

May 14, 1963

G. C. HUNT

3,089,292

LAPPING MACHINE

Filed April 14, 1961

4 Sheets-Sheet 1

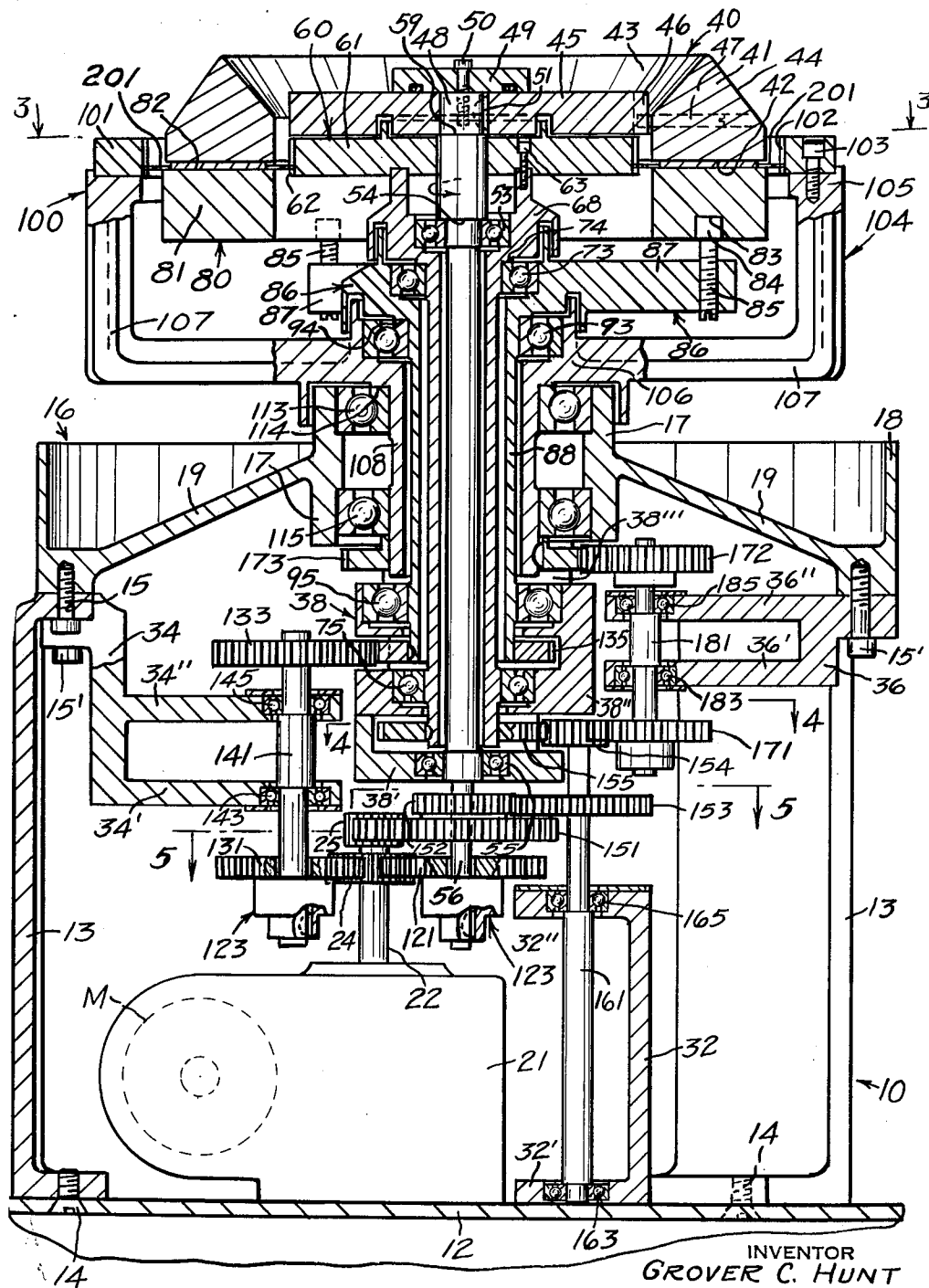


Fig. 1

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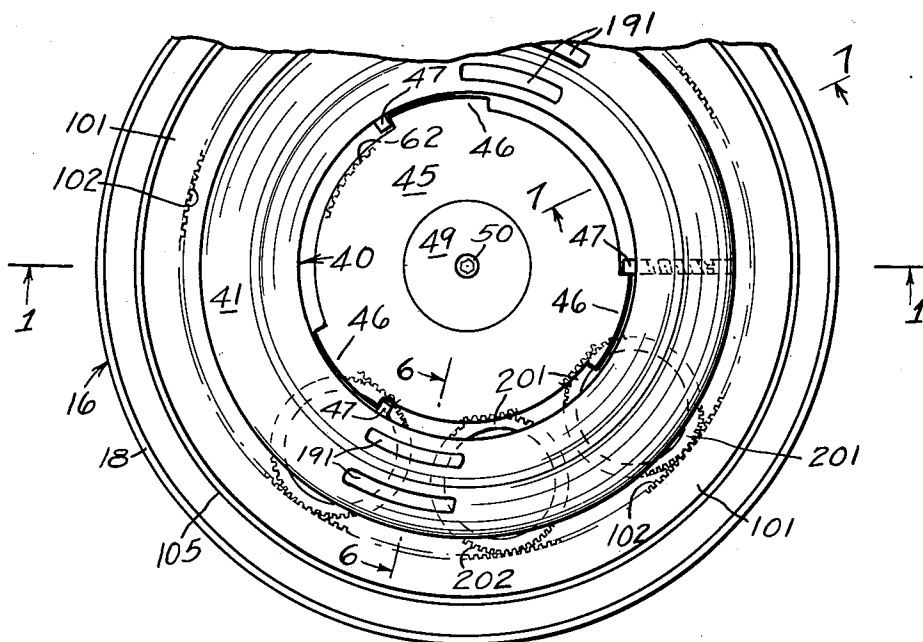


