetic scale readout head 313 is mounted on one side of the sensor head section 312, and the readout head 313 is arranged to read out a magnetic scale 314 which is disposed on the base 310 in parallel with the rail 311, thereby detecting the distance of travel of the sensor head section 312. One end of a constant torque spring 316 is secured to the other end of the sensor head section 312 of a spring device 315 which consistently pulls the section 312 toward one side of the end of the arm section 302.

Fig. 6 shows one example of the construction of the spring device 315. A casing 317 is mounted on the base 310 of the sensor arm section 302, and an electromagneto 318 is disposed inside the casing 317. A slide shaft 319 is inserted into the axis bore of the magneto 318 such as to be capable of sliding in the direction of the axis of the shaft 319. The slide shaft 319 has flanges 320 and 321, and a spring 323 is fitted onto the portion of the shfat 319 which is defined between the flange 320 and the inner wall of the casing 317, the spring 323 consistently biasing the slide shaft 319 leftwardly as viewed in Fig. 6. Clutch plates 324 and 325 are rotatably supported by the other end of the slide shaft 319, and one end of the constant torque spring 316 is secured to the clutch plate 324. A spring 326 is fitted onto the portion of the slide shaft 319 which is defined between clutch plates 324 and 325, so that the clutch plates 324 and 325 are consistently spaced apart in such a manner as to prevent the constant torque spring 316 from coming into contact with the clutch plate 325. In addition, a washer 327 is mounted on the end portion of the slide shaft 319.

Referring to Fig. 8 showing the construction of the sensor head section 312, a slider 350 is supported by the rail 311 and axis bore 351 is vertically formed in the slider 350. The sensor shaft 352 is inserted into the bore 351. The sensor shaft 352 holds ball bearings 353 in the gap between the shaft 352 and the bore 351, and this construction permits the sensor shaft 352 to smoothly rotate about the vertical axis of the shaft 352 and travel in the direction of the vertical axis thereof.

An arm 355 is mounted on the sensor shaft 352, and a bevel feeler 356 is rotatably supported on top of the arm 355. (The bevel feeler 356 is rotatably supported on top of the arm 355.) The bevel feeler 356 is formed in the shape of a disk having inclinations corresponding to the bevel angle of the bevel grinding wheel 3b which is brought into contact with the bevelled groove of each lens frame. The point of the circumference of the bevel feeler 356 is so formed as to be positioned on the vertical axis of the sensor shaft 352.

The construction of the spectacle-frame holder 100 will be described with reference to Figs. 4(A) and 5. Flanges 151 and 151 are formed on both sides 151a and 151a of a fixed base 150, and frame holding bars 152 and 152 are secured by using screws at the center positions of the respective flanges 151 and 151. U-shaped bridges 151b and 151c are secured to flanges 151 and 151, respectively. The bridges 151b and 151c are disposed in such a manner that, when the holder 100 is inserted in the gap between the hands 211 and 212, if it is not inserted in the correct direction, the bridges 151b and 151c are brought into contact with the shoulders of cutouts 215a and 217a of the hands 211 and 212, thereby preventing the unwanted insertion of the holder 100. Movable base 153 having sides 153a and 153a are inserted into the gap between the flanges 151 and bottom plate 150a of the fixed base 150, and the movable base 153 is supported by two leaf springs 154 and 154 which are mounted on the bottom plates 150a of the fixed base 150.

Two parallel guide grooves 155 and 155 are formed in the movable base 153, and as shown in Fig. 5, projecting feet 156a and 156a of sliders 156 and 156 are engaged with the guide grooves 155 and 155 in such a manner that the sliders 156 and 156 are capable of sliding on the movable base 153. A circular opening 157 is formed in the center of the movable base 153, and the ring 158 is rotatably fitted into the periphery of the opening 157. Two pins 159 and 159 are perpendicularly mounted on the upper surface of the ring 158, and the pins 159 and 159 are inserted into slots 156c formed in stepped portions 156b and 156b of the slider 156 and 156.

Furthermore, longitudinal cutouts 156d and 156d are formed in the center of the respective sliders 156 and 156, and the above-described frame holding bars 152 and 152 are so disposed as to be inserted into the cutouts 156b and 156b. Holes 156e and 156e are formed in the upper surface of the sliders 156 and 156 in order to help the operator to move the sliders by inserting his fingers into the holes.

The operation of the above-described frame-configuration measuring device will be described below with reference to Figs. 4(B), 4(C), 7(A) and 7(B).

Referring to Fig. 4(B), fingers are respectively inserted into the holes 156e and 156e of the sliders 156 and 156, and a force is applied so as to sufficiently extend the space therebetween while pressing the sliders downwardly. Concurrently with the movement of the movable base 153, sufficient spaces are respectively provided between the holding bars 152 and the stepped portions 156b and 156b of the slider 156 and 156 against the resiliency of the leaf springs 154 and 154. Subsequently, a lens frame 501 of a spectacle frame 500 to be measured is inserted into the space, and the space between the sliders 156 and 156 are narrowed such that the upper and lower rims of the lens frame 501 are kept in contact with the inner walls of the sliders 156 and 156. In accordance with this preferred embodiment, the sliders 156 and 156, as described above, have a coupled structure based on a ring 158, and, when one of the sliders 156, 156 travels a certain distance, the other slider 156 travels by a distance equivalent to the distance of travel of the former.

The frame 500 is slided in such a manner that the substantial center of the upper rim of the lens frame 501 is positioned under the holding bar 152. Subsequently, when the operator releases his fingers from the sliders 156 and 156, the movable frame 153, as shown in Fig. 4 (c), is pushed upward by the resiliency of the leaf springs 154 and 154. The lens frame 501 is clamped between the stepped portions 156b, 156b and the holding bars 152, 152, and the frame 500 is retained in such a manner that the substantial geometrical center of the lens frame 501 approximately agrees with the center line 157a of a circular opening 157 of the frame holder 100. At this time, a distance d between an apex 501a of the bevel groove of the lens frame 501 and the side 151a of the flange 151 of the fixed base 150 is equal to a distance d between the apex 501a and the side 153a of the movable base 153.

The frame holder 100 which holds the frame 500, as shown in Fig. 7(A), is inserted into the space between the hands 211 and 212 of the support device 200 which is set to a predetermined distance. At the same time, when the contact ring 242 of the right/left lens judgement device 240 is brought into contact with the spectacle frame 500 to cause the rotation of the arm 241, the contact of the microswitch 244 is turned off. On the basis of this operation, the judgement device 240 automatically judges that the lens frame 501 to be measured is for a left eye. The Y-axis motor 224 is rotated by a predetermined angle. The rotation of the Y-axis motor 224 drives the miniature belt 226 and the hand 211 is caused to travel leftwardly by a predetermined distance. Simultaneously, the frame holder 100 and the hand 212 are caused to travel leftwardly, and the flange 228 is released from the pin 229. At the same time, the frame holder 100 is clamped between the hands 211 and 212 by virtue of the action of the pulling spring 230. At this time, the sides 151a and 152a of the flanges 151 of the fixed base 150 of the frame holder 100 are respectively kept in contact with the inclined surace 215 of the hand 211 and the inclined surface 217 of the hand 212, and the sides 153a and 153a of the movable base 153 are respectively brought into contact with the inclined surface 216 of the hand 211 and the inclined surface 218 of the hand 212.

In accordance with the preferred embodiment of the present invention, since the distance d between the apex 501a, of the bevel groove of the lens frame 501 and the side 151a as described above, is the same as the distance d between the apex 501a and the side 153a, when the frame holder 100 is clamped between the hands 211 and 212, the bevel apex 501a of the lens frame 501 is automatically located in the reference plane S formed by the combined edges 219 and 220 of both hands 211 and 212.

When the guide shaft rotating motor 209 is rotated by a predetermined angle, the frameholder 100 is turned to the position indicated by the two-dot chain line in Fig. 7(A), and the reference plane S stops flush with the initial position of the bevel feeler 356 of the measurement section 300.

The Y-axis motor 224 is further rotated so that the hands 211 and 212 holding the frame holder 100 may be caused to travel a predetermined distance in the direction of the Y-axis until the center line 157a of the circular opening of the frame holder 100 substantially agrees with the axis of the rotating shaft 304 of the measurement section 300. At this time, while the hands are travelling, the bevel feeler 356 is brought into contact with the bevel groove of the lens frame 501. As shown in Figs. 7(A) and 7(B), the direction of travel of the bevel feeler 356 is initially restricted since a pin 352a protrusively mounted on the lower end portion of the sensor shaft 352 is arranged to come into contact with hanger 310a mounted on the base 310 of the sensor arm section Therefore, when the spectacle frame 500 is caused to travel by the rotation of the Y-axis motor 224, the feeler 356 can consistently be engaged with the bevel groove.

Subsequently, the motor 301 is rotated in each rotating pulses of unit rotation. At this time, the sensor head section 312 slides over the rails 311 and 311 in accordance with the shape of the spectacle frame 500, namely, the radius-vectors of the lens frame 501, and the distance of travel of the sensor head section 312 is read out by the magnetic scale 314 and the readout head 313.

The configuration of the lens frame is measured in the form of $(\rho n, \theta n)$ (n = 1, 2, 3 ... N) based on the angle of rotation θ of the motor 301 and the amount of readout of the readout head 313. Referring to Fig. 9(A), this first measurement, as described above, is carried out in a state wherein the axis O of the rotating shaft, 304 substantially agrees with the geometrical axis of the lens frame 501. A second measurement is conducted in the following manner. The data $(\rho n, \theta n)$ obtained from the first measurement is subjected to the transformation from polar to orthogonal coordinates. On the basis of the data (X_n, Y_n), the following points are selected: a point B to be measured showing the maximum value in the direction of the X axis (X_b, y_b); a point D to be measured showing the minimum value in the direction of the X axis (x_d, y_d); a point A to be measured showing the maximum value in the direction of the Y axis - (x_a, y_a); and a point C to be measured showing the minimum value in the direction of the Y axis (x_c, y_c). Based on the values, the geometrical centre O_o is found by the following equation:

$$O_o\ (X_o,\ Y_o) = \left(\frac{X_b + X_d}{2},\ \frac{Y_a + Y_c}{2}\right) \quad \cdots\cdots\cdots (1)$$

Referring to Fig. 9(B), the distance FPD between the geometrical centers of both lens frames and the distance PD between the pupils of a person wearing spectacles have previously been input through the later-described key board 1000. From the both distances FPD and PD, an inward distance I is obtained in the form of (FPD -PD) / 2 = I. In addition, based on an upward distance U input from the key board 1000 the positions of the pupils of a person wearing spectacles, namely, the position $O_s({}_sX_o, {}_sX_o)$ of the optical axes of the lenses to be ground are obtained by the following manner:

$$\begin{aligned} O_S({}_SX_O,\ {}_SX_O) &= (X_0 + I,\ Y_0 + U) \\ &= (\frac{X_b + X_d}{2} + I\ \frac{Y_a + Y_c}{2} + U) \\ &= (\frac{X_b + X_d}{2} + \frac{FPD - PD}{2},\ \frac{Y_a + Y_c}{2} + U) \end{aligned} \quad \cdots\cdots\cdots(2)$$

On the basis of the thus-obtained values ${}_sX_o$, ${}_sY_o$, the X-axis motor 206 and the Y-axis motor 224 are driven so as to cause the travel of the frame holder 100 clamped between the hands 211 and 212, thereby making the pupil center spot O_s of the lens frame 501 agree with the rotating axis <u>O</u> of the sensor arm 302. The configuration of the lens frame 501 is measured again, and each measured value (${}_s\rho n$, ${}_s\theta n$) (n = 1, 2, 3, ..., N) is obtained on the pupil center spot O_s.

During the above-described measurement of the radius-vectors of the lens frame 501, if the bevel feeler 356 should come off the lens frame 501, the data obtained from the measurement of the radius-vectors become greatly different from the last measured data as indicated by e in Fig. 9-(A). For this reason, a variable range <u>a</u> of a radius-vector is preset, and, if any radius-vector should come off the variable range <u>a</u>, the sensor arm section 302 stops rotating and simultaneously excites the magneto 318 of the spring 315 shown in Fig. 6, thereby attracting the flange 321. In consequence, the clutch plates 324 and 325 clamps the constant torque spring 316 therebetween and prevents the spring 316 from being wound. Therefore, the arm 355 of the sensor head section 312 adjoins the lens frame 501, so that it is possible to prevent the spectacle frame 500 from being damaged. If the feeler 356 comes off the lens frame 501, the spectacle frame 500 is restored to the initial measurement position, and measurement is restarted. Even if the bevel feeler 356 should not come off the spectacle frame 500, the flap 10a - (refer to Figs. 1 and 3) can be opened to draw out the casing 201, whereby operators can easily remove the feeler 356 from the apparatus.

Lens Measuring Device

Referring to Figs 11 through 13 (c), description will be made of the lens measuring device 600 which is incorporated in the carriage 2 for the purpose of detecting the radius-vectors, the edge thickness, the curve value, etc. of the lens <u>LE</u> to be ground.

The lens measuring device 600 has a base frame 601 on which two parallel guide rails 602 and 602 are disposed, and a movable base 603 slideably disposed on the rails 602 and 602. A feed screw 604 is screwed into the movable base 603 and the feed screw 604 is driven by lens-radius-vector sensor motor 605 consisting of a pulse motor.

The movable frame 610 is secured to the upper surface of the movable base 603. Two parallel rails 612 are disposed between a trailing wall 611 of the movable frame 610 and the movable base 603 (one of them is shown in Fig. 12), and a suspension member 613 is supported by the parallel rails 612 in such a manner as to be capable of sliding along the rails 612. A constant torque spring 614 is disposed between the suspension member 613 and the base frame 601 and acts to press the suspension member 613 against the inner side of the trailing wall of the movable base 603 at the beginning of the operation. An arm 621 of a lens radius-vector sensor 620 is secured to the leading side of the suspension member 613.

A C-shaped flange 622 is formed on the front end of the arm 621, and as shown in Fig. 13, a hand arm 623 of a modified H shape at one end thereof is mounted on the flange 622 in such a manner as to be capable of rotating about an axis O_3. Two disks 624 and 624 are supported by the other end of the arm hand 623 in such a manner as to be capable of rotating about the rotating axis O_1. A contact ring 625 is mounted on the two disks 624 and 624, and the ring 625 has a circular section which is kept in contact with the axis O_1 and is capable of rotating about the axis O_2. As described above, the axis O_2 corresponds to the contact surface of the contact ring 625 and the disk 624 can be rotated about the axis O_2. Therefore, when the contact ring 625, as shown in Fig. 13(B), adjoins the edge of the lens LE to be ground, the adjoining point P agrees with a lens radius-vector ℓ corresponding to the axis A of the arm 621. In consequdnce, it is possible to eliminiate an error Δ occurring when the contact ring 625 is secured to the arm hand 623 without the disks 624 being disposed as shown by the two-dot chain line in Fig. 13(B).

A spring 627 is disposed at a certain position between a central arm portion 626 of the arm hand 623 and the arm 621, acting to consistently pull the arm hand 623 upward. The arm hand 623 is horizontally maintained by a stopper piece 628 formed on one end of the arm 621. The arm hand 623, as shown in Fig. 13(C), is constructed such that, if a large cutout occurs in the lens LE and the contact ring 625 falls into the cutout, the clockwise rotation of the lens LE is prevented from damaging the arm hand 623 and the contact ring 625. Specifically, when the arm hand 623 is exposed to a force exceeding a certain limit, the arm hand 623 is turned about the axis O_3 against the tension of the spring 627. When the spring 627 crosses the axis B connecting between the axis O_3 and the point of fixing the spring 627, the arm hand 623 is quickly turned by the tension of the spring 627 and leaves the lens LE for the purpose of preventing damage to itself.

A dectector head 615a of a magnetic encoder 615, as shown in Fig. 12, is mounted on the lower end of the suspension member 613, and a scale 615b which is secured to a base arm 601 is inserted into the head 615b. This construction permits the measurement of the distance of travel of the lens-radius-vector measuring member 620, thereby measuring each radius-vector ρ_i of the lens LE (i = 1, 2, 3, ...,N).

The following description concerns the construction of a lens-surface-configuration sensor used for obtaining the edge thickness and the bevel curve value of the lens LE.

As shown in Fig. 11, two parallel guide rails 630 and 630 are disposed in the movable frame 610, and movable stages 613, 632 and free stages 633, 634 are slideably supported by the rails 630 and 630. The movable stage 631 and the free stage are coupled with each other by springs 635, 635 while the movable stage 632 and the free stage 634 are coupled with each other by springs 636.

A feed screw 638 is screwed into the movable stages 631 and 632 and is driven by a feeler drive motor 637 consisting of a pulse motor. The feed screw 638 is externally threaded in opposite directions with the middle point as the boundary between right and left sides, so that the rotation of the feed screw 638 causes the movable stages 631 and 632 to travel in the opposite directions with each other.

Pins 640 and 640 fitted into the movable stages 631 and 632 are used for actuating microswitches 641 and 641 mounted on the movable frame 610. Specifically, in Fig. 11, the microswitch 641 is turned on by the pin 641, so that it is possible to detect the fact that the movable stages 631 and 632 are set in the initial position (the maximum separation state) in which the stages are most remote from each other. When the rotation of the feeler drive motor 637 causes the movable stages 631 and 632 to gradually approach each other, the pins 640 actuates the microswitches 642 at a certain point, so that it possible to detect the fact that the stages 631 and 632 are located closest to each other (the minimum separation state), and the feeler drive motor 637 stops rotating on the basis of the detected signal.

A feeler arm 650 is mounted on the front position of the free stage 633 (the position nearer the lens LE), and the front end of the arm 650 extends in parallel with the axis A of the arm 621. A feeler 651 is rotatably mounted on the front bend of the feeler arm 650 which is nearer the lens LE. A contact circumferential edge 651a of the feeler 651 corresponds to the edge of a contact ring 625, namely, the rotating axis O_1 of the oval disks 624. Similarly, a feeler arm 652 is mounted on the front end of the free stage 634 (which is nearer the lens LE), and a feeler 653 is rotatably mounted on the front bend of the arm 652.

A push solenoid 671, as shown in Fig. 12, is mounted on the movable base 603. When the feelers 651, 653 and the arm hand 623 approaches a predetermined radius-vector position, the solenoid 671 is excited and acts to move the suspension member 613 backwardly so as to set back the arm hand 623.

The carriage 2 has an opening 680 through which the leading end of the lens radius-vector sensor 620 and the feeler of the lens-surface-configuration sensor moves toward and away from the lens LE. A shielding plate 681 is provided in order to prevent a lubricating fluid from invading the lens measuring device through the opening 680 during lens grinding. The shielding plate 681 is mounted on a ring 683 which is rotatably fitted onto the lens rotating shaft 28 through an O ring 682.

