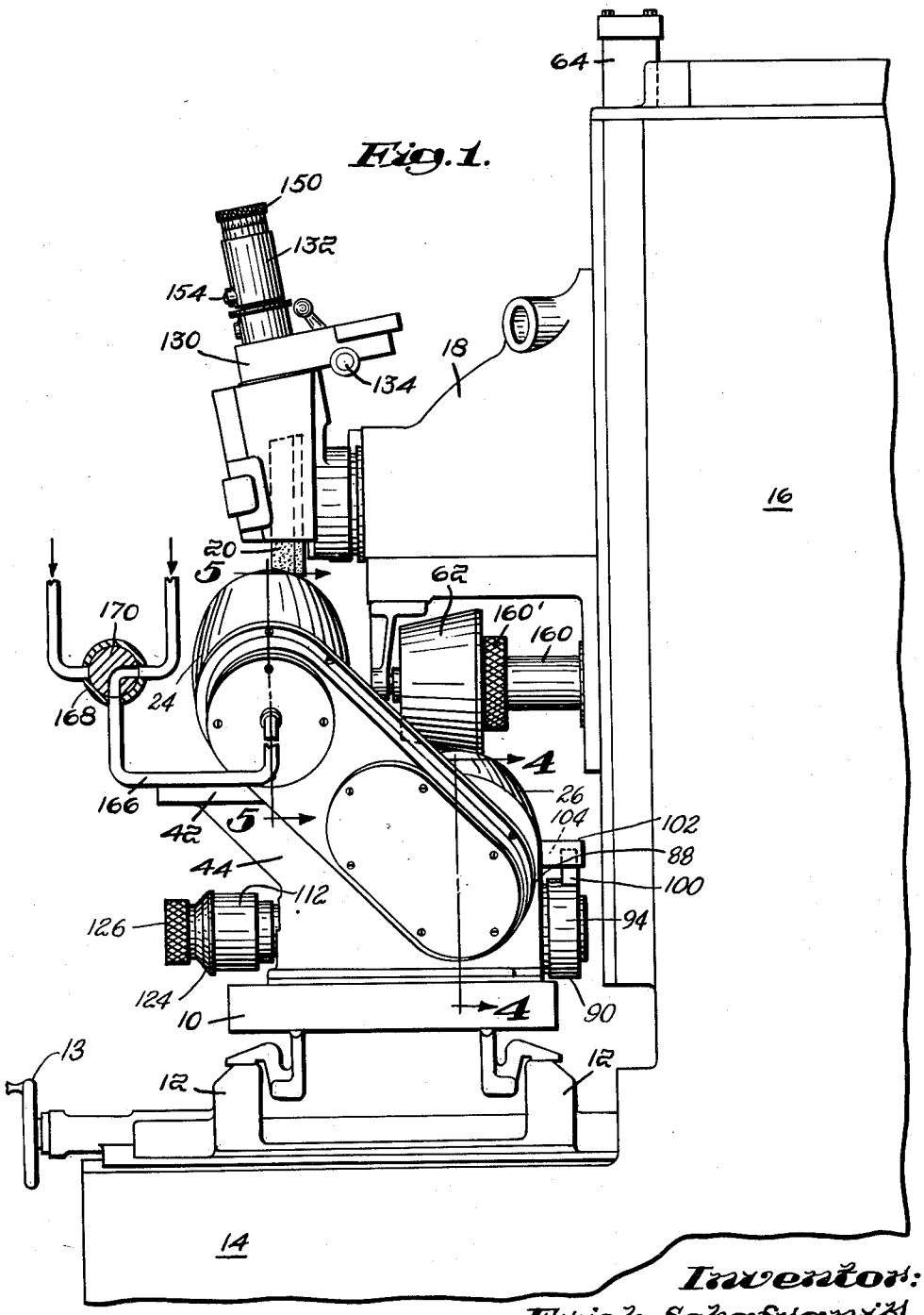
June 26, 1962 E. SCHAFRANIK 3,040,482

FOLLOWER-CONTROLLED CONTOUR-REPRODUCING GRINDING MACHINES

Filed Jan. 14, 1958 8 Sheets-Sheet 1

Fig. 1.



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FOLLOWER-CONTROLLED CONTOUR-REPRODUCING GRINDING MACHINES

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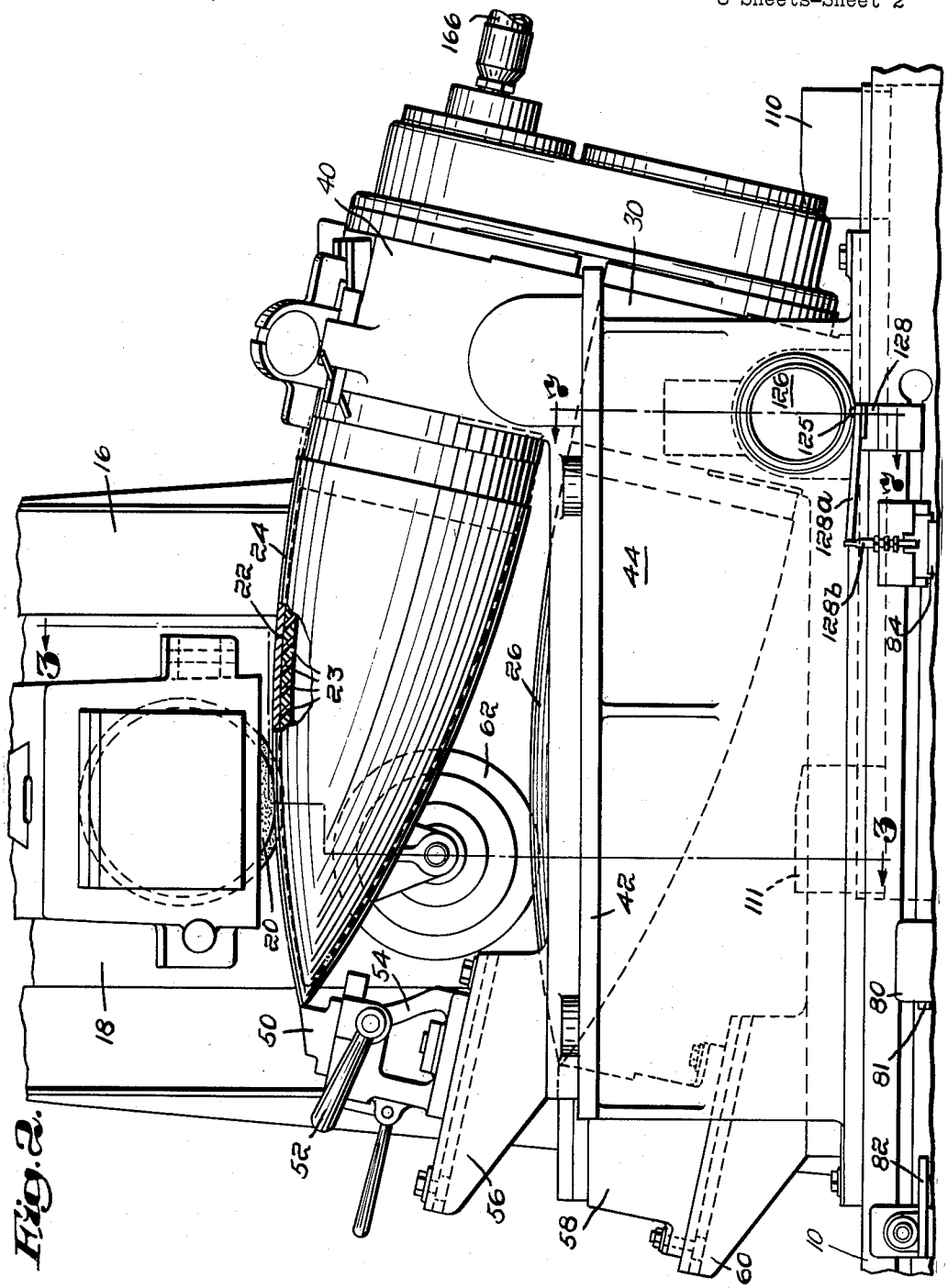


Fig. 2.