Fig. 2

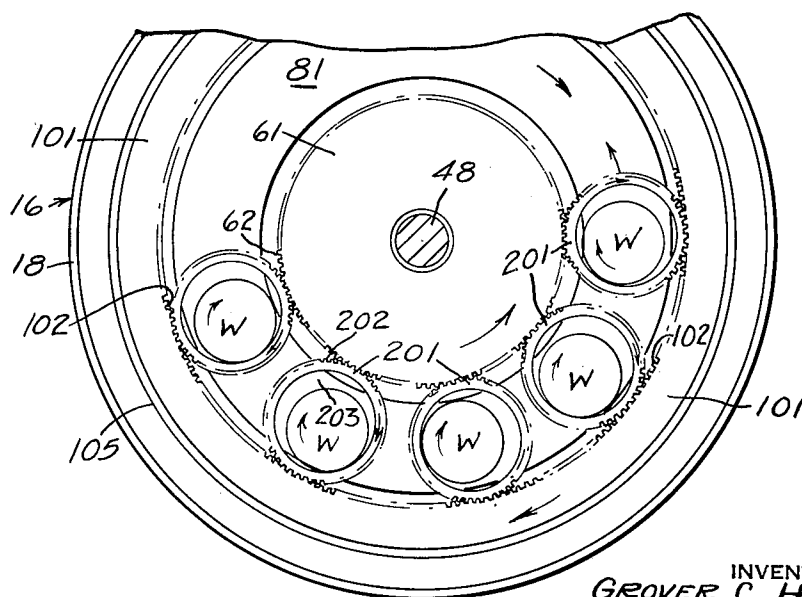


Fig. 3

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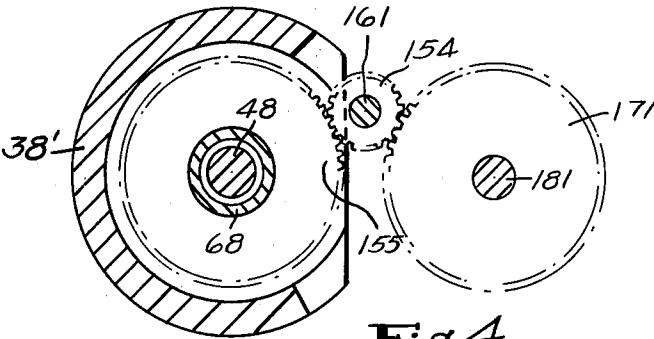