When radius-vectors are to be measured, the lens rotating shaft 28 is rotated in the direction of an arrow 684 shown in Fig. 12 so as to simultaneously cause the rotation of the shielding plate 681 due to the frictional force generated between the ring 683 and the O ring 682. After the opening 608 has been opened, the plate 681 is further rotated and brought into engagement with a projection 686 formed on the carriage 2. In this state, the shielding plate 681 stops turning. Subsequently, the lens rotating shaft 28 alone is rotated against the frictional force generated by the O ring 682, whereby it is possible to turn the lens LE.

On the other hand, during lens grinding, the lens rotating shaft 28 is turned in the direction of an arrow 685 so as to simultaneously rotate the shielding plate 681 in the same direction. After the plate 681 has closed the opening 680, it is brought into engagement with another projection 687 formed on the carriage 2. In this state, the shielding plate 681 stops and continues to close the opening 680.

Electric Control System

Referring to Fig. 14 which is a block diagram, description will be made below of the construction of the electric control system incorporated in the preferred embodiment having the above-described mechanical constitution.

An encoder 615 of the lens radius-vector sensor 620 and encoders 661, 662 of the lens-surface-configuration sensor are respectively connected to counter circuits 820, 821 and 823. Each of the encoders 820, 821 and 823 delivers detected output to each of the counter circuits 820, 821 and 823 in which the output is counted. The result is input to an operation control circuit 810. The photosensor unit 427, the microswitches 641, 642 and 244 are connected to the operation control circuit 810.

The motor controller 824 is connected to the feeler drive motor 637, the lens radius-vector sensor drive motor 605, the lens rotating shaft drive motor 21, the carriage drive motor 60, the stopper drive motor 420 and the grinding-pressure control motor 432. The motor controller 824 receives control command from the operation control circuit 810, and determines how many pulses should be output to a pulse generator 809, that is, controls the rotational speed of each motor. The grinding-wheel motor 5 is energized by an a.c. power supply 826, and is controlled by a switching circuit 825 operating in accordance with the command of the operation control circuit 810.

The operation control circuit 810 is constituted as by microprocessors, and is controlled by the sequence program stored in a program memory 814. The later-described input device 2000 and display 1000 are connected to the operation control circuit 810, and the data on the measured lens LE which is computed in the circuit 810 is transferred to and stored in a lens data memory 827. The circuit 810 further controls the frame-configuration measuring unit 800.

The construction of the electric system of the frame-configuration measuring unit 800 will be described below with reference to Fig. 15.

Driver circuits 801, 802, 803 and 804 are respectively connected to the X-axis motor 206, the Y-axis motor 224, the sensor arm drive motor 301 and the guide shaft drive motor 209. The driver circuits 801 through 804 are controlled by the operation control circuit 810 while they control the rotation of each pulse motor in accordance with the number of pulses supplied from the pulse generator 809.

The readout head 313 delivers readout output to a counter circuit 805 in which it is counted, and the result is input to a comparator circuit 806. The comparator circuit 806 compares the input with the variation of the signal corresponding to the variable radius-vector range a supplied from a reference value generation circuit 805. If the counted value is within the range a, the value counted by the counter 805 and the number of pulses supplied from the pulse generator 809 are transformed into data on radius-vectors ($\rho n, \theta n$) in the operation control circuit 810, and the thus-transformed data is transferred to and stored in a lens-frame data memory 811. If the output of the counter 805 exceeds the variable radius-vector range a, the operation control circuit 810 receives a signal representing the state and excites the electromagento 318 of the spring 315 through a driver 808, thereby preventing the feeler 356 from travelling and stopping the pulse generation circuit 809 from supplying a pulse to the driver 804, so that the motor 301 stops its rotation.

Input Device and Display Device

Referring to Fig. 16(A), the input device 1000 and the display 2000 is constituted by a sheet switch having a main switch 2100, function keys 2200, an input switch group 2303, two start switches 2401 and 2402, and a stop switch 2500 for temporarily stopping the apparatus. The function keys 2200 includes: a pump switch 2201 for merely supplying a lubricating fluid; a hand-operation switch 2203 for commanding the supply of a lubricant fluid and the rotation of the grinding wheel during a hand operation; an operation-type selector switch 2204 which measures the configuration of the lens frame and selects either a copy grinding using a template or a hand operation in which, once the configuration of an individual lens frame is measured and grinding is performed on the basis of the measured data; and auto/manual selector switch 2205; a single/dual selector switch 2206 for determining which the frame-configuration measuring device should measure, the configuration of one lens frame or that of both lens frames; a selector switch 2207 for selecting whether PD and FPD or the relative quantity between PD and FPD - (distance) should be input when inputting the horizontal relationship between the positions of a pupil and the geometrical axis of a lens frame; HIGH/LOW selector switch 2208 for controlling a grinding pressure; and a selector switch 2209 for selecting bevel-grinding or accurate plane grinding for a template operation. The input switch group 2303 is constituted by ten-key input switch 2300, a cancel switch 2301 for cancelling the content of a ten-key input, and a store switch 2301 for storing the ten-key input. The operating state of each switch is displayed by each corresponding pilot lamp 2600.

The display 1000, as shown in Fig. 14, is constituted by: a controller 1400 for generating a signal for driving a liquid crystal display 1100 on the basis of the result supplied from the operation control circuit 810 and the data input of the input device 2000; an X-driver 1200 for driving X lines made of dot-matrix liquid crystal elements on the basis of the signal supplied from the controller 1400; and an Y-driver 1300 for driving Y columns made of dot-matrix liquid crystal elements on the basis of the signal supplied from the controller 1400.

The Operation of the Apparatus

The operation of the above-described lens grinding apparatus will be described with reference to Fig. 17.

Step 1 -1:

After the main switch 2100 has been turned ON, the operation selector switch 2204 is actuated to select a hand operation in which a lens frame of spectacles is directly measured and a lens is ground step by step on the basis of the data or a template operation in which grinding is performed by using a template.

Step 1 -2:

The operator determines whether a bevel is automatically or manually positioned. For automatic positioning, "AUTO" on the selector switch 2205 is pushed while for manual positioning "MANUAL" on the switch 2205 is pushed.

Step 1 - 3

The operation control circuit 810 makes judgement of the selection command input through the switch 2204 of the input device 2000, and in turn reads a hand-operation sequence program or a template-operation sequence program out of the program memory 814.

1) Hand Operation

[The operational sequence of the hand operation will be described below:]

Step 1 -4:

The operator actuates the single-dual selector switch 2206 so as to select: either a method in which the configuration of one lens frame is measured and the other lens is ground by using the data obtained from the inversion of the data on the measured lens frame; or a method in which the configuration of both lens frames are measured and the lenses are ground on the basis of the data thus measured. The operation actuates the single/dual selector switch 2206.

Step 1 -5:

When the operator is to input the relationship between the horizontal positions of the pupil center of a person wearing spectacles and the geometrical center of a lens frame, he makes judgement as to whether PD and FPD are input or the relative quantity between PD and FPD (distance) is input. When inputing PD and FPD, "PD" on the selector switch 2207 is pushed, and when inputting a distance, "distance" on the selector switch 2207 is pushed.

Step 2 -1:

The spectacle frame 500 is set into the frame holder 100 and the lens frame 501 is fastened by the frame holding bars 152. The frame holder 100 holding the lens frame 501 is inserted through the opening 100 of the box 1, and is temporarily held by the hands 211 and 212 of the support device 200A.

Step 2 -2:

The right/left lens frame judgement device 240 makes judgement as to whether the lens frame 501 is for right or left eyes which is set on the measurement section 300 of the lens-frame configuration measuring device. Specifically, if the microswitch 244 of the judgement device 240 is turned OFF, the operation control circuit 810 determines that the left lens frame is held on the measurement section 300. When the frame holder 100 is set in the support device 200A, if the microswitch 244 of the judgement device 240 remains ON, the operation control circuit 810 determines that the right-hand lens frame is placed on the measurement section 300.

Step 2 -3:

The result of the judgement of the device 240, that is, whether the set lens frame is for right or left eyes is displayed by a character 1113 on a liquid crystal display 1100 as shown in Fig. 16(B).

Step 2 -4:

The operator operates the chucking handle 29, so that the lens LE to be ground is chucked by the lens rotating shafts 28 of the carriage 2. At this time, a suction disk clings to the lens LE in such a manner that the center of the disk corresponds to the optical axis of the lens LE. Specifically, the optical axis of the chucked lens LE is set to agree with the lens rotating shaft 28.

Step 2 -5:

The operator inputs the PD value of a person wearing spectacles in accordance with his/her prescription, and after completion of the input, pushes the store switch 2302. The operation control circuit 810 temporarily stores the input data in the internal memory, and simultaneously, the input data is displayed on a "PD" display section 1101 of the display device. The operator in turn inputs an FPD using the ten-key switch 2300, and after completion of the input, pushes the store switch 2302. The operation control circuit 810 temporarily stores the input date in the internal memory, and simultaneously, the input data is displayed on an "FPD" display section 1102 of the display device 1100 through the controller 1400.

Subsequently, the operator inputs an upward distance U toward the optical axis of the lens LE (refer to Fig. 9(B)) by operating the ten-key switch 2300, and after completion of the input, pushes the store switch 2302. The operation control circuit 810 stores the input data in the internal memory, and simultaneously, the input data is displayed on "UP" display section 1103 of the display 1100. However, if the "distance" side is pushed in the above-mentioned step 1 -5, the relative quantity (the relative distance) between PD and FPD is input by the ten-key switch.

Step 2 -6:

The operator judges what the material of the lens LE is. In the case of a glass lens, he pushes a switch 2401 corresponding to "G START" 1105 which is displayed on the liquid crystal display 1100 shown in Fig. 16(A), and in the case of a plastic lens, he pushes a switch 2402 corresponding to "P START" 1106 on the same display 1100.

Step 2 -7:

The operation control circuit 810 receives the ON signal of the store switch 2302 upon completion of inputting the distance toward the optical axis of the lens in the preceding step. The circuit 810 in turn causes the motor 224 to drive the hands 211 and 212 and the frame holder 100 is retained by the hands, causing the motor 209 to move the lens frame 501 to the measurement position, and causing the motor 301 to drive the rotation of the sensor arm 302. The readout head 313 of the encoder delivers output to the counter 805 at each unit angle of rotation and the counter 805 executes counting, thereby obtaining lens-frame radius-vector data ($\rho n' \theta n$) from the angle of rotation of the sensor arm θ_n and the measured value of a radium-vector ρ_n supplied from the counter 805. Such measured data is stored in the lens frame data memory 811 as an auxiliary measured value since the axis of rotation of the sensor arm 302 does not necessarily agree with the geometrical center of the lens frame.

Step 2 -8:

On the basis of the lens-frame radius-vector data -($\rho n' \theta n$) obtained from the preparatory measurement in the preceding step and the PD data, the FPD data, and the upward distance U which is input in the step 2 -2, the optical axis O_s (X_S, Y_s)is computed by the operation control circuit 810 from the above equation (2).

Step 2 -9:

Based on the thus-obtained O_s (X_sY_s), the operation control circuit 810 drives the Y-axis motor 224 and the X-axis motor 206 through the drivers 801 and 803 of the frame-configuration measuring device, so that the right lens frame of the spectacle frame 500 is moved to a position in which the rotating axis of the sensor arm 302 corresponds to the O_s-(X_s, Y_s).

Step 2 -10:

The sensor arm 302 is rotated through the driver 804, and the radius-vectors of the lens frame is measured again. The output from the readout head 318 of the encoder is counted by the counter 805. The counted value and the number of pulses generated by the pulse generator 809 for causing the rotation of the motor 301 are input to the operation control circuit 810. From both data, new radius-vector data ($_{rs}\rho n'$ $rs\theta n$) on the lens frame is stored in the lens frame data memory 811 (hereinafter referred to as a "substantial measurement").

Step 3 -1:

The operation control circuit 810 drives the lens rotating shaft drive motor 21 through the motor controller 824, so that the lens rotating shaft 28 is turned in the direction of the arrow 684 shown in Fig. 12. This rotation causes the shielding plate 681 to move and open the opening 680. Secondly, the operation control circuit 810 reads out of the memory 811 a first data item ($_{rs}\rho 1$' $rs\theta 1$) of the lens frame data ($_{rs}\rho n$' $rs\theta n$) (n = 1, 2, 3, ..., N) based on the substantial measurement which is stored in the lens-frame-data memory 811 and stops the lens rotating axis 28 at the position corresponding to the first data item ($_{rs}\theta 1$). When the lens radius-vector sensor drive motor 605 is supplied with the number of pulses corresponding to the radius-vector ($_{rs}\rho 1$) by the pulse generator 809, the motor 605 causes the movable frame 610 to travel toward the lens LE. As the movable frame 610 moves forward, the arm 621 of the lens radius-vector sensor 620 also moves forward by virtue of the pulling force of the constant torque spring 614 and the contact ring 625 is brought into contact with the edge of lens LE. At this time, the position of the arm 621 is detected by the encoder 615 and is counted by the counter 820. The counted value 810 is calculated by the operation control circuit 810 in the form of the radius-vector (radius) R_1 of the lens LE along the radial line $_{rs}\theta 1$ and the radius-vector R_1 is stored as the data (R_1, $_{rs}\theta 1$) in the lens data memory 827. (Refer to Fig. 18(B)).

When the pin 640 of the movable stage 632 turns on the microswitch 642. and the feeler motor 637 which rotates the feed screw 637 so as to move the movable stages 631 and 632 is stopped through the operation control circuit 810 and the motor controller 824. When the movable stages 631 and 632 travels, since the free stages 633 and 634 are coupled to the stages 631 and 632 through the springs 635 and 636. the stages 633 and 634 slide over the rails 630 and 630. The feelers 651 and 653 are brought into contact with the positions of both front and back sides of the lens LE corresponding to the radius-vector $_{rs}\rho 1$. In this state, the positions of the feelers 651 and 653 are detected by the encoders 661 and 662, and are counted in the counters 821 and 822. The thus-counted values $_fZ_1$, $_bZ_1$ are input to the operation control circuit 810, and the control circuit 810 transfers the values to the lens data memory 827 for storage.

Subsequently, in the same manner as described above, a lens radius R_n at a radius-vector angle of $_{rs}\theta n$, feeler positions $_fZ_n$, $_bZ_n$, every data item ($_{rs}\theta 1$, R_1, $_f$ Z_n and $_bZ_n$) (i = 1, 2, 3, ..., N) is input to and stored in the lens data memory 827. The feelers 651 and 653, as shown in Fig. 18 (B), trace a locus T on the lens LE to be ground on the basis of the lens-frame radius-vector data ($_{rs}\rho n, \theta rs$ n).

Step 3 -2:

The operation control circuit 810 compares the radius R_i of the lens LE obtained in the above step 3 -1 with the lens-frame radius-vector $_i$ at a radius-vector angle of θ_i. If R_i ρ_i, the control circuit 810 judges that it is impossible to obtain a lens having a desired configuration even if the lens is ground. A warning then appears on the display section 1100 of the display device 1000, and the execution of the subsequent steps are stopped. If R_i ρ_i, the process proceeds to the subsequent steps.

Step 3 -3:

On the basis of the data on feeler positions ($_fZ_i$, $_bZ_i$) stored in the lens data memory 827, the operation control circuit 810, as shown in Fig. 19(A), finds: the data ($_fZ_A$, $_bZ_A$) and ($_fZ_A$, $_bZ_A$) on the feeler positions corresponding to two radius-vectors ρ_A and ρ_B; the curvature radius of the front side of the lens to be ground $_fR$; the curvature radius of the back side of the lens to be ground $_bR$; the center of the front curvature radius of the lens $_fZ_o$; and the center of the back curvature radius of the lens $_b Z_o$.

Based on these values, the operation control circuit 810 obtains $_f\,\vec{R}$ and $_b\,\vec{R}$ from the following equations (4) and (5):

$$\left.\begin{array}{l} {}_f\bar{R}^2 = \rho_A^2 + ({}_fZ_O - {}_fZ_A)^2 \\ {}_f\bar{R}^2 = \rho_B^2 + ({}_fZ_O - {}_fZ_B)^2 \end{array}\right\} \quad \cdots (4)$$

$$\left.\begin{array}{l} {}_b\bar{R}^2 = \rho_A^2 + ({}_bZ_O - {}_bZ_A)^2 \\ {}_b\bar{R}^2 = \rho_B^2 + ({}_bZ_O - {}_bZ_B)^2 \end{array}\right\} \quad \cdots (5)$$

Hence, based on ${}_f\bar{R}$ and ${}_b\bar{R}$, the curve value C_r of the front refractive surface of the lens LE and the curve value of C_bs of the back refractive surface are respectively obtained by the following equations (6):

$$\begin{array}{l} C_f = \dfrac{n-1}{R_f} \times 1000 \\ C_b = \dfrac{n-1}{R_b} \times 1000 \end{array} \quad \cdots (6)$$

(where n is the refractive index of the lens LE) and the C_f and C_b are stored in the memory 827. Furthermore, based on ${}_f\bar{R}$ and ${}_b\bar{R}$ and the lens-frame radius-vector data (${}_{rs}\rho n$, ${}_{rs}\theta n$), edge thickness Δ_n is obtained from the following equation (7) at each unit angle at all the radius-vector angles θ_n:

$$\begin{aligned} n &= {}_bZ_n - {}_fZ_n \\ &= \sqrt{{}_bR^2 - \rho n^2} - \sqrt{{}_fR^2 - \rho n^2} \quad \cdots (7) \end{aligned}$$

The edge thickness Δ_n is stored in the lens data memory 827.

Step 3 -4:

The operation control circuit 810 reads out of the lens frame data memory 811 the lens-frame radius-vector data (${}_{rs}\rho M'$ $rs\theta M$) including the maximum edge thickness, Δ_{max} and the lens-frame radius-vector data (${}_{rs}\rho N$, ${}_{rs}\theta N$) including the minimum edge thickness Δ_{min}. Based on a predetermined configuration G of the bevel of the bevel-grinding wheel 3b, the positions of the bevel apexes ${}_eZ_M$, ${}_eZ_N$ are obtained from the following equations (8) so that a bevel apex P of the bevel of the bevel-ground lens may be located at the position corresponding to the ratio of the front side : the back side

$$= 4 : 6: \quad \left.\begin{aligned} {}_eZ_M &= {}_fZ_M + \frac{4}{10}\Delta_M \\ &\cdot \\ {}_eZ_N &= {}_fZ_N + \frac{4}{10}\Delta_N \end{aligned}\right\} \quad \ldots (8)$$

Based on the obtained bevel apex positions ${}_eZ_M$, ${}_eZ_N$, a bevel; curve value C_p is obtained from the above noted equations (4) and (7), and bevel apex positions ${}_eZ_i$ (i = 1, 2, 3, ..., N) at each radius-vector angle from the bevel curve value C_p and the edge thickness Δ_n. The positional data is stored in the lens data memory 827.

Step 3 -5

1 As shown in Fig. 16(B), the liquid crystal display 1100 displays as an automatically-bevelled section 1110 the configuration of the bevels at the positions of the maximum edge thickness and of the minimum which are obtained in the preceding Step 3 -4. In Fig. 16(B), the solid line represents the configuration of the bevel formed at the position of the maximum edge Δ_{max} and the broken line represents that of the bevel at the position of the minimum edge Δ_{min}, and they are schematically displayed such that the two bevel apexes correpond to each other.