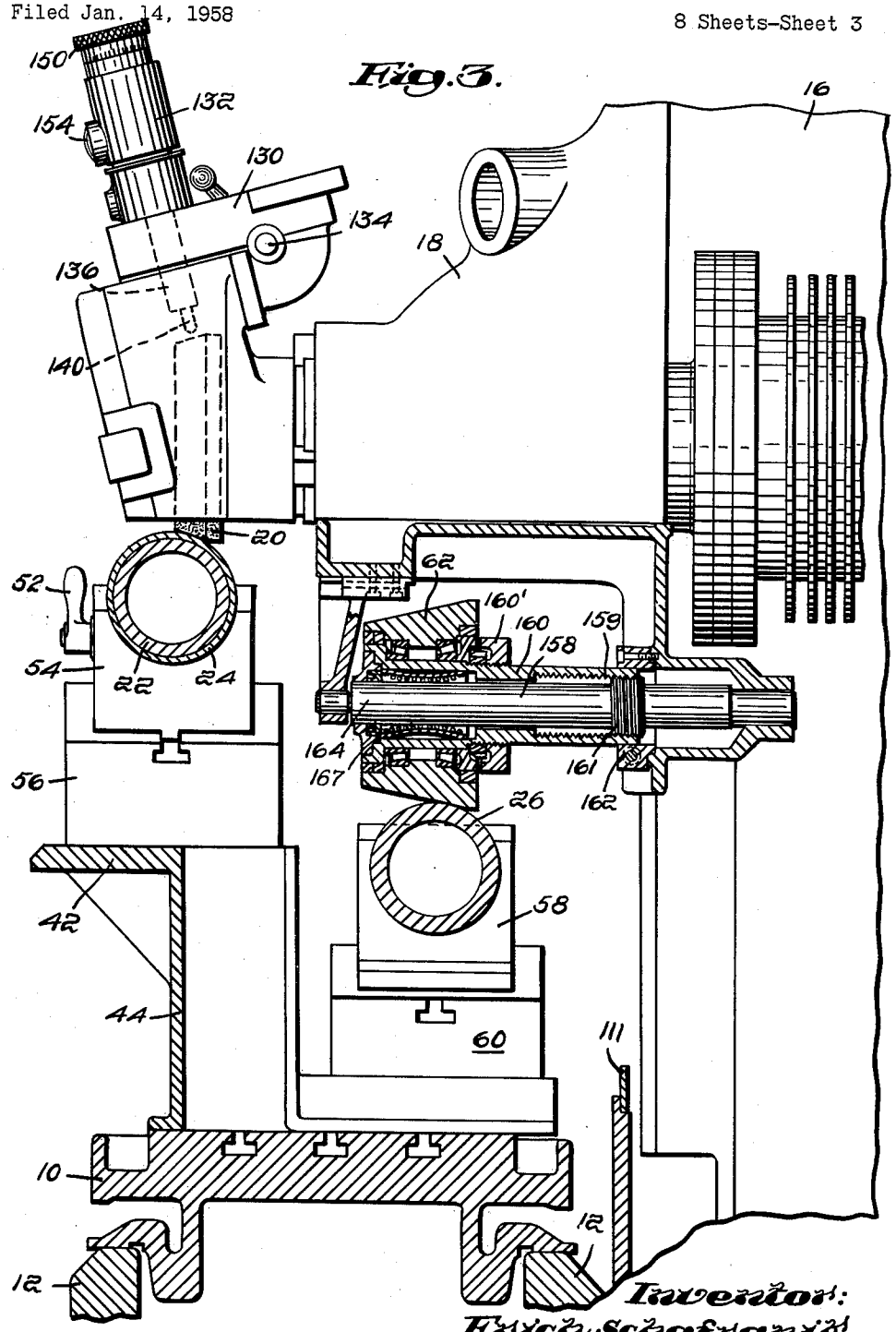
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June 26, 1962 E. SCHAFRANIK 3,040,482

FOLLOWER-CONTROLLED CONTOUR-REPRODUCING GRINDING MACHINES

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Fig. 3.



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FOLLOWER-CONTROLLED CONTOUR-REPRODUCING GRINDING MACHINES

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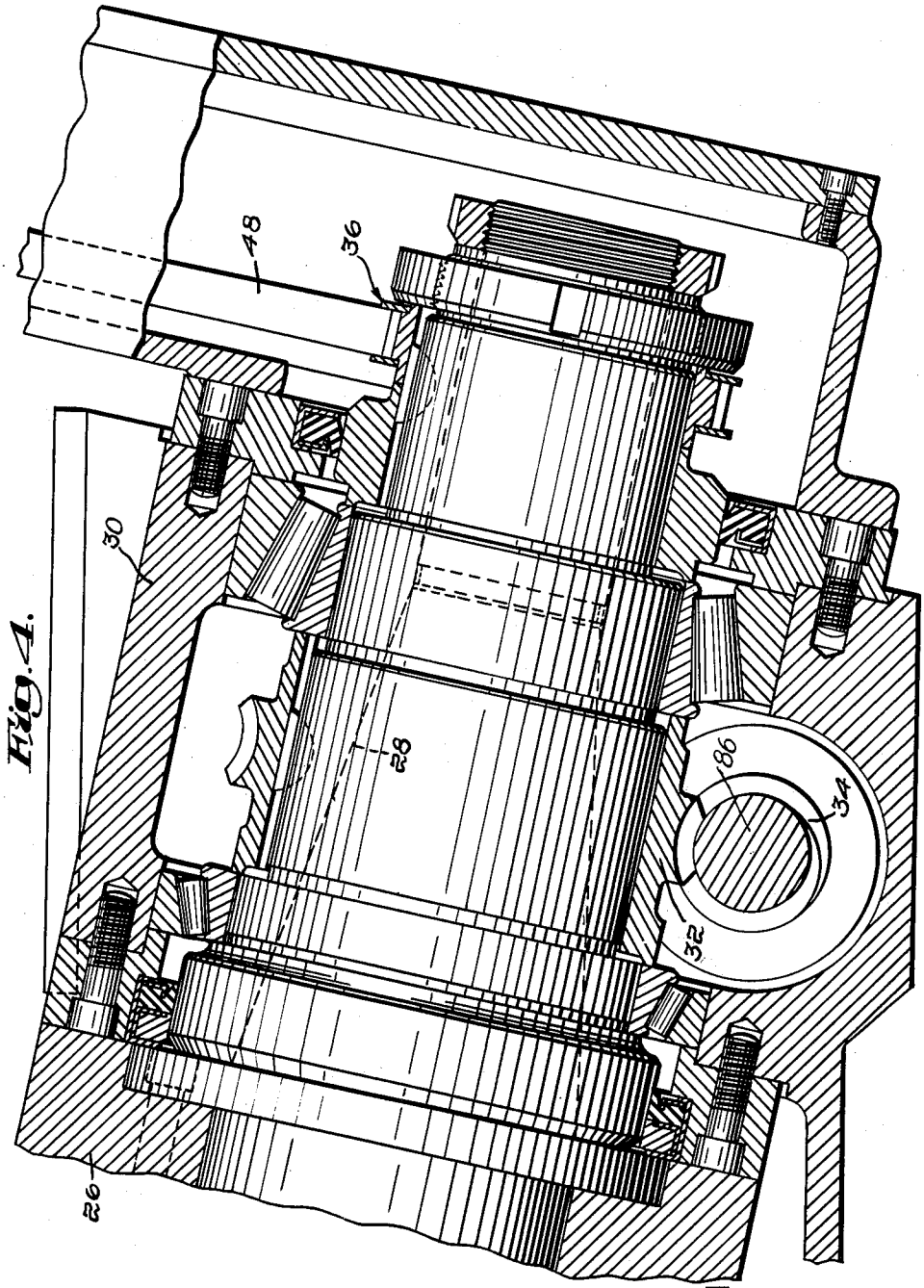


Fig. 4.