Fig. 4

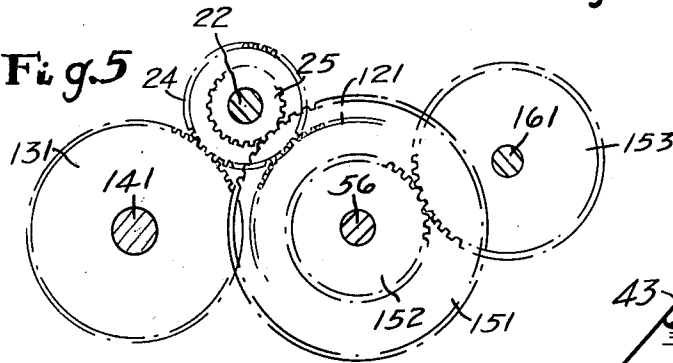


Fig. 5

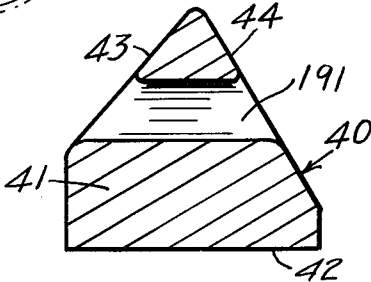


Fig. 6

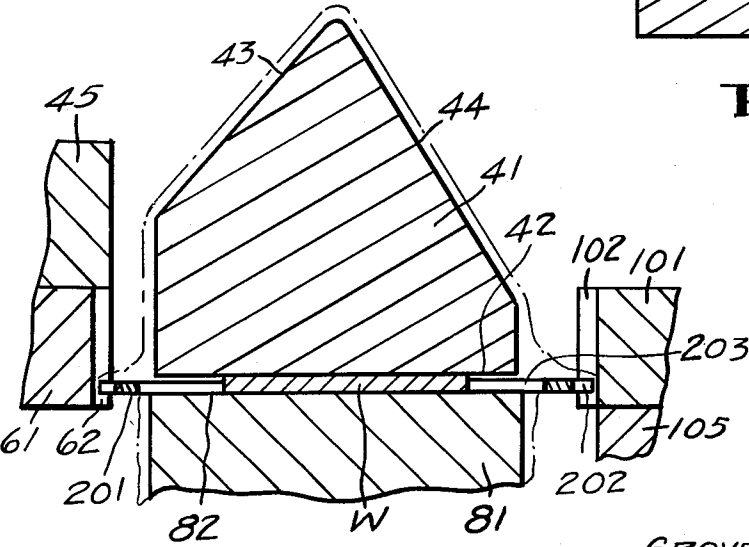


Fig. 7

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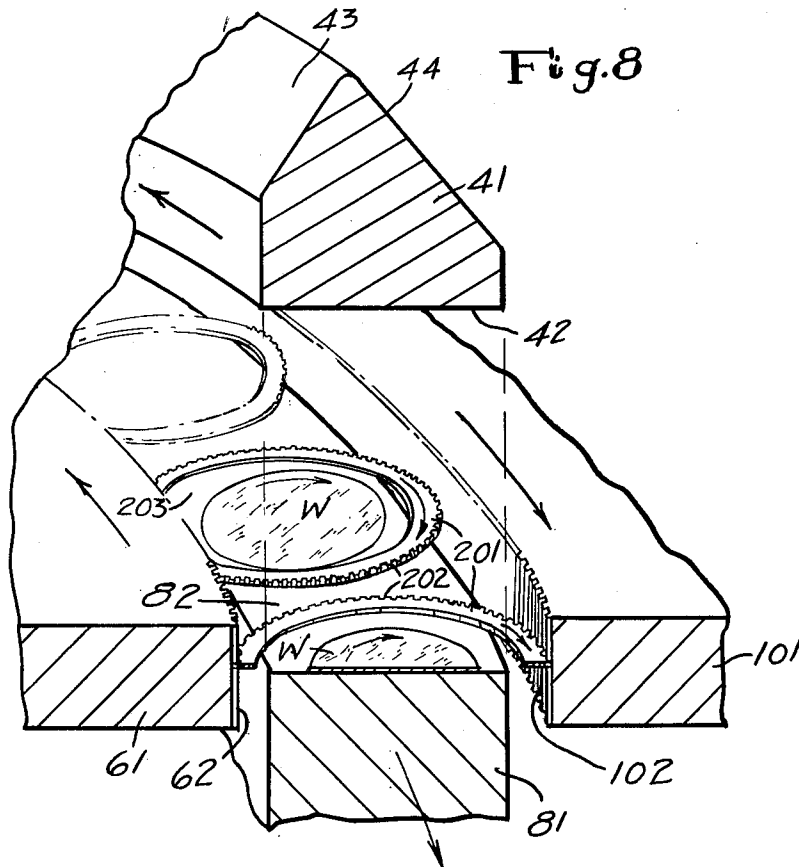
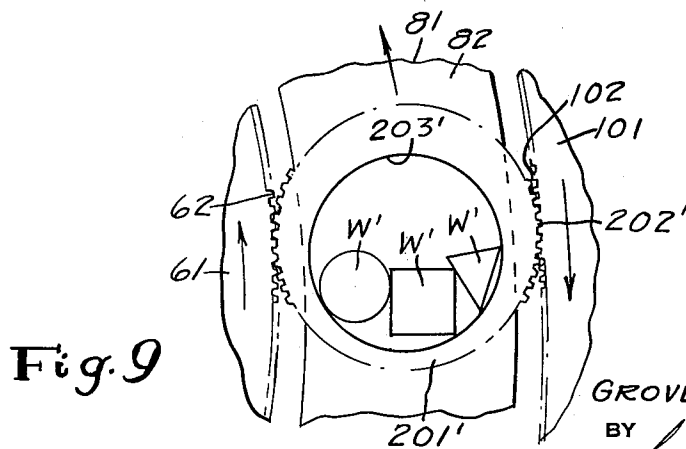
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4 Sheets-Sheet 4



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LAPPING MACHINE

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14 Claims. (Cl. 51-118)

The invention relates to a lapping machine and more particularly to a lapping machine incorporating a pair of opposed annular cast iron laps arranged to finish the opposing surfaces of thin frangible elements supported and displaced by carriers driven by opposing driving elements.

Various arrangements for supporting and driving opposing laps to finish the opposing faces of various types of work pieces are generally well known. However, the difficulties encountered in finishing the opposing surfaces of generally flat work pieces tend to increase as the thickness to which the work pieces are finished is reduced to a few thousandths of an inch. These difficulties are intensified when such work pieces consist of relatively brittle material such as germanium or silicon or the like.

The instant invention contemplates apparatus for lapping thin brittle work pieces to a finished thickness of the order of .003" or less. This apparatus is further characterized by a capability for producing opposing flat surfaces of good quality on such work pieces while maintaining the work piece thickness uniform throughout and by the capability of producing such surfaces more rapidly and without the risk of destroying other work pieces if one work piece should break during the lapping operation.

An object of this invention is the provision of power driven apparatus for lapping a plurality of thin frangible work pieces to close tolerances with respect to surface finish and parallelism of the opposed flat surfaces.

