June 11, 1935. M. H. ARMS ET AL 2,004,361

CALIPERING MECHANISM

Filed June 17, 1932 7 Sheets-Sheet 1

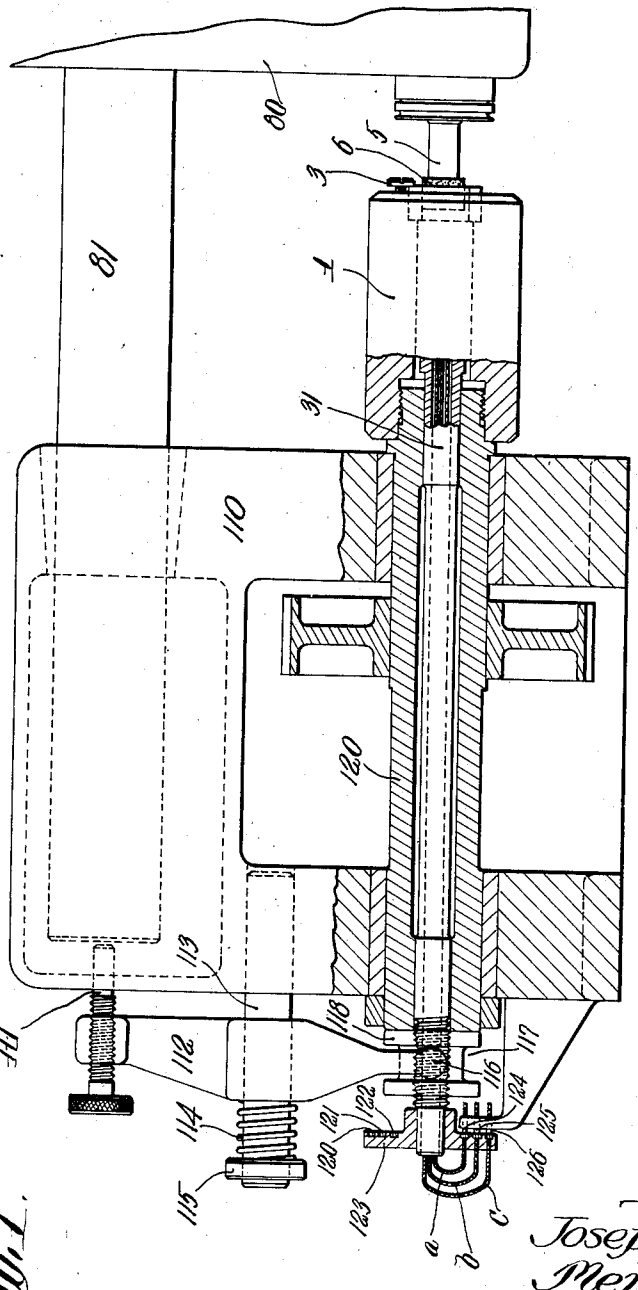

Fig. 1.

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Filed June 17, 1932 7 Sheets-Sheet 2

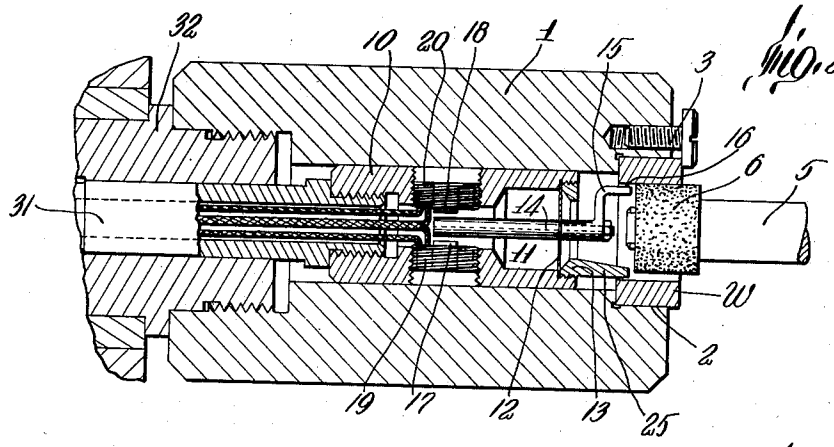

Fig. 2.

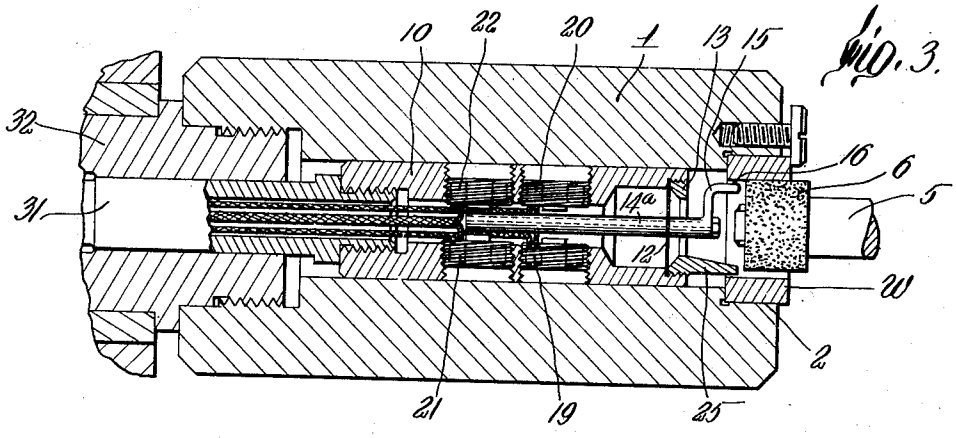

Fig. 3.

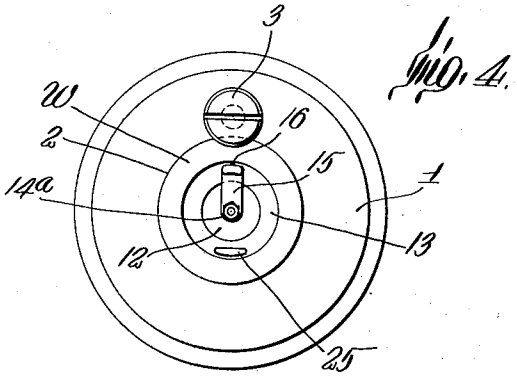

Fig. 4.

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CALIPERING MECHANISM.

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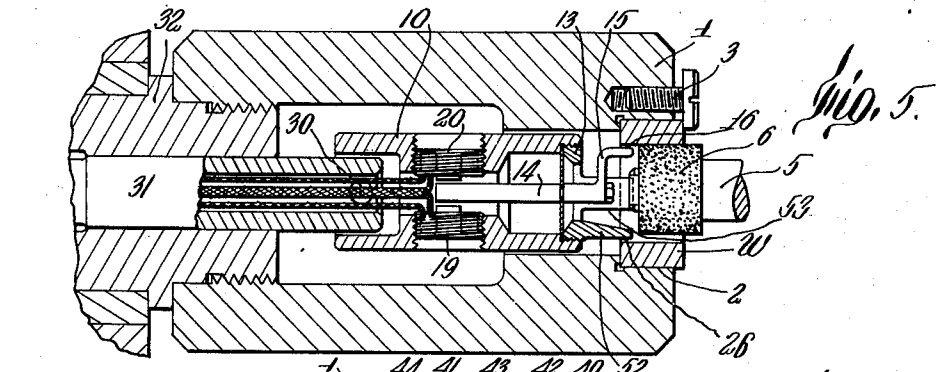

Fig. 5.