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FOLLOWER-CONTROLLED CONTOUR-REPRODUCING GRINDING MACHINES

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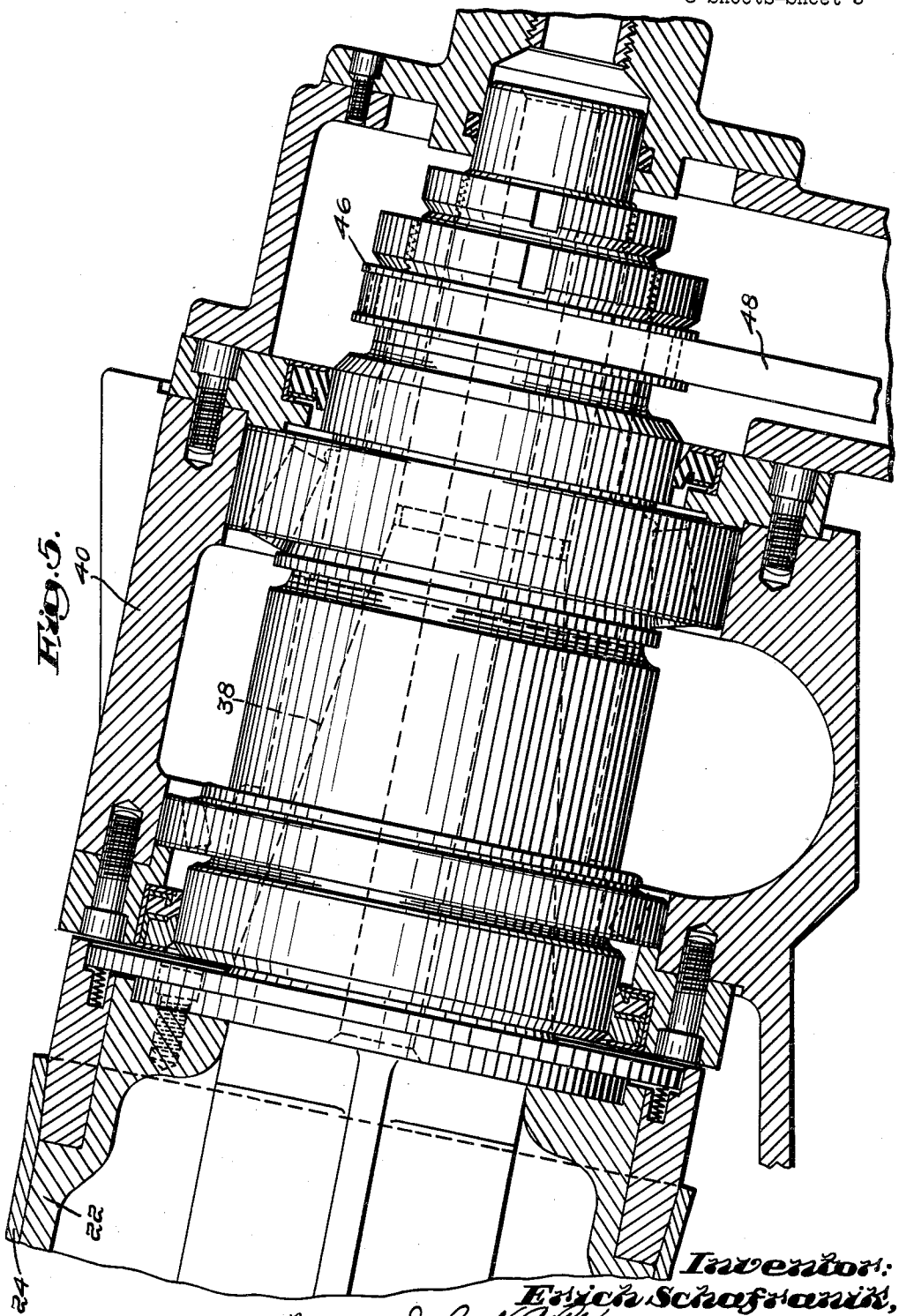


Fig. 5.

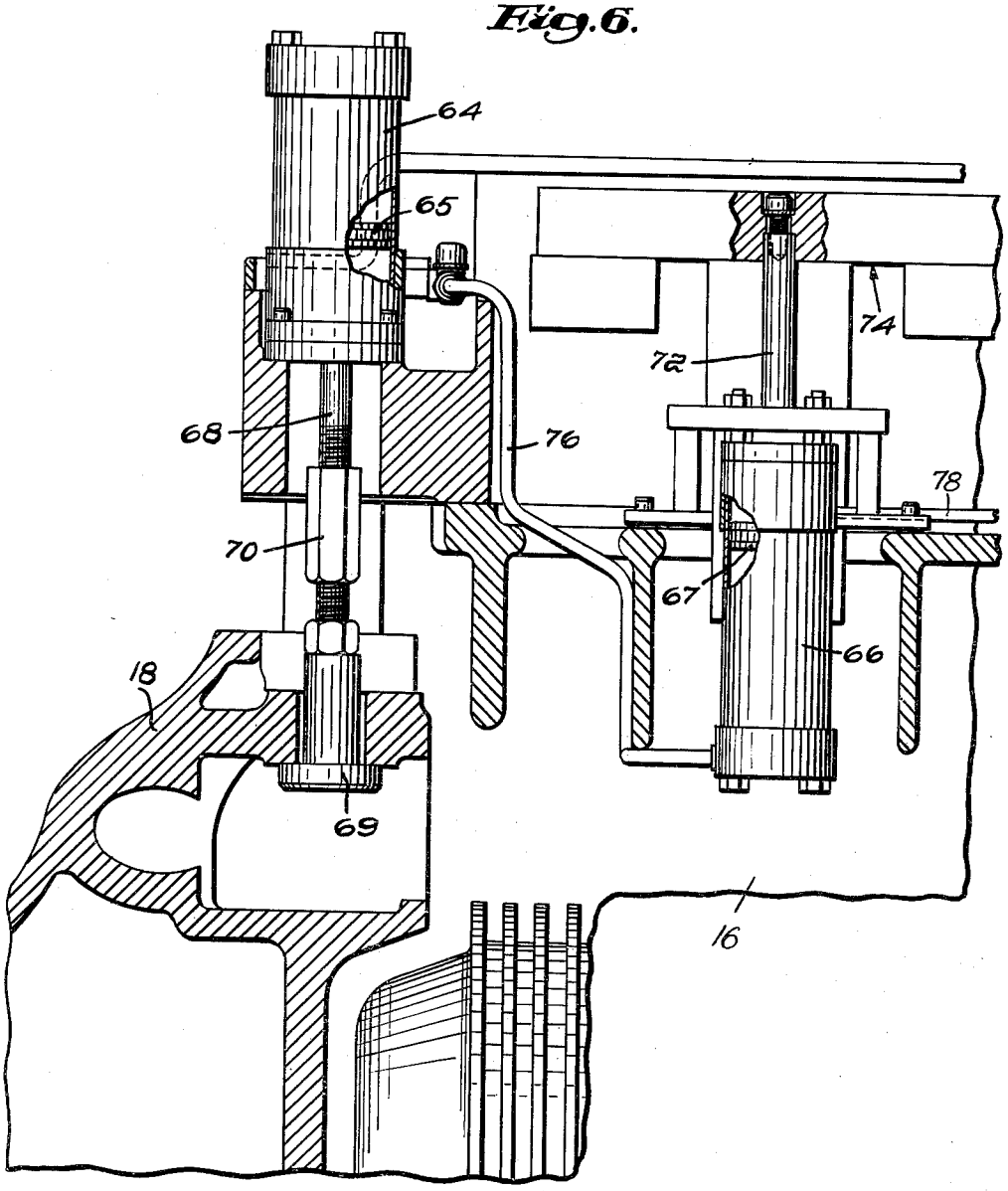
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FOLLOWER-CONTROLLED CONTOUR-REPRODUCING GRINDING MACHINES