Another object is the provision of driving means for opposed laps and for a plurality of work piece carriers interposed therebetween arranged to produce relative motion of the respective elements such that the risk of fracturing thin frangible work pieces during the lapping operation is minimized, and that the risk of damaging additional work pieces is minimized if one work piece fractures during the lapping operation.

Still another object of this invention is the provision of supporting means for a lower lap arranged to preclude distortion of the lower lap by the supporting means when the lap is mounted thereon, said supporting means being readily adjustable to position the lapping surface of the lower lap in the desired plane.

Yet another object is the provision of an upper lap comprising a unitary annular element having a relatively deep transverse section to render the upper lap rigid and thereby highly resistant to distortion.

A final object is the provision of a plurality of concentrically disposed power transmitting means interconnecting a power source and the respective coaxial rotatable elements of a lapping apparatus.

Other objects and advantages of the instant invention will be apparent from the following description considered in relation to the showing in the accompanying drawings wherein:

FIG. 1 is a vertical section through the preferred embodiment of the instant invention taken substantially on line 1-1 of FIG. 2;

FIG. 2 is a plan view, partially broken away, with the upper lap in place;

FIG. 3 is a plan view, partially broken away, with the upper lap removed;

FIG. 4 is a detailed view of a portion of the gear train substantially on line 4-4 of FIG. 1;

FIG. 5 is a detailed view of a portion of the gear train taken substantially on line 5-5 of FIG. 1;

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FIG. 6 is a vertical section through the upper lap taken on line 6-6 of FIG. 2;

FIG. 7 is a vertical section, partially broken away, through the upper and lower laps shown in operative relation to a carrier encircling a work piece and to the driving elements for the work carrier showing the distribution of a slurry to the work piece;

FIG. 8 is a vertical section in a radial plane through a perspective showing partially broken away showing work piece carriers supported upon the lower lap and operatively engaged by the respective inner and outer driving elements with the upper lap shown displaced vertically from its lapping position; and

FIG. 9 is a detailed plan view partially broken away showing a modified work carrier in operative relation to portions of the respective inner and outer driving elements.

Referring now to the drawings wherein like reference numerals refer to like or corresponding parts, the apparatus comprising the instant invention, as illustrated in FIG. 1, comprises a base assembly generally designated by the reference numeral 10 arranged to support a plurality of relatively rotatable elements together comprising a lapping device, a drive means, and means for transferring power from the drive means to the respective rotating elements. As shown in FIG. 1, the base assembly 10 includes a flat base plate 12 to which a plurality of vertically extending legs 13 may be secured by means of suitable attachment means such as screws 14. The upper ends of the respective legs 13 may be secured adjacent to the periphery of an annular top member generally designated by the numeral 16 by means of suitable attachment means such as machine bolts 15. The annular top member 16 may conveniently consist of a central cylindrical sleeve or hub 17, a cylindrical upstanding outer rim 18, and an annular web 19 extending outwardly from the sleeve 17 and sloped downwardly to join the rim 18 adjacent its lower edge.

A drive motor M coupled to a suitable gear reduction assembly 21 may conveniently be mounted upon the base plate 12 by any suitable attachment means such as screws not shown. The output shaft 22 projecting vertically from the gear reduction assembly 21 is fitted with pinion gears 24 and 25 fixedly secured thereto to be driven by the motor M.

The base assembly additionally includes a first shaft supporting bracket 32 including a lower leg 32' secured to the base plate 12 and an upper leg 32'' generally parallel to and spaced from the lower leg 32'; a second shaft supporting bracket 34 dependent from the top member 16 and secured thereto by at least one machine bolt 15', which includes spaced parallel substantially elongated lower and upper legs 34' and 34''; a third shaft supporting bracket 36 depending from the top member 16 and secured thereto by at least one machine bolt 15, which includes spaced parallel substantially elongated lower and upper legs 36' and 36''; and a generally cylindrical bearing support assembly generally designated by the reference numeral 38 dependent from the central sleeve 17 of the top member 16 and including segments 38', 38'', and 38''' all secured fixedly to the sleeve 17 by through bolts not shown in FIG. 1.