Step 3 -6:

If "MANUAL" is selected in Step 1 -2, the process proceeds to the following Step 3 -7, while if "AUTO" is selected in Step 4 -1, the process jumps to Step 4 -1.

Step 3 -7:

If the operator selects "MANUAL" in the preceding Step 1 -2, the operation control circuit 810 causes the liquid crystal display 1100 of the display device 1000 to display the characters "CURVE" and "DISTANCE" as shown in Fig. 16(B), so that the operator is asked to input desired numerical values.

The operator inputs a desired curve value by operating the ten-key board 2300. After the operator has confirmed the input data appearing on the "CURVE" display portion 1111 of the liquid crystal display 1100, the operator pushes the "store" switch 2303 and stores the data in the internal memory of the operation control circuit 810. The operator pushes the "DISTANCE" side of the switch 2207 and inputs the millimeter-unit distances of the bevel apexes obtained in the preceding Steps 3 -5 and 3 -6 by operating the ten-key switch 2300. The input data appears on the "DISTANCE" display portion 1112 of the liquid crystal display 1100.

Step 3 -8:

Concurrently with the above-described operation, the operation control circuit 810 causes the position of the bevel apex on the minimum edge obtained in Step 3 -5 to be moved by a distance corresponding to the distance input. At the same time the circuit 810 calculates bevel position data ${}_eZ_i$ at each radius-vector angle of ${}_{rs}\ {}_i$ based on the input bevel curve values. In addition, the bevel apex positions of the maximum edge thickness and of the minimum edge thickness are diagramatically shown on the manually-bevelled configuration display portion 1120 of the liquid crystal display 1100. In Fig. 16(B), the solid line represents the bevel configuration of the maximum edge thickness and the broken line represents the bevel configuration of the minimum edge thickness. Fig. 16(B) shows one example of the bevel configuration in which the bevel apex is moved backwardly and the bevel curve is small (the curvature radius is large) as compared with that of automatic bevelling.

When the operator confirms the displayed bevel configuration, if he feels unsatisfactory, he inputs new distance and bevel curve again and makes the operation control circuit 810 calculate a bevel configuration based on the new input. The result is displayed on the display screen, and the operator stores the finally determined bevel position data ${}_eZ_i$in the lens data memory 827.

Step 3 -9:

The operator confirms the automatically or manually bevel-ground configurations 1110 or 1120. If he needs to select automatic bevel-grinding, he turns on the start switch 2401 corresponding to the display 1110. If he needs to select manual-bevel grinding, he turns on the start switch 2402 corresponding to the display 1120.

Step 4 -1:

The operation control circuit 810 judges which of the start switches supplies a signal to it. If the signal is a command of the selector switch 2401 on the "G START" side, the process proceeds to the next Step 4 -2, and if the signal is a command of the selector switch 2404 on the "P START" side, the process proceeds to Step 4 -3.

Step 4 -2

The operation control circuit 810 reads a data item ($_{rs}\rho max$, $_{rs}\theta max$) including the maximum radius-vector $_{rs}\rho max$ out of the lens-frame radius-vector date ($_{rs}\rho n$, $_{rs}\theta n$) stored in the lens frame data memory 811. Subsequently, the circuit 810 causes the rotation of the lens rotating shaft drive motor 21 through the motor control circuit 824, thereby continuously rotating the lens LE.

The operation control circuit 810 then turns on the switching circuit 825, thereby causing the rotation of the grinding-wheel drive motor 5. The circuit 810 drives the motor 420 on the basis of the radius-vector $_{rs}\rho max$, and the horizontal cut surface 422b of the stopper member 422 is moved downwardly to the position d_{max} lower than the level of the grinding surface of the rough grinding wheel 3a. In this case, the relationship between the distance d_{max} and the maximum lens-frame radius-vector $_{rs}\rho max$ and the radius r of the ring 27a is given by:

$d_{max} = {}_{rs}\rho max - r$ . . . .(9)

As the stopper member 422 moves down, the carriage 2 also moves down, so that the lens LE is ground by the rough grinding wheel 30. When any radius-vector of the lens LE is ground until it reaches $_{rs}\rho max$, the ring 27a is brought into contact with the stopper member 422 in such a manner as to swing the member 422. In consequence, the intercepting bar 429 intercepts the optical path between the photosensor units 427 (refer to Fig. 2), and the interception signal is input to the operation control circuit 810. The operation control circuit 810 further continues to count the number of pulses corresponding to one rotation of the lens rotating shafts 28a and 28b. In the meantime, if no interception signal is supplied from the photosensor 427, it is judged that the entire peripheral edge of the lens LE is ground in accordance with the radius-vector $_{rs\ max}$.

Subsequently, the operation control circuit 810 reads the data ($_{rs}\rho 1$, $rs\theta 1$) out of the lens frame data memory 811, and controls the rotation of the lens rotating shaft drive motor 21 on the basis of the data $_{rs}\theta 1$, thereby turning the lens LE to be ground. Next, the circuit 810 controls the stopper drive motor 420 on the basis of the radius-vector data $_{rs}\rho 1$, so that the stopper member 422 is lowered to the level corresponding to d_1. As shown in Fig. 20, the height of the stopper member 422 is generally obtained from the following equation (8)' in the same manner that the relationship between the radius-vector $_{rs}\rho i$ and the ring r is found from the equation (8):

$d_i = {}_{rs}\rho i - r$ (i = 1, 2, 3, ..., N) ... (8)'

As the stopper member 422 continues to move downwardly, the lens LE is further roughly ground until the radius-vector of $_{rs}\rho i$ is obtained. At this time, the photosensor unit 427 inputs an interception signal to the operation control circuit 810. When the circuit 810 receives the signal, it reads the data ($_{rs}\rho 2$, $_{rs}\theta 2$) out of the lens frame data memory 811, causing the lens LE to rotate at an angle of $_{rs}\theta 2$, lowering the stopper member 422 to the level d_2 on the basis of the radius-vector $_{rs}\rho 2$, thereby grinding the lens LE. Subsequently, the grinding of the lens LE is continued until a given data item ($_{rs}\rho N$, $_{rs}\theta N$) is executed, whereby the lens LE is ground in the form corresponding to the lens frame data ($_{rs}\rho i$, $_{rs}\theta i$)

Step 4 -3;

The carriage drive motor 60 causes the lens to travel so as to be positioned on the rough-grinding wheel for a plastic lens, and rough grinding is executed in the same manner as that shown in Step 4 -2.

Step 4 -4:

The operation control circuit 810 controls the stopper drive motor 420 through the motor controller 824, and causes the carriage 2 to move upwardly. After the roughly-ground lens LE has been separated from the rough grinding wheel 3a, the circuit 810 controls the carriage drive motor 60 so that the lens LE may be positioned on the bevel-grinding wheel 3b.

The operation control circuit 810 sequentially reads each item of the lens-frame radius-vector data ($_{rs}\rho i$, $_{rs}\theta i$) (i = 1, 2, 3, ..., N) out of the lens frame data memory 811, and in addition, sequentially reads out of the lens data memory 827 each item of the bevel position data $_eZ_i$corresponding to such data item. Based on such data, the operation control circuit 810 controls the lens rotating shaft drive motor 21, the stopper drive motor 420, and the carriage drive motor 60, thereby bevel-grinding the roughly-ground lens using the bevel-grinding wheel 3b.

Step 4 -5:

After completion of bevel-grinding, the operation control circuit 810 controls the stopper drive motor 420, restoring the carriage 2 to the fixed position on the bevel-grinding wheel, thereby turning OFF the switch 825 so as to stop the rotation of the grinding motor 5.

The operation control circuit 810 in turn controls the lens rotating shaft drive motor 21, and causes the lens rotating shaft 28 to turn in the direction of the arrow 684 shown in Fig. 12. This motion turns the interceptor plate 681 and opens the opening 680. As shown in Figs. 21(A) and 21-(B), the operation control circuit 810 causes the lens radius-vector sensor drive motor 605 to rotate, moving the movable frame 610 forwardly. Concurrently with this movement, the lens radius-vector sensor 620 is moved forward by the pulling force of the constant torque spring 614 so that the contact ring 625 is brought into contact with the bevel apex of the bevel-ground lens LE. Since the lens rotating shaft 28 is rotating, the encoder 615 detects the degree of travel corresponding to the radius-vector data on the lens LE ($_{rs}\rho i'$, $_{rs}\theta i'$) (i = 1, 2, 3, ..., N), and the result is measured in the operation control circuit 810 through the counter 820.

Step 4 - 6:

The operation control circuit 810 compares the lens-frame radius-vector date ($_{rs}\rho i$, $_{rs}\theta i$) stored in the lens frame data memory 827 and the lens radius-vector data ($_{rs}\rho i'$, $_{rs}\theta i'$) of the lens LE measured in the preceding Step 4 -5, and judgement is made as to whether or not both data items are the same. If both are the same, it proceeds to Step 4 - 8, and if both are not the same, it proceeds to Step 4 -7.

Step 4 -7:

If $_{rs}\rho i$ is greater than $_{rs}\rho i'$, the height d_i of the stopper member 422 is lowered to a slight degree and the process returns to Step 4 -4 for bevel-grinding.

Step 4 -8:

If judgement is made in Step 4 -6 that $_{rs}\rho i$ agrees with $_{rs}\rho i'$, the apparatus restores to the initial state. Subsequently, the ground lens is removed from the carriage 2.

Step 6 -1:

The operation control circuit 810 judges whether or not both lenses have completely been ground. If they have not been ground yet, the process proceeds to Step 5 -2. If it is judged that both lenses hae been ground, the entire steps are completed.

Step 6 -2 and Step 6 -4:

The operation control circuit 810 determines whether the measurement of dual lens frames or the measurement of a single lens frame is selected in Step 1 -4. If "SINGLE" is selected, the process proceeds to the following Step 6 -3. If "DUAL" is selected, the message "Please set the other lens frame of the spectacle frame" appears on the liquid crystal display 1100 of the display device 1000, so that the operator is asked to set the other lens frame 501. Subsequently, the above-described Steps 2 -2 through 2 -4 are executed and the process proceeds to Step 2 -7.

Step 6 -3:

When the measurement of a single lens frame is selected in Step 1 -4, the system of coordinates of the measured data on the right lens frame ($_{rs}\rho n$, $_{rs}\theta n$) obtained in Step 2 -6 is transformed from the polar coordinates to the orthogonal coordinates. On the basis of the orthogonal coordinate data ($_{rs}X_i$, $_{rs}Y_i$) (i = 1, 2, 3, ..., N), new lens-frame configuration data ($_{rs}X_i$, $_{rs}Y_i$) is obtained from the following equations:

$$\left.\begin{aligned} {}_{\ell s}X_i &= -{}_{rs}X_i \\ {}_{\ell s}Y_i &= -{}_{rs}Y_i \end{aligned}\right\} \quad \cdots\cdots\cdots (3)$$

This data, as shown in Fig. 9(c), is obtained by inverting the right lens-frame configuration symmetrically about the Y_s axis of the X_s -Y_s coordinates having the optical axis as the origin. The coordinate system of such data is again transformed from the orthogonal coordinates to the polar coordinates, and ($_{\ell s}\rho n$, $_{\ell s}\theta n$) is stored in the lens frame data memory 811 as data on the left lens frame configuration.

Subsequently, Steps 2 -4 and 2 -6 are executed and the process proceeds to Step 3 -1.

2) Template Operation

If it is judged in Step 1 -2 that a template operation is selected, grinding is performed in accordance with the following steps.

Step 5 -1:

A template SP which is previously formed in accordance with the configuration of the lens frame 500 is mounted on the template holding portion 27a of the carriage 2.

(Refer to Fig. 22)

Step 5 -2:

The lens LE to be ground is chucked by the lens rotating shaft 28 of the carriage 2.

Step 5 -3:

The operator judges what the material of the lens LE is. If it is made of glass, he pushes the switch 2401 corresponding to the "G START" sign. If it is made of plastics, he pushes the switch 2402 corresponding to the "P START" sign. If the switch 2401 is turned ON, the process proceeds to Step 5 -4, and if the switch 2402 is turned ON, it proceeds to Step 5 -5.

Step 5 -4:

The operation control circuit 810 turns on the switch 825, causing the grinding wheel 3 to turn, thereby rotating the grinding wheel 3 at high speed. The operation control circuit 810 in turn causes the lens rotating shaft drive motor 21 to turn, thereby rotating the lens LE at low speed. The circuit 810 further controls the stopper drive motor 420, and causes the curved portion 422a of the stopper member 422 to move down to the same level as the height of the glass rough-grinding wheel 3a. In this state, the lens LE starts to be roughly ground. When the photosensor 427 continuously outputs intercepting signals for the period corresponding to one turn of the lens rotating shaft 28, the operation control circuit 810 judges that rough grinding has been completed, and controls the stopper drive motor 420, thus causing the carriage 2 to moving upward to the fixed position. After the switch 825 has been turned OFF, the grinding wheel 3 stops its rotation.

Step 5 - 5:

The lens LE is located on the plastic rough grinding wheel 3C by the drive of the carriage drive motor 60. Subsequently, rough grinding is carried out in the same manner as the above-described Step 5 -4.

Step 5 -6:

The operator determines whether the roughly-ground lens is subjected to bevel grinding or to accurate plane grinding and input the selection through the selector switch 2209.

Step 5 -7:

If bevel-grinding is selected in Step 5 -6, the process proceeds to the following Step 5 -8. If accurate plane grinding is selected in the same Step, it jumps to Step 7 -1.

Step 5 -8:

The operation control circuit 810 causes the rotation of the motor 21, turning the lens rotating shaft 28 and opening the opening 680. In the meantime, as shown in Figs 23(A) and 23(B), the circuit 810 controls the lens radius-vector sensor drive motor 605 so as to move the movable frame forward. and the contact ring 625 is brought into contact with the edge of the roughly-ground lens LE by the pulling force of the constant torque spring 614. The encoder 615 measures lens LE grinding radius-vectors $\overline{P}_i$ (i = 1, 2, 3, ..., N), and delivers the data to the operation control circuit 810 through the counter 820. The operation control circuit 810 further controls the motor 605 such that the feelers 651 and 653 may reach the position corresponding to radius-vector $\overline{P}_i$ less a predetermined length $(\alpha\ \overline{P}_i\ -\alpha)$. The circuit 810 controls the motor 637 so as to bring the free stages 633 and 634 into the free state, and the encoders 661 and 662 measure the front positions $_fZ_i$ of the roughly-ground lens LE and the back positions $_bZ_i$ thereof by using the feelers 651 and 653.

Subsequently, Steps 3 -3 through 3 -9 and 4 -4 are executed, and grounding is completed.

Step 7 - 1:

If the operator selects accurate plane grinding in the above-described Step 5 -6, the operation control circuit 810 reads out the command in Step 5 -7, causing the carriage drive motor 60 to rotate so as to move the lens LE on the accurate plane grinding wheel 3d, thereby moving the carriage 2 downwardly for starting accurate plane grinding.

Automatic Detector for Template Operation

While the above preferred embodiment is arranged such that either the hand opeation or the template oepration is selected by the command of the selector switch 2204, Figs. 10(A) and 10(B) show an example in which the selection can be automatically performed by providing a template.

A bearing 710 is mounted on the arm 34 of the carriage 2. A slot 711 is formed over the length of the bearing 710. A stopper lever 712 is secured to one end of the bearing 710, and a shaft 714 having a tapered portion 713 is rotatably fitted into the other end of the bearing 710. The pin 715 is protrusively secured to the outer periphery of the shaft 714. The pin 715 is consistently kept in contact with one end of the bearing 710 so as to prevent the shaft 714 from travelling in the axial direction. A spring 718 is hooked on one end of the shaft 714 in such a manner that the shaft 714 is consistently pulled in the direction of an arrow 716 shown in Fig. 10(A). The spring 718 is hooked such that it is twisted in the direction of an arrow 716, so that the shaft 714 is subjected to a force acting to turn the shaft 714 in the direction opposite to that of the arrow 716. A contact ring 720a of the microswitch 720 is kept in contact with the tapered portion 713. A microswitch 720 is connected to the operation control circuit 810.

The stopper lever 712, as shown in Fig. 10(B), has a cutout 712a. When the lever 712 is turned, the cutout 712a is engaged with the axis pin 28a which is protrusively provided on the lens rotating shaft 28 and which is used for retaining the template SP, thereby preventing the template SP from coming off.

The operation of the second embodiment will be described below. When the operator needs to perform the template operation, he attaches the template SP to the template retaining pin of the lens rotating shaft 28 disposed in the carriage 28. Next, the stopper lever 712 is rotated clockwise until the cutout 712a is brought into contact with the axis pin 28a. When the pin 715 is brought into engagement with the slot 711, the shaft 714 is subjected to the pulling force of the spring 718 and travels in the direction of the arrow 716. Concurrently with the travel of the shaft 714, the tapered portion 713 moves the contact ring 720a upwardly to turn on the mircroswitch 720, whereby the operation control circuit 810 is capable of automatically receiving the command relating to the template operation.

The invention has thus been shown and described with reference to a specific embodiment, however, it should be noted that the invention is in no way limited to the details of the illustrated structure but changes and modifications may be made without departing from the scope of the appended claims.