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Fig. 6.



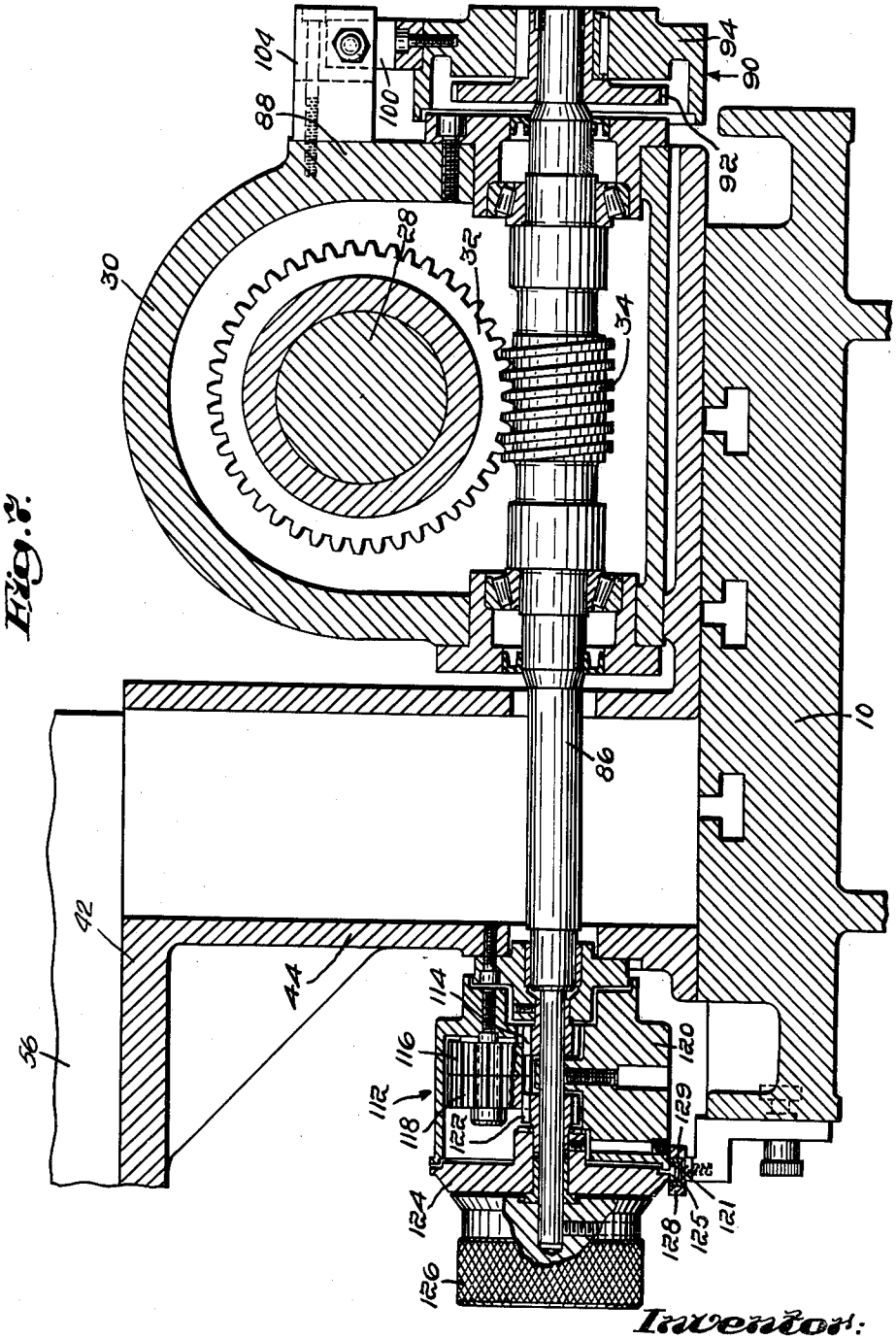
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FOLLOWER-CONTROLLED CONTOUR-REPRODUCING GRINDING MACHINES

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Fig. 9.



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Fig. 8.

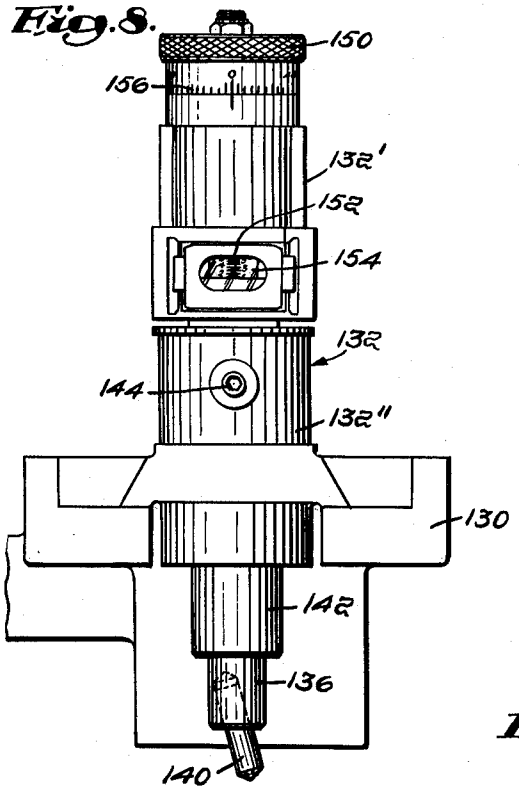


Fig. 9.

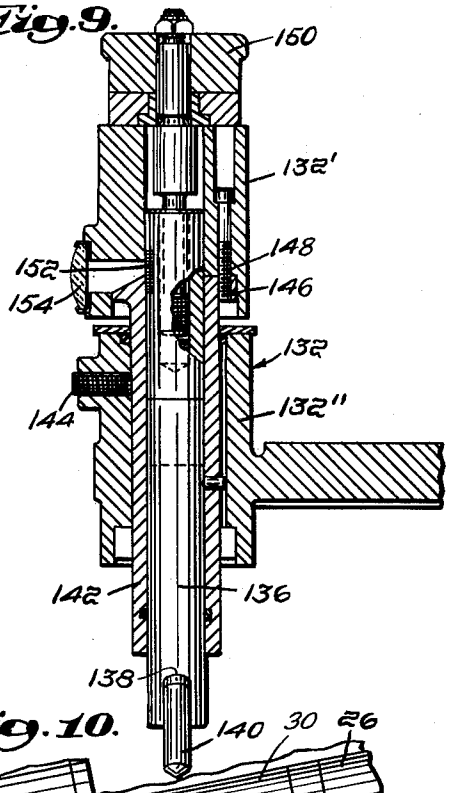


Fig. 10.

