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

(72) Inventor: Hara, Atsushi c/o Tokyo Kogaku Kikai,
Kabushiki Kaisha 75-1, Hasunuma-cho, Itabashi-ku
Tokyo (JP)
Inventor: Isokawa, Nobuhiro c/o Tokyo Kogaku Kikai,
Kabushiki Kaisha 75-1, Hasunuma-cho, Itabashi-ku
Tokyo (JP)
Inventor: Suzuki, Yasuo c/o Tokyo Kogaku Kikai,
Kabushiki Kaisha 75-1, Hasunuma-cho, Itabashi-ku
Tokyo (JP)
Inventor: Hatano, Yoshiyuki c/o Tokyo Kogaku Kikai,
Kabushiki Kaisha 75-1, Hasunuma-cho, Itabashi-ku
Tokyo (JP)
Inventor: Oogushi, Hiroaki c/o Tokyo Kogaku Kikai,
Kabushiki Kaisha 75-1, Hasunuma-cho, Itabashi-ku
Tokyo (JP)

(74) Representative: Hertel, Werner, Dipl.-Phys. et al,
Patentanwälte Müller-Boré, Deufel, Schön, Hertel
Lewald, Otto Isartorplatz 6 Postfach 26 02 47,
D-8000 München 26 (DE)

(54) **Edge grinding method and apparatus.**

(57) A method for grinding an edge portion of a spectacle lens comprising steps of digitally measuring a shape of a spectacle frame to which the lens is to be fitted to obtain first digital values of measurement, and grinding the edge portion of the lens based on the digital values to obtain a peripheral configuration of the lens which conforms to the shape of the spectacle frame.

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BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a method and apparatus for edging a spectacle lens so that it fits to a spectacle frame. More specifically, the present invention relates to a method and apparatus for grinding the edge portion of a spectacle lens in accordance with the shape of a spectacle frame.

Description of Prior Art

Conventionally, a spectacle lens is ground at the edge portion before it is fitted to a spectacle frame so that its peripheral configuration conforms to the shape of the frame. For the purpose, a template is usually prepared modeling the spectacle frame and the lens edge is ground copying the template. In an alternative procedure, the lens is ground directly copying the spectacle frame. In such known procedures, there is no means for measuring the accuracy of the grinding operation, so that the only way of confirming that the lens has been edged to a satisfactory extent is to try to fit the lens to the spectacle frame. Further, when it is found that the edging work is incomplete, it has been very difficult to determine the portion and the amount of additional grinding required for completing the edging work. Thus, in the conventional methods, skills and experiences of workmen have been required and it has been difficult to maintain the accuracy of the edging. Particularly, in the method wherein the edging work is performed copying the spectacle frame directly, it is required to remove the spectacle frame from the grinding machine each time when the result of the grinding work is to be inspected. When it is found that a further grinding is necessary, the spectacle frame has to be mounted on the machine but it is very difficult to locate the spectacle frame exactly at the same position where it was located before it was removed. Therefore, there is a high possibility of working errors being produced due to errors in locating the spectacle frame.

OBJECT OF THE INVENTION

It is therefore an object of the present invention to provide a spectacle lens edging method and apparatus therefor which can perform an accurate edging work.

Another object of the present invention is to provide a method and apparatus for edging a spectacle lens, in which accuracy of the edging work can be readily measured.

SUMMARY OF THE INVENTION

According to the present invention, the above and other objects can be accomplished by a method for grinding an edge portion of a spectacle lens comprising steps of digitally measuring a shape of a spectacle frame to which the lens is to be fitted to obtain first digital values of measurement, and grinding the edge portion of the lens based on the digital values to obtain a peripheral configuration of the lens which conforms to the shape of the spectacle frame. According to another aspect of the present invention, further steps are carried out for digitally measuring the peripheral configuration of the lens which has been ground to obtain second digital values of measurement and comparing the first and second digital values to judge accuracy of the grinding. The present invention further provides an apparatus for performing the aforementioned method.

According to a specific aspect of the present invention, there is provided an apparatus for grinding an edge portion of a spectacle lens comprising a grinding wheel rotatable about a first axis, driving means for rotating the grinding wheel about said first axis, a carriage including lens holding means for holding the lens and rotating it about a second axis, shifting means for controlling a spacing between said first and second axes in accordance with an angle of rotation of said lens, first measuring means including a rotating arm rotatable about a enter of rotation and a feeler provided on said arm and adapted to be moved along a shape of a spectacle frame to which the lens is to be fitted so as to measure digitally the shape of the spectacle frame in terms of a distance from said center of rotation of the rotating arm and an angle of rotation of said rotation arm, memorizing means for memorizing values obtained by measurements of said first measuring means, control means for controlling the angle of rotation of said lens and the spacing between said first and second axes in accordance with the values memorized in said memorizing means, second measuring means including a second feeler adapted to be contacted with a periphery of said lens for measuring digitally the peripheral configuration of said lens in terms of a radial displacement of the second feeler in relation to the rotation of the lens, comparator means for comparing the values memorized in said memorizing means with values obtained by measurements of said second measuring means.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view showing the lens edging apparatus in accordance with one embodiment of the present invention;

Figure 2A is an exploded perspective view showing the spectacle frame measuring means;

Figure 2B is an perspective view showing the frame holding means;

Figure 3 is a side view partly in section showing a detector for measuring the eyeglass frame;

Figure 4 is a perspective view showing a lens periphery measuring means;

Figures 5, 6A and 6B are explanatory views for explaining an operation of the frame measuring means;

Figure 7 is an explanatory view for explaining an operation of an lens periphery measuring means;

Figure 8 is an explanatory view for explaining lens edging;

Figure 9 is a perspective view showing a lens measuring means;

Figure 10 is a top view showing the lens measuring means;

Figure 11 is a sectional side elevation showing the lens measuring means;

Figure 12 is a sectional view of a contact portion of the lens measuring means along a line XII-XII in Figure 10;

Figure 13 is a sectional view of a contact portion of the lens measuring means along a line XIII-XIII in Figure 10;

Figure 14 is an explanatory view for explaining measurement of configuration of an edged lens;

Figure 15 is a perspective view showing an edged lens;

Figure 16 is a plane view of the lens measuring means for explaining measurement of a periphery thickness of lens;

Figure 17 is a schematic view of lens for showing geometric value thereof;

Figure 18 is a block diagram of operation and control unit; and

Figure 19 is a flow chart showing whole operations of the present embodiment.

DESCRIPTIONS OF THE PREFERRED EMBODIMENT

[General explanation of lens edging apparatus]

Referring to Figure 1, there is shown a grinding section in accordance with one embodiment of the lens edging apparatus of the present invention. In a grinding room 2 of a housing 1 there is provided a grinding wheel 3 comprising a roughing wheel 3a, a beveling wheel 3b having a large V-shaped groove in its periphery, and a cylindric precision grinding wheel 3c, and the wheel 3 is secured on a shaft 5 having a pulley 4. The pulley 4 is connected with a grinding motor 6 through a belt 7 so that the wheel 3 is rotated by the motor 6.

In the housing 1 there are provided with bearing members 10, 11 which are adapted to rotationally, axially-movably hold a carriage shaft 12. One end of the carriage shaft 12 is rotationally mounted on a bearing member 21a provided on a later mentioned transfer station 20. There is provided with a carriage 13 arm members 14, 15 of which are secured on the shaft 12. On other arm members 16, 17 of the carriage 13 there is provided with a work holding shaft 18 comprising a pair of shafts 18a, 18b for holding a lens LE to be edged. The shaft 18a has an operation handle 19 at its end, and by rotation of the handle 19 the shaft 18a is slided along its axis so that the shafts 18a, 18b supports the lens LE between them.

There is provided with a lens measuring means 30 mentioned later, an arm portion 31 of which is mounted on the shaft 12 so as to swing on an axis in common with one of the carriage 13.

A base plate 21 of the station 20 has a pair of wheels 22 which are adapted to roll on rails 23 secured on the housing 1 so that the station 20 is possible to move along the rails 23. The station 20 has a female screw 24 to be engaged with a transfer male screw 41, which is rotated by a motor 40 so that the station 20 is moved in both directions as shown by an arrow 25. The shaft 12, as mentioned above, is rotationally mounted on the member 21a, and therefore the carriage 13 horizontally moves simultaneously with the station 20.

The base plate 21 has two vertical shafts 26, 26' parallel to each other, which movable mount a stopping member 27. The stopping member 27 has a female screw 28 to be engaged with a transfer male screw 43, which is rotated by a Z-axis motor 40 so that the stopping member 27 is upward or downward moved. The carriage 13 also has an arm portion 16a which mounts a rotation wheel 16b at its end, and the rotation wheel 16b is placed on an upper surface of the stopping member

27 so that the carriage 13 is possible to swing in response to a vertical motion of the stopping member.

[Eyeglass frame measuring means]

Referring to Figure 2A, there is shown means for digitally measuring a configuration of the eyeglass frame or a lens pattern previously made in accordance with the eyeglass frame. The shaft 18b is supported by a bearing member 50 formed on the carriage 13. The shaft 18b mounts a detecting arm 51 at its end 18c, and a long side frame 52 of the detecting arm 51 is mounted on an end portion 18c of the shaft 18b at right angle to a rotation axis of the shaft 18b. A detector 54 is provided on another long side frame 53 to be moved thereon and biased to the end portion of the frame 53 by a pressure spring 59 coiled around the frame 53. On short side frames 55, 56 of the arm 51 there are rotationally provided with pulleys 57, 58, respectively.

while, the shaft 18b rotationally supports a pulley 60 which is united with a code disc 62 of an encoder 61. A detecting head 62a of the encoder 61 is secured to an outside of the arm 16. A first wire 80 is wound around the pulley 60 and secured to the detector 54 through the pulley 57 and the side of the pulley 60 at their ends, respectively. A second wire 81 is would around the pulley 60 in an opposite direction to the first wire 80 and secured to the detector 54 through the pulley 60 and the side of the pulley 60 at their ends, respectively, thereby, displacement of detector 54 on the frame 53 may be detected as rotation angle of the pulley 60 or the disc 62.

The detector 54, as shown in Figure 3, comprises a sliding seat 541 movably mounted on the frame 53, a sliding rotationed shaft 543 rotationally supported by the seat 541, and a detecting feeler 542 secured to the shaft 543. The detecting feeler 542 has a lens pattern feeler 544 and an eyeglass frame contacting wheel 546. The feeler 542 is a portion of the shaft 543, which is partionally cut down so as to form a semicircular cross section. The wheel 546 is rotationally provided on an end of a U-shaped arm member 545 which is mounted on the shaft 543. A contacting surface 544a of the feeler 544 and a contacting periphery 546a of the wheel 546 are located so as to include an axis 0, of the shaft 543. On another end of the shaft 543 a pin 547 is inserted so as to be parallel to the surface 544a, and the pin 547 engages with a stopping member 548 fixed on the frame 52 on its side surface when the detector 54 is on the first position.

Referring now to Figure 2A, in the carriage 13 there are provided with a motor 70 for rotating the shafts 18, 18a and sprocket wheel shaft 71 having a pair of sprocket wheels to be rotated by the motor 70 at its opposite ends. The shafts 18, 18a have sprocket wheels 74, 75, respectively. Chains 76, 77 link between the sprockets 72, 74, the sprockets 73, 75, respectively, so that the shafts 18, 18a are rotated by the motor 70.

In the housing 1, there is further provided with an eyeglass frame holding means 90, a station 91 of which is located parallel to longitudinal direction of the arm member 16 at the time when the carriage 13 is on the first position. The station 91 has a pair of rails 92, 93 parallel to the longitudinal direction of the arm member 16, which movably support eyeglass frame supporting members 94, 95. The supporting members 94, 95 are always biased by a spring 96 toward each other. The supporting member 95 has a screw portion at its leg portion 95a, which engages with a transfer screw 97a provided on a shaft of a Y-axis motor 97. The supporting members 94, 95 have fitting member 94c, 95c at upper portions of arms 94b, 95b in order to fit an eyeglass frame holding member 100.

The holding member, as shown in Figure 2B, has a base plate 101 providing a circle opening 102 at its center, eyeglass frame holding arms 103, 104 provided on the plate 101 being opposite to each other, and a pressure member 105 for pressing an eyeglass frame 200.

The arms 103, 104 hold upper and lower limbs of the eyeglass frame 200 and the pressure member 105 presses the lens frame 200, so that the eyeglass frame 200 is secured on the opening 102 of the member 100. At this time, a fore end 105a and a rear end 105b of the pressure member 105 are projected from concavities 103a, 104a of the arms 103, 104, thereby a fore end 101a and a rear end 101b (not shown in Figures) of the plate 101 are on the same plane with the ends

105a, 105b, respectively. The member 100 holding the eyeglass frame 200 is supported by the members 94c, 95c.

The base plate 101, the pressure member 105 and the concavities 103a, 104a are designed so that an upper edge of the rear and 106b and a lower edge of the rear end 101b are positioned at the same distance d from a center axis of a V-shaped groove of the lower limb. The supporting members 94c, 95c have V-shaped grooves 94d, 95d, respectively. Thereby, when the holding member 100, as shown in Figure 2C, is supported by the supporting members 94c, 95c, the upper edge of the rear end 105b and the lower edge of the rear end 101b slide on surfaces of the V-shaped grooves 94d, 95d so that a center between the upper edge and the lower edge becomes coincident with a center of the V-shaped groove. In this way a center 201b of a V-shaped groove of the lower limb coincides with the one of the supporting members 94c, 95c.

A template holding member 110, as shown in Figure 4, is used in the case of that a lens template 210 is supported by the supporting members 94, 95. The member 110 comprises a holding frame 111, pole members 112, 113 secured on an opposite ends of the holding frame 111, a template holding pole 111a fixed to the frame 111 at its center, and pins 114, 115, 116 projected from the template holding pole 111a at its end. The pattern 210 has three holes to be engaged with the pins 114, 115, 116.