The lapping device includes four major components, an upper lap assembly generally designated by the reference numeral 40, an inner driving element generally designated by the reference numeral 60, a lower lap assembly generally designated by the reference numeral 80 and an outer driving element generally designated by the reference numeral 100.

The upper lap assembly 40 includes an upper lap 41 consisting of an annular cast iron ring provided with a

flat planar uninterrupted lapping surface 42 and having an inwardly sloping upper surface 43 and an outwardly sloping upper surface 44. The upper lap 41 is positioned and driven by a driving plate 45 disposed concentrically of the lap and provided with a plurality of enlarged radially projected segments 46 shaped to be closely but freely interfitted with the annular inner side wall of the lap 41. At least one pin 47 is mounted in the upper lap 41 so that it extends radially inwardly therefrom for engagement with one edge of at least one of the relatively enlarged segments 46 of the driving plate 45. The driving plate 45 is mounted upon the upper end of a shaft 48 with the joint therebetween covered by a cap 49 secured in place by an attachment bolt 50. The driving plate rests upon a shoulder 59 on the shaft 48, and rotation of the driving plate 45 relative to the shaft 48 is precluded by a key 51. A shoulder 54 on the shaft 48 engages the inner race of a thrust bearing assembly 53 and the lower end of the shaft 48 is supported by a bearing assembly 55 located within the bearing support assembly 38. The lower end of the shaft 48 is provided with an extension 56 of reduced diameter arrangement to support a plurality of gears to be described in detail hereinbelow.

While the single pin 47 visible in FIG. 1 satisfies the minimum requirement for driving engagement between the driving plate and the lap 41, the lap 41 may be provided with three pins 47 projecting radially inwardly from the lap 41 for engagement with one edge of each of the three radially projected segments 46 of the driving plate 45, as shown in FIG. 2.

The inner driving element 60 includes a gear 61 provided with peripheral teeth 62 and secured by attachment means such as machine bolts 63 to the upper end of a hollow spindle 68 provided with a shoulder 74 engaging the inner race of a thrust bearing assembly 73 and supported adjacent its lower end by a bearing assembly 75 mounted within the bearing support assembly 38.

The lower lap assembly 80 includes a lower lap 81 consisting of an annular cast iron ring provided with a flat planar uninterrupted lapping surface 82. The lower lap 81 is provided with three equally spaced generally cylindrical recesses 83 to receive the respective heads 84 of three adjustably positioned machine bolts 85 threadably engaged with and projecting from the upper surface of a spider 86 adjacent the respective ends of three equally spaced radially extending legs 87 thereof. A dependent hollow spindle 88, either fixedly secured to or formed integrally with the spider 86, as shown in FIG. 1, is supported adjacent its upper end upon a thrust bearing assembly 93 with its inner race in engagement with a shoulder 94 at the upper end of the spindle 88, and adjacent its lower end by a bearing assembly 95 contained within the bearing support assembly 38.

The outer driving element 100 includes a ring gear 101 provided with internal gear teeth 102 and secured by suitable attachment means such as bolts 103 to the upper rim 105 of a frame member generally designated by the reference numeral 104 including a hub 106 and a plurality of supporting arms 107 each including a horizontal portion extending radially from the hub 106 and a vertical portion extending vertically from the horizontal portion to the rim 105. The frame member 104, either fixedly secured to or formed integrally with a hollow spindle 108 depending therefrom, as shown in FIG. 1, is rotatably supported by a thrust bearing assembly 113 disposed with its inner race in engagement with the shoulder 114 and by the bearing assembly 115.