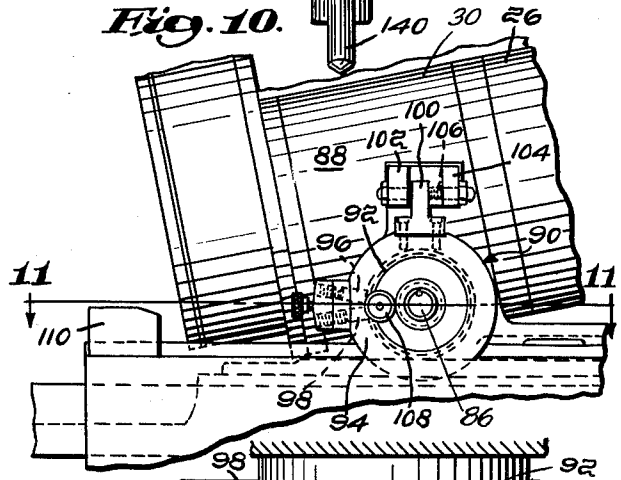
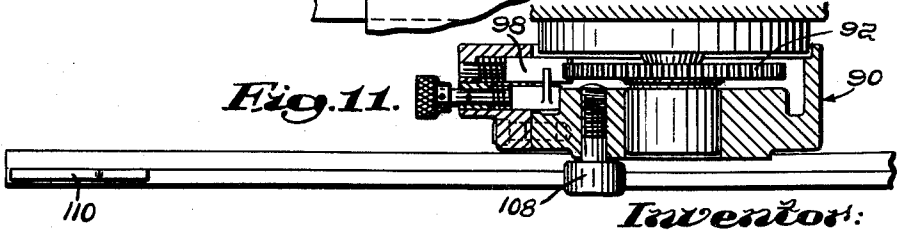


Fig. 11.



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United States Patent Office 3,040,482 Patented June 26, 1962

3,040,482

FOLLOWER-CONTROLLED CONTOUR-REPRODUCING GRINDING MACHINES

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Filed Jan. 14, 1953, Ser. No. 708,814
10 Claims. (Cl. 51—101)

This invention relates to improvements in follower-controlled contour-reproducing grinding machines. More particularly, the invention provides an improved surface grinding machine for follower-controlled geometrically precise and accurate reproduction of surface contours which may include substantial concavities and/or convexities on objects which can be mounted for rotation in the grinding process.

It is among the objects of the invention to provide a grinding machine of the mentioned variety which can more accurately and efficiently reproduce simple and complex curved surface contours which are disposed around and along an axis of rotation of an object whose surface contours are to be reproduced, as compared with any prior comparable proposal.

Another object of the invention is to provide a surface contour reproducing grinding machine having improved means for intermittent increment rotational advance of work and a master pattern prior to the commencement of each cycle of reciprocatory linear relative travel of a grinding wheel and a work piece.

A further object of the invention is to provide a follower-controlled contour reproducing surface grinding machine having improved means for accurate compensation for reductions of grinding wheel diameter.

It is, moreover, an object and purpose of the invention generally to improve the structure, efficiently and capabilities of contour reproducing grinding machines, and especially such machines of the follower-controlled variety wherein the grinding is accomplished linearly of a non-rotating work piece having intermittent rotational increment feed during the contour-reproducing grinding process.

In the accompanying drawings:

FIG. 1 is an end elevation of upper portions of a grinding machine embodying features of the present invention;

FIG. 2 is a front elevation, on a larger scale, showing the mounted work holder with a work piece thereon in the process of being ground to reproduce the contours of a master member under the control of a follower roller riding on the surface of the master member;

FIG. 3 is a cross-sectional view approximately on line 3—3 of FIG. 2;

FIG. 4 is a cross-sectional view approximately on line 4—4 of FIG. 1, on a larger scale;

FIG. 5 is a cross-sectional view approximately on line 5—5 of FIG. 1, on the scale of FIG. 4;

FIG. 6 is a vertical cross-sectional view through the upper portion of the column of the machine and an upper portion of the vertical slide, showing the slide counter-balancing means in elevation;

FIG. 7 is a cross-sectional view on line 7—7 of FIG. 2, on a larger scale;

FIG. 8 is a front elevation of the truing tower;

FIG. 9 is a medial cross-sectional view of the truing tower;

FIG. 10 is a fragmentary rear elevational view of the ratchet indexing feed mechanism; and

FIG. 11 is a cross-sectional view approximately on line 11—11 of FIG. 10, on a larger scale.

Referring to the drawings, a horizontal table 10 is suitably mounted for longitudinal travel on any suitable

support which, preferably, will be a carriage 12 mounted for transverse movement on a base 14. A substantial generally hollow vertical column 16 extends upwardly from the base rearward of the said table and carriage. Table 10 may be driven hydraulically, or otherwise, in any conventional manner, and carriage 12 may have any conventional means, which may include hand wheel 13, for feeding it transversely on base part 14, toward and from the column 16.

A vertical slide is indicated generally at 18, it being mounted on column 16 for vertical movements and having substantial extent forwardly over the table 10. Grinding wheel 20 is mounted on vertical slide 18 for rotation on a horizontal axis, and may be driven by any suitable power means (not shown).

In the illustrated embodiment of the invention, a work-holding member 22 is mounted on table 10 and has a work piece 24 thereon whose exterior surface is to be ground to precisely reproduce the generally conical surface contour of a master member 26 which is mounted on table 10 somewhat below and rearward of the work-holding member 22.

Master member 26 is mounted on table 10 by means of a shank 28 which is secured to its larger end and journaled in a bearing unit 30 which is suitably secured to table 10. The master member 26 is thus rigidly but rotatably supported with its axis at a predetermined inclination to the horizontal plane of table 10, and its shank 28 has a wormwheel 32 fixed thereon in constant mesh with a transversely disposed worm 34. A pulley 36, or other drive member, is fixed on an end portion of shank 28.

Work-holding member 22 is rotatably mounted by means of a shank 38 which is secured to its larger end and journaled in a bearing unit 40 which is suitably secured on the elevated shelf part 42 of a supporting wall 44 secured to and extending upwardly from the table 10. Member 22 is supported with its axis parallel with and at precisely the same inclination from horizontal as the axis of master member 26. A pulley 46, or other drive member, is fixed on an end portion of shank 38, and a cog belt 48, or other non-slip transmission means, extends between and around the pulleys 36 and 46, whereby any rotational movement of master member 26 produces equal and like rotational movement of-workholding member 22.

The somewhat elevate pointed end of the work piece 24 on work-holding member 22 is engaged and steadied by a supporting abutment 50 which may be locked, by means of handle 52, in a selected position on member 54 which, in turn, is adjustable along the inclined top surface of a short platform 56 which rises from and is secured to shelf part 42.

The somewhat elevated pointed end of master member 26 is engaged and steadied by a supporting abutment 58 which is adjustable along the inclined top surface of a lower platform 60 which rises from and is secured to table 10.

Grinding wheel 20 is positioned and adapted for engaging and grinding work piece 24 when vertical slide 18 is permitted to move downward enough to bring wheel 20 into grinding engagement with the work piece. A frusto-conical control roller 62 is rotatably mounted on slide 18, below the axis of grinding wheel 20, in position to rest and ride upon the surface of master member 26, with gravity acting on slide 18 to maintain control roller 62 in constant engagement with master member 26. The relationship of the grinding wheel 20 and control roller 62 initially will be such that, when a larger diameter portion of control roller 62 is engaging master member 26, the inclined surface portion of grinding wheel 20 will be in grinding relation to work piece 24 whereby, as the

work piece is carried past wheel 20, the latter follows the roller-engaged linear contour of master member 26 to precisely reproduce that contour on the work piece 24.