(Operation of eyeglass frame measuring means)

Hereinafter, there is shown the operation of the eyeglass frame measuring means described above. The eyeglass holding member 100 is held by the supporting members 94, 95, and the carriage 13 is moved by rotation of the Z-axis motor 40 in a direction of an arrow A (shown in Figure 1) by the predetermined displacement. In accordance with rotation of the Y-axis motor 97 the eyeglass handling member 100 is moved along the rails 92, 93 by the predetermined displacement and the eyeglass frame 200 is moved to the first set position so that the center 201b of the V-shaped groove of the lower limb is in contact with the contacting wheel 546 in the same plane, and the rotation axis 0_1 of the detecting arm 51 is located in the eyeglass frame 200. At this time the wheel 546 is engaged with the V-shaped groove of the lower limb, and the pin 547 is released from the stopping member 548 to make the shaft 543 free of rotation. Displacement of the detector 54 along the frame 53 is converted into rotation angle to be measured by the encoder 61 through the wires 80, 81.

When the carriage 13 and the detecting arm 51 are located at the first position as shown in Figure 2A and the detector 54 is located at the first position as shown in Figure 5 where the detector 54 is pressed by the spring 59 not to abut on the eyeglass frame 200, an origin O is taken to be on the axis 0_1 and a distance between the origin O and the rotation axis 0_2 of the arm 51 is taken to be ℓ. The assumption is further made that the encoder 61 counts counting value

C_n in accordance with said predetermined displacement of the eyeglass frame 200 and the rotation of the detecting arm 51, the encoder 61 has e^{o}/pulse resolution, the detector 54 has d (mm)/pulse resolution in response to the resolution of the encoder 61, and rotation angle θ_n of the detecting arm 51 is 0^{o} when the detecting arm 51 is positioned at the first standard position or parallel to the arm member 16 of the carriage 13. Under the present embodiment, when the displacement of the detector 54 along the detecting arm 51 is measured by the encoder 61, a radius vector ρ_n of the detecting arm 51 being at the rotation angle θ_n includes rotation of the detecting arm 51, and therefore

$$\rho_n = \ell - (C_n - \frac{\theta n}{e})d \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (1)$$

When the detecting arm 51 is positioned at the standard position or $\theta_n = 0$, the radius vector ρ_0 is presented from the equation (1) as follows;

$$\rho_0 = \ell - C_0 \cdot d \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (2)$$

In this way digital values (ρ_n, θ_n) (n = 0, 1, 2, ..., N) of a configuration of the eyeglass frame 200 about the axis 0_2 is obtained through the rotation of the detecting arm 51 along a whole periphery of the eyeglass frame 200.

The values (ρ_n, θ_n) are those in the case where the rotation center 0_2 of the detecting arm 51 is located at any position in the eyeglass frame 200 and not in the case where the rotation center 0_2 is located at a geometric center of the eyeglass frame 200. Referring to Figures 6A and 6B there is shown a method to invert the former into the latter. Locating the carriage 13 at the first position, a Y-axis is taken to be line connecting between the rotation center 0_2 and a swing center 0 of the carriage 13, and a X-axis is taken to be one crossing the Y-axis at a right angle. On the conditions mentioned above, the eyeglass frame data (ρ_n, θ_n) under rectangular coordinate are converted into those (x_n, y_n) under polar coordinate through the following transforming equations (3);

$$\begin{aligned} x_n &= \rho_n \times \cos \theta_n \\ y_n &= \rho_n \times \sin \theta_n \end{aligned} \quad \cdots\cdots\cdots\cdots (3)$$

From the eyeglass frame data (x_n, y_n) the minimum coordinate point A (x_a, y_a) and the maximum coordinate point C (x_c, y_c) in the X-axis direction and the minimum coordinate point D (x_d, y_d) and the maximum coordinate point B (x_b, y_b) in the Y-axis direction are selected, coordinate values 0_3 (x_3, y_3) of the geometric center 0_3 of the eyeglass frame 200 are calculated from the following equation (4);

$$0_3\ (x_3,\ y_3) = \left(\frac{x_c - x_a}{2},\ \frac{y_b - y_d}{2}\right) \quad \cdots\cdots\cdots\cdots (4)$$

Then, differences Δx, Δy between the rotation center 0_2 (x_0, y_0) under the first position and the 0_3 (x_3, y_3) are calculated from equations $\Delta x = x_0 - x_3$, $\Delta y = y_0 - y_3$. Shift of Δy is carried out so that the frame holding means 90 is moved by Δy by the Y-axis motor 97. While, shift of Δx is carried out so that the carriage 13 is swung by going up and down the stopping member 27 by h. Under the present embodiment a swing radius M of the detecting arm 51 is twice as long as a swing radius m of the wheel 16b,

$$\Delta x \fallingdotseq M \tan \beta$$

$$h \fallingdotseq m \tan \beta$$

thereby, $h \fallingdotseq \frac{\Delta x}{2}$ .... (5)

The operation mentioned above leads to make the rotation center of the detecting arm 51 coincident with the geometric center O_3 of the eyeglass frame 200. Subsequently, the detecting arm 51 is rotated by an angle β in order to shift a position of the origin. In the present condition, the detecting arm 51 is rotated along the whole periphery of the lens frame 200 again, so that the digital configuration values (ρ_n, θ_n) of the eyeglass frame 200 are obtained and memorized.

[Lens template measuring means]

Referring to Figure 7, there is shown a method for measuring the lens template which is used instead of the eyeglass frame. In Figure 7 elements corresponding to those shown in Figure 5 are with the same reference numerals and explanations thereof are omitted. To measure a configuration of the lens template 210 the feeler 544 is moved to be in contact with a periphery of the lens template 210 and the detecting arm 51 is rotated. The detecting arm 51 is shifted from the origin O by the predetermined distance to locate the rotation axis 0_2 thereof in the lens pattern 210. In case where the detecting arm 51 is rotated by angle θ_n from the first standard position thereof, a radius vector ${}_t\rho_n$ is represented as follows;

$$ {}_t\rho_n = (C_n - \frac{\theta_n}{e})d - \ell \quad \cdots\cdots (6)$$

while, in case where the detecting arm 51 is positioned at the first standard position, a radius vector ${}_t\rho_0$ is represented as follows;

$$ {}_t\rho_0 = C_0 \cdot d - \ell \quad \cdots\cdots (7)$$

In the same method as that of measuring of the eyeglass frame mentioned above, the geometric center of the lens template 210 is calculated from lens pattern configuration $({}_t\rho_n, \theta_n)$ $(n = 0, 1, 2, ..., N)$, the rotation center 0_2 of the detecting arm 51 is moved to the geometric center and rotated along the whole periphery of the lens pattern 210, and the measured valves are memorized.

In this embodiment a contact point 546a between the groove of the eyeglass frame 200 and the contacting wheel 546 and the contacting surface 544a, as shown in Figure 3, are adapted to be located on the axis 0, of the shaft 543, at the measuring time the contacting wheel 546 and the feeler 544 supported by the U-shaped arm member 545 are pressed against the groove of the eyeglass or the lens template, and the member 545 is turned to a line perpendicular to a contact surface between the wheel 546 and the groove or the feeler 544 and the lens pattern. Consequently, the measurement mentioned above is always carried out with precision.

[Edging means and operation thereof]

Referring to Figure 8, there is shown an edging means for edging pre-edged lens LE in accordance with the values obtained by the above mentioned measuring means and the operation thereof. The pre-edged lens is mounted by the shafts 18, 18a (refer to Figure 1), and the motor 6 is energized, so that the pre-edged lens falls on the wheel 3 by its gravity in order to be edged thereby.

In accordance with the present invention the pre-edged LE is edged on the basis of the value (ρ_n, θ_n) (n = 0, 1, 2, ..., N) mentioned above. Displacement of the carriage 13 is measured by the linear encoder 610, which comprises a scale 611 provided on a side of the arm portion 31 of the lens measuring means 30 so as to rotate it about a pivotal point P, and a detector head 612 pivoted on the side of the carriage 13. A rotation angle γ of the carriage 13 in response to displacement from the center 0_3 to the center 0_2 is the same as the rotation angle γ' of the detector head 612. The rotation angle γ' being equal to one of the carriage 13 is read out on the scale 611. Since the scale 611 is pivoted on the arm portion 31 at the pivotal point P, a distance between e, and ℓ_2 is substantially equal to a length c between e'_1 and e_2. While, the present embodiment is designed so that, suppose that a radius is equal to the length between the shaft 12 and the point P and an included angle is equal to a rotation angle γ of the carriage 13, a hypotenuse $\overline{P}$ in response to an arc 613 becomes equal to the length C. Thereby, the value read by the encoder 610 becomes equal to the hypotenuse $\overline{P}$ in the case where the carriage 13 is rotated by angle γ, and the length ℓ_n becomes twice as much as the above value. In this way, while each portion of the periphery in response to every radius vector ρ_0 is measured, the each portion is edged until the female screw 28 of the stopping member 27 is in contact with the rotation wheel 16b. Subsequently, the motor 70 is energized by the same predetermined angle as one on measuring lens frame to make the lens LE rotate by an angle θ'_n, and the lens LE is edged until it has a radius vector ρ'_n. The operation mentioned above is carried out on every eyeglass frame value (ρ_n, θ_n) $(n = 0, 1, 2, ..., N)$, so that whole periphery of the lens LE is edged upon the eyeglass frame values.

[Lens measuring means]

Referring to Figures 9 through 13 there is shown the lens measuring means 30 disclosed in Figure 1. Shafts 302, 303 are fixed on a base 301 normally projected from the arm portion 31 and pivot link arms 304, 305 at their ends, respectively. Arm members 309, 310 are mounted on a link bar 306 at its ends and pivoted by the link arms 304, 305 at their other ends through shaft 307, 308, respectively. The link arms 304, 305 the link bar 306 and the base 301 form a link motion. The arm members 309, 310 have shafts 311, 312 lying parallel to the link bar 306 through deformed elliptical frames 317, 318. Other deformed elliptical frames 313, 314 pivot the shafts 311, 312 at their ends, respectively. A U-shaped arm portion 315a of a shaft member 315 is movably engaged with the shaft 311 at its middle portion and the shaft member 315 is movably engaged with a bearing portion 316a of a moving member 316. The moving member 316 has a pin 319 on its upper surface which is movably engaged with a slit 320a of an arm member 320. The arm member 320 is pivoted by a shaft 321 projected from the base 301 at its end. In the same way, a U-shaped arm portion 322a of a shaft member 322 is movably engaged with the shaft 312 at its middle portion and the shaft member 322 is movably engaged with a bearing portion 323a of a moving member 323. The moving member 323 has a pin 319 on its upper surface which is movably engaged with a slit 325a of an arm member 325. The arm member 325 is pivoted by a shaft 326 projected from the base 301 at its end.

The base 301 mounts an arm motor 330 a rotation shaft of which is provided with an arm plate 331. The arm plate 331 has rotary wheels 332, 333 at its opposite ends, which are pressed to each side of the arm members 320, 325. The arm member 320 mounts a detecting head 335 of an encoder 334 at its middle portion, and a scale 337 of the encoder 334 passes through the detecting head 335. The base 301 pivots a scale 337 at its end. In the same way, a detecting head 339 is mounted on the arm member 325 at its middle portion, and a scale 340 of the encoder 334 passes through the detecting head 339.

Two rail members 341, 342 passing through frames 313, 314 are supported by frames 317, 318 parallel to the link bar 306 so as to support the frames 313, 314. The frame 313 is engaged with a cylindric member 345 at its end into which a cylindric member 343 is rotationary inserted on a common axis thereof. The U-shaped arm portion 315a of the shaft member 315 is movally engaged with a groove 343a formed on an outer periphery of the cylindric member 343. In the same way, the frame 314 is engaged with a cylindric member 345 at its end into which a cylindric member 346 is rotationally inserted on a common axis thereof. The U-shaped arm portion 322a of the shaft member 322 is movably engaged with a groove 346a formed on an outer periphery of the cylindric member 343. A ring 347 having a bevel 347a and a ring 348 having a bevel 348 are movably mounted on the cylindric member 345. The cylindric member 345 has a groove 345a parallel to an axis thereof, and a pin 349 connects the ring 347 with the cylindric member 343 and a pin 350 connects the ring 348 with the cylindric member 346. Pins 351, 352 pulled by spring 353, as shown in Figure 11, penetrates into the cylindric members 343, 346, thereby the cylindric members 343, 346 are forced to be pulled toward each other and the rings 347, 348 linked to the cylindric members 343, 346 are also forced to be pulled toward each other.

[**Operation of lens measuring means**]

Referring to Figures 14 through 18, there is shown operations of the lens measuring means mentioned above. In

Figure 14 the carriage 13 is returned to the first position so that the edged lens LE is brought to the predetermined position. Subsequently, an eccentric cam 360 is rotated by a driving means (not shown in Figure) so that the lens measuring means is turned about the shaft 12 to make the cylindric member 345 contact with the periphery of the edged lens LE. Next, the rotary work holder 18 is stepwise rotated by the predetermined angle in the same manner as edging the lens, and the radius vector ρ' of the edged lens is measured at each stepped angle. The encoder 610 used on edging, as shown in Figure 8, was utilized for measuring the radius vector ρ'. However, in case of edging, the radius vector is read out by the detecting head 612 moving on the scale 611 in response to swing of the carriage 13, while on measuring the radius vector of the edged lens the radius vector, as shown Figure 14, is read out on the scale 611 moved in response to the swing of the arm portion 31 by the detecting head 612 mounted on the fixed carriage 13.

Referring to Figures 15 through 17 there is shown measuring of curvature and peripheral thickness of lens by the lens measuring means 30. The motor 330 is energized not to make the arm plate 331 press the arm members 320, 325, so that the cylindric members 343, 346 are moved toward each other by the spring 353. Thereby, the periphery of the lens LE is got between the rings 347, 348 linked with the cylindric members 343, 346. At this time the cylindric members 343, 346 make the arm member 320, 325 swing, and the rotation angle of the arm members 320, 325 or the displacement of the rings 347, 348 are measured by the encoders 334, 338. By energizing the motor 70 the lens LE is stepwise rotated, and the displacement of the rings 347, 348 are measured at each rotation angle of the lens LE.