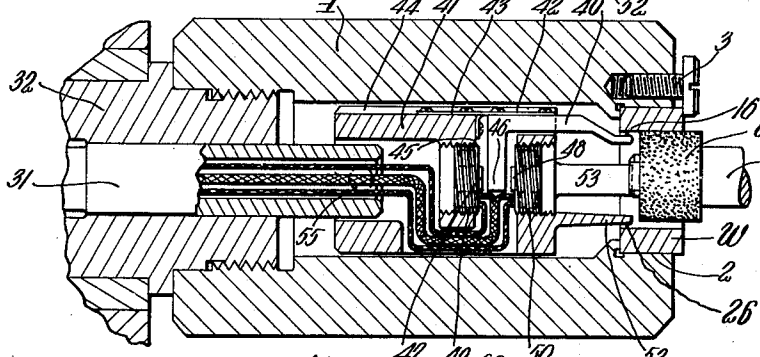

Fig. 6.

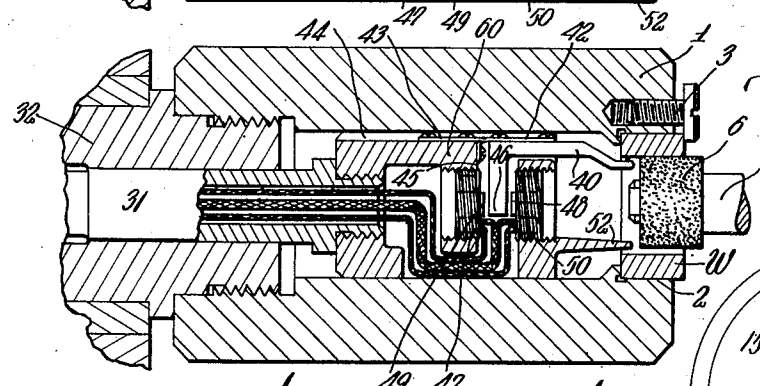

Fig. 7.

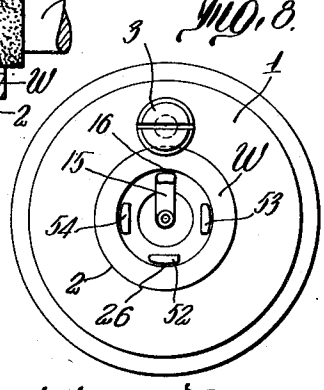

Fig. 8.

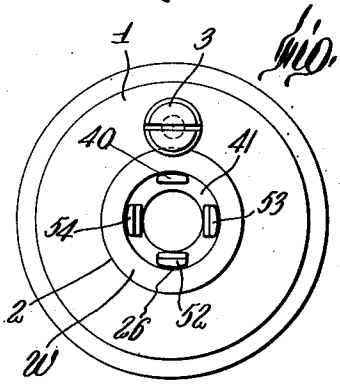

Fig. 9.

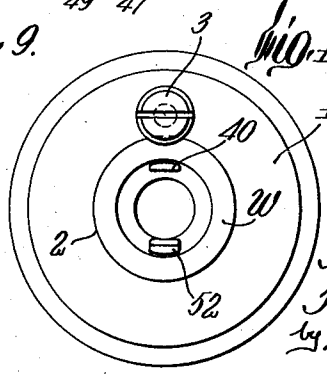

Fig. 10.

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CALIPERING MECHANISM

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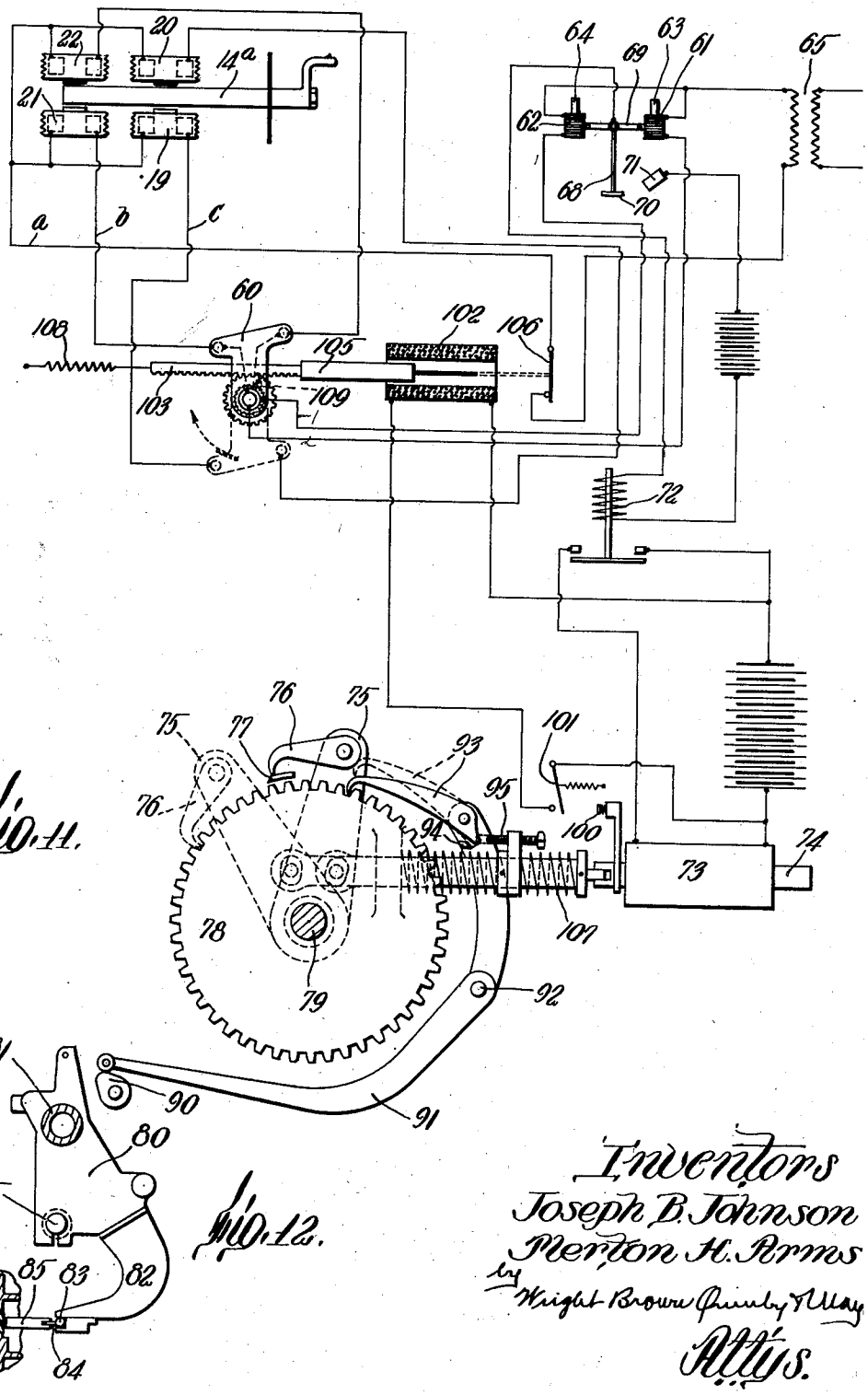

Fig. 11.