From consideration of the showing in FIG. 1, it will be evident that the bearing assemblies 113 and 115 supporting the spindle 108 and the frame member 104 and thence the ring gear 101 are in turn supported within the sleeve 17 of the top member 16; that the bearing assemblies 93 and 95 supporting the spindle 88 and the spider 86 and thereby the lower lap 81 are supported by the spindle 108

and the support assembly 38, respectively; that the bearing assemblies 73 and 75 supporting the spindle 68 and thereby the gear 61 are supported by the spindle 88 and the support assembly 38, respectively; and that the bearing assemblies 53 and 55 supporting the shaft 48 and thereby the driving plate 45 for the upper lap 41 are supported by the spindle 68 and the support assembly 38, respectively.

The gear train for driving the upper lap assembly 40 and more particularly the upper lap 41 includes a spur gear 121 mounted rotatably upon the shaft extension 56 and connected to the driving element of a conventional over-running clutch assembly 123 mounted upon the extension 56 with its driven element keyed thereto as shown in FIG. 1. With this gearing arrangement, rotation of the output shaft 22 produces rotation of the pinion gear 24 transmitted to the spur gear 121 and thence through the driving and driven elements of the over-running clutch assembly 123 to the extension 56 to produce rotation of the shaft 48 and the driving plate 45 keyed thereto so that the segment 46 engaging the pin 47 produces rotation of the upper lap 41.

The gear train for driving the lower lap assembly 80 and more particularly the lower lap 81 includes a spur gear 131 rotatably mounted upon a shaft 141 and connected to the driving element of another conventional over-running clutch assembly 123 mounted upon the shaft 141 and having its driven element keyed thereto as shown in FIG. 1. The shaft 141, rotatably supported in a pair of bearing assemblies 143 and 145 respectively mounted in the legs 34' and 34'' of the brackets 34, has a spur gear 133 fixedly secured to its upper end for engagement with a spur gear 135 fixedly secured to the lower end of the spindle 68. With this gearing arrangement, rotation of the pinion gear 24 produced by rotation of the output shaft 22 is transferred to the spur gear 131 and thence through the driving and driven elements of the over-running clutch assembly 123 to the shaft 141 for transmission to the spur gear 133 to rotate the spur gear 135 and the spindle 68 to rotate the lower lap 81 resting upon the heads 84 of the bolts 85 projecting from the legs 87 of the spider 86. An additional showing of the relationship between the pinion gear 24 and the spur gear 131 respectively supported on the output shaft 22 and the shaft 141 is provided in FIG. 5.

The gear train for driving the inner driving element 60 and more particularly the gear 61 includes the pinion gear 25 described above as fixedly secured to the output shaft 22 of the reduction gear assembly 21, coaxially disposed spur gears 151 and 152 inter-connected for rotation as a unit and both rotatably supported upon the extension 56 of the shaft 48. A spur gear 153 fixedly secured to and rotatable with a supporting shaft 161 rotatably supported in bearing assemblies 163 and 165 mounted in the respective legs 32' and 32'' of the bracket 32, a pinion gear 154 also fixedly secured to and rotatable with the shaft 161, and a spur gear 155 fixedly secured to the lower end of the spindle 68, arranged as shown in FIG. 1 so that rotation of the pinion 25 produces rotation of the spindle 68 transmitted to the gear 61 through the attachment bolts 63 securing gear 61 to the spindle 68. The relationship between the pinion gear 25 secured to output shaft 22 and spur gear 151 rotatable on shaft extension 56 is also illustrated in FIG. 5 along with a further showing of the relationship between the spur gear 153 fixedly secured to shaft 161 and spur gear 152 fixedly secured to spur gear 151 and rotatable therewith upon the shaft extension 56.