Referring to Figure 17, suppose that ${}_fZ_A$ and ${}_fZ_B$ mean readings measured through the ring 347 at position A and B, respectively, ρ'_A and ρ'_B mean radius vectors at the position A and B, respectively, and R_f means curvature radius of a front surface having a curvature center ${}_fZ_0$ on the rotation axis of the lens LE,

$$\left.\begin{aligned} \rho'^2_A + ({}_fZ_0 - {}_fZ_A)^2 = R_f^2 \\ \rho'^2_B + ({}_fZ_0 - {}_fZ_B)^2 = R_f^2 \end{aligned}\right\} \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (8)$$

Suppose, further, that n means a refractive index of lens or usually 1.523, and C_f means a curve value of the front surface of the lens,

$$C_f = \frac{n-1}{R_f} \times 1000 \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots, \quad (9)$$

Then, the curvature radius R_f is calculated from the equation (8) and the curve value C_f is calculated from the equation (9) using the above radius R_f.

On the other hand, suppose that ${}_iZ_A$, ${}_rZ_B$ mean readings measured through the ring 348, and R_r means curvature radius of a rear surface having a curvature center ${}_rZ_0$,

$$\left.\begin{aligned} \rho'^2_A + ({}_rZ_0 - {}_rZ_A)^2 = R_r^2 \\ \rho'^2_B + ({}_rZ_0 - {}_rZ_B)^2 = R_r^2 \end{aligned}\right\} \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (10)$$

Suppose that C_r means a curve value of the rear surface,

$$C_r = \frac{n-1}{R_r} \times 1000 \quad \cdots\cdots \quad (11)$$

The peripheral thicknesses ΔA, ΔB of the lens LE is calculated from the following equation;

$$\begin{aligned} {}_fZ_A - {}_rZ_A &= \Delta A \\ {}_fZ_A - {}_rZ_B &= \Delta B \end{aligned} \quad \cdots\cdots \quad (12)$$

[Control circuit]

Referring now to Figure 18, there is shown a block diagram of control circuit for the aforementioned lens edging apparatus. The control circuit includes an operation and control circuit 1500 comprising a micro-processor for carrying out various operations and program control, a motor control circuit 1200, a counting circuit 1100 for counting output signals of the encoders 61, 334, 338 and 610, a frame configuration memory 1300 for memorizing value signals of the eyeglass frame and the lens pattern produced by the circuit 1500, a bevel edge input and output system 1400 having an input keyboard 1401, a liquid crystal display device 1402 and an interface 1403, and a bevel edge data memory 1600. The motor control circuit 1200 is adapted to control the Y-axis motor 97, the motor 70 for rotating the lens shaft 18, the motor 1208 for rotating the lens measuring means 30, the Z-axis motor 40 for moving the carriage 13 in the Z-axis, the X-axis motor 42 for moving the stopping member 27 in the X-axis and the grinding motor 6.

[Whole operation of the lens edging apparatus]

Referring to Figure 19 there is shown the whole operation of the aforementioned lens edging apparatus.

(1) Eyeglass frame measuring step

Step 1-1: Having received starting instructions, the operation and control circuit 1500 makes the motor control circuit 1200 operate in accordance with the program memorized in a program memory to energize the motor 40, so that the detector 54 fixed on the carriage 13 is moved to the eyeglass frame holding position.

Step 1-2: The motor control circuit 1200 energizes the Y-axis motor 97 so that the eyeglass frame 200 is moved to be in contact with the detector 54 and further to include the rotation center of the detecting arm 51 in the eyeglass 200.

Step 1-3: The motor control circuit 1200 energizes the motor 70 under controlled by clock pulses CP generated by a clock pulse generating circuit 1501 included in the circuit 1500, so that the detecting arm 51 is rotated. The detector 54 is moved along the periphery of the eyeglass frame 200 so as to be moved on the detecting arm 51 by the radius vector ρ, and displacement of the detector 54 is measured by the encoder 61 the outputs of which are counted by the counting circuit 1100. Since the counting circuit 1100 is connected with an output of the clock pulse generating circuit 1501 to receive the clock pulses therefrom, so that the circuit 1100 counts the radius vector ρ under synchronizing with the clock pulses or responding to the rotation angle θ of the detecting arm 51. A set of value signals of the radius vector (ρ_n, θ_n) in a rotation of the detecting arm 51 are given to the frame configuration memory 1300 through the operation and control circuit 1500 and memorized in the memory 1300. The present step is called a pre-measuring step of a configuration of eyeglass frame.

Step 1-4: After the pre-measured values under the rectangular coordinate memorized in the memory 130 are converted into the one under the polar coordinate through the equation (3), the geometric center of the eyeglass frame 200 is calculated from the equation (4). The motor control circuit 1200 energizes the X-axis motor 42, the Y-axis motor 42 and the motor 70 to let the rotation center of the detecting arm 51 locate at the geometric center of the eyeglass frame 200.

Step 1-5: The same operation as that of the step 1-3 is carried out to get the radius vector (ρ_n, θ_n) in the case where the rotation center of the detecting arm 51 is positioned on the geometric center of the eyeglass frame. The readings are memorized in the memory 1300. The present step is called a final measuring of frame configuration.

(2) Roughing step

Step 2-1: The motor control circuit 1200 energizes the grinding motor 6.

Step 2-2: The motor control circuit 1200 energizes the Z-axis motor 40 so that the pre-edged lens supported by the carriage 13 is moved to be positioned on the roughing wheel 3a.

Step 2-3: The motor 70 for rotating the lens shaft 18 is energized in response to the clock pulse CP generated in the pulse generating circuit 1501 in order to make the shaft 18 get in the standard position ($\theta=0$). Then, the X-axis motor 42 is energized to lower the stopping member 27, thereby the carriage 13 is swung so that the pre-edged lens LE supported by the carriage 13 is contact with the roughing wheel 3a to be roughed thereby. While, the operation and control circuit 1500 receives the radius vector ρ_θ ($\theta=0$) as a standard value from the memory 1300.

Step 2-4: While the operation and control circuit 1500 is comparing the radius vector ρ measured by the encoder 610 and the counting circuit 1100 with the standard value ρ_0, the lens LE is roughed by the roughing wheel 3a positioned at the rotation angle $\theta=0$ until the value ρ becomes the standard value ρ_0. When the value becomes the standard valve ρ_0, the X-axis motor 42 is energized to raise the stopping member 27 so that the carriage 13 is raised to stop roughing the lens LE.

Step 2-5: The motor 70 is energized so that the lens LE is rotated to get in the direction θ_2. While, the operation and control circuit 1500 receives the radius vector ρ_1 ($\theta = \theta_1$) as the standard value from the memory 1300. The X-axis motor 42 is energized to lower the stopping member 27, the carriage 13 is swinged so that the lens LE is in contact with the roughing wheel 3a. While the circuit 1500 is comparing the radius vector ρ thus measured with the standard value ρ_1, the lens LE is roughed by the roughing wheel 3a positioned at the rotation angle $\theta = \theta_1$ until the value ρ becomes the value ρ_1. When the value ρ becomes the value ρ_1, the X-axis motor 42 is energized to raise the stopping member 27 so that the carriage 13 is raised to stop roughing the lens LE.

The aforementioned operation is repeated while the value ρ as measured is being compared with the value ρ_n memorized in the memory 1300.

Step 2-6: After the whole periphery of the lens LE is roughed, the X-axis motor 42 is energized to let the carriage 13 return to its original position and the rotation of the grinding motor 6 is stopped.

(3) First lens measuring step

Step 3-1: In accordance with instructions from the operation and control circuit 1500, the motor 1208 is energized by the motor control circuit 1200 to rotate the eccentric cam 360, thereby the cylindric member 345 is placed on the edged lens LE by its gravity.

Step 3-2: The arm motor 330 is energized by the motor control circuit 1200 to make the arm members 320, 325 free, so that the rings 347, 348 are placed on the periphery of the lens LE.

Step 3-3: The motor 70 is energized to rotate the lens LE roughed in the way of the aforementioned steps. The encoder 610 measures the radius vector ρ'_n at each rotation direction of the lens shaft 18, for example, referring to Figure 17, the radius vector ρ'_A is measured at the rotation angle θ_A. The outputs of the encoder 610 are counted by the counting circuit 1100 and the radius vector ρ'_A thus counted is fed to the operation and control circuit 1500.

The encoder 334 measures the position of the front periphery of the edged lens LE or the value ${}_fZ_a$ at the rotation angle θ_A as shown in Figure 17. The outputs of the encoder 334 are counted by the counting circuit 1100 and the counted value ${}_fZ_a$ is fed to the circuit 1500. In the same way, the encoder 334 measures the position of the rear periphery of the edged lens LE or the value ${}_rZ_a$ at the rotation angle θ_A. The outputs of the encoder 334 are counted by the counting circuit 1100 and the counted value ${}_rZ_a$ is fed to the circuit 1500.

As a result, the circuit 1500 receives the values ${}_fZ_n$, ${}_rA_n$ of the positions of the front and rear peripheries of the edged lens LE, and the radius vector ρ'_n at each rotation angle θ_n, the curve values C_f, C_r, of the front and rear surfaces and the peripheral thickness Δ_n are calculated from the equation 8 through 12 (n = 0, 1, 2, ..., n).

Step 3-4: The motor 1208 is energized by the motor control circuit 1200 to make the lens measuring means 30 return to the original position.

(4) Input step of curve value and bevel edge position

Step 4-1: Wheather an output display of a V-shaped bevel edge configuration is determined by an automatic calculation or by a result calculated according to an operator's optional input is selected by the keyboard 1401.

Step 4-2: In reviewing the curve values C_f, C_r and the peripheral thickness Δn calculated in the step 3-3, the best curve values and the best peripheral thickness are selected. Based on the best ones mentioned above, the cross sections of the bevel edges of the thickest and thinest peripheral portions are displayed by the display device 1402. A curve value of the bevel edge, a shift length of the bevel edge or a distance between the front periphery and a top of the bevel edge, and the like as desired as also displayed thereby.

Step 4-3: The selected curve values and shift length of the bevel edge are fed through the keyboard 1401.

Step 4-4: The input fed through the keyboard 1401 is transferred to the circuit 1500 through the interface 1403. Based on the curve value C_f, C_r, the peripheral thickness Δn, and the curve value and shift of the bevel edge, the circuit 1500 calculates the cross sections of the thickest and thinest peripheral portions which are displayed by the display device 1402 in the ways of picture images and numerals.

(5) Beveling step

Step 5-1: In the case where an operator admits that the bevel edge displayed by the device 1402 is proper a beveling starting button on the keyboard 1401 is depressed, and in accordance with the instructions given thereby, the grinding motor 6 is energized by the motor control circuit 1200, and at the same time, the bevel edge data memory 1600 memorizes the finally selected value of bevel edge, for example, the curve value and the shift as related with the radius vector (ρ'_n, θ_n).

Step 5-2: The Z-axis motor 40 is energized by the circuit 1200 to let the edged lens LE supported by the carriage 13 place on the beveling wheel 3b.

Step 5-3: The X-axis motor 42 is enegized by the circuit 1200 to lower the stopping member 27, so that the lens LE supported by the carriage 13 is downward swinged to be placed on the beveling wheel 3b and then the beveling starts.

The circuit 1500 controls the circuit 1200 in such a way that, while the counting circuit 1100 is counting the output of the encoder 610, the Z-axis motor 40 and the X-axis motor 42 are energized until the beveling wheel 3b performs the curve value and the shift of the bevel edge at the radius vector (ρ'_n, θ_n) memorized by the memory 1600. The operation is repeated at every radius vector angle θ_n.

Step 5-4: After finishing the beveling at every radius vector angle θ_n, the X-axis motor 42 is energized to return the carriage 13 to the first position and the rotation of the grinding motor 6 is stopped.

(6) Second lens measuring step

Step 6-1: The aforementioned steps 3-1 through 3-4 are carried out to measure the radius vector (ρ''_n, θ_n) of the beveled lens.

Step 6-2: By the circuit 1500 the radius vector (ρ''_n, θ_n) detected in the step 6-1 is compared with the radius vector (ρ_n, θ_n) memorized by the memory 1300. In case both the radius vectors are the same as each other, the display device 1402 display "finish edging". In another case, the steps 5-2 and below are carried out to bevel the lens again.

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 structures but changes and modifications may be made without departing from the scope of the appended claims.

CLAIMS:

1. A method for grinding an edge portion of a spectacle lens comprising steps of digitally measuring a shape of a spectacle frame to which the lens is to be fitted to obtain first digital values of measurement, and grinding the edge portion of the lens based on the digital values to obtain a peripheral configuration of the lens which conforms to the shape of the spectacle frame.

2. A method in accordance with claim 1 which further included steps of digitally measuring the peripheral configuration fo the lens which has been ground to obtain second digital values of measurement and comparing the first and second digital values to judge accuracy of the grinding.

3. A method in accordance with claim 1 in which said first values of measurement are obtained by measuring directly the spectacle frame.

4. A method in accordance with claim 1 in which said first values of measurement are obtained by measuring a template of the spectacle frame.

5. An apparatus for grinding an edge portion of the spectacle lens comprising first measuring means for digitally measuring a shape of a spectacle frame to which the lens is to be fitted and providing first digital values of measurement, and grinding means for grinding the lens by means of a digitally control in accordance with the first digital values of measurement.

6. An apparatus in accordance with claim 5 which further includes second measuring means for digitally measuring a peripheral configuration of the lens to provide second digital values of measurement, comparator means for comparing the first and second values of measurement.