Fig. 12.

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CALIPERING MECHANISM

Filed June 17, 1932 7 Sheets-Sheet 5

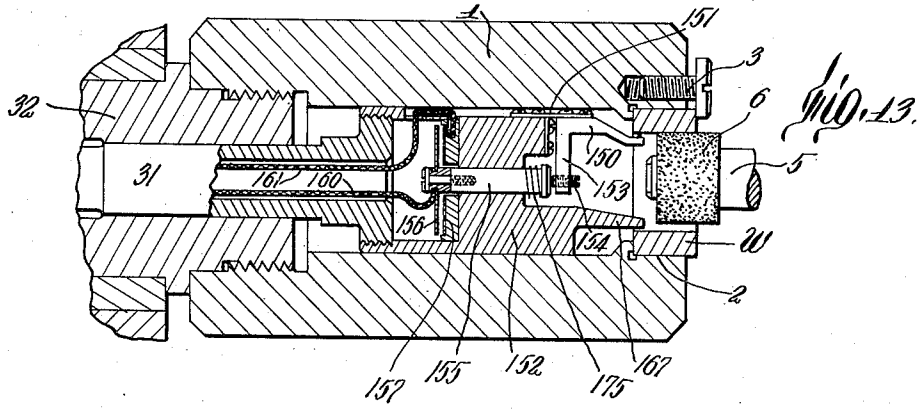
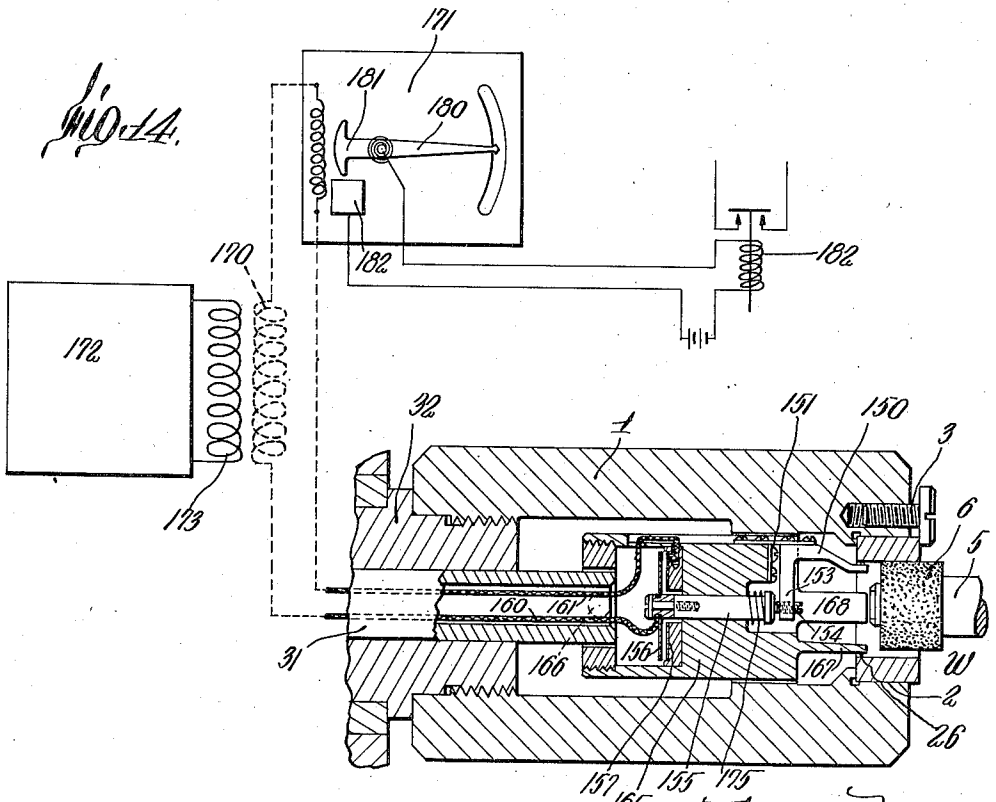


Fig. 13.

Fig. 14.



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CALIPERING MECHANISM

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Fig. 19.

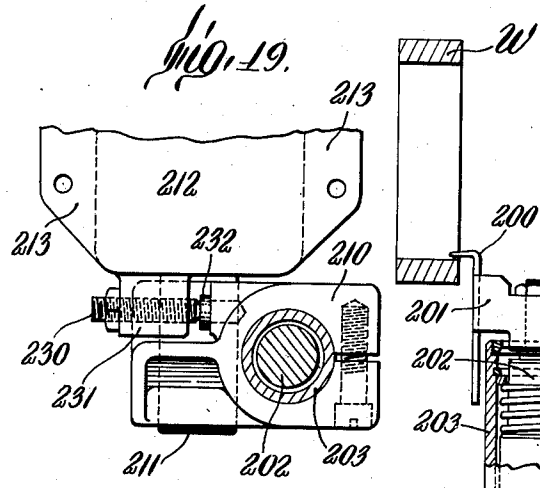


Fig. 16.

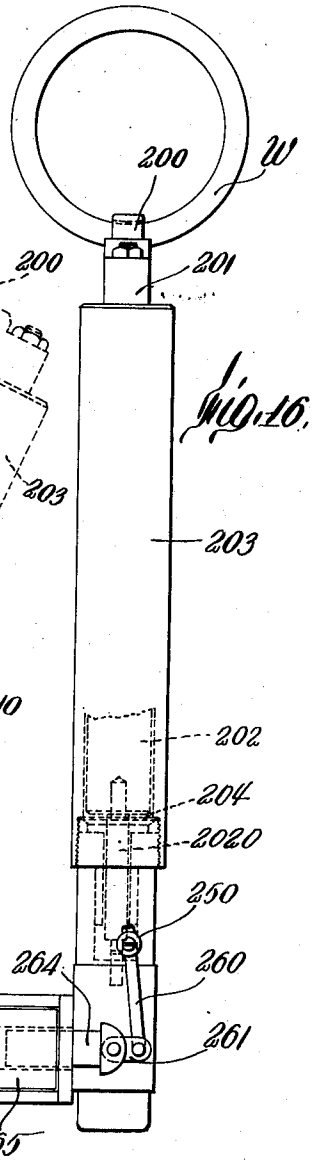


Fig. 15.

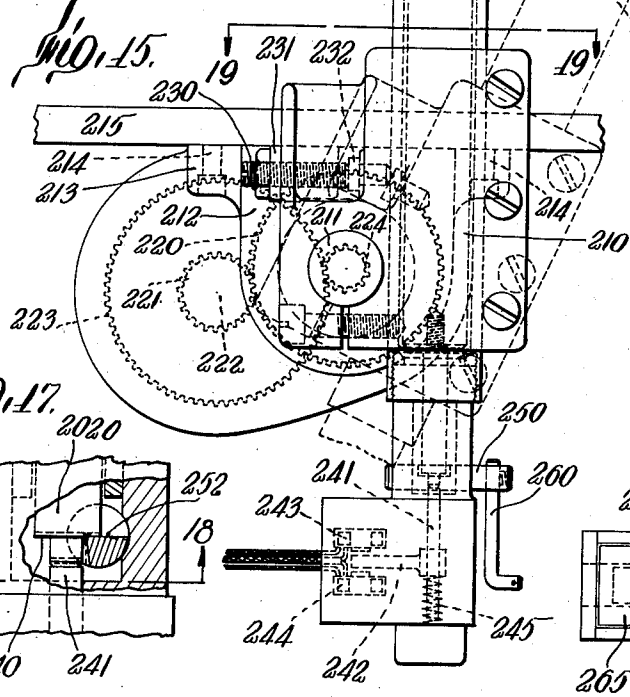
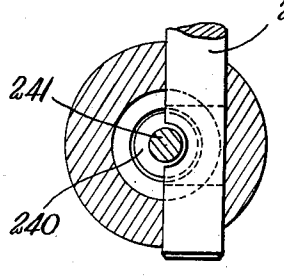


Fig. 17.