Claims

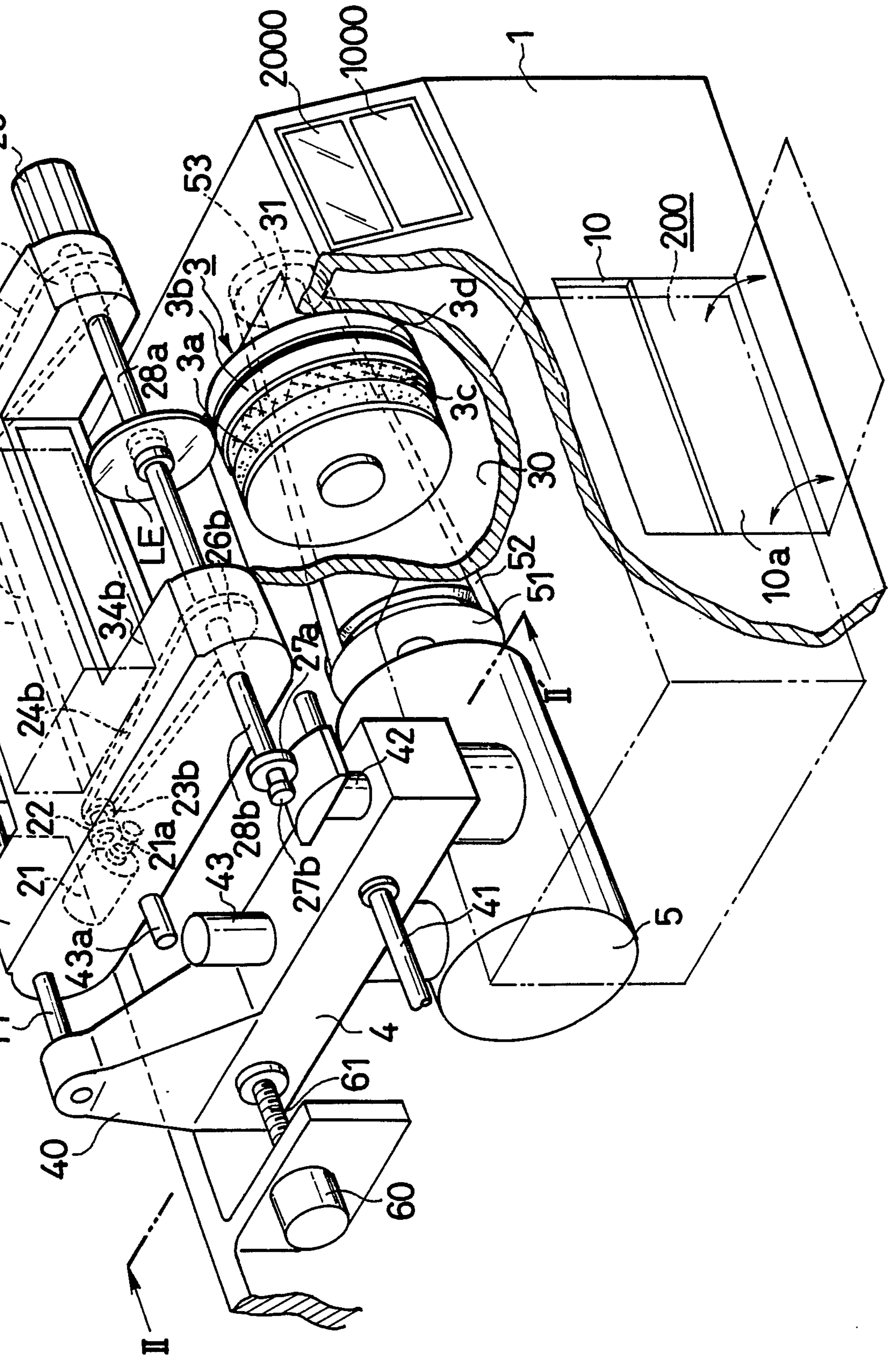
(1) A lens grinding apparatus having: a carriage 2 including lens rotating shafts 28a, 28b for clamping and rotating a lens LE to be ground; and a grinding wheel 3 for grinding said lens LE,

said grinding apparatus being characterized in that the box of said carriage 2 accommodates lens-configuration measuring means 600 constituted by: at least one of the feelers 625, 651, and 653 which can be brought into contact with said lens LE; and detecting means 615, 661 and 662 for detecting the magnitude of travel of said feelers 625, 651 and 653.

(2) A lens grinding apparatus according to Claim 1, wherein said lens-configuration measuring means comprises: a first feeler 625 which is brought into contact with an edge surface of said lens LE to be ground or a bevel apex of said bevel-ground lens LE; a first detecting means 615 for detecting the magnitude of travel of said first feeler 625; a second feeler 651 which can be brought into contact with the front refractive surface of said lens LE to be ground; a second detecting means 661 for detecting the magnitude of travel of said second feeler; a third feeler 653 which can be brought into contact with the back refractive surface of said lens LE to be ground; and a third detecting means 662 for detecting the magnitude of travel of said third feeler.

(3) A lens grinding apparatus according to either one of Claims 1 and 2, wherein said carriage 2 comprises: an opening 680 through which said feelers 652, 651, and 653 can pass; and an intercepting member 681 for closing said opening as required.

(4) A lens grinding apparatus according to Claim 3, wherein said intercepting member 681 comprises: an intercepting plate for covering said opening 680; and an arm portion which has said intercepting plate at one end and, at the other end, is rotatably mounted on said lens rotating shaft under a predetermined frictional force, being characterized in that limiting members 686, 687 for limiting the magnitude of travel of said intercepting plate is formed in the vicinity of said opening.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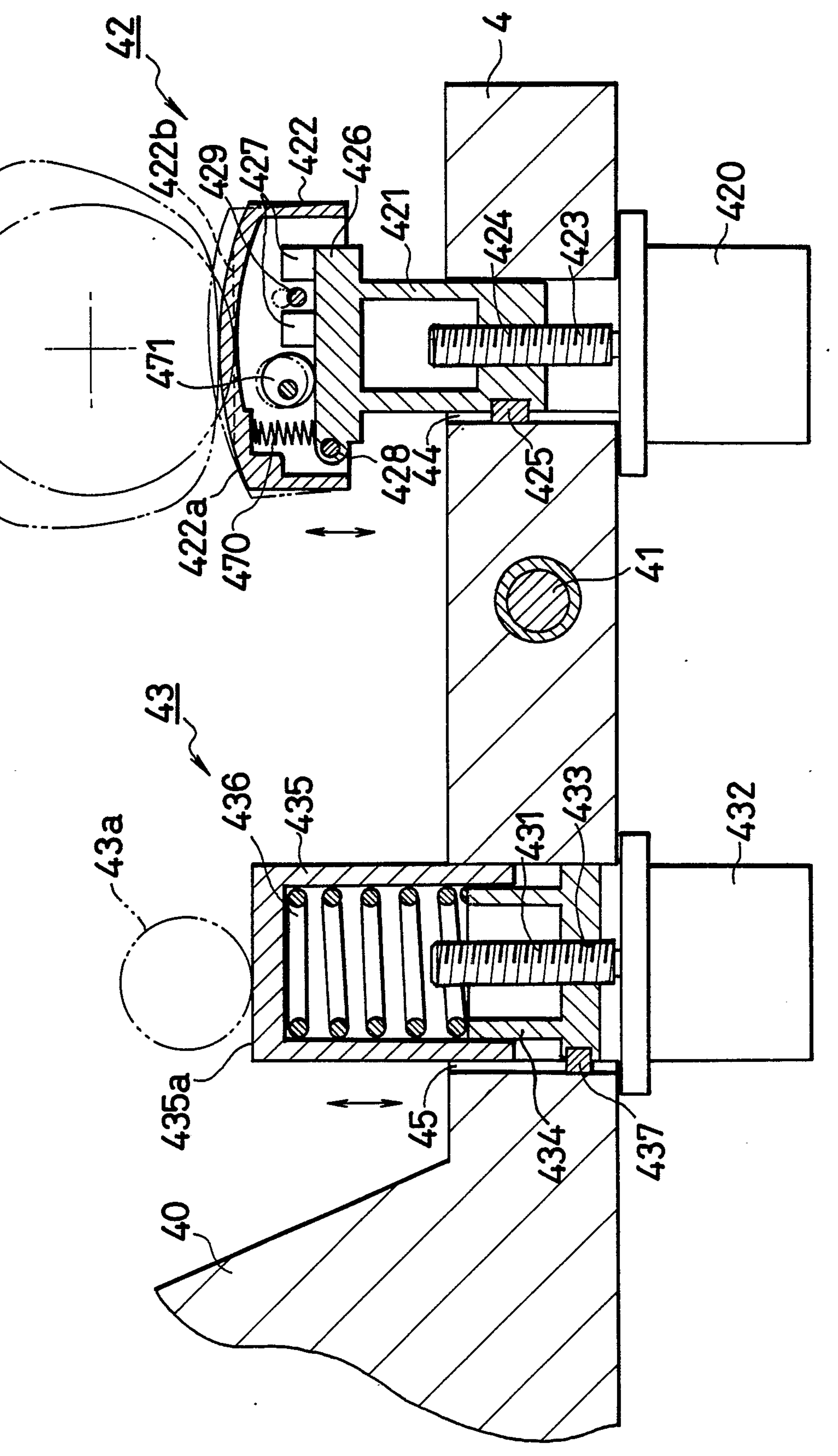
1000
2000
29
53
31
3
3b
3a
3d
3c
30
200
10
10a
24a
26a
34a
23a
2
600
28a
LE
26b
52
51
II
33a
25
34b
27a
12
24b
42
22
23b
21a
28b
27b
43
33b
21
43a
41
5
11
4
61
40
60
II

FIG.1

FIG.2


42
4
SP
27a
422b
429
427
422
426
421
424
423
420
471
428
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425
422a
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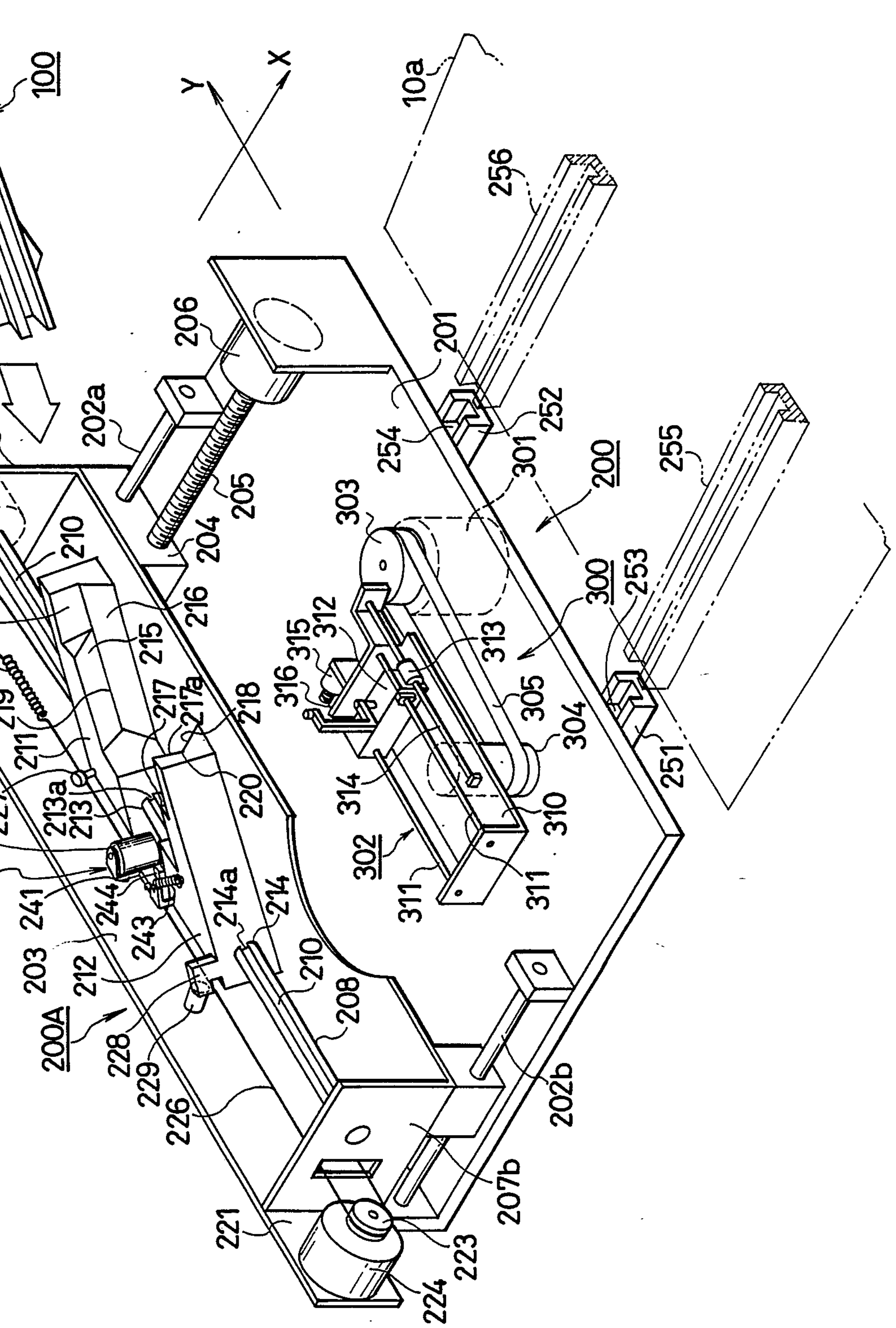
43
436
435
43a
431
433
432
435a
45
434
437
40


100
151b
151c
Y
X
10a
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255
201
252
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301
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202a
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207a
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221
210
215a
216
215
225
219
211
217
217a
218
227
213a
213
220
242
240
241
244
243
203
212
214a
214
210
208
200A
228
229
226
221
223
224
207b
202b
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300
253
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304
314
310
302
311
311
251

FIG.3

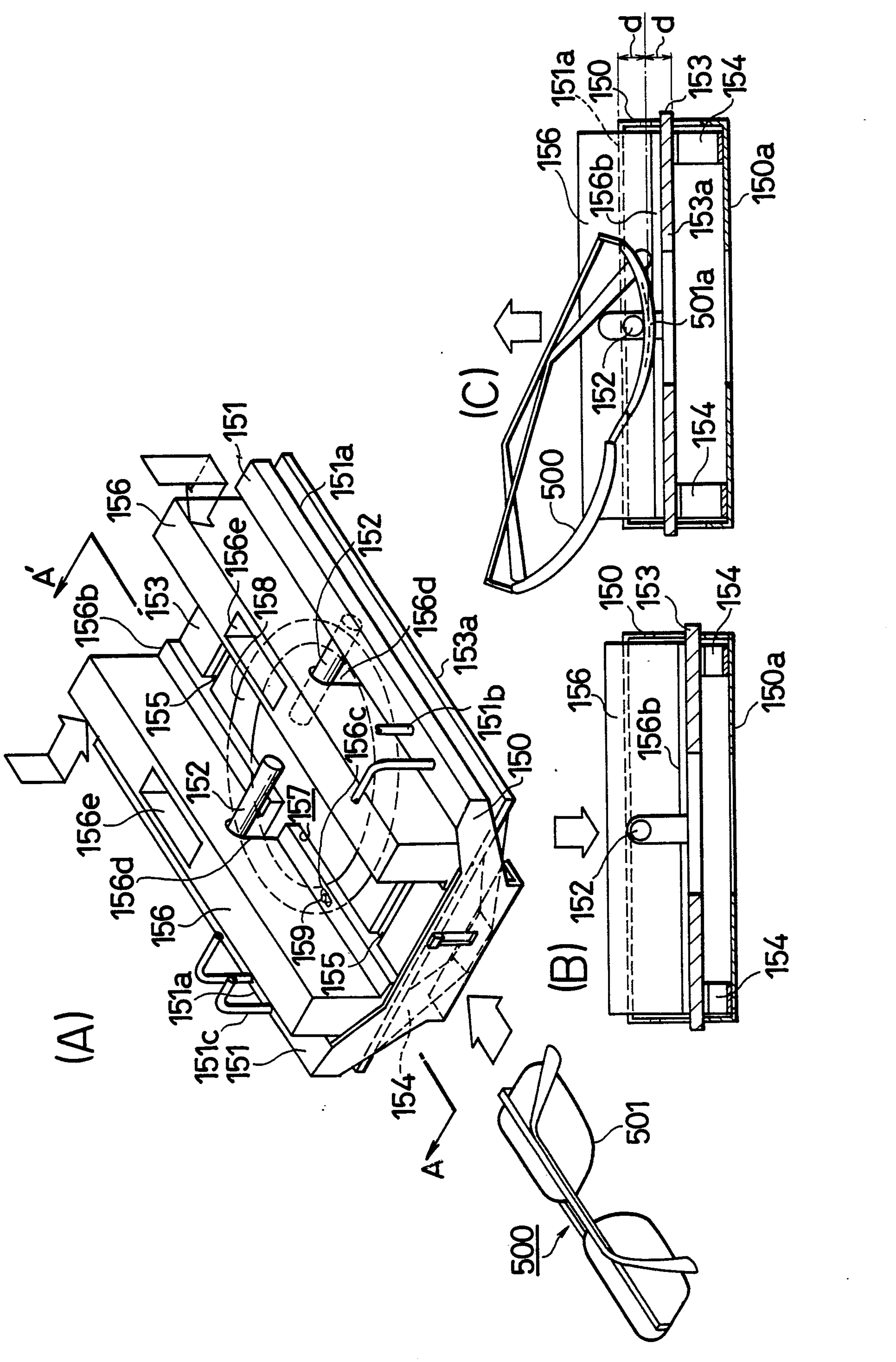
(A)
(B)
(C)
A
A'
151
151a
151b
151c
152
153
153a
154
155
156
156b
156c
156d
156e
157
158
159
150
150a
501
501a
500
d

FIG.4

FIG.5

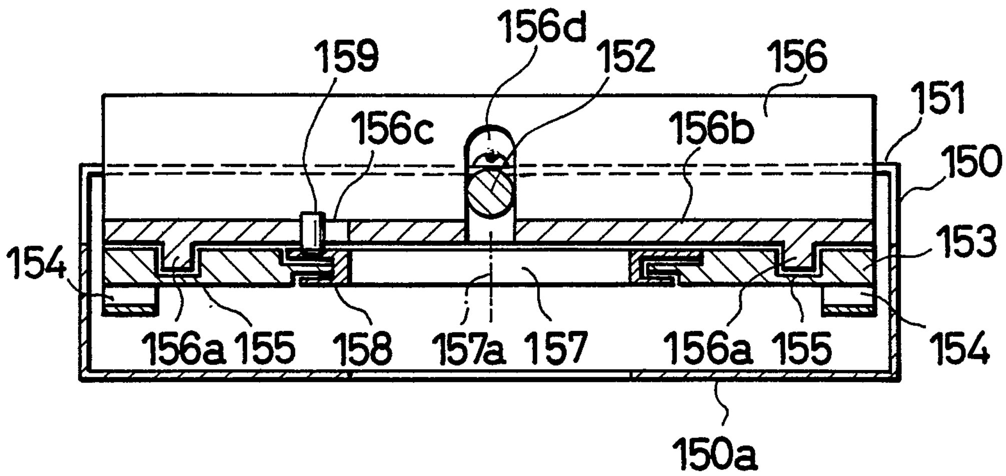
156d
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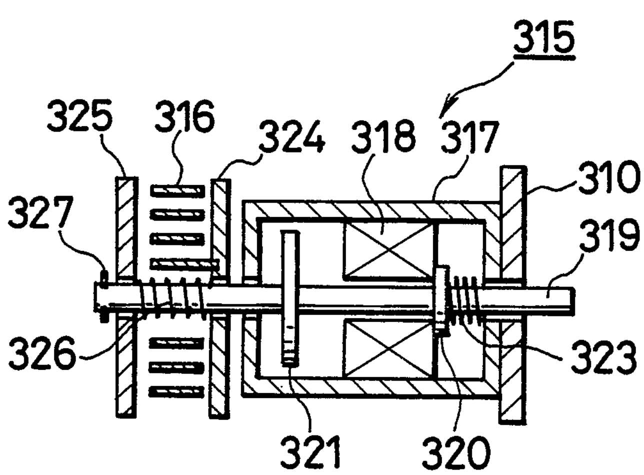
FIG.6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325
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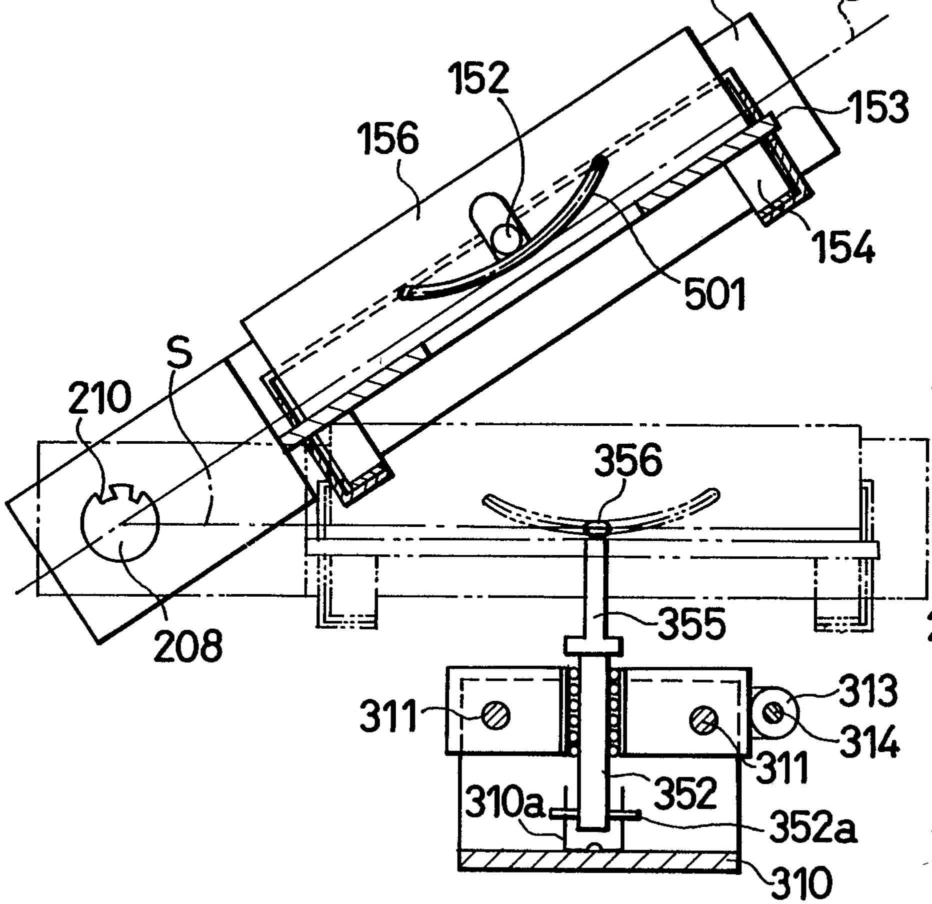
323
321
320