7. Apparatus for grinding an edge portion of a spectacle lens comprising a grinding wheel rotatable about a first axis, driving means for rotating the grinding wheel about said first axis, a carriage including lens holding means for holding the lens and rotating it about a second axis, shifting means for controlling a spacing between said first and second axes in accordance with an angle of rotation of said lens, first measuring means including a rotating arm rotatable about a enter of rotation and a feeler provided on said arm and adapted to be moved along a shape of a spectacle frame to which the lens is to be fitted so as to measure digitally the shape of the spectacle frame in terms of a distance from said center of rotation of the rotating arm and an angle of rotation of said rotation arm, momorizing means for memorizing values obtained by measurements of said first measuring means, control means for controlling the angle of rotation of said lens and the spacing between said first and second axes in accordance with the values memorized in said memorizing means, second measuring means including a second feeler adapted to be contacted with a periphery of said lens for measuring digitally the peripheral configuration of said lens in terms of a radial displacement of the second feeler in relation to the rotation

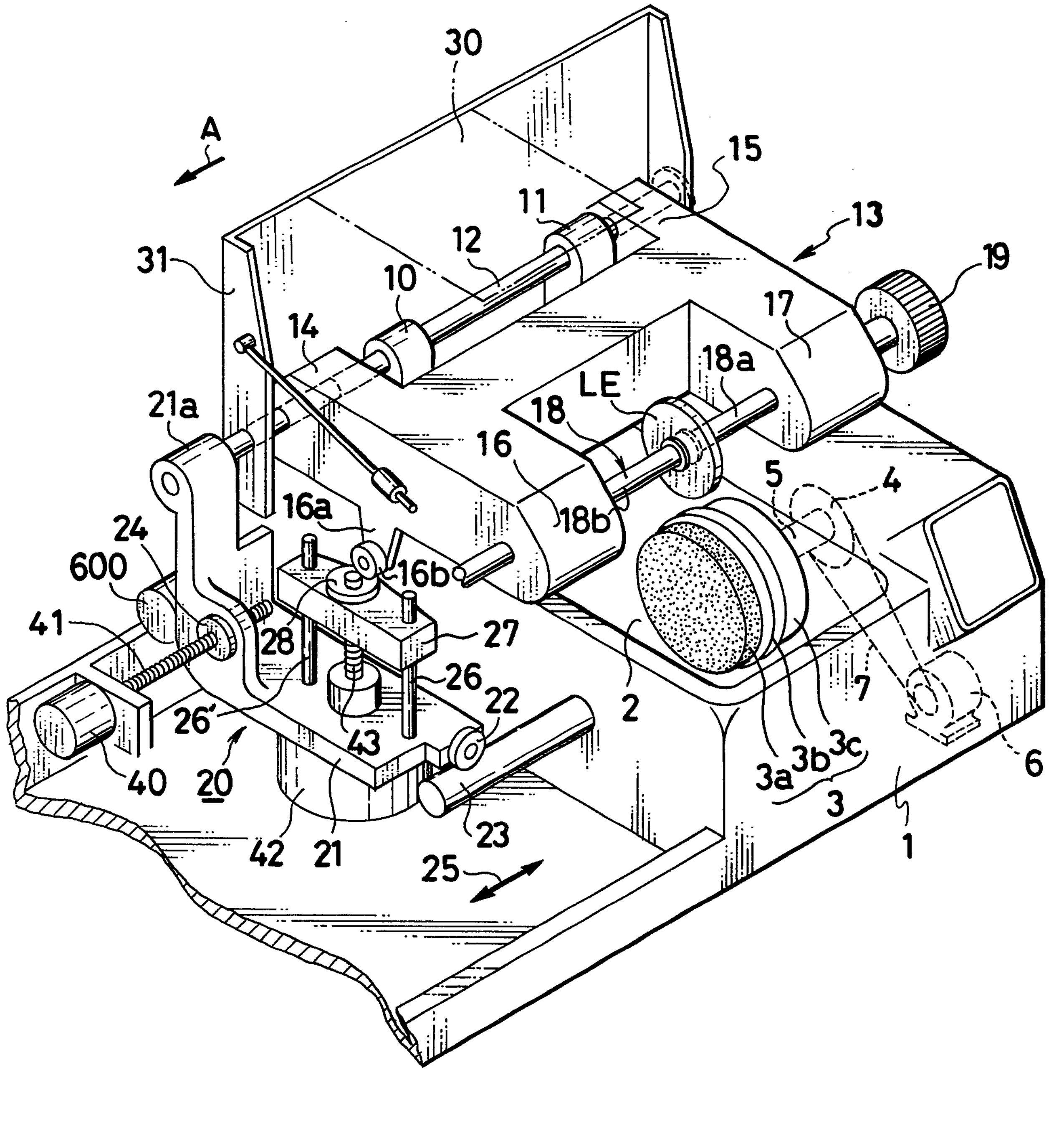
of the lens, comparator means for comparing the values memorized in said memorizing means with values obtained by measurement of said second measuring means.

8. An apparatus for grinding an edge portion of a spectacle lens comprising a set of coaxial grinding wheels including at least a rough grinding wheel and an edge shaping wheel which are rotatable about a first axis, a carriage having means for holding the lens rotatably about a second axis, acrriage moving means for moving the carriage with respect to the grinding wheels so that one of said grinding wheels is placed in engagement with said lens, means for controlling the spacing between the first and second axes in relation to an angle of rotation of the lens, locating means for locating a spectacle frame or a template having a peripheral shape identical to the shape of the frame, first measuring means including a rotatable arm rotatable about a center of rotation and a first feeler adapted to be engaged with the frame or the template to measure digitally the shape in terms of a distance from the rotatable arm and produce first digital values of measurement, memorizing means for memorizing the first digital values of measurement, first control means for controlling the rotation of the lens and the spacing between the first and second axes in accordance with the first digital values of measurement memorized in said memorizing means so that the lens is ground by said rough grinding wheel, lens measuring means including a second feeler adapted to contact with the outer periphery of the lens, a

third feeler adapted to contact with the front end of the periphery of the lens, a fourth feeler adapted to contact with the rear end of the periphery of the lens, second measuring means for digitally measuring the movement of the second feeler, third measuring means for digitally measuring the movement of the third feeler and fourth measuring means for digitally measuring the movement of the fourth feeler, calculating means for obtaining values of the radius and the angle of rotation of the lens from the movement of the second feeler and calculating the thickness and/or curvature of the lens from said radius and the angle of rotation of the lens and the movements of the third and fourth feelers to thereby calculate the required amount of grinding work at each angular position of the lens, second control means for controlling the grinding work of the lens in accordance with the results of the calculation by the calculating means, comparing means for obtaining second digital values of measurement relating to the radius and the angle of rotation of the worked lens from the movement of the second feeler and comparing the second digital values with the first digital values of measurement memorized in the memorizing means.

9. An apparatus in accordance with claim 8 which further includes display means for displaying the peripheral shape of the lens at each angular position in accordance with the calculation of the calculating means.

FIG.1



30
A
15
11
13
12
31
19
10
17
14
18a
LE
21a
18
16
4
5
16a
18b
24
16b
600
28
27
41
26
2
7
26'
22
43
3a
3b
3c
6
40
20
3
42
21
23
1
25

FIG.2A

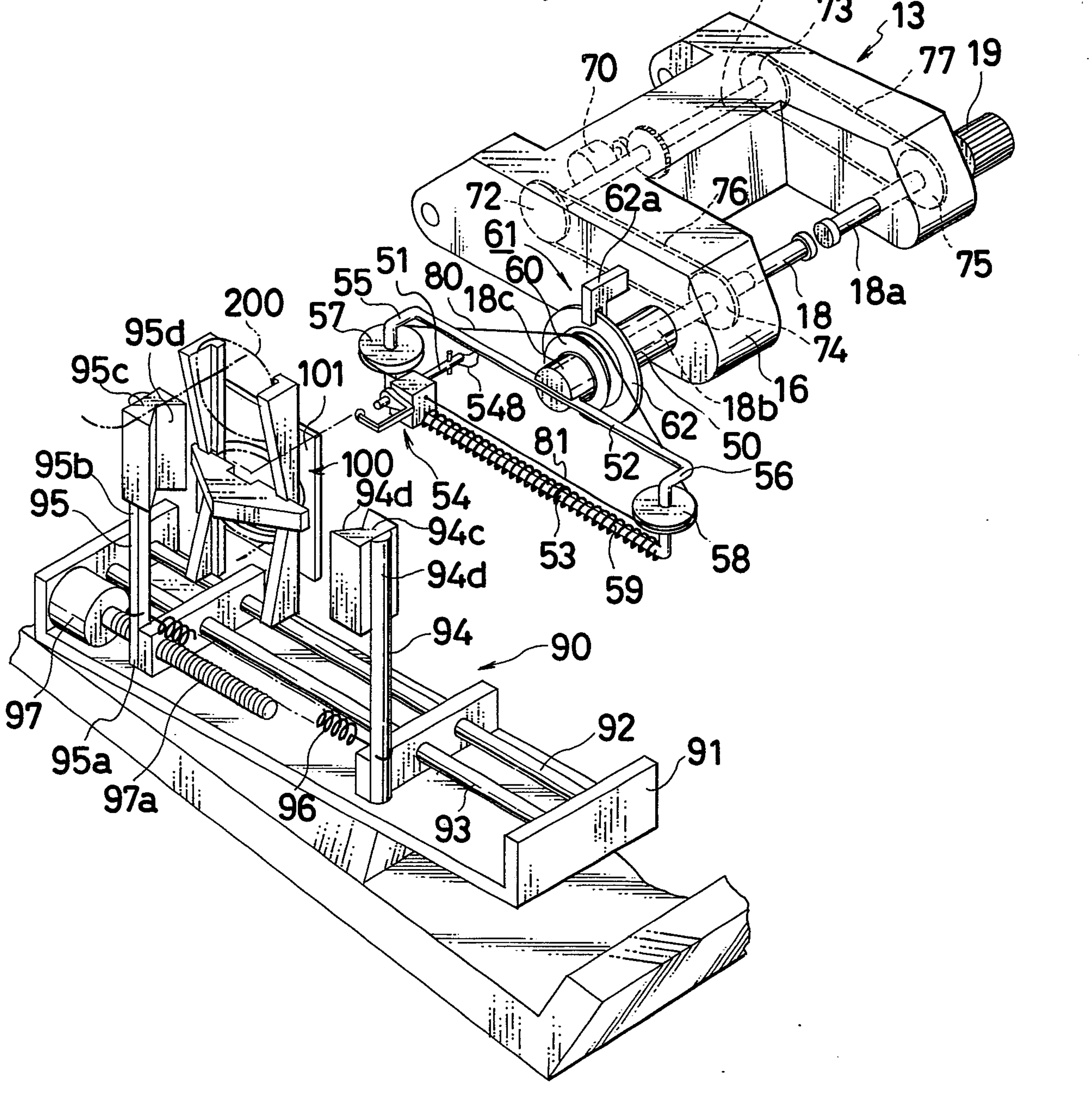

71
73
13
70
77
19
72
62a
76
61
75
51
60
80
55
18c
57
18a
18
74
200
95d
95c
101
548
16
18b
62
50
52
56
81
100
95b
54
94d
95
94c
53
58
59
94d
94
90
97
95a
97a
96
93
92
91

FIG.2B

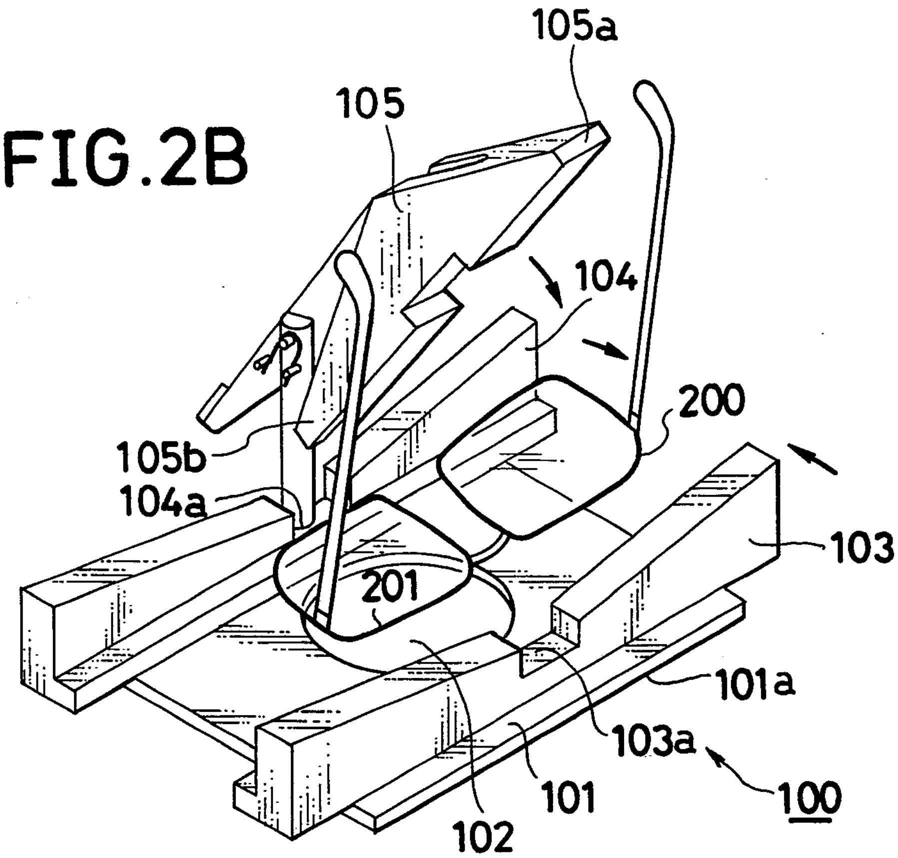
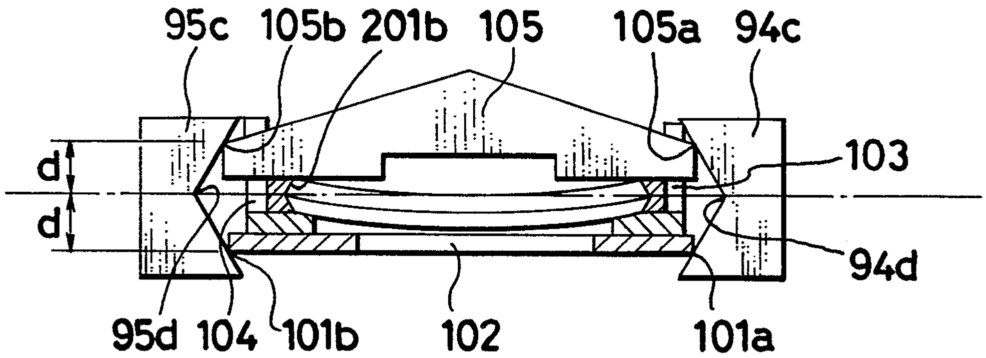