Fig. 18.



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CALIPERING MECHANISM

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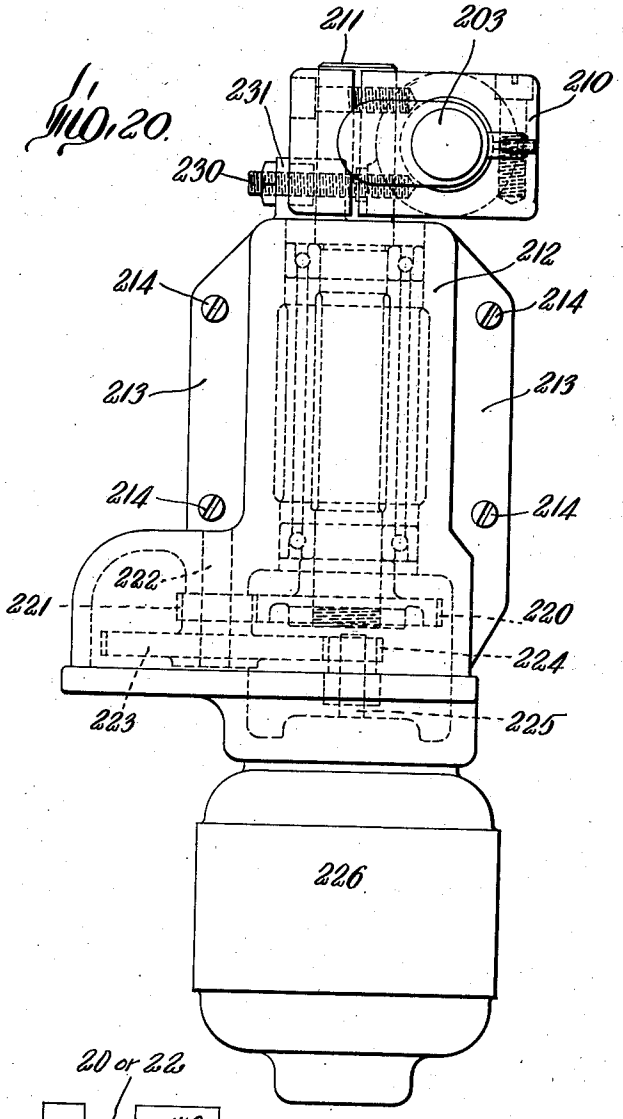

Fig. 20.

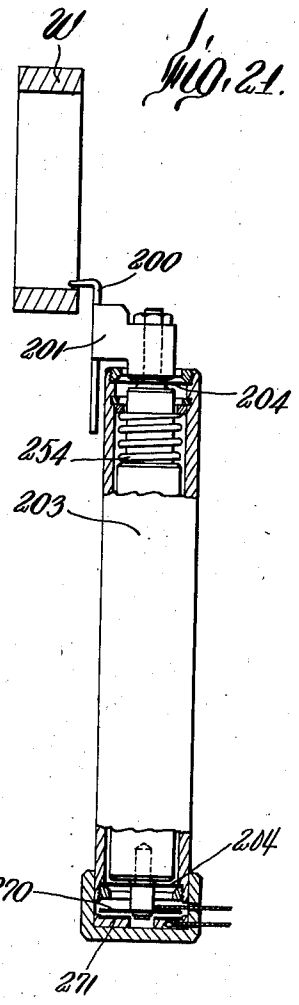

Fig. 21.

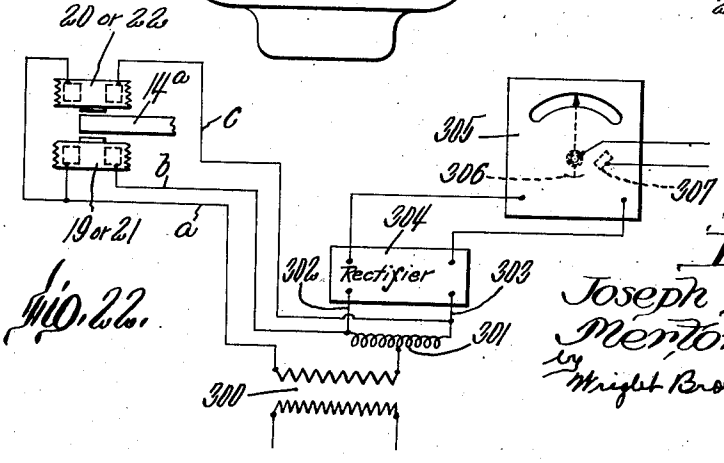

Fig. 22.

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2,004,361

UNITED STATES PATENT OFFICE

2,004,361

CALIPERING MECHANISM

Merton H. Arms and Joseph B. Johnson, Springfield, Vt., assignors to Bryant Chucking Grinder Company, Springfield, Vt., a corporation of Vermont

Application June 17, 1932, Serial No. 617,820

27 Claims. (Cl. 51—165)

This invention relates to mechanism for calipering work and more particularly while it is in the machine by which it is being cut to a desired finished size. It has for an object to effect the measurement by electrical mechanism of great accuracy, but which does not require making or breaking of the measuring circuit for its operation.

Another object is to provide a mechanism of this type applicable to internal grinding.

A still further object is to provide such a mechanism applicable to show when the work has reached the proper size for both rough and finish grinding and which may effect certain machine controls when such sizes are reached and automatically for both rough and finished sizes.

A further object is to provide a calipering mechanism which may gage from the front of the hole in internal work and which may be moved away from the work when the tool is in operation or the work is to be removed or replaced.

Further objects and advantages will appear from a more complete description of certain embodiments of this invention shown in the accompanying drawings in which

Figure 1 is a fragmentary view partly in side elevation and partly in section of an internal grinder showing the mounting of a sizing caliper.

Figure 2 is a fragmentary longitudinal section of a work holder and the contact end portion of one form of caliper.

Figure 3 is a view similar to Figure 2 but showing a modification.

Figure 4 is an end elevation of the work holder showing the work and caliper.

Figures 5, 6 and 7 are sections similar to Figure 2, but showing different forms of caliper.

Figures 8, 9 and 10 are end elevations corresponding to Figures 5, 6 and 7, respectively.

Figure 11 is a diagrammatic view showing automatic feed retraction of the grinding wheel relative to the work when the desired rough and finished sizes have been reached.

Figure 12 is a diagrammatic view of the feed connection from the feed shaft to the wheel carrier.

Figure 13 is a view similar to Figure 6, but showing a different electrical responsive element.

Figure 14 is a view showing a construction somewhat modified from Figure 13 and showing a diagram of the electrical connections applicable to both.