A counter-balancing system is associated with vertical slide 18, as best seen in FIG. 6. The illustrated system comprises an upper cylinder 64 and a lower cylinder 66, each rigidly mounted on column 16 with their axes vertical and parallel. Cylinder 64 has a piston 65 therein with its piston rod 68 extending out through the lower end of the cylinder and loosely through an upper portion of slide 18. The lower end of rod 68 has an abutment 69 thereon for limiting permissible downward travel of the slide 18. However, the piston rod may include means 70 therein for selectively adjusting its length, thereby to vary the permissible vertical travel of slide 18.

The lower cylinder 66 has a piston 67 therein with its piston rod 72 extending out through the upper end of the cylinder and has a counter-weight means 74 mounted on its upper end. A conduit 76 connects the lower end of cylinder 66 to the lower end of cylinder 64. Hence, referring to FIG. 6 and assuming that fluid originally in cylinder 64 has been forced into cylinder 66 as a result of downward travel of slide 18, with the counter-weight means 74 opposing and steadying the travel of the slide, any subsequent lifting of the slide will involve transfer of fluid in cylinder 66 back into cylinder 64. During the grinding process, the counter-weight means 74 aids when slide 18 moves upward as control roller 62 rides from a lower to a higher contour portion of master member 26. However, a conduit 78 leads from any suitable source of fluid and opens into the upper end of cylinder 66. Normally, this conduit will be open for free flow of fluid back to the source when piston 67 is being forced upwardly in cylinder 66. But when it is desired to elevate slide 18, independently of master member 26, pressure fluid from the source may be directed through conduit 78 into the upper end of cylinder 66 for driving piston 67 downward in its cylinder and piston 65 upwardly in cylinder 64. The slide 18 may be maintained at its upper limit of travel until the fluid delivered into cylinder 66, above the piston therein, is released through conduit 78 back to the source, or to a waste receptacle.

The grinding process involves a multiplicity of longitudinal reciprocations of work piece 24 relative to grinding wheel 20, the table 10 being reciprocated back and forth on its carriage 12, and each of the master members 26 and the work-holding member 22 being rotated a minute fraction of a complete rotation at the end of each cycle of reciprocating travel of table 10. In the illustrated embodiment of the invention, table 10 is hydraulically driven by conventional means (not shown), the carriage 12 having a reversing valve actuator 80 thereon including a projecting finger 81, and the table 10 having adjustably fixed dogs 82 and 84 for respectively engaging finger 81 at the opposite limits of table travel, for actuating the reversing valve.

A simultaneous increment rotation of the master and work-holding members 26, 22 is effected each time that table 10 approaches either limit of its travel as determined by the locations of reversing dogs 82, 84, as seen in FIG. 2. This is accomplished through the medium of the worm 34 which is in mesh with worm wheel 32 on the shank 28 of master member 26. The worm 34 is fixed on a transverse shaft 86 which is rotatably mounted (FIG. 7) in the walls of the casing within which the worm wheel 32 is located, this casing being secured to table 10, and a rear end portion of the shaft having extent through and beyond the rear casing wall 88. A ratchet and pawl mechanism, indicated generally at 90, is carried on the projecting rear end of shaft 86 and comprises a ratchet wheel 92 fixed on the shaft and a pawl-carrying housing 94 rotatable relative to wheel 92 and concentric therewith. Housing 94 carries two spring-backed pawls 96, 98 (FIGS. 10, 11) which constantly are spring-pressed into engagement with the ratchet wheel 92. Housing 94 also has an up-standing lug 100 thereon which projects into a space between two ears 102, 104 which may be secured in any suitable manner on casing wall 88. A spring 106 constantly biases lug 100 and housing 94 counter-clockwise as viewed in FIG. 10. A roller 108 is mounted at the rear face of housing 94, outward from the axis thereof and in position to be cammed upwardly by either of two cam plates 110, 111 suitably fixed on the transverse carriage 12 and located so that one is in the path of roller 108 as it is carried by table 10 either to the right or left in FIG. 10. A cam actuation of roller 108, at each limit of travel of table 10, advances the ratchet wheel 92 a relatively small amount which may be predetermined to effect, through worm 34, a minute rotational advance of master member 26, such as an advance of the order of 11 seconds, for example. Spring 106 yields to permit the needed increment rotation of housing 94 and moves the housing back to its position of FIG. 10 as soon as roller 108 rides off a cam plate 110 or 111 in response to a reversed movement of table 10.

Obviously, the amount of the increment of rotation of shaft 86, and the worm 34 thereon, is determined by the relative heights of the top horizontal edge portion of cam plates 110, 111 and the point at which roller 108 initially engages the inclined edge portion of the plate.

Reduction gearing, indicated generally at 112 in FIG. 7, is associated with shaft 86, and may comprise a gear 114 non-rotatably fixed on the wall element 44 which supports shelf part 42, and a pair of planetary gears 116, 118 on a carrier housing 120 which is secured on a forward end portion of shaft 86. Planetary gear 116 is in mesh with gear 114, and planetary gear 118 is in mesh with gear 122 which is loose on the shaft 86 but fixed to a disk member 124 which is concentric to the shaft and rotatable thereon. A knob 126 is fixed on the extreme forward end of shaft 86 whereby the said shaft may be manually rotated to rotate the master member 26 as may be desired. Yieldable means 128 on table 10 carries a transverse pin 129 adapted to ride on peripheral portions of housing 120 and disk member 124 as they are advanced intermittently. However, housing 120 and disk member 124 each has a peripheral notch therein, indicated at 121 and 125, respectively, and the reduction gearing effects increment advances of disk member 124 precisely equal to the increment advances of the master member 26. Meanwhile, the housing 120 advances with shaft 86, making several complete rotations while disk member 124 is making one complete rotation. Hence, disk member 124 may have graduations thereon for indicating the angular point around a work piece 24 at which the grinding is being effected at any particular time. The coordination is such that the peripheral notches 121, 125 come into alignment at the under side of the disk member 124 when the latter said member has completed a rotation, at which time the pin 129 on means 128 moves upwardly into the grooves. This upward movement of means 128 rocks lever 128^a enough to depress reversing dog 84 to a position in which it clears finger 81 of the reversing valve actuator 80, the dog 84 being hinged and connected to lever 128^a by an adjustable link 128^b. When dog 84 is thus lowered to clear finger 81 the table 10 moves to the left (FIG. 2), without reversal, and stops at its extreme left hand limit of travel, for unloading and re-loading.