105a
105
104
200
105b
104a
103
201
101a
103a
100
101
102

FIG.2C


95c
105b
201b
105
105a
94c
d
d
103
94d
95d
104
101b
102
101a

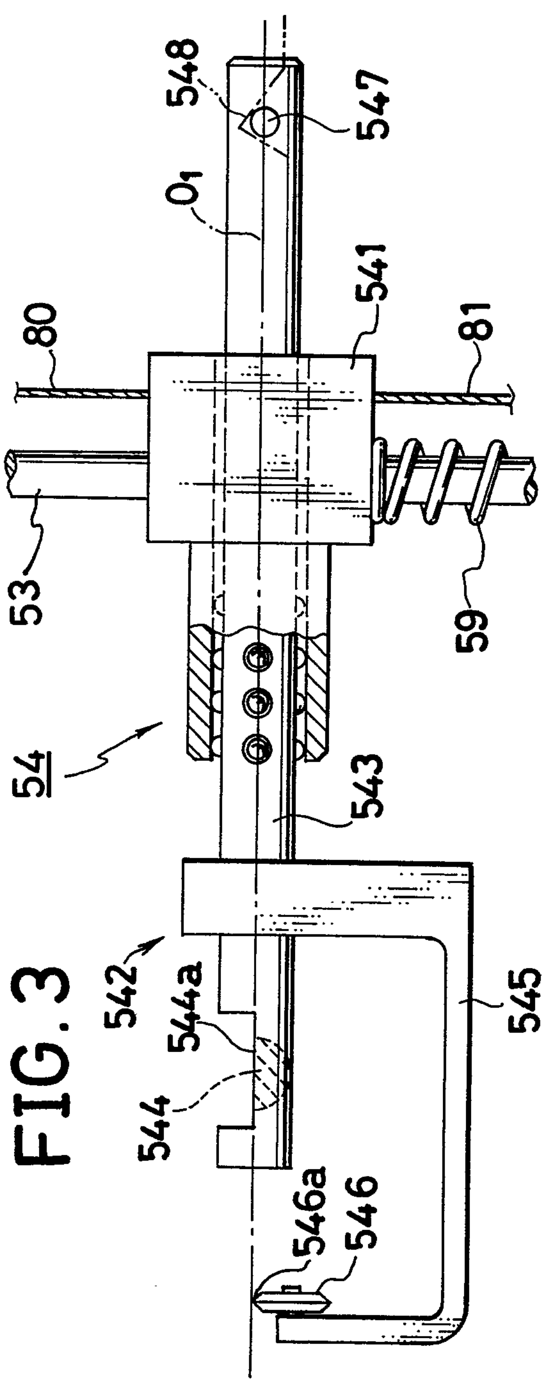

80
53
541
81
59
54
543
548
547
0_1
542
544a
544
545
546a
546

FIG.3

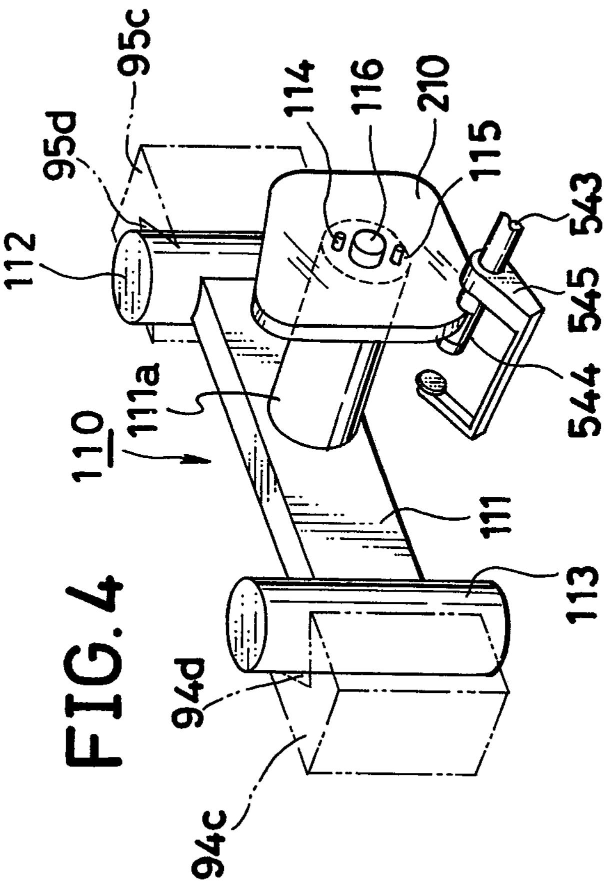
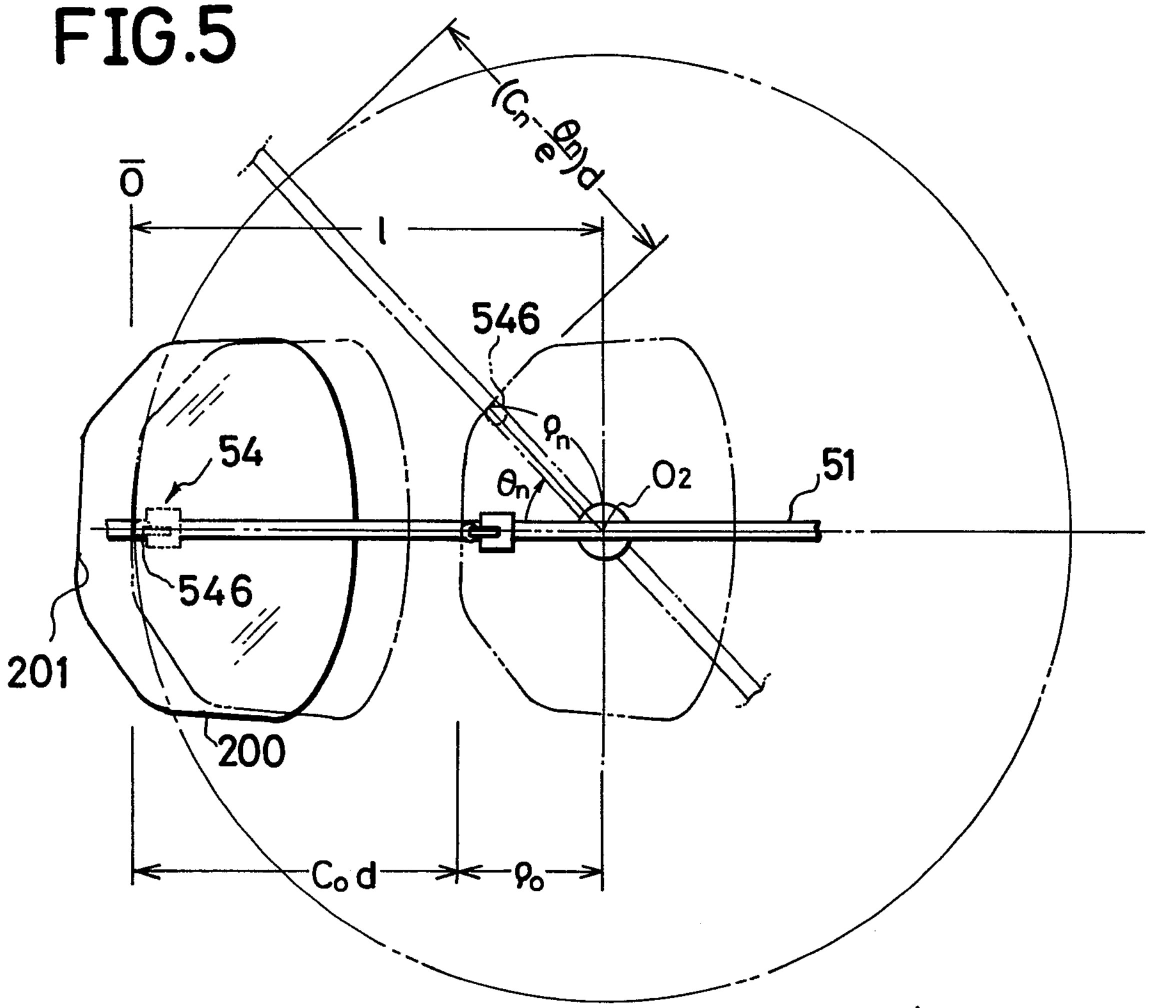

95c
95d
114
116
210
115
543
112
545
544
111a
110
111
113
94d
94c

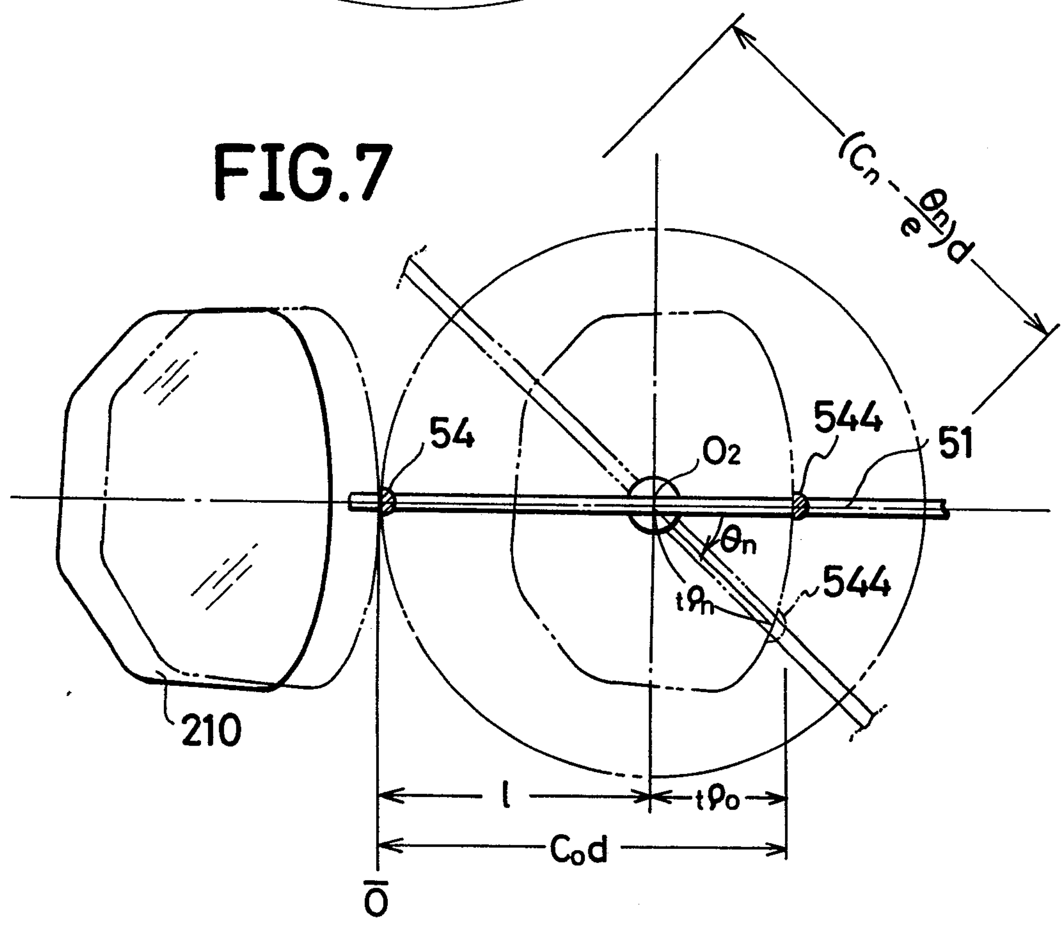
FIG.4

FIG.5



$(C_n - \frac{\theta_n}{e})d$
Ō
l
546
ρ_n
54
θ_n
O_2
51
546
201
200
$C_o d$
ρ_o

FIG.7



$(C_n - \frac{\theta_n}{e})d$
54
O_2
544
51
θ_n
$t\rho_n$
544
210
l
$t\rho_o$
$C_o d$
Ō

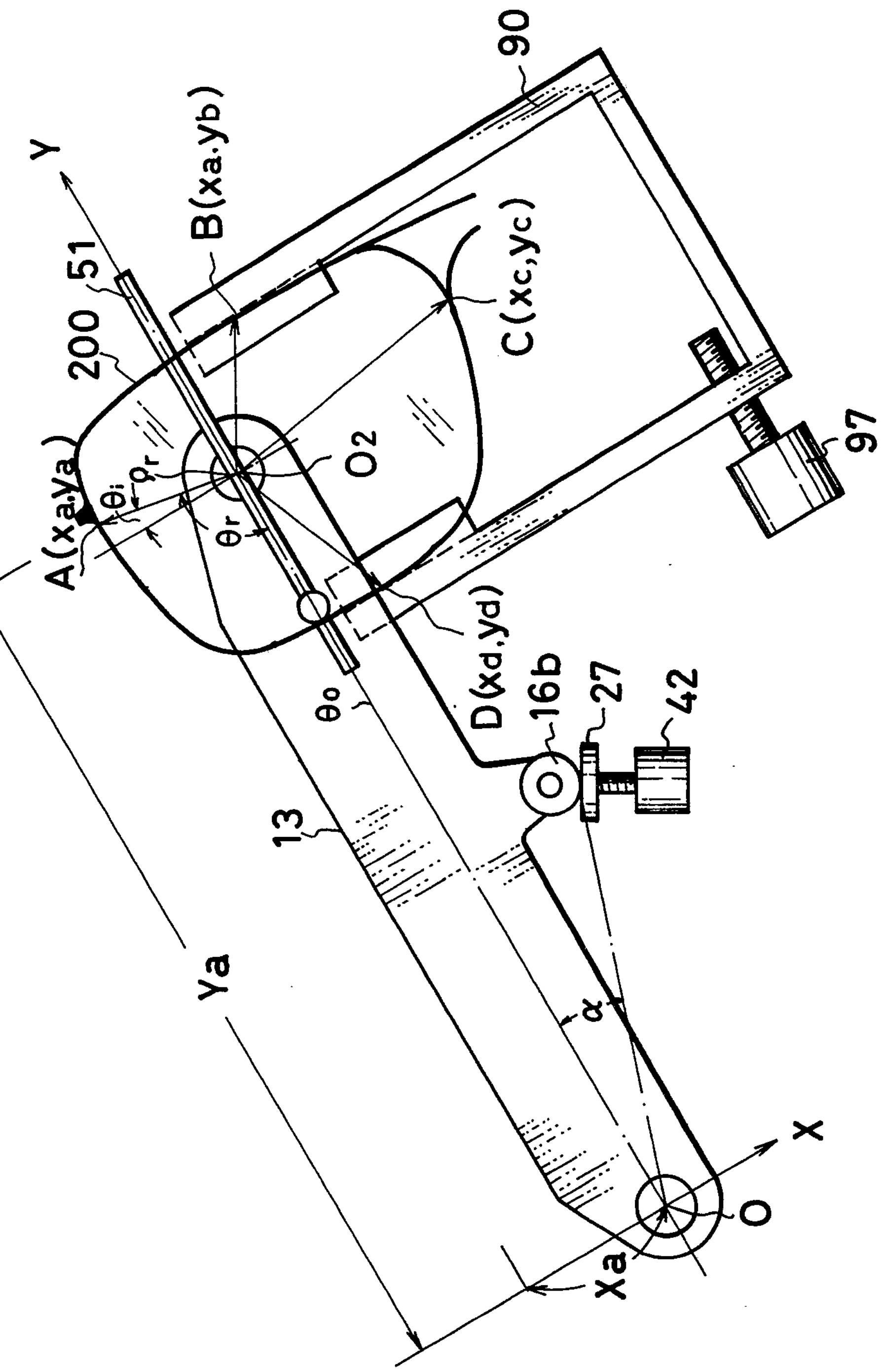

Y
B(xa,yb)
51
200
A(xa,ya)
θi
ρr
θr
O2
C(xc,yc)
90
97
D(xd,yd)
16b
27
42
θo
13
Ya
α
X
O
Xa