Figure 15 is a view partly in elevation and partly in section showing a front caliper applied to internal work.

Figure 16 is an end elevation of the same.

Figure 17 is a fragmentary view partly broken away of a part of the machine of Figures 15 and 16.

Figure 18 is a fragmentary section on line 18—18 of Figure 17.

Figure 19 is a detail section on line 19—19 of Figure 15.

Figure 20 is an elevation of the caliper-retracting mechanism.

Figure 21 is a view similar to a portion of Figure 15 but showing a different electrical responsive element.

Figure 22 is a fragmentary wiring diagram showing a different form of responsive mechanism which may be used in place of portions of Figure 11.

Referring first to Figure 2, at 1 is shown a work support which may be a portion of a rotary work spindle as therein illustrated. This support is shown as provided with a counterbored portion 2 at its outer end within which may be placed the work W, which is of ring form. The work may be secured in this counterbored portion for rotation with the support and spindle as by means of the screw 3, the head of which bears against the outer face of the work. At 5 is shown the grinding wheel spindle having a grinding wheel 6 at its end which is intended to work upon the interior of the work ring W and to grind this to a predetermined diameter. Within the support 1 is positioned a carrier 10 which is shown as axially movable within the support. This carrier is provided with an enlarged internal chamber 11 at its outer end across which is placed a diaphragm 12, this being secured in position about its margin by a ring member 13 threaded into the outer end of the chamber 11. This diaphragm 12 supports a stem 14 which extends substantially centrally therethrough and which carries on its outer end a work feeler 15, which preferably is provided with a suitable diamond point 16 which may be brought into engagement with the internal face of the work. The diaphragm 12 forms a yielding mounting member for the stem and feeler which yieldingly presses the point 16 outwardly into engagement with the internal face of the work so that as the work is ground away the inner end of the stem 11 moves laterally of the carrier 10 and in between a pair of cores 17 and 18 of a pair of electromagnet coils 19 and 20. The stem portion 14 between these cores 17 and 18 is of a magnetic material, such as iron, so that the distance between the stem and the cores act to vary the relative reluctances of the coils to the passage of an alternating current therethrough, swinging of the stem as the work reaches size acting to progressively decreases the reluctance of the coil 20 and increase the reluctance of the coil 19. As will later be pointed out, this provides a delicate electric indication of the size of the hole in the work, which through any suitable responsive device may be employed to indicate work size and if desired

also to effect withdrawal of the grinding wheel from the work when the desired size has been reached.

In Figure 3 a modified construction has been shown in which in place of the single magnet coils 19 and 20, two pairs of such coils are employed, the carrier 10 being of sufficient length to include besides the coils 19 and 20, coils 21 and 22. The stem 14a in this construction is also prolonged to pass between the cores of both pairs of coils. As will later more fully appear, one of these pairs of coils may be used to indicate when the roughing size of the work has been reached and the other pair may be used to indicate when the finished size has been reached.

Cooperating with the feeler finger 15 may be a relatively stationary finger 25, which, in the form shown in Figures 2 and 3, is integral with the diaphragm-retaining ring 13. This single finger acts to prevent the entry of the gage into the work until the hole approaches so near the desired finished size that the indicator may not be injured in passing thereinto. The measuring is thus taken between the carrier and one side of the hole being ground.

In Figure 5 a somewhat modified construction is shown in which the carrier 10 is pivotally connected as on the pin 30 to a sleeve 31 which passes through the work spindle 32, whereas in the construction shown in Figures 2 and 3 the carrier is secured directly to the corresponding sleeve. In the construction shown in Figure 5 also the carrier is somewhat loosely guided within the work support 1, and instead of a single finger such as shown at 25 in Figures 2, 3 and 4, a pair of oppositely positioned fingers 53 are employed to prevent the entry of the gage until the hole is nearly the correct size and the measurement is thus across the diameter of the work between the finger 15 and a relatively stationary finger 52 carried by the ring 13 which may be fixed to or integral with the ring 13 and which may be provided with a work-engaging diamond 26.

In Figure 6 a further modification is shown in which instead of mounting the feeler stem on a diaphragm the feeler 40 shown as of angle shape is secured to the carrier 41 by means of a leaf spring 42. One end of this leaf spring is secured as by screws to one arm of the stem 40 and the other is divided, one portion 43 being fixed to the side face of the carrier in a groove 44 therein and the other being bent inwardly and secured to an end face 45 of this carrier. The inturned arm 46 of the stem passes between the cores 47 and 48 of the electromagnet coils 49 and 50, respectively, these being connected to the responsive mechanism similarly to the electromagnet coils 19 and 20 shown in Figures 2, 3 and 5. In this figure also there is shown provided three relatively stationary work-engaging fingers 52, 53 and 54, the position of these fingers being shown best in Figure 9 and being integral with a portion of the carrier 41, which is recessed to receive threaded therein the electromagnet coil 50. A similar three-finger construction is shown in Figures 5, 6, 8 and 9 and is employed wherever the carrier is pivotally mounted on its stem, the middle finger cooperating with the feeler to measure the diameter of the work and the other fingers preventing entry of the feeler until the work is nearing size as explained with reference to Figure 5.

In Figure 7 a still further modification is shown in which the carrier 60 is rigidly secured to its supporting sleeve similarly to the construction of Figures 2 and 3, and in this form but a single relatively fixed work-engaging finger as at 52 is employed.

In Figure 11 is shown somewhat diagrammatically one form of responsive mechanism which may be employed, this being controlled by the position of the feeler stem to indicate when the correct work size has been reached, or if desired, also, to withdraw the wheel from the work. As illustrated in this figure, two controls, one for roughing size and the other for finishing size, have been shown, this corresponding to the showing of Figure 3 in which there are two sets of controlling electromagnets. It should be understood, however, that when but a single pair of electromagnets are to be employed the mechanism may be simplified accordingly. One or the other of these sets of electromagnets are connected through a switch mechanism 60 in series with solenoids 61 and 62, which are movable relative to magnetic cores 63 and 64, respectively, the circuit receiving alternating current as through a transformer at 65. In the position shown in this figure the electromagnet coils 21 and 22 are in this circuit with the solenoids 61 and 62. When the stem 14a is midway between the cores of the electromagnets 21 and 22 the reluctances of these electromagnets are equal, the current then being evenly balanced between the electromagnets and equally balanced between the solenoids 61 and 62. If, however, the stem 14a is nearer to one of the coils 21 and 22 than to the other, this reluctance varies and there is a proportionate variation in flow through the corresponding solenoids 61 and 62, thus unbalancing their pulling effect on their cores 63 and 64, causing these solenoids to move and swinging the pointer 68 secured to a lever 69 connecting these solenoids in a corresponding direction and to an amount dependent on the amount of the unbalance of current through the two solenoids. When this unbalance has reached a determined point, a contact arm 70 on the pointer 68 makes contact with a contact 71, which may be a mercury cup, which closes a circuit through the relay 72, which in turn, closes a circuit through a solenoid 73. Energization of this solenoid forces its core 74 to the left, as shown in this figure, swinging an arm 75 into the dotted line position shown in this figure, so that a dog 76 carried thereby falls off from a stationery retaining plate 77 and engages the teeth of a feed wheel 78 on the feed shaft 79 and moves this feed wheel backwardly, thus retracting the grinding wheel from the work. A connection by which this may be accomplished is illustrated somewhat diagrammatically in Figure 12 in which the grinding wheel spindle 5 is shown as supported on an arm 80 turnable about the axis of a supporting bar 81. The bar 81 may be moved axially to impart the working traverses to the grinding wheel. The arm 80 has an extension 82 provided with a cam follower 83 against which bears a member 84 carried by a feed screw 85. The gear 78 forms part of a nut 79 engaging this feed screw and by the rotation of this nut the arm 80 through its intermediate connections 82 and 85 is caused to impart feed and retracting motions to the wheel shaft 5, depending on the direction of rotation of the gear 78. Rotation of this gear 78 effected by energization of the solenoid is in a direction to retract the grinding wheel. The normal feed motions of the wheel are shown in Figure 11 as produced by a cam 90 acting on an arm 91 pivoted at 92 and carrying at its free