FIG.7(A)


211
S
152
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S
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313
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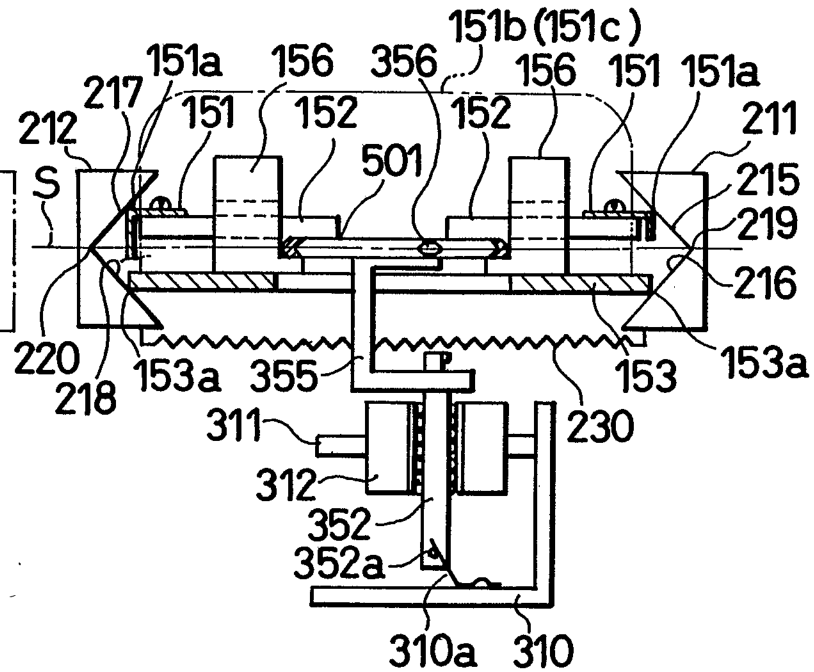
310a
352a
310

FIG.7(B)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151a
156
356
156
151
151a
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151
152
152
212
501
211
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153a
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153
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352a
310a
310

FIG.8

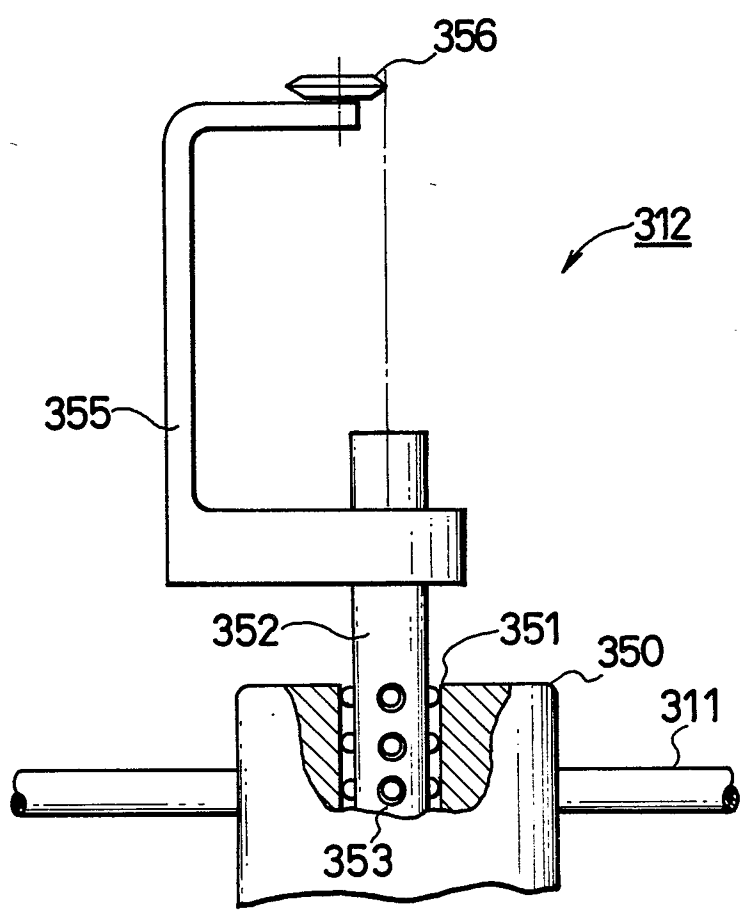


FIG.9

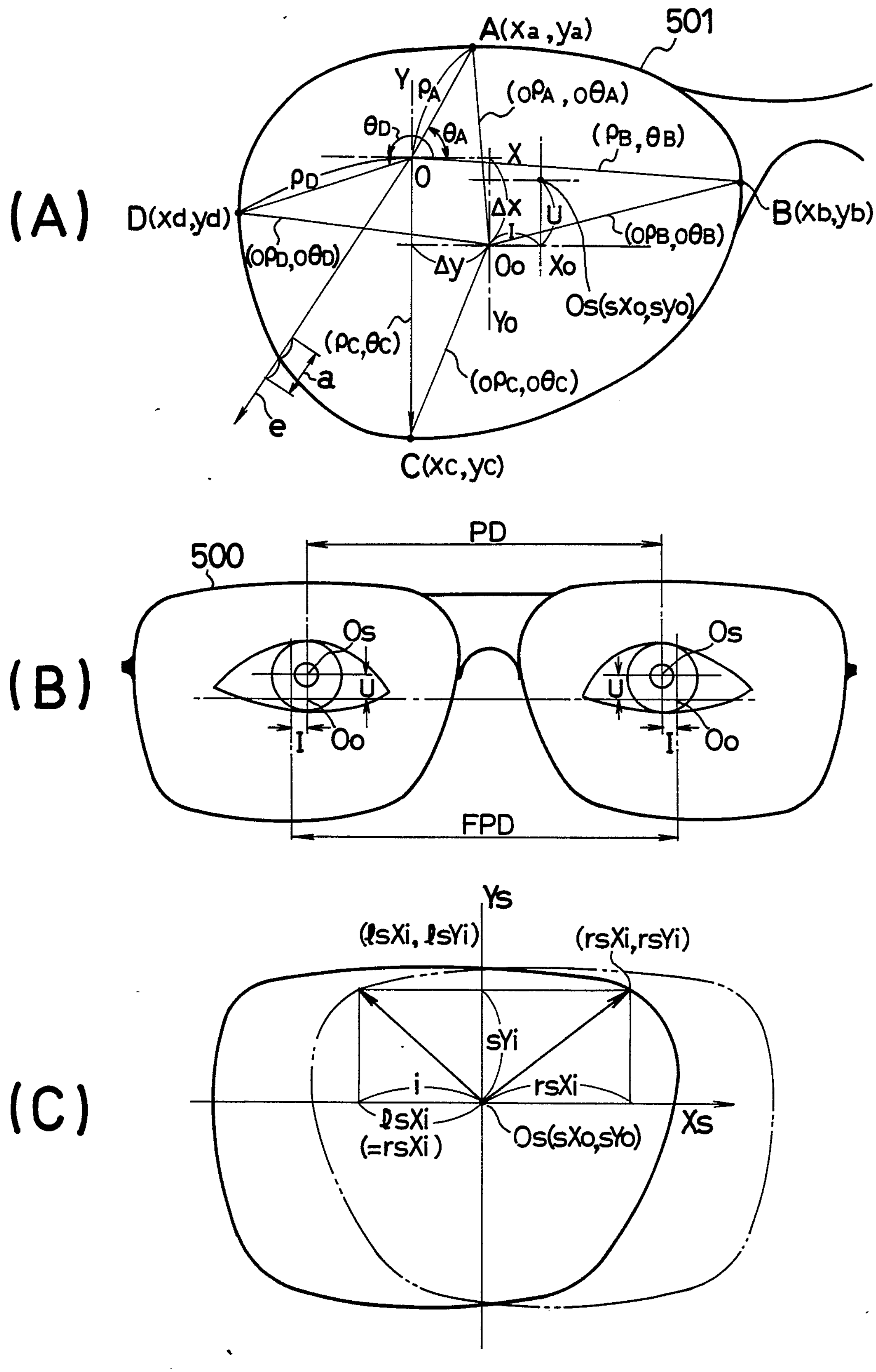

(A)
A(Xa, ya)
501
Y
ρA
(oρA, oθA)
θD
θA
X
(ρB, θB)
O
ρD
ΔX
U
D(xd,yd)
B(xb,yb)
I
(oρB,oθB)
(oρD,oθD)
Δy
Oo
Xo
Os(sXo,sYo)
Yo
(ρC,θC)
a
(oρC,oθC)
e
C(xc,yc)
(B)
PD
500
Os
U
I
Oo
FPD
(C)
Ys
(ℓsXi, ℓsYi)
(rsXi,rsYi)
sYi
i
rsXi
ℓsXi
(=rsXi)
Os(sXo,sYo)
Xs

FIG.10(A)

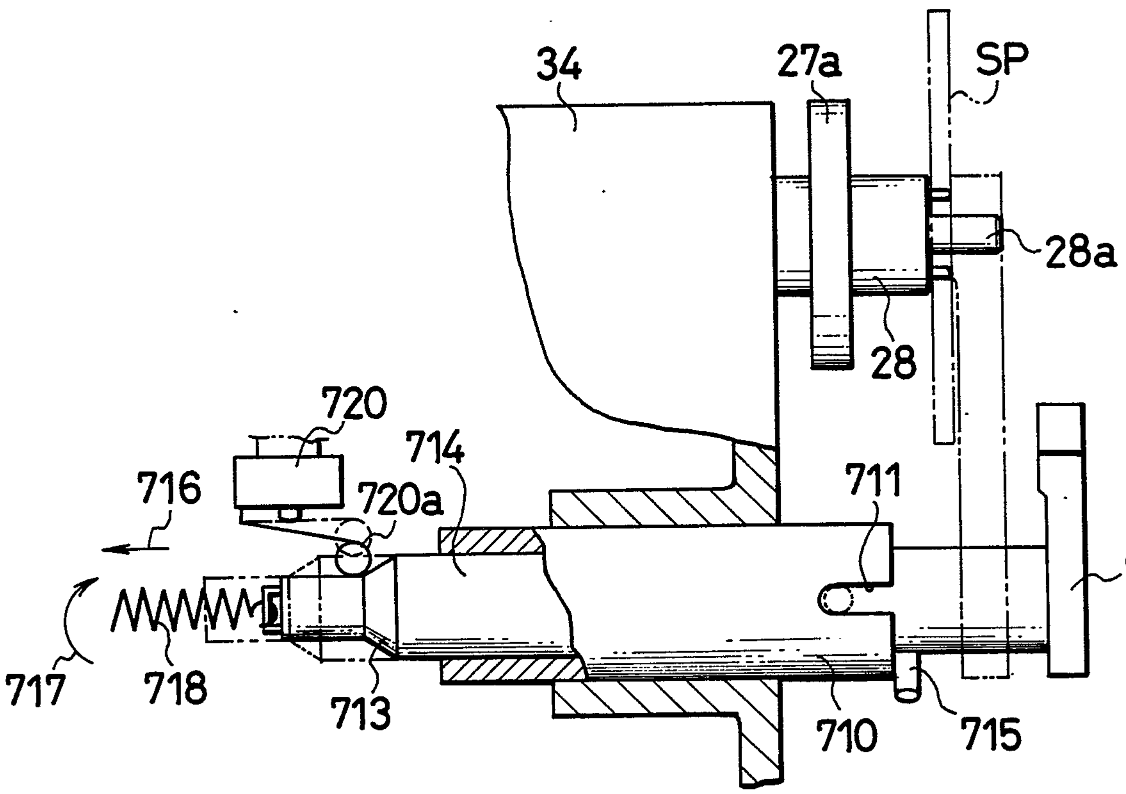


FIG.10(B)

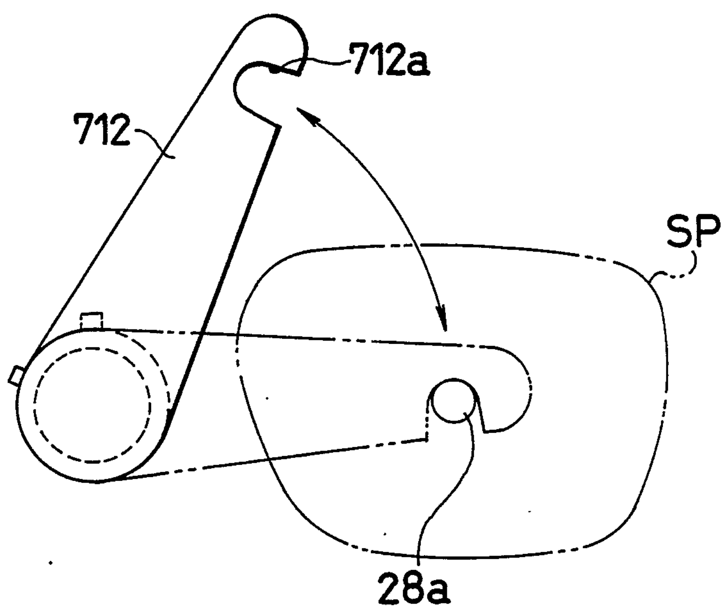
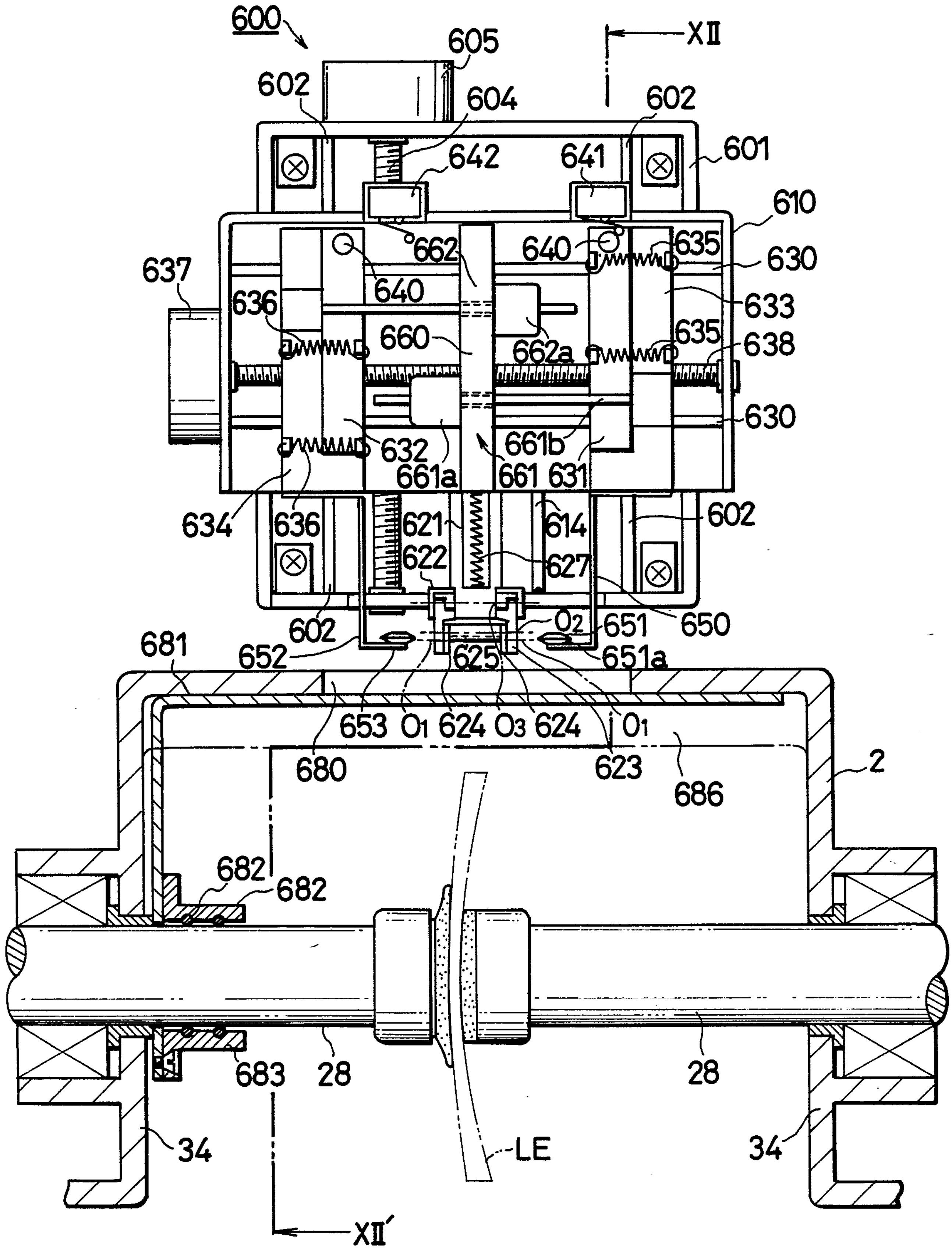