FIG.6A

FIG.6B

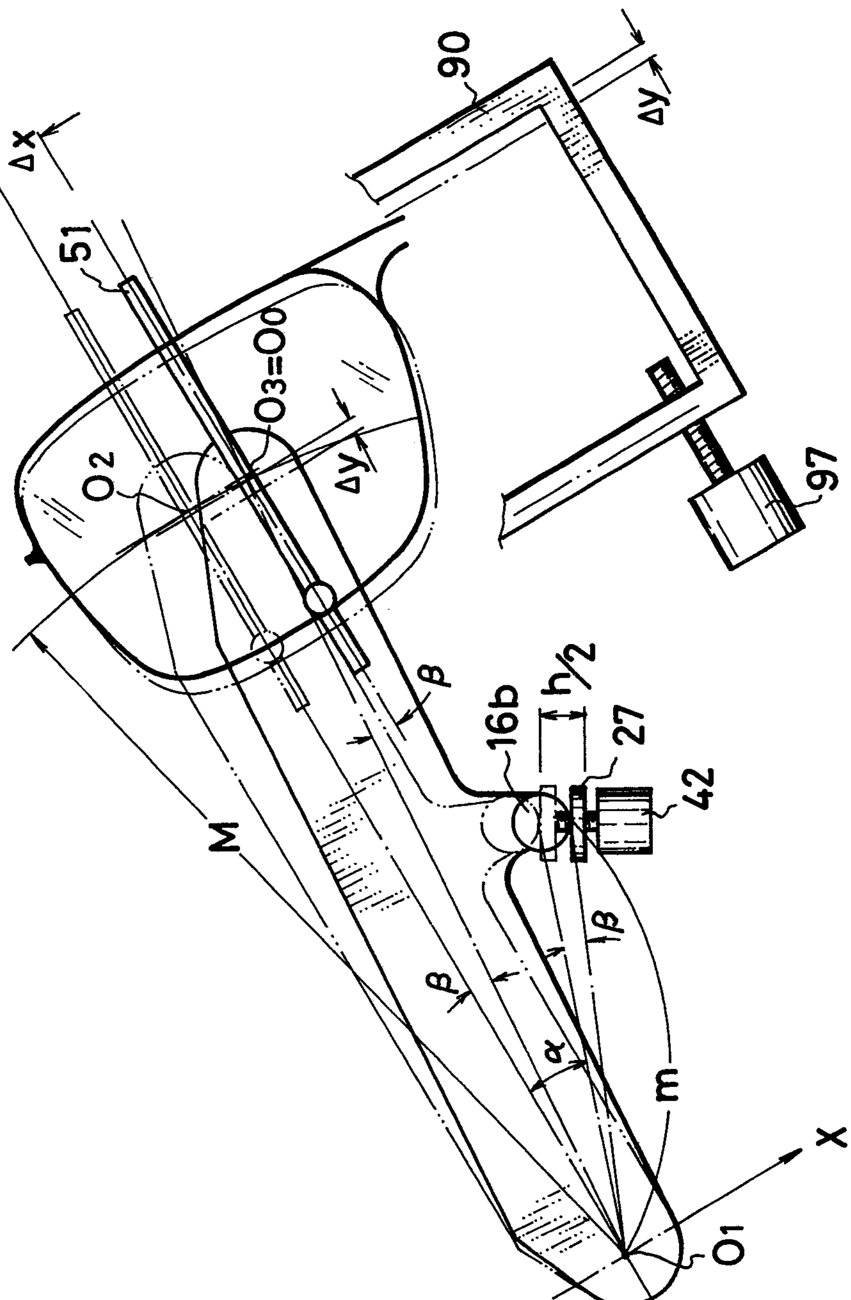
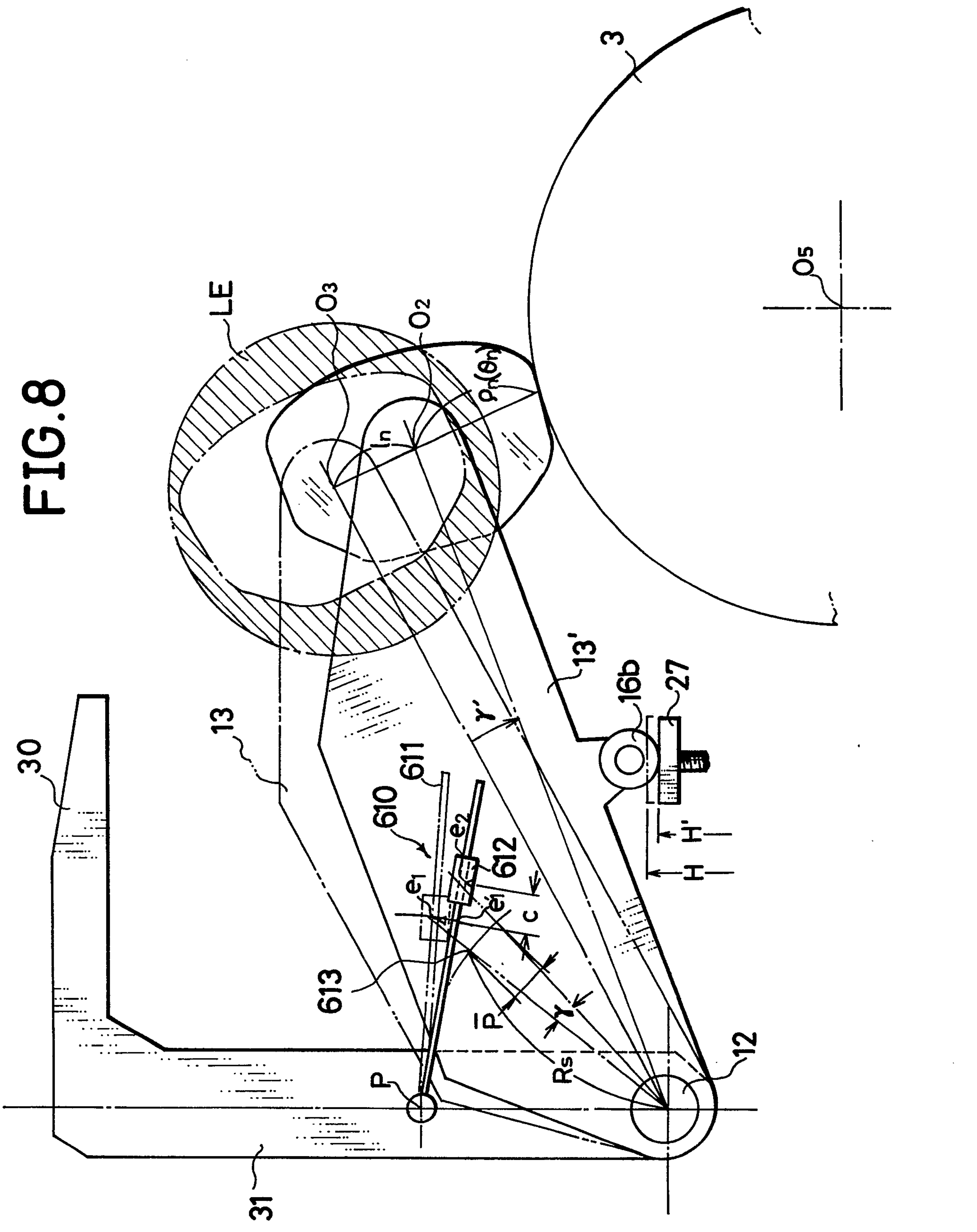


FIG.8


3
O5
LE
O3
O2
ρn(θn)
ln
13
13'
30
610
611
612
613
e1
e2
e1'
c
γ'
γ
P̄
Rs
12
P
31
16b
27
H'
H

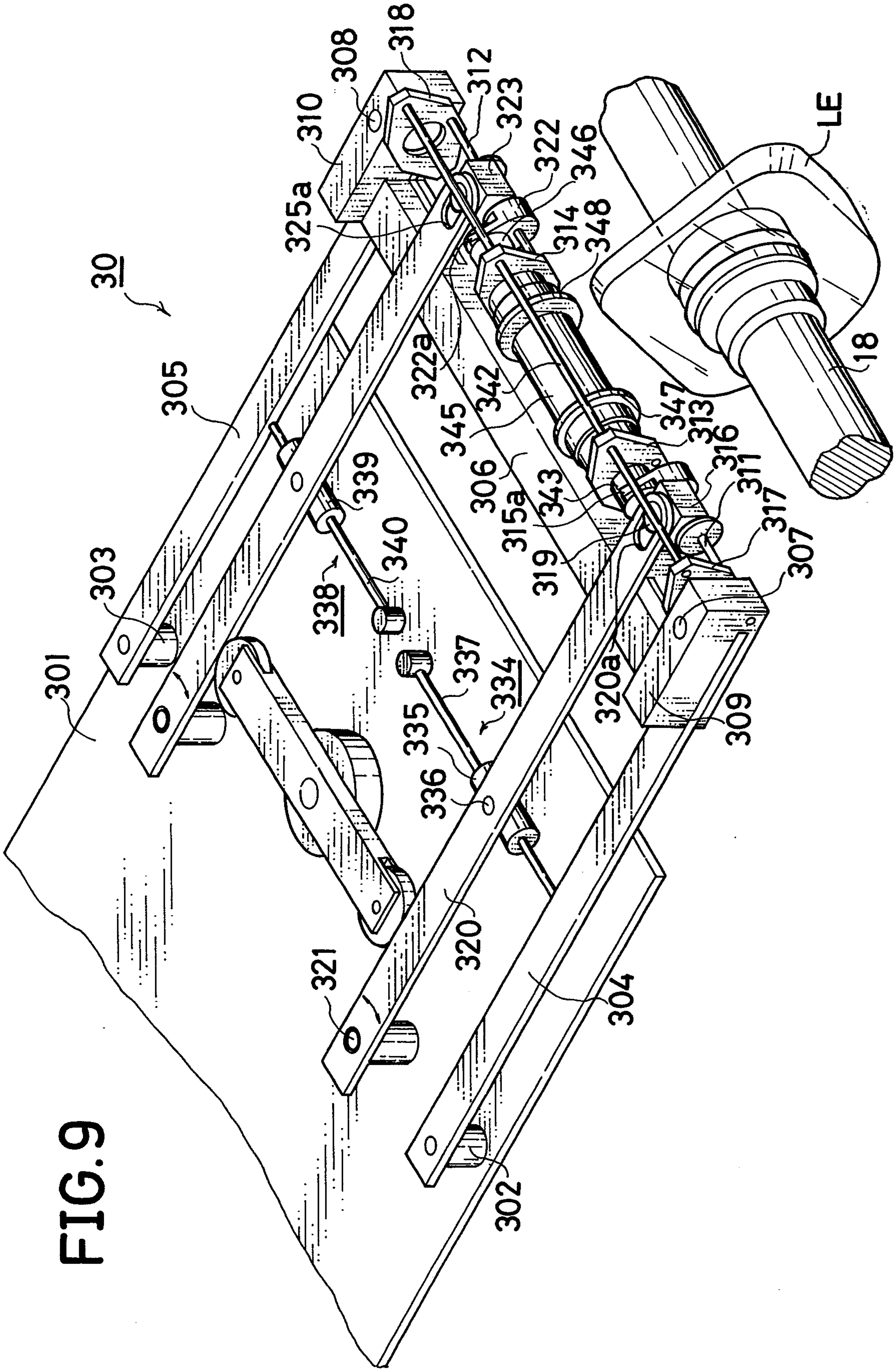
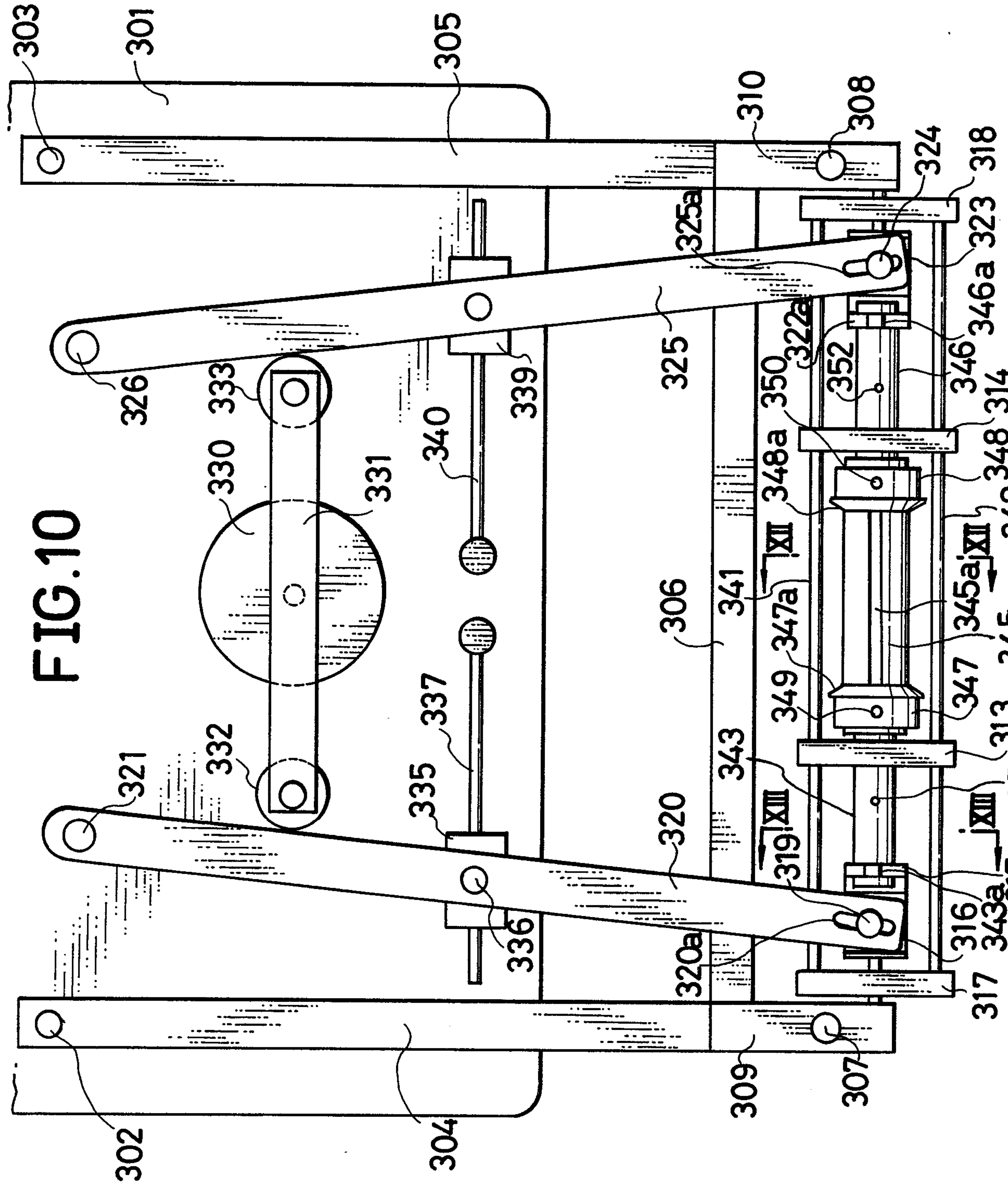