end a feed dog 93 which may engage the teeth of a gear 78 so that by rocking of the arm 91 this gear 78 is rotated in a reverse direction by that produced by the action of the dog 76. Suitable controlling elements 94 and 95 may be employed to limit the motion of the dog 93 to cause it to produce the desired feed motion.

As soon as the solenoid 73 has been energized and the gear 78 turned to retract the grinding wheel, an abutment 100 carried by the plunger 74 closes the switch 101 and energizes the solenoid 102. This acts through the rack bar 103 to throw the switch 60 through an arc of 180°, breaking connection to the magnet coils 21 and 22 and making connection to the magnet coils 19 and 20, and near the termination of stroke of the core 105 of the solenoid 102, this core breaks the circuit to both of these electromagnet coils 19 and 20 at the switch 106. This interrupts the holding circuit to the relay 72, de-energizing the solenoid 73 and permitting the spring 107 to return the arm 75 to its inoperative position, and this in turn permits the switch 101 to open, de-energizing the solenoid 102, which permits the rack bar 103 to be returned by the spring 108. A suitable ratchet mechanism is shown at 109 permitting this to be done without moving the switch 60. This permits the switch 106 to close, thus re-establishing conditions for control of the mechanism through the size of the work but through the second set of electromagnets 19 and 20. This mechanism each time the desired size is reached causes the wheel to retract from the work and the opposite set of electromagnets is placed into controlling relation with the mechanism. Thus by proper setting of the parts the wheel may be withdrawn from the work first after the work has been reduced to a rough size and then on the next grinding operation the wheel will be retracted when the work has been reduced to the desired finished size. This finished work may then be removed from the machine and a new unground piece placed therein for the next cycle of roughing and then finishing cuts by the grinding wheel.

In Figure 22 is shown a mechanism responsive to variations of impedance in a pair of coils such as 19, 20 or 21, 22 of Figure 11 due to movement of a feeler actuated stem, somewhat different from that shown in Figure 11. The line *a* common to the two opposed electromagnet coils leads through the secondary of an energizing transformer 300 to the mid point of a coil 301 to opposite ends of which are connected the lines *b* and *c* from the magnet coils. So long as the impedances of these magnet coils are equal there is no difference of potential between the ends of the coil 301. As the stem 14*a* is moved by contact with the work nearer to one of these coils and further from the other, the impedances of the two magnet coils become out of balance, and a potential difference is set up between the ends of the coil 301. Lines 302 and 303 lead from these ends to a rectifier of any suitable type at 304, the rectified current due to such potential differences between the ends of the coil 301 passing to the microammeter 305 which indicates the amount of this current and at the proper time closes the contacts at 306 and 307 and closes a circuit to the relay 72 of Figure 11, thus retracting the feed as heretofore described.

Where the caliper mechanism is engaged with the work entering from the back end opposite to that end at which the grinding wheel enters, it is desirable to provide means for withdrawing the sizing mechanism in advance of the wheel so that the wheel may grind the full length of the hole in the work and may not strike the sizing mechanism. To this end a construction such as illustrated in Figure 1 may be employed. Referring to this figure, the bar 81 which carries the wheel-supporting arm 80 is slidably and rockably mounted in the frame 110 of the machine and a suitable adjustable abutment 111 is arranged to be contacted by a suitable portion of this bar, such as the end, when the grinding wheel approaches the inner end of its traversing path. As shown this abutment comprises a screw threaded into an arm 112. This arm is slidably mounted on a suitable guide member 113 and is normally pressed toward the wheel-carrying arm 80 as by means of a coil spring 114 bearing at one end thereon and at its opposite end against a collar 115 secured to the outer end of the guide 113. This arm 112 is provided at its opposite end from the abutment 111 with a forked portion having enlarged ends at 116 which engage within a peripheral groove 117 of a collar 118 fixed to the work spindle 120 which slidably carries the sleeve, as 31, to which is secured the carrier for the work feeler. The three conductors *a*, *b* and *c* leading from the measuring electromagnet coils pass through this sleeve and at the opposite end from the indicator these conductors are secured to slip rings 120, 121 and 122, respectively, on the inner face of a disk 123 either of insulating material or otherwise formed to insulate the slip rings from each other, the disk 123 being secured to the outer end of the carrier sleeve. Normally bearing against these rings are contacts 124, 125 and 126 to which are secured conductors corresponding to *a*, *b* and *c* and which lead to the solenoids 61 and 62. When the grinding wheel approaches the work feeler, therefore, the bar 81 acting through the arm 112 retracts the feeler from the hole in the work and at the same time operatively disconnects the electromagnets carried thereby from the control circuit, thus to render the feeler finger inoperative to effect the indication of the pointer 68, or to operate the tool-withdrawing mechanism. For simplification in the diagram of Figure 11 this mechanism for breaking the control circuit has not been shown thereon.

Instead of employing electromagnet coils and solenoids and the variations in impedance of their windings by variations of position of the feeler stem with relation thereto, other electrical devices may be employed, preferably of non-contacting type, that is, those which do not require the making or breaking of electric circuits for operation but rely on varying electrical characteristics of the circuit produced by the position of the work feeler. For example, as shown in Figures 13 and 14, the device directly responsive to the feeler position may comprise a pair of spaced electro-conducting plates forming portions of an electrical condenser. In Figure 13, for example, the feeler is shown at 150 pivotally secured by the spring 151 to the carrier 152, which is slidably guided in the work support 1. The inwardly turned end 153 of the feeler acts through an adjustable abutment screw 154 on the axially slidable stem 155 mounted in the carrier 152. At its rear end this stem carries the movable condenser plate 156 which cooperates with a stationary annular condenser plate 157. Conductors 160 and 161 lead from these spaced plates through the carrier supporting sleeve.

In Figure 14 the construction is very similar

to Figure 13, except that the carrier 165 is pivotally supported at 166 on its supporting sleeve and the carrier is also provided with three relatively stationary work-engaging elements, two of which are shown at 167 and 168, in this respect being similar to the construction shown in Figures 5, 6, 8 and 9, respectively. As shown in Figure 14, the conductors 160 and 161 are connected in series with an inductance 170 and a radio frequency ammeter indicated diagrammatically at 171. This circuit, through the inductance 170, is excited by an oscillator indicated generally at 172, which, as shown, is provided with a coil 173 in inductive relation to the coil 170 of the measuring circuit. The natural frequency of the oscillator 172 is so related to the frequency of the measuring circuit as determined by the relative values of capacity between the measuring plates 156 and 157 and the inductances of this circuit so that as the plates approach each other or separate, as through the action of the spring 175 acting on the stem 155, the natural frequency of the measuring circuit approaches or departs from that of the oscillator. This causes the current induced in the measuring circuit by the oscillator circuit to increase or decrease, depending on the adjustment of the apparatus, resulting in the swinging of the ammeter arm 180 in a direction to make a connection between the contact 181 and the mercury cup 182 when the desired work size is reached, this closing a circuit through the relay 182 which actuates any suitable mechanism such as the wheel feed retractive mechanism shown in Figure 11, or other suitable means which may indicate to the operator that the correct size has been reached.