A feature of importance resides in means for quick and accurate correction for reduction of grinding wheel diameter as a result of truing or dressing of wheel 20. In this connection, a truing means is permanently mounted on the wheel housing, above the wheel 20, comprising a base part 130 and a tower part 132 having slide means thereon for engaging in ways of base part 130 as best seen in FIGS. 8 and 9. The said ways must be disposed at precisely the same inclination as the conical surface portion of control roller 62 for dressing wheel 20 to the same inclination of control or

follower roller 62. Base part 130 is fixed on the wheel housing and has a shaft 134 associated with it and carrying mechanism (not shown) for moving the tower part 132 back and forth in the ways of base part 130 in the wheel-truing process. A truing tool holder is adjustably mounted in the tower, comprising a rod 136 having a socket 138 at its lower end for reception of a truing tool 140, and a sleeve 142 fixed to and depending from an upper section 132' of the tower, within which sleeve the said rod 136 is non-rotatably fixed, with its lower end portion protruding. The sleeve 142 extends slidably and non-rotatably through the lower tower section 132'', with a locking set screw 144 available to assist the initial proper setting of the truing mechanism. The upper portion of rod 136 has a threaded hole 146 extending a substantial distance axially of the rod. An adjusting screw 148 is threadedly engaged within hole 146 and has a non-threaded portion extending out through the upper end of tower section 132', with a knob 150 secured on its upper end and with means preventing any axial movement of the screw and knob relative to tower section 132'. The upper end portion of rod 136 has scale markings thereon at at 152, and tower section 132' has an opening through its wall opposite the scale markings, with a magnifying window 154 in the said opening. Hence, the rod 136 and truing tool 140 may be adjusted downwardly by rotating knob 150 in the proper direction, and the amount of the adjustment may be clearly seen on the scale through window 154. A scale 156 preferably is provided on knob 150, and its zero mark should be in register when the zero mark of rod scale 152 is in register at window 154.

When not in use, the truing means moves forward down the inclined ways out of contact with wheel 20.

Compensation for any reduction in grinding wheel diameter may be quickly and precisely accomplished by a predetermined adjustment of control roller 62. For this purpose, the roller, as best seen in FIG. 3, has the frusto-conical shape as illustrated and is adjustably mounted on a shaft 158 which is fixed against rotation. A sleeve member 160 is mounted on the shaft and roller 62 is mounted on the sleeve with suitable anti-friction bearing means intervening between them. Shaft 158 has an enlarged threaded portion 161 thereon and the adjacent end portion of sleeve 160 is interiorly threaded at 159 for screwing on shaft portion 161. An annular enlargement 160' on the sleeve 160, adjacent to roller 62, constitutes a knob facilitating manual rotation of sleeve 160. A clamp 162 is mounted on a portion of vertical slide 18 and normally clamps sleeve 160 against rotation. However, when roller 62 is to be adjusted, the clamp quickly may be loosened to permit manual rotation of sleeve 160 in direction to move roller 62 to the right, in FIG. 3, thereby to lower slide 18 and grinding wheel 20. Scale markings at 164 on the left hand end of shaft 158 become successively uncovered as the sleeve and roller move to the right for indicating the amount wheel 20 is lowered. By coordinating the scale 164 on shaft 158 with the scale 152 at the window 154 of the shaft 134, a one graduation movement of roller 62 to the right on shaft 158 (FIG. 3), will precisely compensate for a one graduation downward movement of truing tool 140 as observed through window 154. Preferably, linear anti-friction means 167 intervene between shaft 158 and sleeve 160 at the roller end of the sleeve, facilitating movements of the sleeve along the shaft.

The work 24 may be mounted and held on work holder 22 in any suitable manner. As herein illustrated, the work holder is hollow and its walls or portions thereof, are provided with holes 23, and the non-rotating right hand end of the work holder has a conduit 166 connected thereto by means of which the interior of the work holder may be connected to any suitable source of vacuum which acts through holes 23 to draw the work piece into place on the work holder and to hold it thereon by relatively strong suction. Also, the conduit 166 may be connected to any suitable source of air pressure which acts through holes 23 to blow the work piece from the work holder in the unloading process. In FIG. 1, the conduit 166 is diagrammatically represented as leading to a valve casing 168 whose valve 170 is rotatable to selectively connect the conduit to vacuum or to air pressure. An intermediate position of the valve closes both the vacuum line and the air pressure line.

It will be obvious from the foregoing description, in connection with the drawings, that I have provided a grinding machine which is capable of the utmost accuracy in reproducing curving contours of objects which may be mounted for intermittent increments of rotational feed and whose contours may include portions having curvatures in direction around the axis of rotation and curvatures which may be convex or concave in direction along the said axis, the latter said curvatures being required to be of sufficient dimensions to permit the follower control roller to negotiate the curved contours in the grinding process. It will be understood that various changes may be made in the details of construction of the disclosed machine and mechanism, within the scope of the appended claims, and it is intended that the patent shall cover, by suitable expression in the appended claims, whatever features of patentable novelty exist in the invention disclosed.

I claim as my invention:

1. A contour grinding machine having a horizontally reciprocable table and a rotating grinding wheel movably mounted on a transverse axis above the table for vertical movements toward and from the table, said grinding wheel having a frusto-conical grinding surface, means on said table for supporting a work-piece for rotation thereon about an axis extending generally in directions along the path of travel of the table and disposed below said wheel in position to be engaged thereby, a master member mounted on said table and rotatable thereon about an axis in spaced precise parallelism with said axis of the work piece, said master member having curved contours which are to be reproduced on said work piece, a control roller mounted on an axis parallel with the axis of rotation of said wheel and movable vertically in unison with said wheel, said roller having a frusto-conical peripheral portion corresponding to the grinding surface of the wheel, and being adapted to engage said master member and follow its longitudinal contour as said table reciprocates, thereby to effect corresponding movements of said wheel in grinding engagement with said work piece, means for effecting a minute increment rotational advance of both said master member and said work piece each time that said table approaches one of its limits of reciprocating travel, and means associated with said control roller for precisely adjusting the roller in one axial direction to change the point of contact between the roller and master member in direction toward the smaller end of the frusto-conical roller thereby to effect a predetermined lowering of said wheel for precisely compensating for reduction in diameter of said wheel.

2. A contour grinding machine having a horizontally reciprocable table and a rotating grinding wheel movably mounted on a transverse axis above the table for vertical movements toward and from the table, said grinding wheel having a frusto-conical grinding surface, means on said table for supporting a work-piece for rotation thereon about an axis extending generally in directions along the path of travel of the table and disposed below said wheel in position to be engaged thereby, a master member mounted on said table and rotatable thereon about an axis in spaced precise parallelism with said axis of the work piece, said master member having curved contours which are to be reproduced on said work piece, a control roller mounted on an axis parallel with the axis of rotation of said wheel and movable vertically in unison with said wheel, said roller having a frusto-conical peripheral por-

tion corresponding to the grinding surface of the wheel, and being adapted to engage said master member and follow its longitudinal contour as said table reciprocates, thereby to effect corresponding movements of said wheel in grinding engagement with said work piece, means for effecting a minute increment rotational advance of both said master member and said work piece each time that said table approaches one of its limits of reciprocating travel, wheel truing means associated with said grinding wheel and comprising a truing tool and means for effecting precisely scaled adjustment of the tool toward said wheel preparatory to truing of the wheel, and means associated with said control roller for effecting a precisely scaled adjustment of the roller in one axial direction to change the point of contact between the roller and master member in direction toward the smaller end of the frusto-conical roller an axial distance sufficient to lower said wheel an amount to precisely compensate for the reduction in wheel diameter produced by said truing tool.

3. A contour grinding machine having a horizontally reciprocable table and a rotating grinding wheel movably mounted on a transverse axis above the table for vertical movements toward and from the table, means on the table for supporting a work-piece for rotation thereon about an axis extending generally in directions along the path of travel of the table and disposed below said wheel in position to be engaged thereby, a master member mounted on said table and rotatable thereon about an axis in spaced precise parallelism with said axis of the work piece, said master member having curved contours which are to be reproduced on said work piece, a control roller mounted on an axis parallel with the axis of rotation of said wheel and movable vertically in unison with said wheel, said roller being adapted to engage said master member and follow its longitudinal contour as said table reciprocates, thereby to effect corresponding movements of said wheel in grinding engagement with said work piece, means for effecting a minute increment rotational advance of both said master member and said work piece each time that said table approaches one of its limits of reciprocating travel, said grinding wheel and control roller being mounted on a vertical slide member, and a pair of cylinders mounted in fixed positions relative to said table and slide member, one cylinder having a piston operable therein with its piston rod connected to said slide for elevating the slide when said piston is propelled in one direction within its cylinder, the other cylinder having a piston operable therein with its piston rod supporting a counter-weight means, constantly biasing the latter said piston downwardly within its cylinder, less than the weight of said vertical slide.