FIG.11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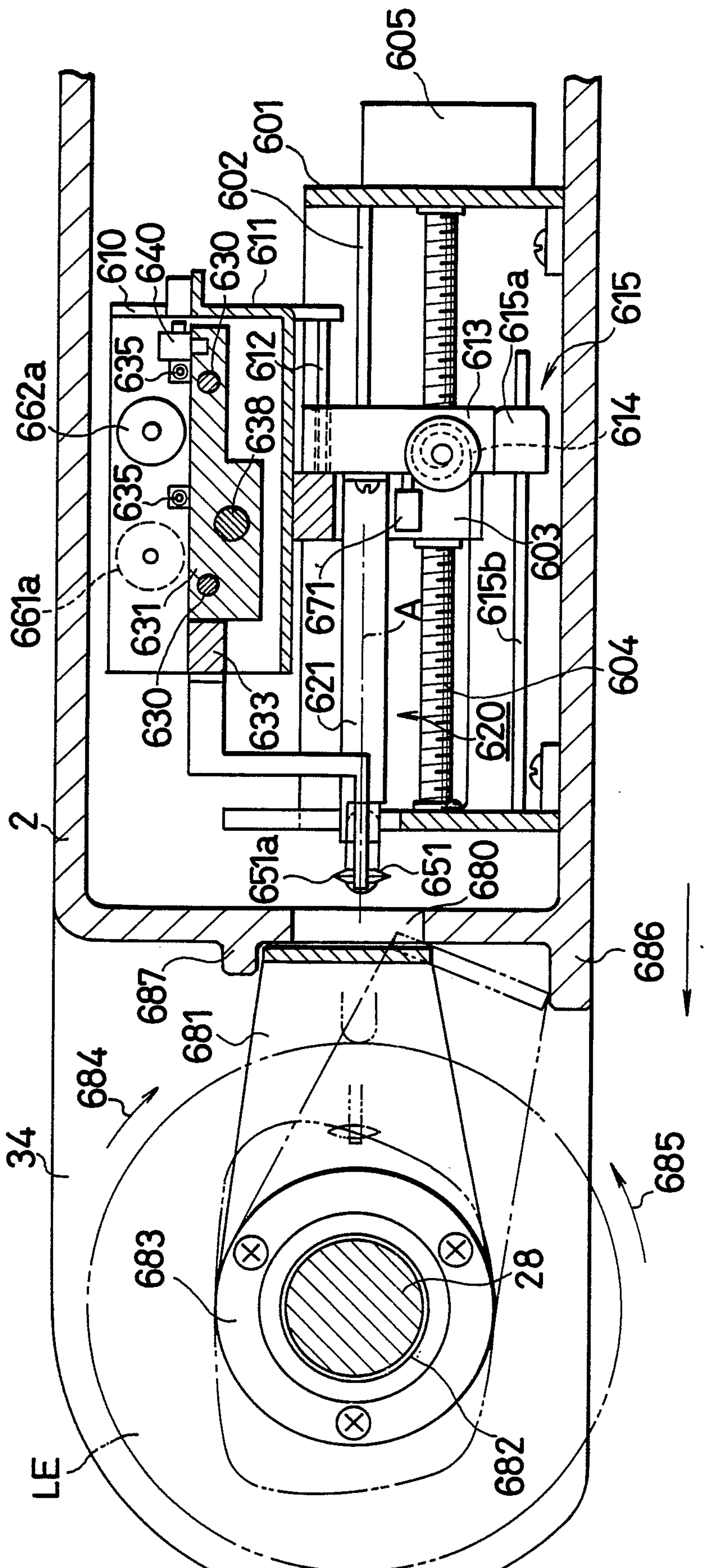
662a
635
638
630
632
661b
661a
661
631
634
636
621
614
602
622
627
602
650
651
652
O_2
681
625
651a
653
O_1
624
O_3
624
O_1
680
623
686
2
682
682
683
28
28
34
34
LE
XII
XII'


605
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630
611
615a
615
662a
635
612
613
614
638
635
603
661a
631
671
A
615b
604
630
633
621
620
2
651a
651
680
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687
681
684
34
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683
28
682
LE

FIG.12

FIG.13(A)

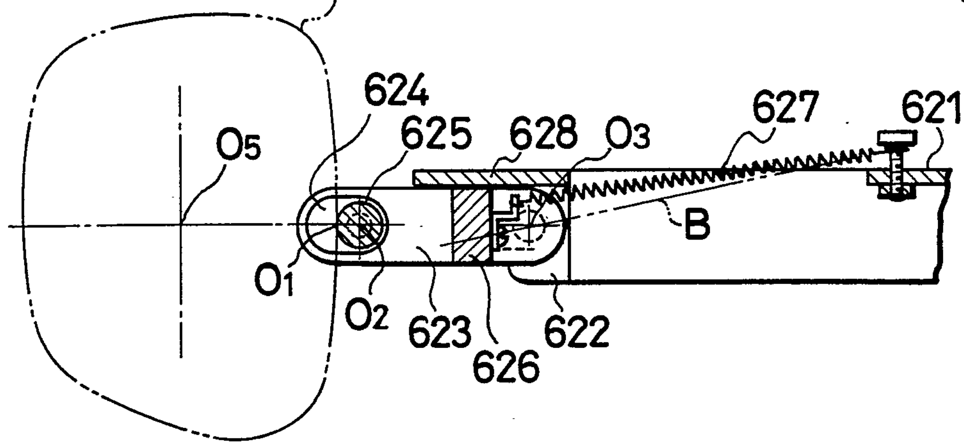


FIG.13(B)

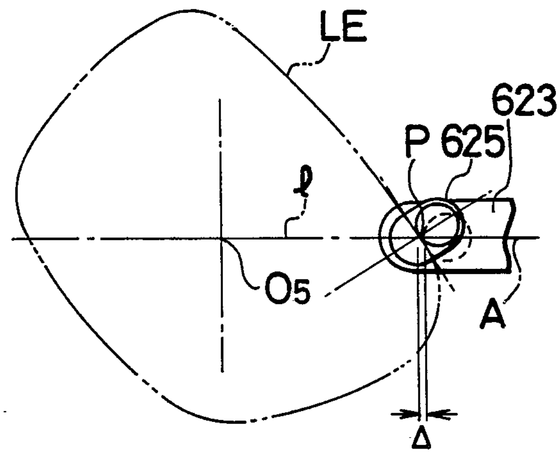


FIG.13(C)

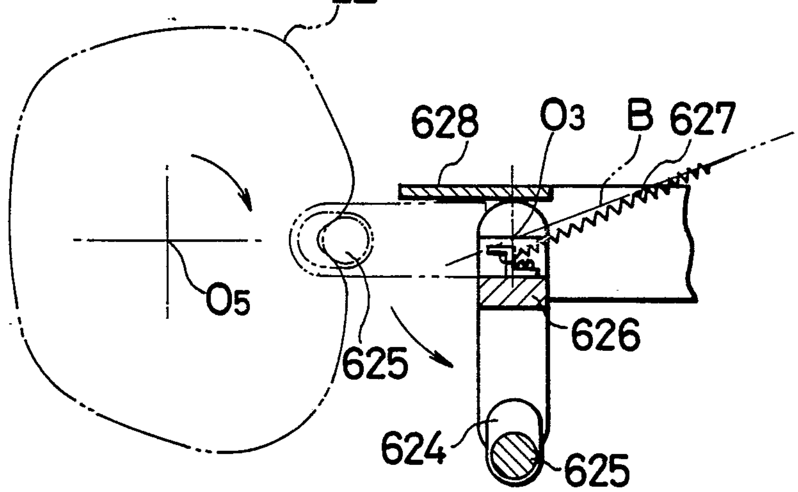
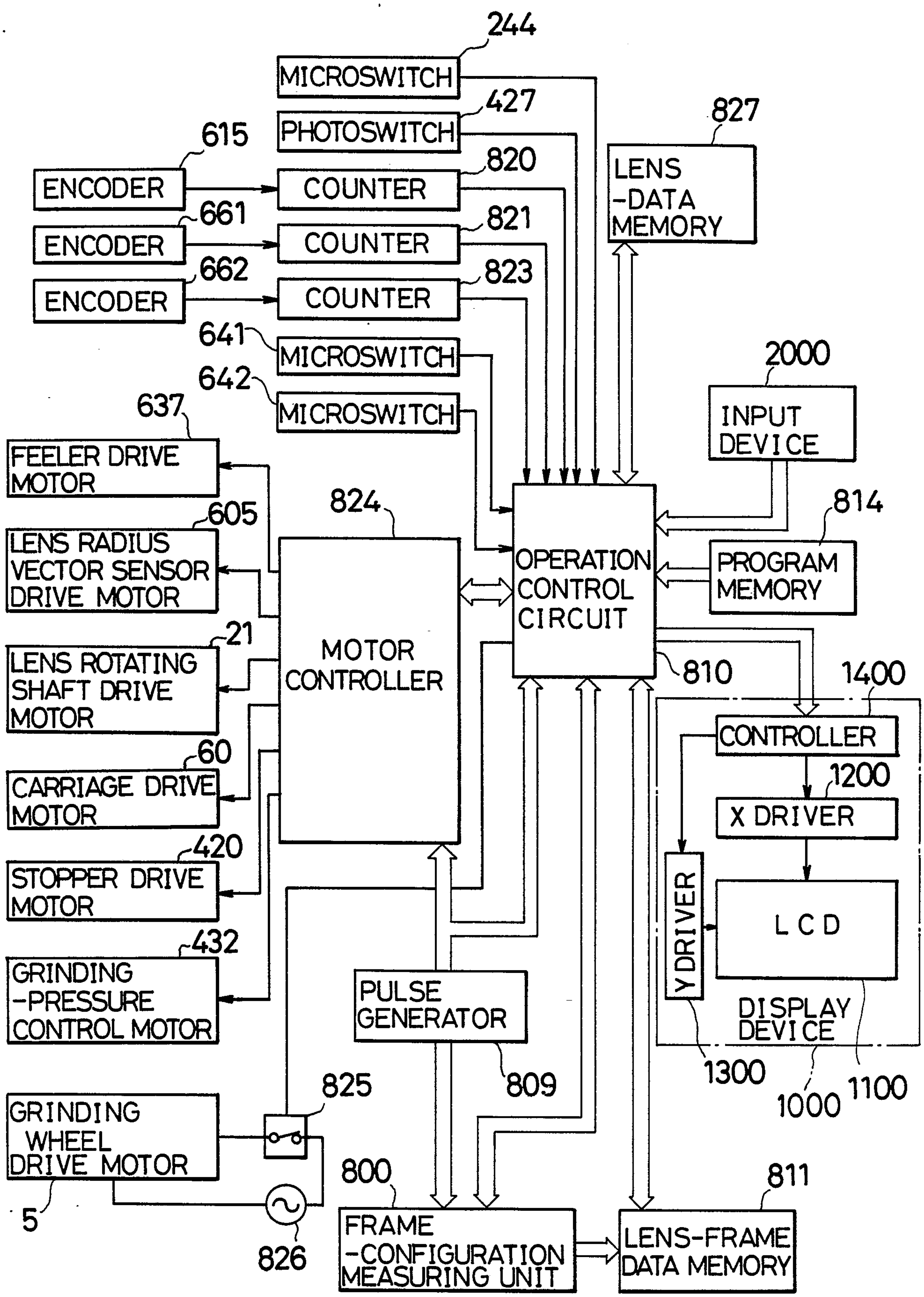


FIG.14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MICROSWITCH
427
PHOTOSWITCH
827
LENS
-DATA
MEMORY
615
ENCODER
COUNTER
820
661
ENCODER
COUNTER
821
662
ENCODER
COUNTER
823
641
MICROSWITCH
642
MICROSWITCH
2000
INPUT
DEVICE
637
FEELER DRIVE
MOTOR
605
LENS RADIUS
VECTOR SENSOR
DRIVE MOTOR
824
MOTOR
CONTROLLER
OPERATION
CONTROL
CIRCUIT
814
PROGRAM
MEMORY
21
LENS ROTATING
SHAFT DRIVE
MOTOR
810
1400
CONTROLLER
60
CARRIAGE DRIVE
MOTOR
1200
X DRIVER
420
STOPPER DRIVE
MOTOR
Y DRIVER
L C D
432
GRINDING
-PRESSURE
CONTROL MOTOR
PULSE
GENERATOR
DISPLAY
DEVICE
809
1300
1000
1100
825
GRINDING
WHEEL
DRIVE MOTOR
5
826
800
FRAME
-CONFIGURATION
MEASURING UNIT
811
LENS-FRAME
DATA MEMORY

FIG.15

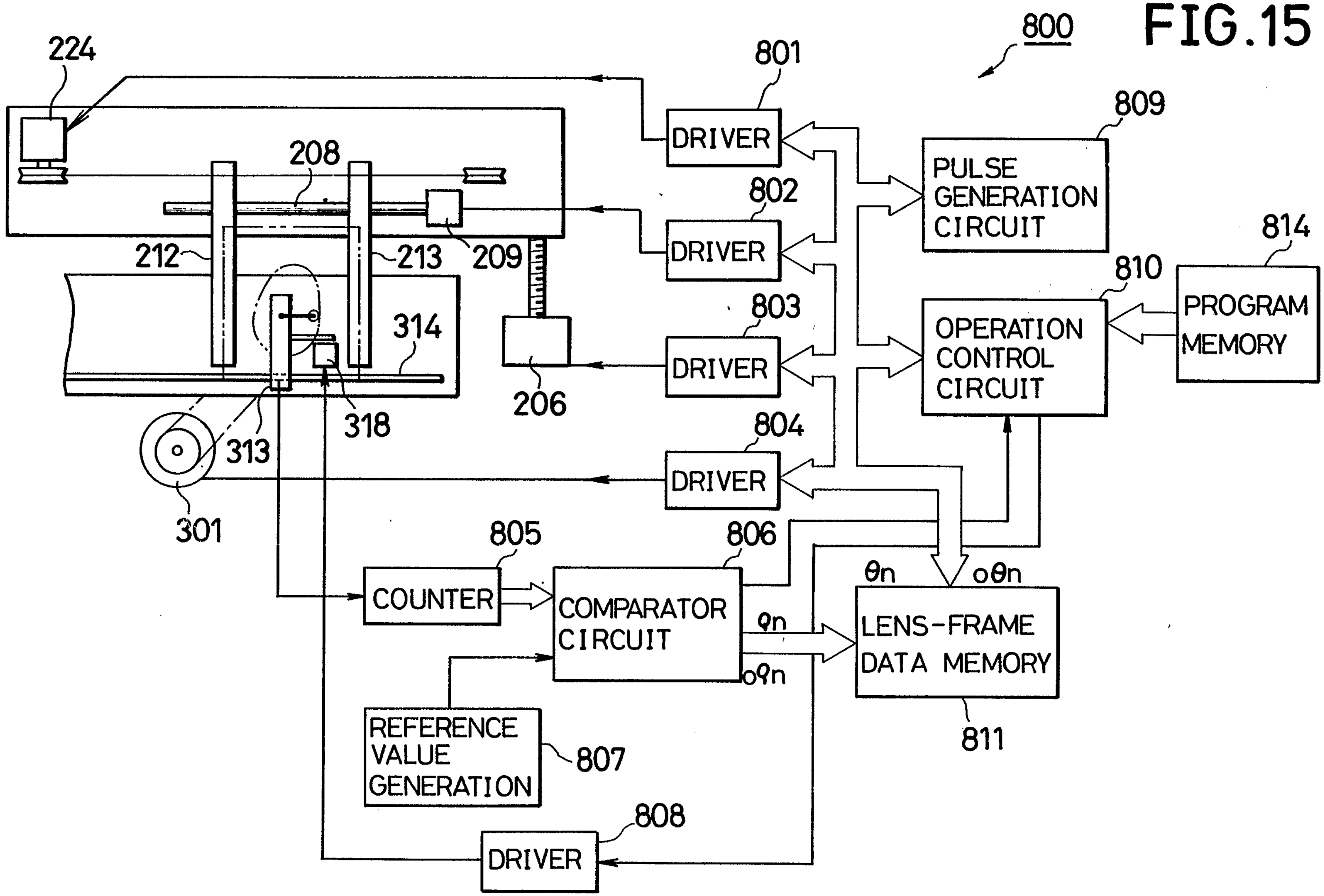
800
224
208
212
213
209
314
206
318
313
301
801
DRIVER
802
DRIVER
803
DRIVER
804
DRIVER
809
PULSE GENERATION CIRCUIT
810
OPERATION CONTROL CIRCUIT
814
PROGRAM MEMORY
805
COUNTER
806
COMPARATOR CIRCUIT
θn
oθn
LENS-FRAME DATA MEMORY
811
REFERENCE VALUE GENERATION
807
808
DRIVER

FIG.16(A)