30
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315a
316
317
318
319
320
320a
321
322
322a
323
325a
334
335
336
337
338
339
340
342
343
345
346
347
348
18
LE

FIG.9


301
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313
314
315a
316
317
318
319
320
320a
321
322a
323
324
325
325a
326
330
331
332
333
335
336
337
339
340
341
342
343
343a
345
345a
346
346a
347
347a
348
348a
349
350
351
352
XII
XIII

FIG.10

FIG.11

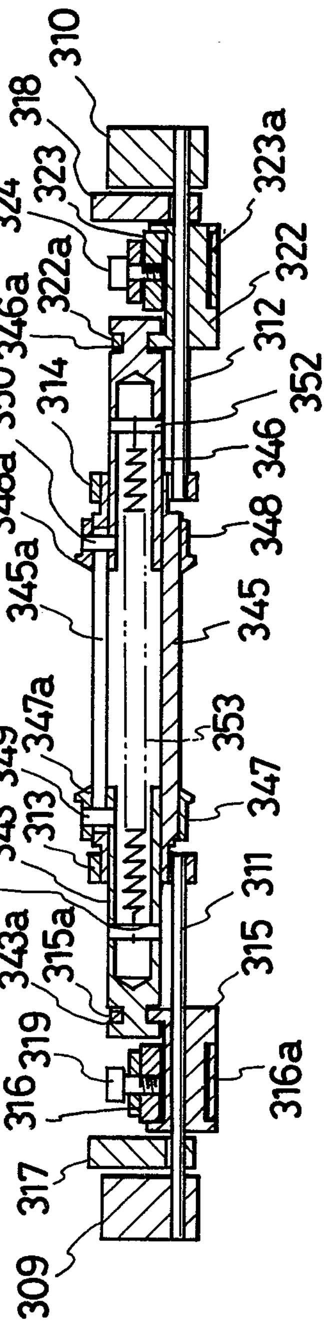


FIG.12

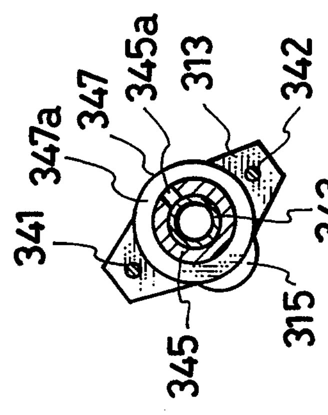
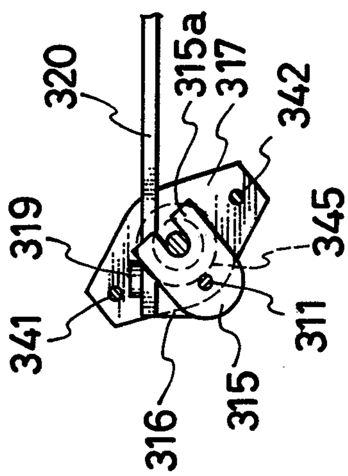


FIG.13



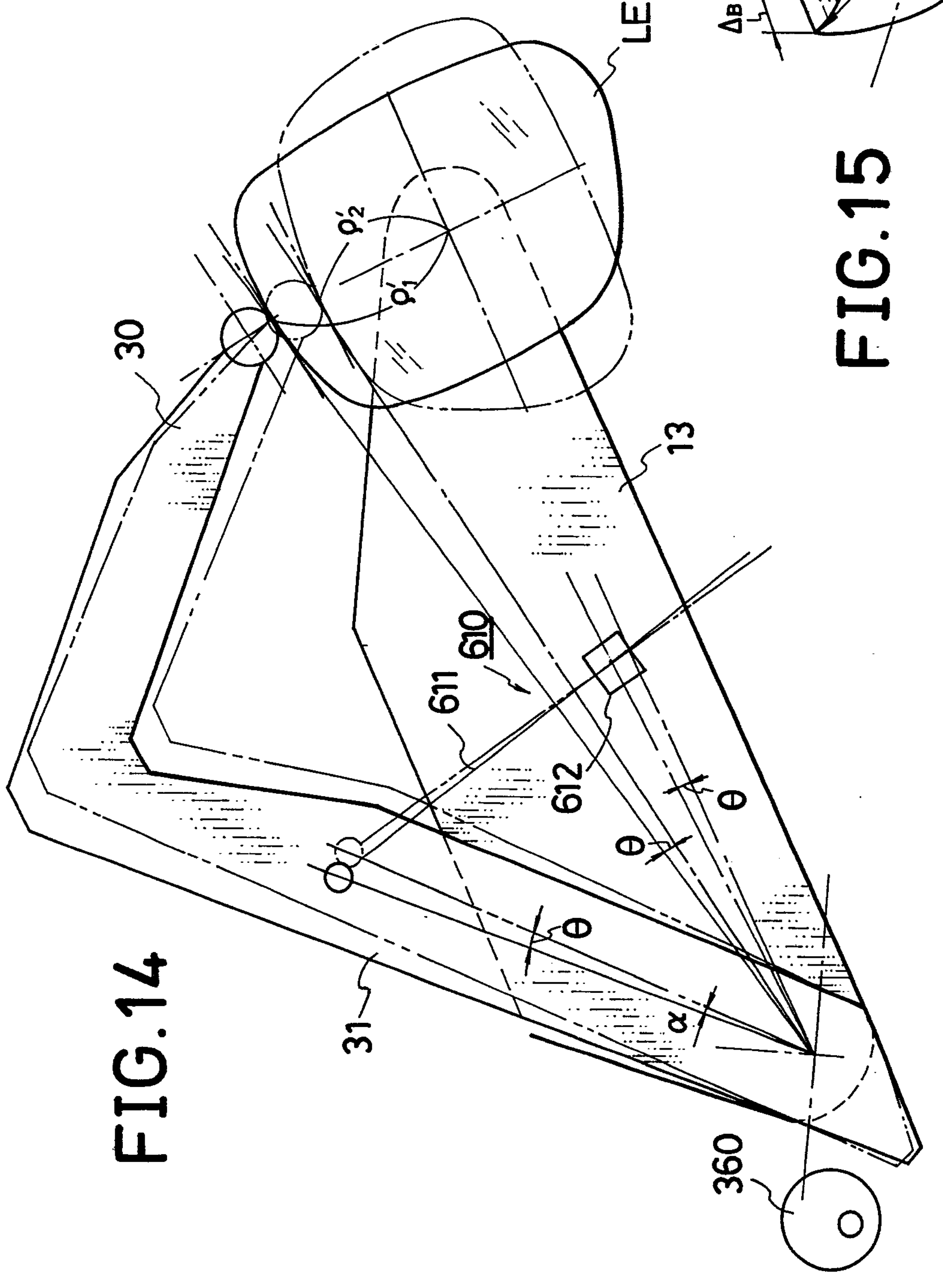


FIG.14

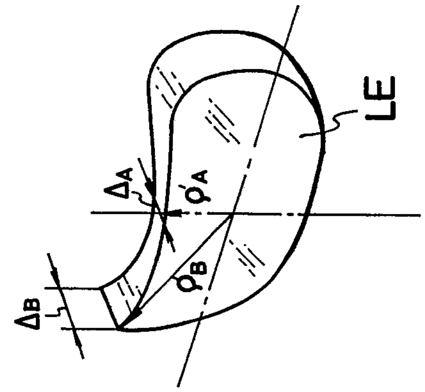


FIG.15

FIG. 16

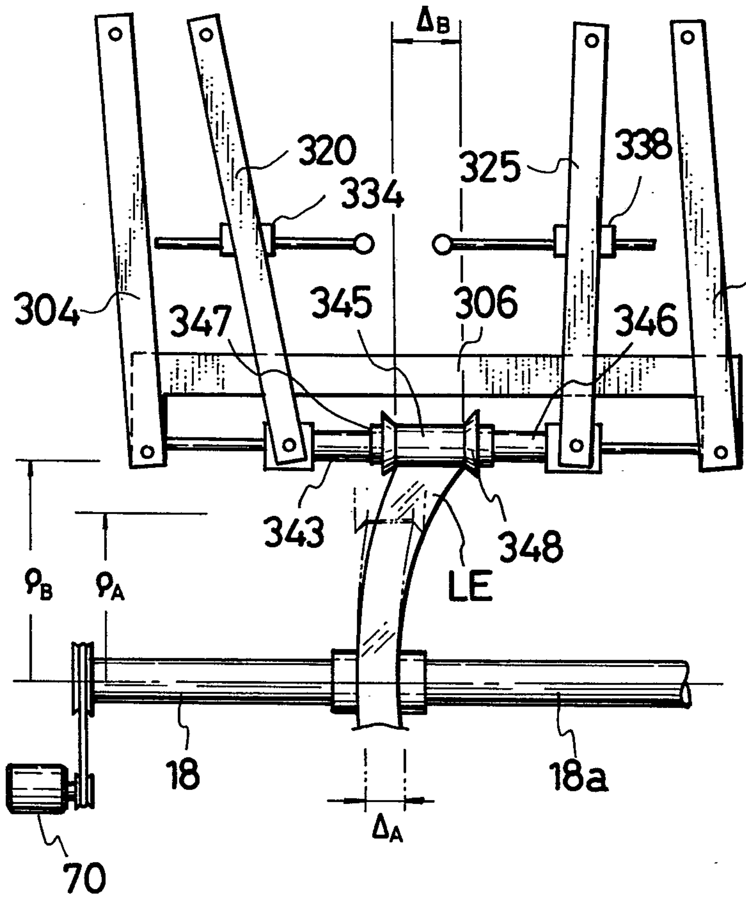

Δ_B
320
334
325
338
305
304
347
345
306
346
343
348
LE
ρ_B
ρ_A
18
18a
Δ_A
70

FIG.17

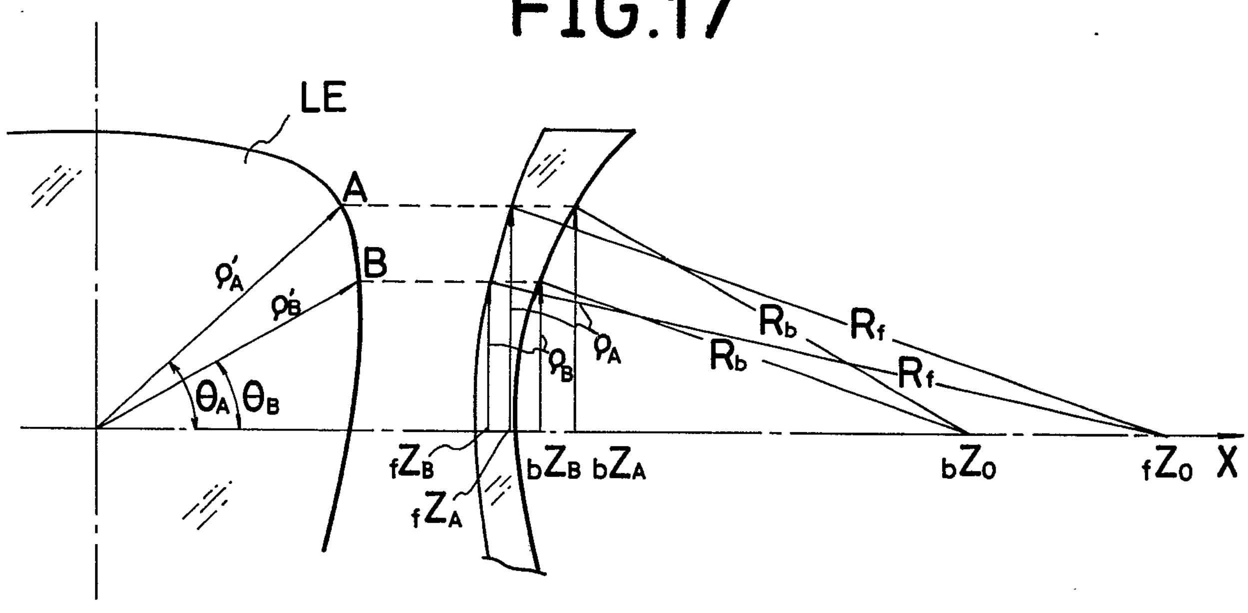

LE
A
B
ρ'_A
ρ'_B
θ_A
θ_B
ρ_A
ρ_B
R_b
R_f
R_b
R_f
${}_fZ_B$
${}_bZ_B$
${}_bZ_A$
${}_fZ_A$
${}_bZ_0$
${}_fZ_0$
X