In some cases it may be desirable to cause the indicator mechanism to approach the work from the front, that is, from the side at which the grinding wheel enters the work. Where this is desired mechanism, such as is shown in Figures 15 to 22, may be employed. Referring to these figures, the work feeler as shown comprises an L-shaped element 200 which is secured through a suitable holder 201 to one end of the stem 202. This stem is slidably mounted in the tubular carrier 203 and as shown may be supported by a pair of suitably spaced diaphragms 204 adjacent to opposite ends of the carrier similarly to the diaphragm shown at 12 in Figures 2 and 3. This carrier 203 is shown as mounted in a split sleeve 210 which is secured to one end of a rock shaft 211. This rock shaft is journaled in a casing 212 having flanges 213 by which it may be secured as by the screws 214 to a web 215 which forms a portion of the grinding machine frame. The rock shaft 211 is designed to be rocked through an angle of approximately 45°. At one limit of its position the feeler is presented into engaging relation with the work as shown in full lines in Figure 15. By rocking this shaft 211, however, it may be turned to the dotted line position shown in Figure 15, or further, if desired, in order to remove it from the front of the work and out of the way.

In order to accomplish such angular motion of the shaft 211 it is shown as having secured thereto a gear 220 within the casing 212 and with which meshes a pinion 221 on a stub shaft 222 also carried by the casing 212. Fixed to rotate with the pinion 221 is a gear 223 with which meshes a pinion 224 on the armature shaft 225 of a reversible electric motor 226 by the action of which the rock shaft 211 supporting the carrier 203 may be rocked to and from operative position. Its limit of motion toward its operative position may be determined by an adjustable abutment screw 230 carried by a boss 231 projecting from the casing 212 with which may contact a boss or pad 232 on the member 210.

Besides the swinging motion of the sizing indicator from and to operative position it may be desired to hold the feeler point away from contact with the work when it is in operative angular relation thereto. Where this is desired the construction shown in Figures 15, 16, 17 and 18 may be employed. Normally in engagement with the end of an extension piece 2020 of the stem 202 is a rod 241 mounted for axial movement and carrying a stem or finger portion 242 of iron or other magnetic material which is arranged between the electromagnets 243 and 244. These electromagnets may be arranged in a suitable responsive circuit similarly to the electromagnets 19 and 20 or 21 and 22 shown in the mechanism previously described, so that the position of the feeler under normal conditions determines the indications of a suitable indicator or controls for retracting the wheel from the work when the desired size has been reached. A spring 245 may be employed to press the rod 241 into contact with the stem extension 2020, the limit of this motion being determined by engagement of the member 242 against the core of the electromagnet 243. Extending transversely of the carrier 203 is a cam rock shaft 250, which as shown best in Figure 17, is cut away to form a cam shoulder 252 which may engage the shoulder portion 240 of the piece 2020, so that by rocking this shaft 250 the stem 202 may be pushed axially away from the rod 241 and against the action of the spring 254 surrounding the stem 202 adjacent to its opposite end. This rocking of the cam shaft 250 to effect such separation and to retract the feeler 200 from the work may be actuated by a crank arm 260 secured to one end of the cam shaft 250 and having its outer end connected through a link 261 (see Figure 16) with a solenoid core or plunger 264 which passes within the solenoid at 265. By energizing this solenoid the plunger 264 is drawn therein, this acting to rock the cam shaft 250 and move the feeler 200 away from the work although the carrier may be in operative angular relation thereto.

Instead of employing the electromagnets 243 and 244, as shown in Figure 15, relatively movable condenser plates may be employed, as in the mechanism shown diagrammatically in Figure 14. Such a construction is shown in Figure 21, where the movable condenser plate 270 is secured to the feeler stem 202 and the fixed plate 271 is secured to the carrier 203. In the form shown in this figure there is no provision for separating the feeler from the work while its carrier is in operative angular operative relation thereto, but it is evident that an arrangement similar to that shown in Figures 15, 16, 17 and 18 might be employed if desired.

From the foregoing description of certain embodiments of this invention, it should be evident to those skilled in the art that various changes and modifications might be made without departing from the spirit or scope of this invention as defined by the appended claims.

We claim:

1. In combination with a tool, a work holder, and means for relatively feeding and retracting said tool and work holder, of a work-engaging feeler, a relatively movable element responsive in position to the position of said feeler when said

feeler is in engagement with the work, a pair of relatively fixed means arranged in spaced relation and coacting with said movable element, and electrical means responsive to the relative positions of said movable element and one or the other of said fixed means for indicating when the work has been reduced to a desired rough or finished dimension, mechanism for making operative connection to one only of said fixed means at a time, and means for operating said mechanism to cause said fixed means to be alternately effective with said movable element.

2. In combination with a tool, a work holder, and means for relatively feeding and retracting said tool and work holder, of a work-engaging feeler, a relatively movable element responsive in position to the position of said feeler when said feeler is in engagement with the work, a pair of relatively fixed means arranged in spaced relation and coacting with said movable element, and electrical means responsive to the relative positions of said relative movable element and one or the other of said fixed means for retracting said tool relative to the work when the work has been reduced to a desired rough or finished dimension, and means for causing said fixed means to be alternately effective with said movable element.

3. In combination with a tool, a work holder, and means for relatively feeding and retracting said tool and work holder, of a work-engaging feeler, a relatively movable element responsive in position to the position of said feeler when said feeler is in engagement with the work, two pairs of relatively fixed elements, the elements of each pair being arranged in spaced relation to said movable element, and electrical means responsive to the spacing of said movable elements relative to the fixed elements of one or the other of said pair for indicating when the work has been reduced to a desired rough or finished dimension, mechanism for making operative connection to the fixed elements of one pair only at a time, and means for operating said mechanism to cause the two pairs of fixed elements to be alternately effective with said movable element.

4. In combination with a tool, a work holder, and means for relatively feeding and retracting said tool and work holder, of a work-engaging feeler, a relatively movable element responsive in position to the position of said feeler when said feeler is in engagement with the work, two pairs of relatively fixed elements, the elements of each pair being arranged in spaced relation to said movable element, and electrical means responsive to the spacing of said movable element relative to one or the other of said pair of fixed elements for retracting said tool relative to the work when the work has been reduced to a desired rough or finished dimension, and means for causing said two pairs of fixed elements to be alternately effective with said movable element.

5. In combination with a tool, a rotary work holder for tubular work, and means for effecting relative feed and retraction between said tool and work on said holder, of a feeler engageable with the inner wall of the work and rotatable with said holder, a plate rotatable with said work holder, a plate operatively related to said feeler to be moved thereby toward and from said rotatable plate with the movements of said feeler due to dimensional changes of the work, and means responsive to electrical capacity between said plates for indicating when the work has been reduced to a predetermined dimension.