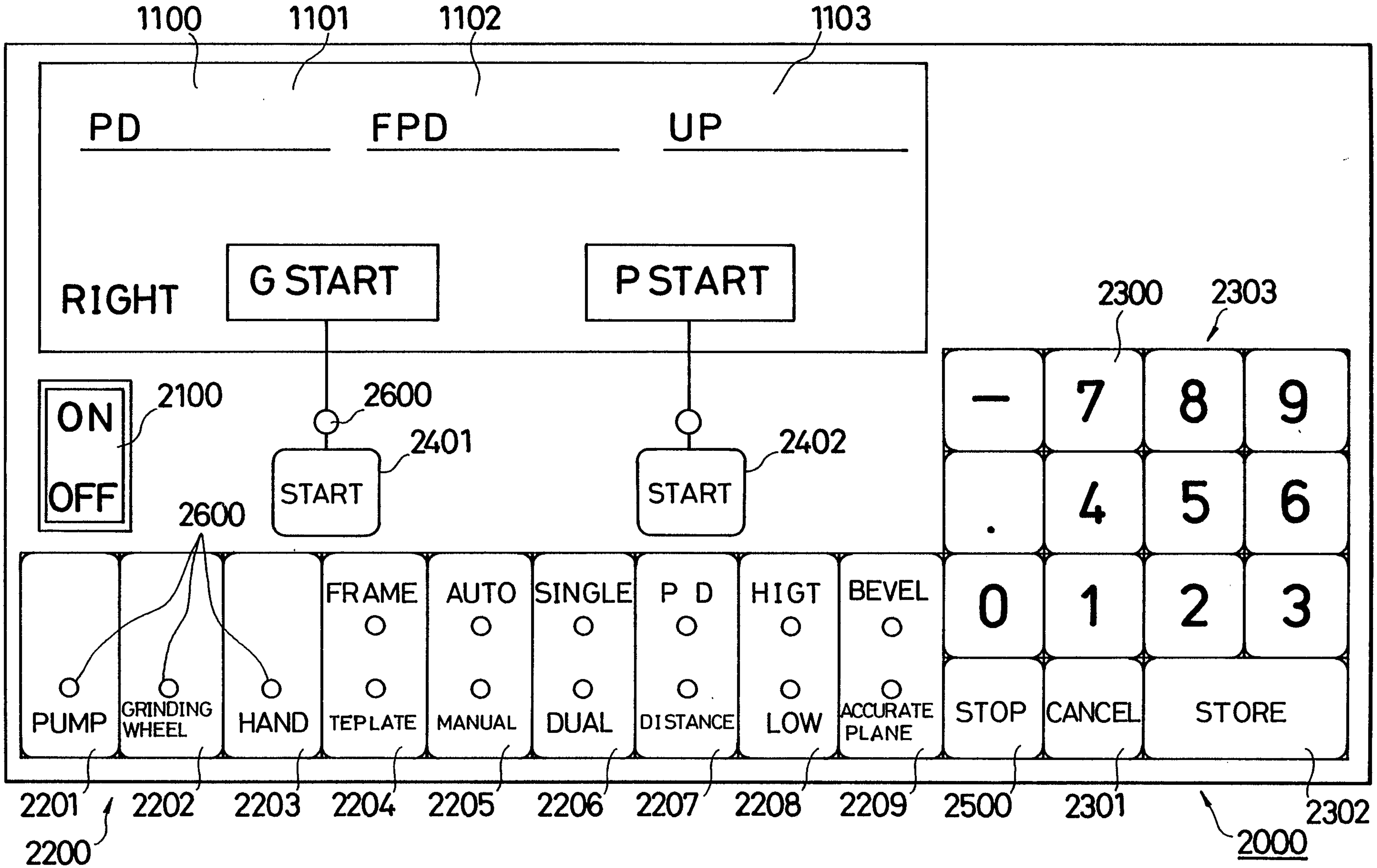
1100
1101
1102
1103
PD
FPD
UP
RIGHT
G START
P START
ON
OFF
2100
2600
2401
2402
START
START
2600
2300
2303
— 7 8 9
. 4 5 6
0 1 2 3
STOP
CANCEL
STORE
PUMP
GRINDING WHEEL
HAND
FRAME
TEPLATE
AUTO
MANUAL
SINGLE
DUAL
P D
DISTANCE
HIGT
LOW
BEVEL
ACCURATE PLANE
2201
2202
2203
2204
2205
2206
2207
2208
2209
2500
2301
2302
2200
2000

FIG.16(B)

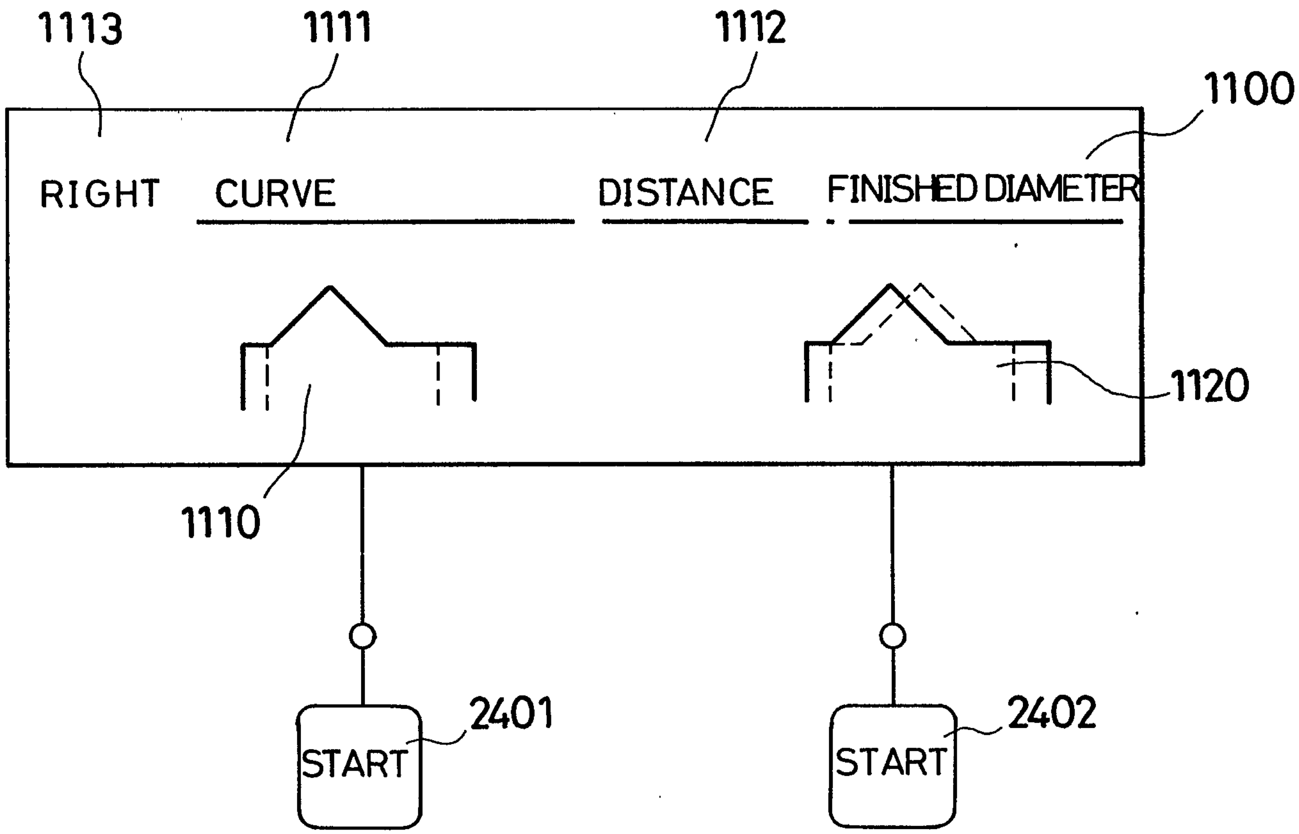
1113
1111
1112
1100
RIGHT
CURVE
DISTANCE
FINISHED DIAMETER
1120
1110
START
2401
START
2402

FIG.17

FIG.17A	FIG.17B	FIG.17C

FIG.17(A)

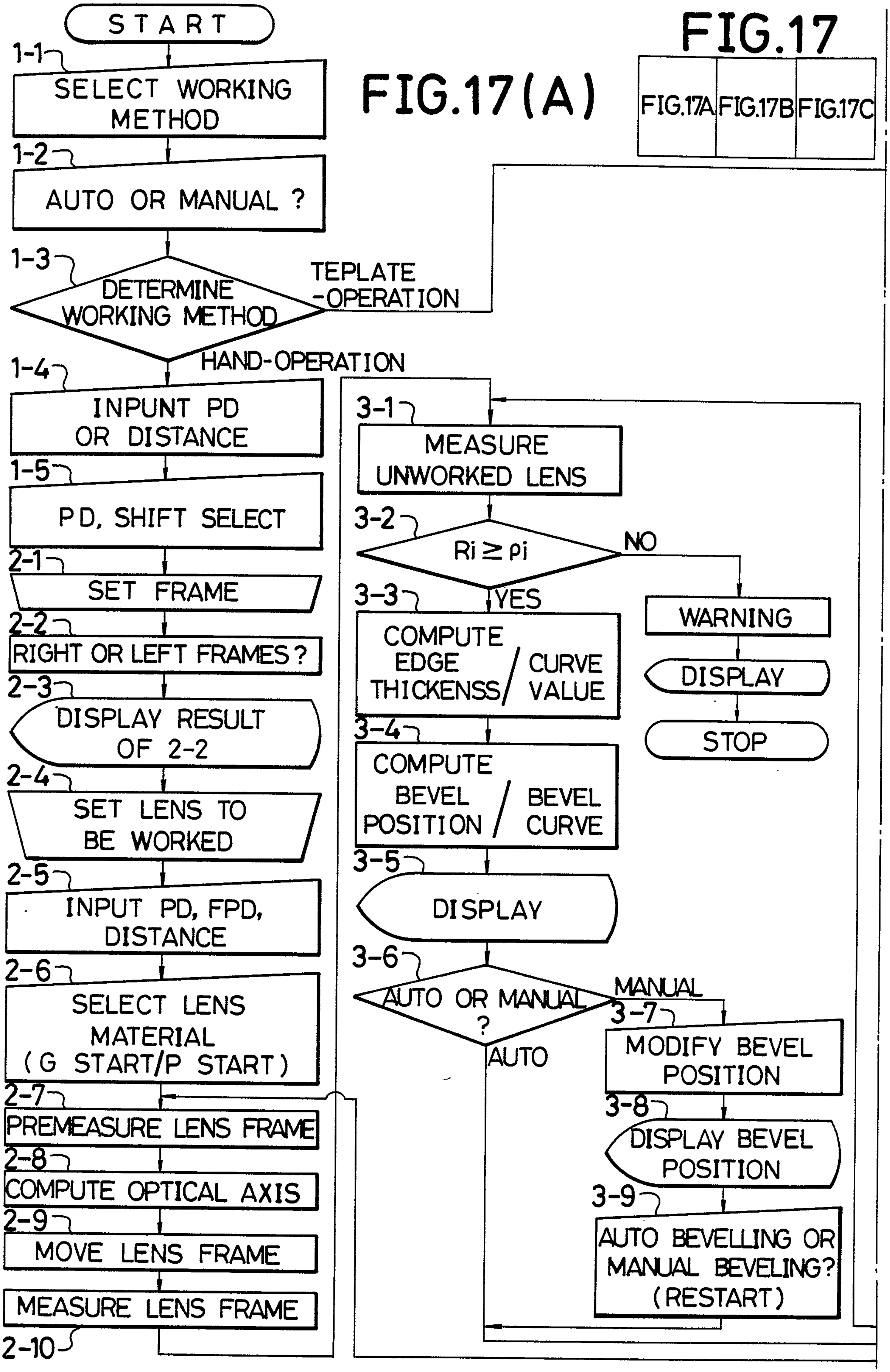

FIG.17(B)

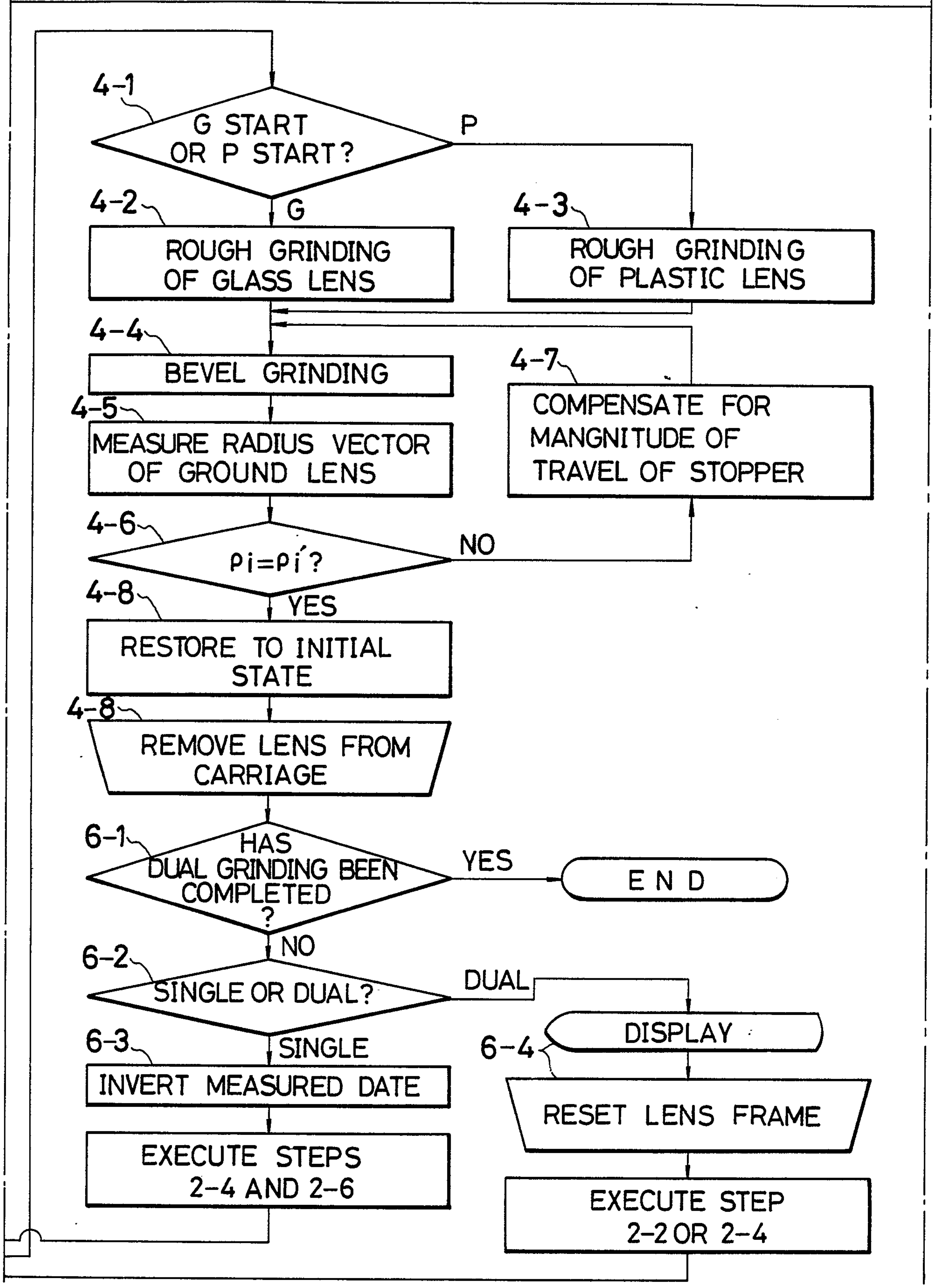
4-1
G START OR P START?
P
G
4-2
ROUGH GRINDING OF GLASS LENS
4-3
ROUGH GRINDING OF PLASTIC LENS
4-4
BEVEL GRINDING
4-7
COMPENSATE FOR MANGNITUDE OF TRAVEL OF STOPPER
4-5
MEASURE RADIUS VECTOR OF GROUND LENS
4-6
ρi=ρi'?
NO
4-8
YES
RESTORE TO INITIAL STATE
4-8
REMOVE LENS FROM CARRIAGE
6-1
HAS DUAL GRINDING BEEN COMPLETED ?
YES
END
NO
6-2
SINGLE OR DUAL?
DUAL
DISPLAY
6-4
6-3
SINGLE
INVERT MEASURED DATE
RESET LENS FRAME
EXECUTE STEPS 2-4 AND 2-6
EXECUTE STEP 2-2 OR 2-4

FIG.17(C)

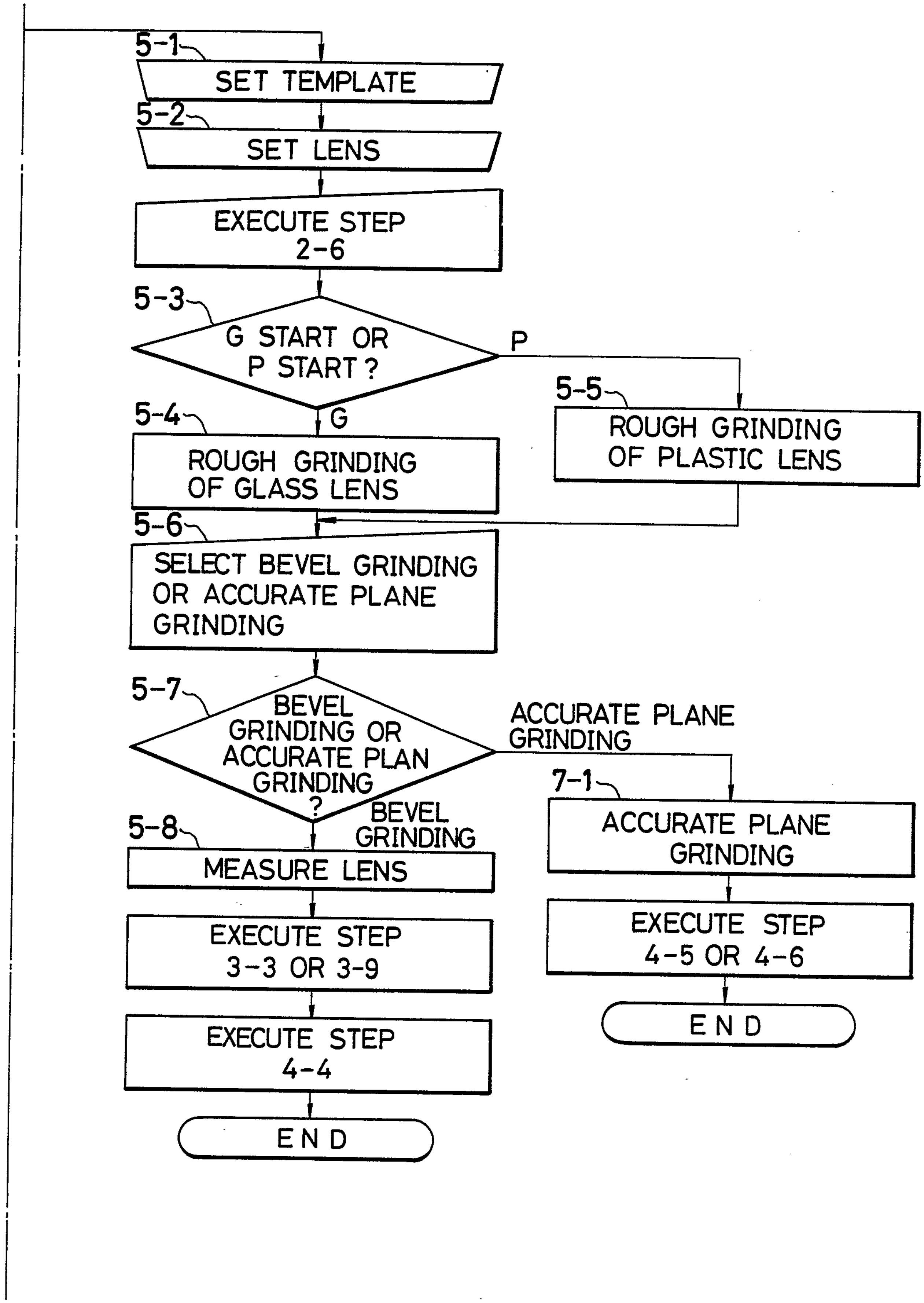
5-1
SET TEMPLATE
5-2
SET LENS
EXECUTE STEP 2-6
5-3
G START OR P START ?
P
G
5-4
ROUGH GRINDING OF GLASS LENS
5-5
ROUGH GRINDING OF PLASTIC LENS
5-6
SELECT BEVEL GRINDING OR ACCURATE PLANE GRINDING
5-7
BEVEL GRINDING OR ACCURATE PLAN GRINDING ?
ACCURATE PLANE GRINDING
BEVEL GRINDING
5-8
MEASURE LENS
7-1
ACCURATE PLANE GRINDING
EXECUTE STEP 3-3 OR 3-9
EXECUTE STEP 4-5 OR 4-6
EXECUTE STEP 4-4
END
END

FIG.18(A)