FIG.18

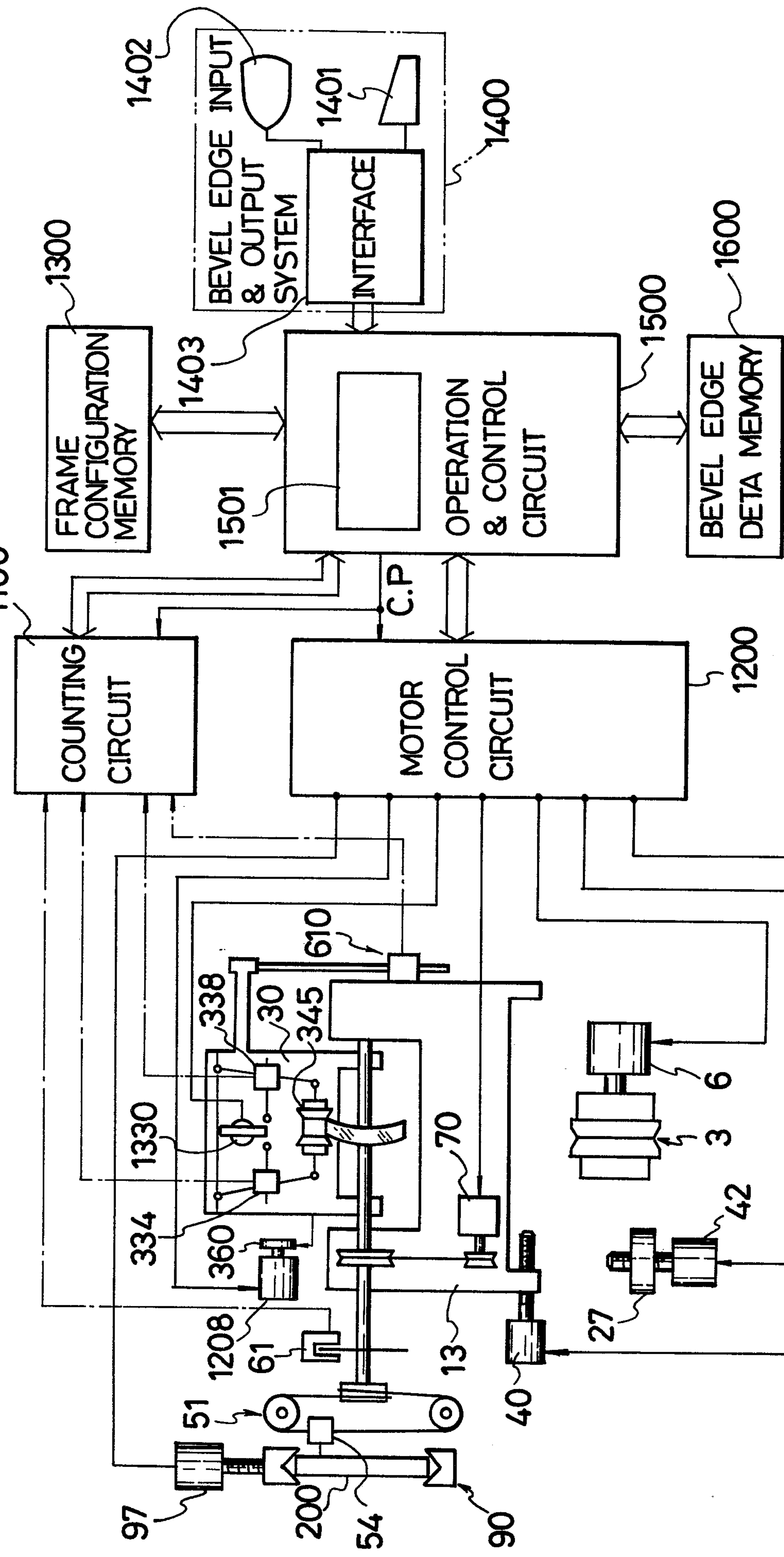

BEVEL EDGE INPUT & OUTPUT SYSTEM
INTERFACE
1402
1401
1400
1403
FRAME CONFIGURATION MEMORY
1300
OPERATION & CONTROL CIRCUIT
1501
1500
BEVEL EDGE DETA MEMORY
1600
COUNTING CIRCUIT
1100
C.P
MOTOR CONTROL CIRCUIT
1200
610
338
30
345
1330
334
360
70
6
3
42
27
1208
61
13
40
51
97
200
54
90

FIG.19

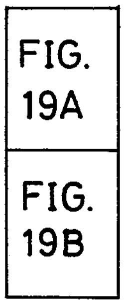
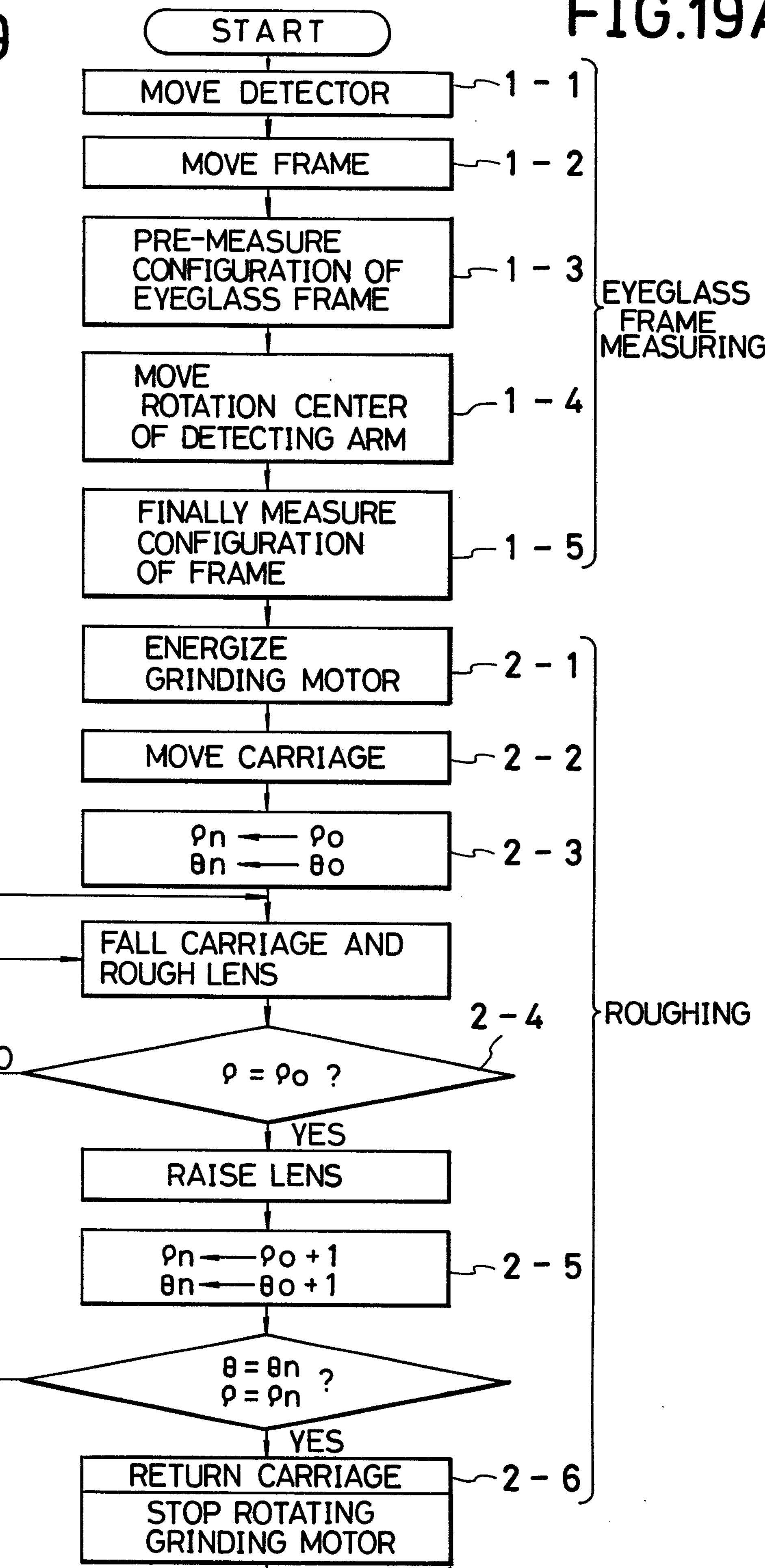


FIG.19A



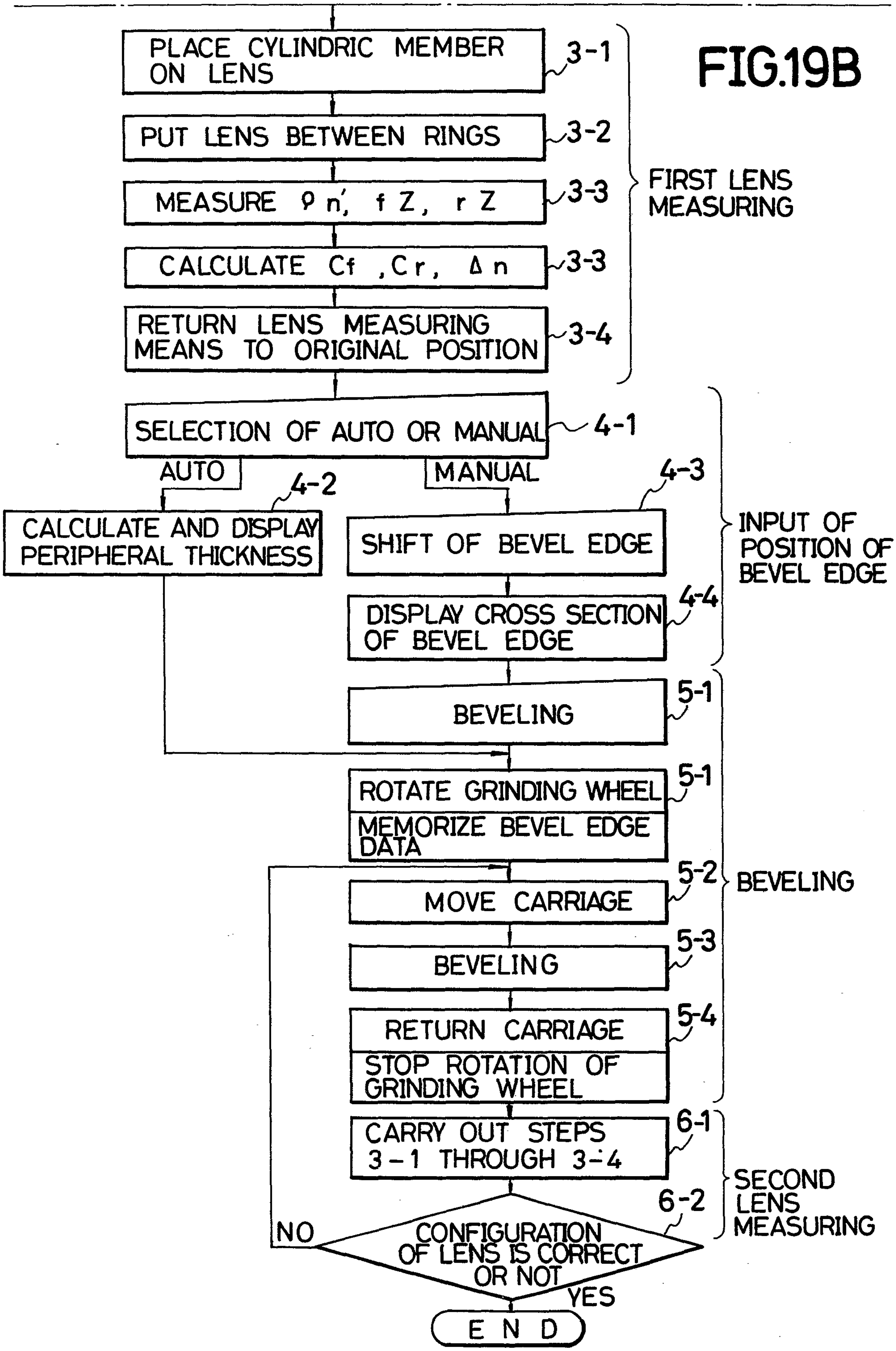

PLACE CYLINDRIC MEMBER ON LENS
3-1
PUT LENS BETWEEN RINGS
3-2
MEASURE ρ n', f Z, r Z
3-3
CALCULATE Cf, Cr, Δ n
3-3
RETURN LENS MEASURING MEANS TO ORIGINAL POSITION
3-4
FIRST LENS MEASURING
SELECTION OF AUTO OR MANUAL
4-1
AUTO
MANUAL
4-2
CALCULATE AND DISPLAY PERIPHERAL THICKNESS
4-3
SHIFT OF BEVEL EDGE
4-4
DISPLAY CROSS SECTION OF BEVEL EDGE
INPUT OF POSITION OF BEVEL EDGE
5-1
BEVELING
5-1
ROTATE GRINDING WHEEL
MEMORIZE BEVEL EDGE DATA
5-2
MOVE CARRIAGE
BEVELING
5-3
BEVELING
5-4
RETURN CARRIAGE
STOP ROTATION OF GRINDING WHEEL
6-1
CARRY OUT STEPS 3-1 THROUGH 3-4
SECOND LENS MEASURING
6-2
NO
CONFIGURATION OF LENS IS CORRECT OR NOT
YES
END

FIG.19B