6. In combination with a tool, a rotary work holder for tubular work, and means for effecting relative feed and retraction between said tool and work on said holder, of a feeler engageable with the inner wall of the work and rotatable with said holder, a plate rotatable with said work holder, a plate operatively related to said feeler to be moved thereby toward and from said rotatable plate with the movements of said feeler due to dimensional changes of the work, and means responsive to electrical capacity between said plates for relatively retracting said tool and work when the work has been reduced to a predetermined dimension.

7. In combination, a carrier having an opening, a diaphragm extending across said opening, a member supported by said diaphragm for movement relative to said carrier, a work feeler associated with said member to move the same in accordance with the position of a work surface with which said feeler may engage, and a device responsive to the position of said member.

8. In combination, a carrier, a spring plate having a portion secured to said carrier, an element having a work feeler secured to another portion of said spring plate to be movable with respect to said carrier, a part rigid with respect to said element, and a device responsive to the position of said part with respect to said carrier.

9. In combination, a tubular work support, means for holding hollow work to said support, a carrier movable in said work support from and toward the work, an element fixed to said carrier for engagement with an inner face of the work, a work feeler movably carried by said carrier for engagement with the work remote from the engagement therewith of said fixed element, and a device responsive to the position of said movable element with respect to said carrier.

10. In combination, a tubular work support, means for holding tubular work in substantially axial alinement with said support, a member movable axially of said support, a carrier pivoted to said member and having an element fixed thereto for engagement with the inner face of the work, a feeler element normally carried by said carrier for engagement with the work spaced from engagement therewith of said fixed element, and a device responsive to the relative positions of said movable element and said carrier.

11. In combination, a tubular work support, means for supporting hollow work in one end portion of said support, a wheel carrier movable relative to said work support axially thereof, a grinding wheel on said carrier for traversing the inner face of said work as said work support and carrier are being moved, a work calipering device within said work support and movable to enter the work from the opposite end to said wheel, said device having a movable work feeler and electrical means responsive to the position of said feeler, one or more conductors extending from said electrical means through said work support, a responsive device in electrical connection through said conductors with said electrical means when said device is in calipering relation to the work, and means actuated by the relative movement of said support and carrier to withdraw said device from the work and interrupt said electrical connections in advance of the movement of said wheel through the work.

12. In combination, a carrier, means for pivotally supporting said carrier, means for swing-

ing said carrier about its pivot, a work feeler movably carried by said carrier to be moved by swinging of said carrier into and out of engaging relation to work, a device carried by said carrier normally responsive to the position of said feeler when in work-engaging relation, means actuable to move said feeler relative to said carrier out of operative relation to the work and out of operative relation to said responsive device, and electrical mechanism for actuating said feeler-moving means.

13. In combination, a carrier, a stem movable axially of said carrier, a work feeler operatively related to said stem to cause motion of said feeler to move said stem, spring means yieldingly pressing said stem in one direction, a responsive device having an axially movable rod against which said stem normally engages, a spring yieldingly pressing said rod toward said stem, and means engageable with the adjacent end of said stem actuable to separate said stem and rod and to move said stem against the action of said spring means.

14. In combination, elements comprising a carrier and a work feeler, a diaphragm secured around its periphery to one of said elements and substantially centrally to the other of said elements, and a device responsive to the position of said work feeler with reference to said carrier.

15. In combination, elements comprising a carrier and a work feeler, a pair of spaced diaphragms each secured around its periphery to one of said elements and substantially centrally to the other of said elements, and a device responsive to the position of said work feeler with reference to said carrier.

16. In combination, a carrier, a diaphragm supported about its margin by said carrier, a work feeler carried by the central portion of said diaphragm, and a device responsive to the position of said feeler with reference to said carrier.

17. In combination, a carrier, a pair of spaced diaphragms each supported about its margin by said carrier, a work feeler carried by the central portion of each diaphragm, and a device responsive to the position of said feeler with reference to said carrier.

18. In combination, a carrier movable in the direction of the axis of hollow work, a work feeler device yieldingly carried by said carrier, and means on said carrier for preventing the entrance of said device into said work until said work has been cut to a predetermined internal diameter.

19. In combination, a carrier movable in the direction of the axis of hollow work, a work feeler yieldingly carried by said carrier, and a part carried by said carrier in position to strike on the end of the work until the work has been cut to a predetermined diameter thus to prevent the entrance of said feeler into said work until such predetermined diameter has been reached.

20. In combination, a tool, a work holder, a rotary spindle carrying said work holder, a feeler carried by said spindle for engagement with work carried by said holder, a device carried by said spindle in proximity to a portion of said feeler, and means responsive to the relative positions of said feeler portion and device for indicating when the work has been cut by said tool to a predetermined size.

21. In combination, a tool, a work holder, a rotary spindle carrying said work holder, a feeler carried by said spindle for engagement with work carried by said holder, a device carried by said spindle in proximity to a portion of said feeler, and means responsive to the relative positions of said feeler portion and device for separating the tool and the work when the work has been cut by said tool to a predetermined size.

22. In combination, a tool, a work holder, a rotary spindle carrying said work holder, and an electrical condenser of variable capacity rotatable with said spindle, a feeler carried by said spindle for engagement with work carried by said holder and controlling by its position the capacity of said condenser, and means responsive to the capacity of said condenser for indicating when the work has been cut to a predetermined size.

23. In combination, a tool, a work holder, a rotary spindle carrying said work holder, and an electrical condenser of variable capacity rotatable with said spindle, a feeler carried by said spindle for engagement with work carried by said holder and controlling by its position the capacity of said condenser, and means responsive to the capacity of said condenser for separating the tool and work when the work has been cut to a predetermined size.

24. In combination, a tool, a rotary spindle, a holder for supporting tubular work carried by said spindle, a gage mechanism within and movable axially of said spindle, said gage mechanism comprising a feeler for engagement with the inner face of the work and an electrical device responsive to the position of said feeler relative to the axis of said spindle, and means controlled by said device for indicating when the hole in the work has been cut to a predetermined size.

25. In combination, a tool, a rotary spindle, a holder for supporting tubular work carried by said spindle, a gage mechanism within and movable axially of said spindle, said gage mechanism comprising a feeler for engagement with the inner face of the work and an electrical device responsive to the position of said feeler relative to the axis of said spindle, means for effecting traverse between said tool and work on said holder, means controlled by said device for indicating when the hole in the work has been cut to a predetermined size, and means for moving said mechanism axially of said spindle in time with such traverse to prevent contact between said feeler and said tool.

26. In combination, a tool, a rotary spindle, a work holder carried by said spindle, a work gage mechanism movable axially of said spindle, said mechanism comprising a feeler for engagement with the work and an electrical device responsive to the position of said feeler relative to the axis of said spindle, means for effecting traverse of said tool and work, means for moving said mechanism and spindle relatively axially of said spindle to prevent contact between said feeler and said tool, and means controlled by said device.

27. In combination, a tool, a rotary spindle, a work holder carried by said spindle, a gage mechanism rotatable with said spindle, said gage mechanism having a work feeler and an electrical device responsive to the position of said feeler relative to the axis of the work, means supported independently of said spindle and controlled by said electrical device, and electrical connections including slip rings between said device and controlled means.

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