4. A contour grinding machine having a horizontally reciprocable table and a grinding wheel transversely mounted in a vertical slide for vertical movements toward and from the table, a generally conical work holding member having means at its larger end rotatably supporting it on said table with its axis extending generally along the path of travel of the table but appreciably inclined relative to the horizontal plane of travel of the table and with its smaller end elevated, said member being adapted to receive thereon a generally conical shell-form work piece in position to be engaged by said wheel, a generally conical master member having means at its larger end rotatably supporting it on said table, beside said work holding member, with its axis precisely parallel with the axis of the work holding member, said master member having curved contours to be reproduced by said wheel on said work piece, transmission means connecting said work holding and master members whereby any rotation of the master member produces equal and like rotation of the work holding member, a control roller mounted on said vertical slide with its axis parallel with the wheel axis, said roller being located above and adapted to engage and follow the longitudinal contour of said master member when said table reciprocates to carry said members past said roller and wheel respectively, and means associated with said master member for effecting a minute increment rotational advance thereof each time said table approaches one limit of its reciprocating travel.

5. A contour reproducing grinding machine comprising a horizontally reciprocating table, a grinding wheel carrying vertical slide movable toward and from said table, a work holding member and a master member each rotatably mounted in spaced parallelism on said table with said work-holding member under said wheel in position for work therein to be engaged by the wheel, a control roller on said slide in position to engage and ride upon said master member when said table is reciprocated, means for effecting a minute increment rotational advance of each of said work holding and master members each time said table approaches one limit of its reciprocating travel, and counter-balancing means for said vertical slide comprising a fluid pressure system intervening between said slide and a substantial counter-balancing weight, said weight acting through said system tending to elevate said slide, and the weight of said slide appreciably exceeding said counter-weight, said fluid pressure system including a conduit leading from a pressure source for selectively aiding said counter-weight in overcoming the weight of said slide, for quickly elevating the slide.

6. A contour grinding machine having a horizontally reciprocable table, a slide vertically movable above the table, a grinding wheel rotatably mounted on the slide, said wheel having a frusto-conical grinding surface, means on said table for supporting a work-piece for rotation about an axis extending in the direction of the travel of the table and disposed below the wheel in position to be engaged thereby, a master member mounted on said table and rotatably thereon about an axis in spaced parallelism with the axis of said workpiece, a control roller mounted on said slide on an axis parallel with the axis of said wheel, said roller having a frusto-conical shape corresponding to said grinding wheel to engage said master member, means for simultaneously rotating said master member and said workpiece by minute increments, a shaft journaled on the table and geared to the master member, a ratchet wheel on said shaft, a reciprocable cam having a pawl in engagement with the ratchet wheel, relatively fixed cam plates in the path of the cam at the limiting positions of the table, a wheel truing tool mounted on the slide, means for adjusting the tool relative to the grinding wheel, and means for adjusting the roller axially relative to the master member to compensate for reduction in wheel diameter due to truing.

7. A contour grinding machine having a horizontally reciprocable table, a slide vertically movable above the table, a grinding wheel rotatably mounted on the slide, means on said table for supporting a work-piece for rotation about an axis extending in the direction of the travel of the table and disposed below the wheel in position to be engaged thereby, a master member mounted on said table and rotatably thereon about an axis in spaced parallelism with the axis of said workpiece, a control roller mounted on said slide on an axis parallel with the axis of said wheel, means for simultaneously rotating said master member and said workpiece by minute increments, a shaft journaled on the table and geared to the master member, a ratchet wheel on said shaft, a reciprocable cam having a pawl in engagement with the ratchet wheel, relatively fixed cam plates in the path of the cam at the limiting positions of the table, a wheel truing tool mounted on the slide, means for adjusting the tool relative to the grinding wheel, and means for adjusting the roller axially relative to the master member to compensate for reduction in wheel diameter due to truing.

8. A contour grinding machine having a horizontally reciprocable table, a slide vertically movable above the

table, a grinding wheel rotatably mounted on the slide, means on said table for supporting a workpiece for rotation about an axis extending in the direction of the travel of the table and disposed below the wheel in position to be engaged thereby, a master member having curved contours mounted on said table and rotatable thereon about an axis in spaced parallelism with the axis of said workpiece, a control roller mounted on said slide on an axis paralllel with the axis of said wheel, said roller being in following engagement along the longitudinal contour of the master member as the table reciprocates, means for effecting simultaneous rotation of said master member and workpiece by minute increments when the table approaches the limit of its travel, a pair of interconnected fixedly mounted pressure cylinders, a piston in one cylinder connected to the slide for elevating the latter, a piston in the second cylinder, a counterweight supported on the second named piston, a wheel truing tool mounted on the slide, means for adjusting the tool into engagement with the wheel, and independent means for adjusting the control roller to lower the slide toward the workpiece to compensate for reduction of wheel diameter as determined by the adjustment of the truing tool.

9. A contour grinding machine having a horizontally reciprocable table, a slide vertically movable above the table, a grinding wheel rotatably mounted on the slide, means on said table for supporting a workpiece for rotation about an axis extending in the direction of the travel of the table and disposed below the wheel in position to be engaged thereby, a master member mounted on said table and rotatably thereon about an axis in spaced parallelism with the axis of said workpiece, said master member having curved contours, a control roller of frusto-conical shape mounted on said slide on an axis parallel with the axis of said wheel, said roller being in following engagement along the longitudinal contour of the master member as the table reciprocates, means for effecting simultaneous rotation of said master member and workpiece by minute increments when the table approaches the limit of its travel, a pair of interconnected fixedly mounted pressure cylinders, a piston in one cylinder connected to the slide for elevating the latter, a piston in the second cylinder, a counterweight supported on the second named piston, a wheel truing tool mounted on the slide, means for adjusting the tool into truing engagement with the wheel, and independent means for adjusting the frusto-conical control roller to lower the slide toward the workpiece in an amount compensating for reduction of wheel diameter as determined by the adjustment of the truing tool.

10. A contour grinding machine having a horizontally reciprocable table, a slide vertically movable above the table, a rotatable grinding wheel carried by the slide, a work-holding member mounted on the table below the grinding wheel for rotation on an axis longitudinally of the table, a contoured master member mounted on the table for rotation on an axis parallel to that of the work-holding member, means for rotating said master member and work-holding member in unison by minute increments each time the table approaches one of its limits of reciprocation including a shaft in driving connection with the master member, a ratchet wheel and pawl mechanism associated with said shaft, a fixed cam in the path of travel of said table at its limit of movement for actuating the ratchet wheel and pawl mechanism, a control roller of frusto-conical shape rotatably mounted on a shaft on the slide beneath and on an axis parallel to that of the wheel and in engagement with said master member, and means for adjusting said control member axially of the shaft to change the spacing of its shaft from the master member and compensate for wear of the wheel.

References Cited in the file of this patent

UNITED STATES PATENTS

1,473,520	Rosak	Nov. 6, 1923
2,235,578	Ford	Mar. 18, 1941
2,520,228	Thomte	Aug. 29, 1950
2,767,520	Rudnicki	Oct. 23, 1956

FOREIGN PATENTS

927,128	Germany	May 31, 1955