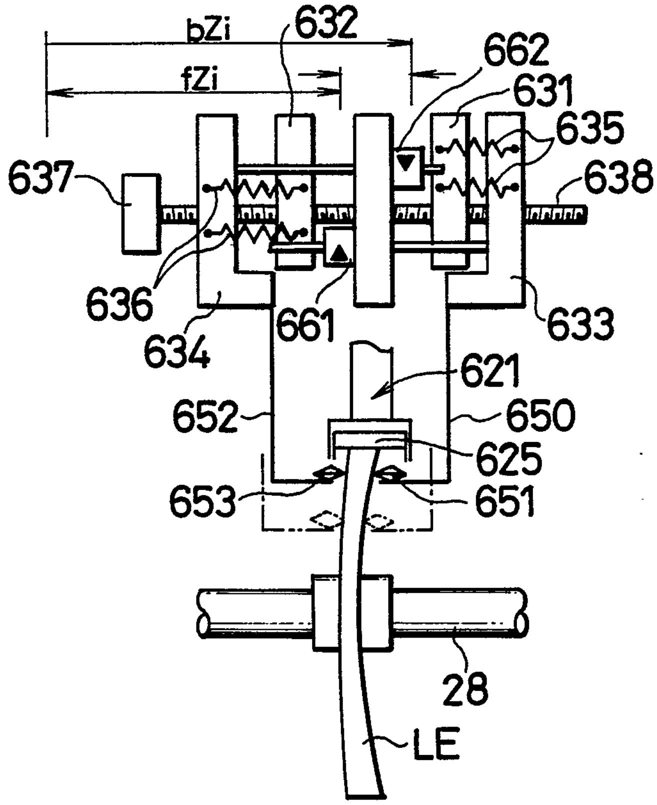

FIG.18(B)

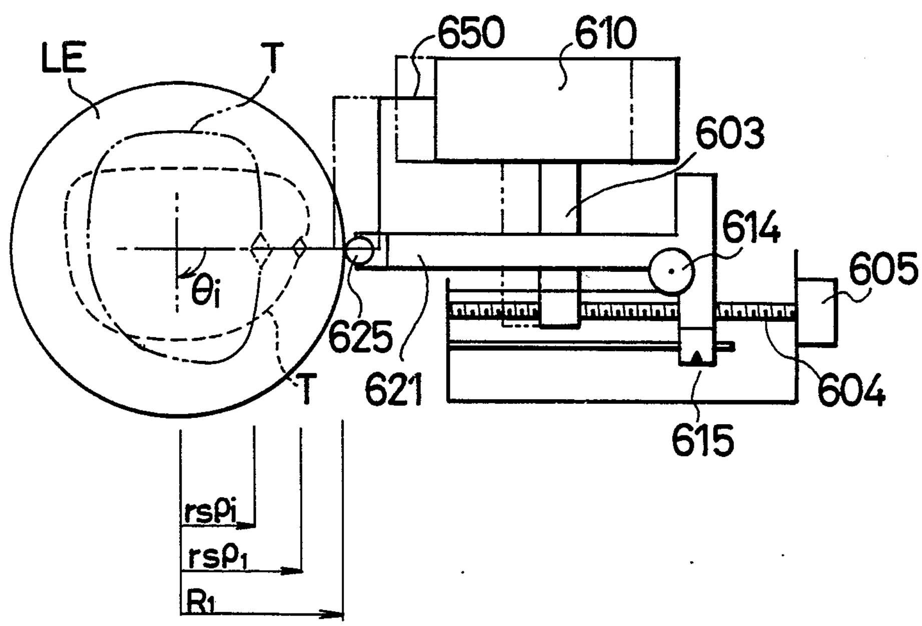

FIG.19(A)

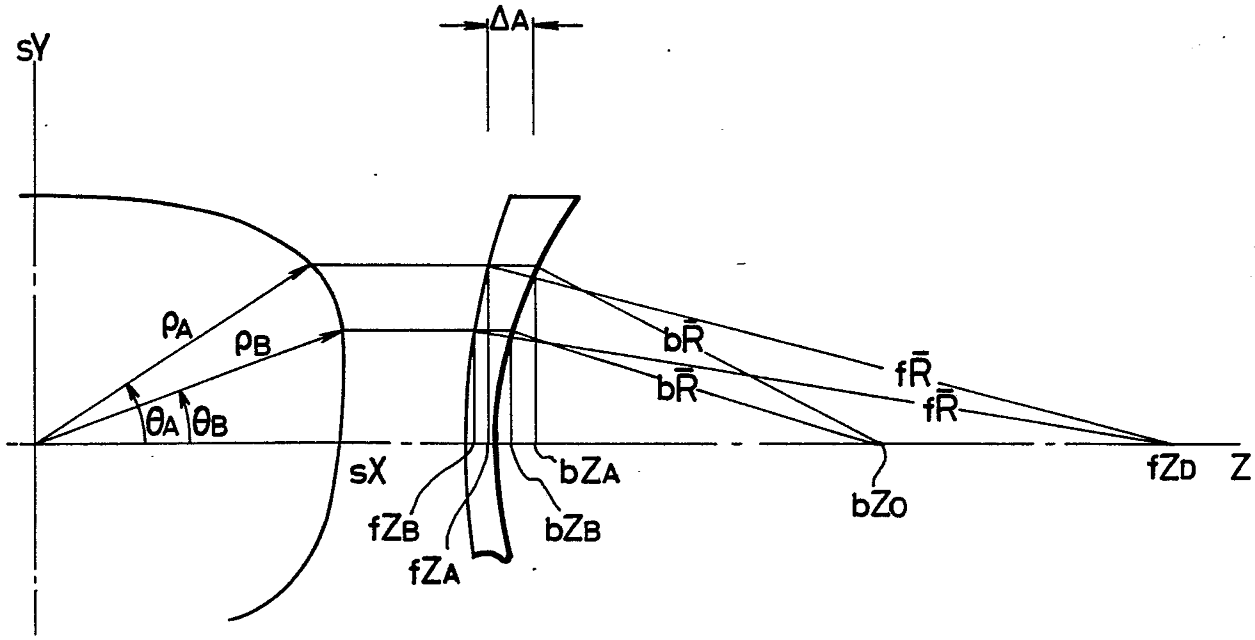

FIG.19(B)

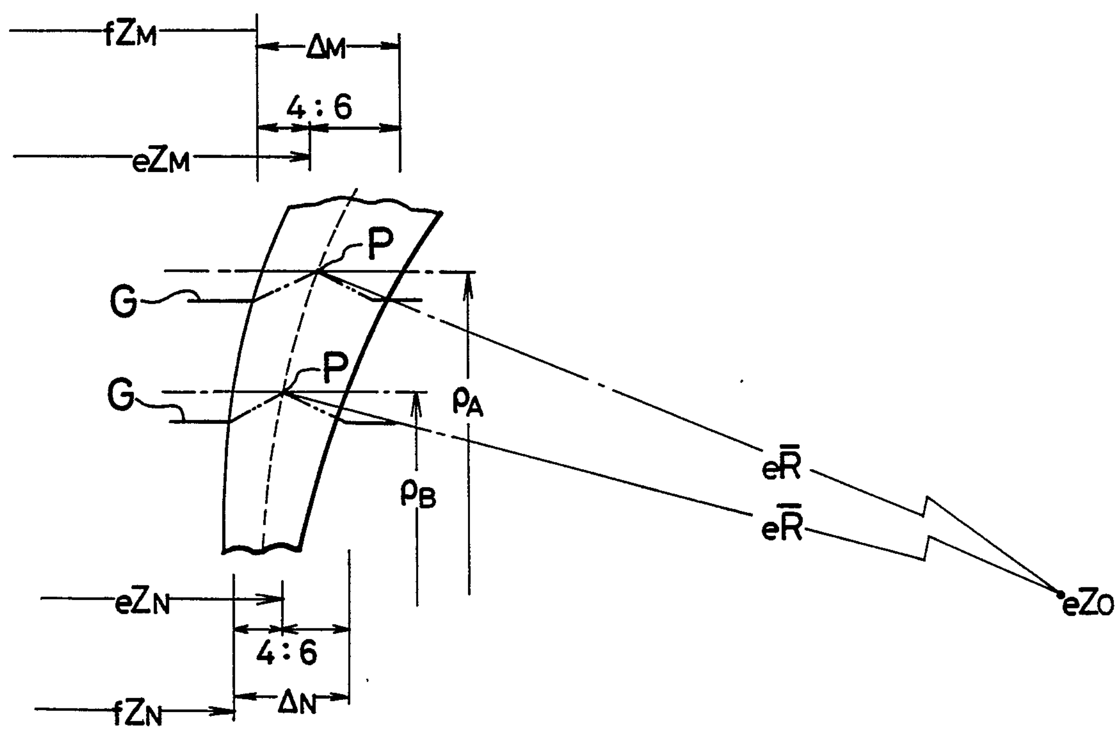

FIG.20

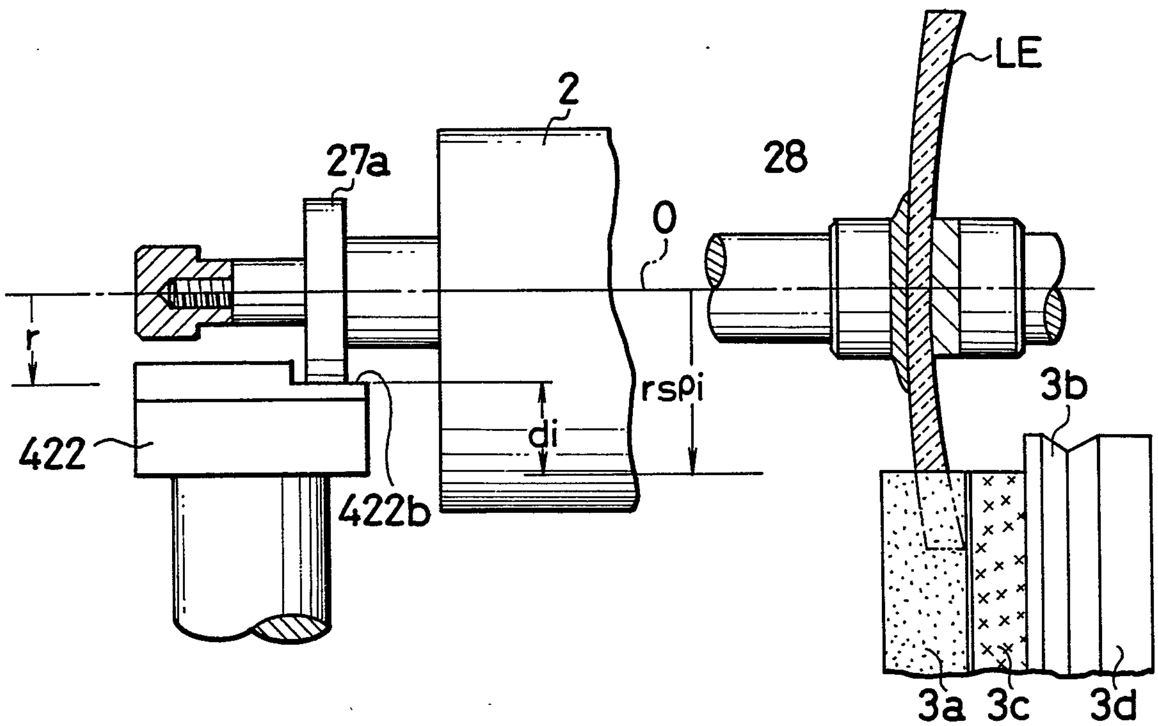
LE
2
27a
28
0
r
rsρi
3b
di
422
422b
3a
3c
3d

FIG.22

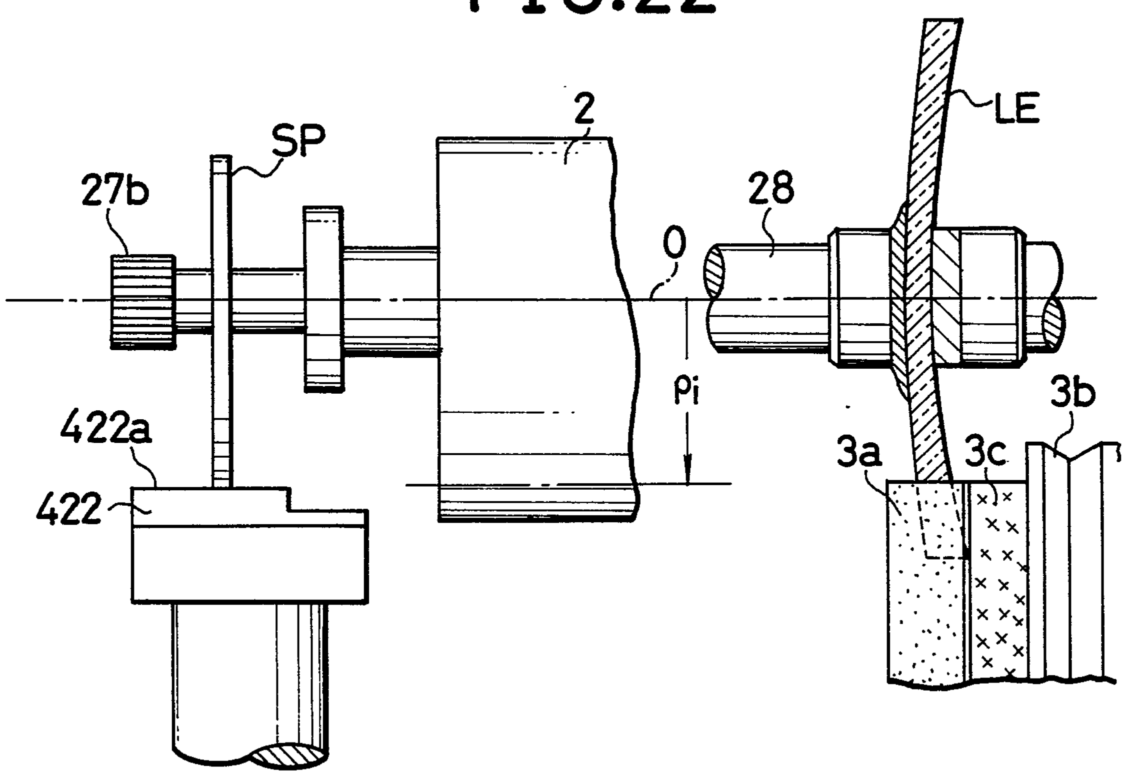
LE
2
SP
27b
28
0
ρi
3b
422a
3a
3c
422

FIG.21(A)

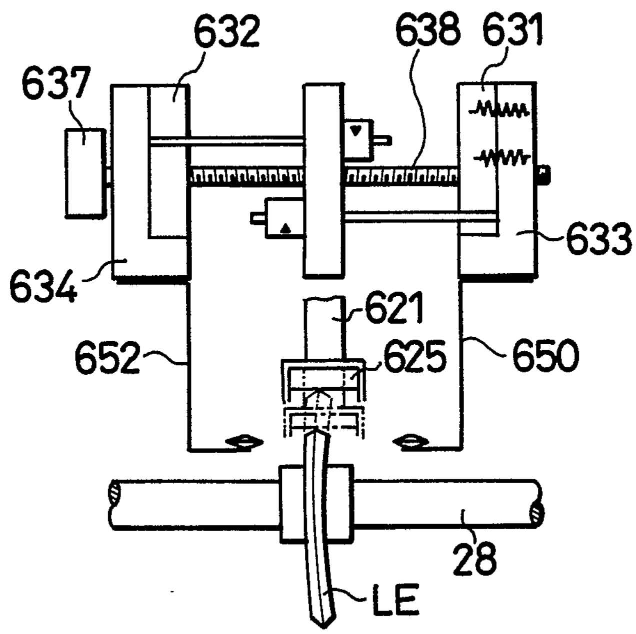

FIG.21(B)

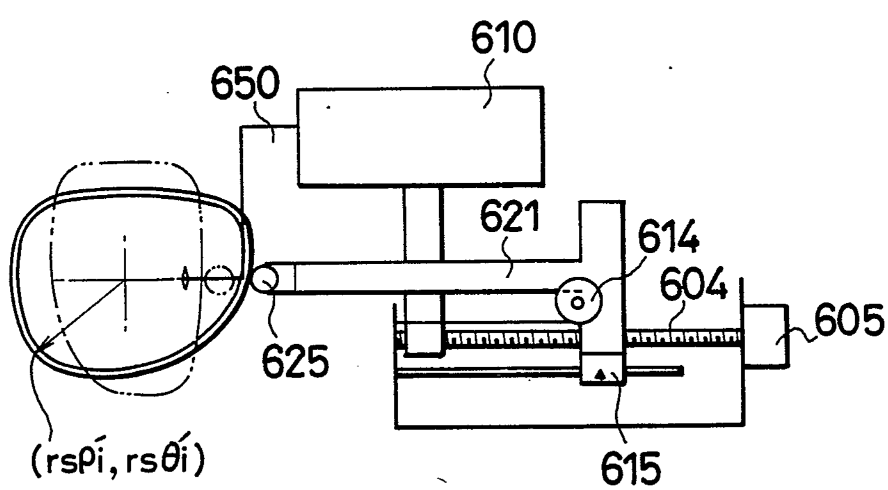

FIG.23(A)

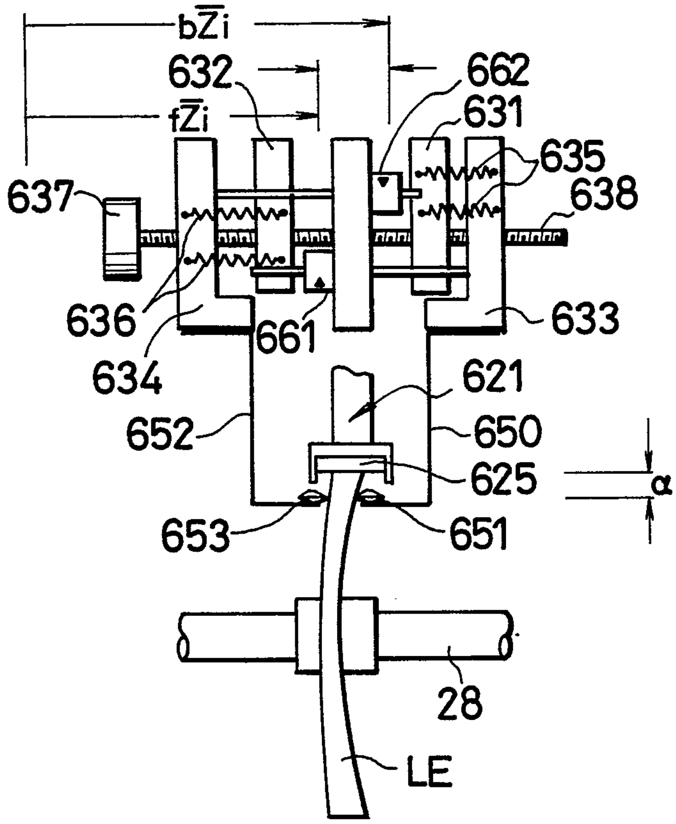

FIG.23(B)