The gear train for driving the outer driving element 100 and more particularly the ring gear 101 includes all of the elements for driving the inner driving element assembly 60 enumerated above from the pinion 25 through the pinion 154, and additionally includes a spur gear 171 and a spur gear 172 secured to the opposite ends of a shaft 181 rotatably supported in a pair of bearing

assemblies 183 and 185 respectively supported in the legs 36' and 36'' of the bracket 36, and a spur gear 173 fixedly secured to the lower end of spindle 108, so that rotary motion of the pinion 25 transmitted to the pinion 154 is also transmitted through spur gears 171 and 172 to spur gear 173 and thence through the spindle 108 to the frame member 104 to which the ring gear 101 is secured by attachment bolts 103 for rotation therewith. A further showing of the relationship between spur gear 171 fixedly secured to shaft 181, the pinion gear 154 fixedly secured to shaft 161, and spur gear 155 fixedly secured to spindle 68 is provided in FIG. 4.

From consideration of the above descriptions of the respective gear trains, it will be evident that the rate of rotation of each of the four relatively rotatable elements of the lapping device of the instant invention relative to the other three relatively rotatable elements of this device is determined by the design of the particular gear train controlling the rotation of that element, notwithstanding the fact that all of these elements are rotated concurrently in response to rotary motion of a single driving means illustrated in FIG. 1 as an electric motor M.

A plurality of work pieces to be lapped may be supported in a series of carriers 201 shown best in FIG. 3 each provided with peripheral gear teeth 202 for engagement with the external teeth 62 of the driving gear 61 and with the internal teeth 102 of the external driving ring gear 101 so that rotation of the gear 61 and the ring gear 101 in opposite directions produces rotation of the respective work carriers 201 about their respective centers. In addition, the gear trains for the respective driving elements 60 and 100 are so arranged that the respective carriers are advanced slowly along a path concentric to the axis of rotation of the central shaft 48 and the respective spindles concentric thereto. In addition, the respective laps 41 and 81 are driven in opposite directions at substantially the same speed with a small difference of the order of one tooth in the gear trains for the respective laps in order to preclude a cyclic relationship between the rotation of the upper lap and the rotation of the lower lap. The operative relationship between the respective relatively rotatable elements of the lapping device and the work piece carriers as well as the relative movement of these elements and the carriers is best illustrated in FIG. 8.

It is to be understood that the internal configuration of the carriers 201 may be varied as necessary to accommodate different sizes and shapes of work pieces W. For example, the carriers 201 may be provided with a single relatively large concentric opening 203 as shown best in FIGS. 3 and 8 to accommodate an individual relatively large circular work piece. Alternatively, the carriers 201' may be provided with one or more eccentric openings 203' therethrough, one configuration of such carriers being illustrated in FIG. 9. It will be evident that, when the carrier is sufficiently larger than the work piece openings required, there may be two or more such openings through a single carrier, eccentric of and preferably equally spaced about the center of the carrier.

Another advantage inherent in the design of the lapping device characterizing the instant invention is its capability for finishing a plurality of relatively small work pieces W' contained within a single relatively much larger opening through a carrier 201' as illustrated in FIG. 9.

In preparation for the operation of the device comprising the instant invention, the upper lap 41 must be removed from its normal operating position as shown in FIGS. 1 and 2. Since the ring comprising the upper lap 41 is relatively heavy, its removal may be facilitated by providing a pair of hand holds therefor in the form of transverse openings 191 therethrough shown best in FIGS. 2 and 6.

With the upper lap 41 removed, a series of work piece carriers 201 may be inserted between the gear 61 and the ring gear 101 to rest upon the lapping surface 82 of the lower lap 81 at regularly spaced intervals in the manner best illustrated in the sectional view comprising FIG. 3. In this connection, while FIG. 3 is taken through line 3—3 of FIG. 1 for the clearest showing of the relationship between the respective carriers 201 and the driving gear 61, it is to be understood that the carriers can be inserted into this machine without removing the driving plate 45 from the upper end of the shaft 48. After the work piece carriers 201 have been positioned as shown in FIG. 3, the work pieces W may be placed within the respective carriers for the lapping operation.

When the upper lap 41 is replaced, its correct alignment with the shaft 48 is assured by the interaction of the inner edge of the lap 41 with the peripheral surfaces of the respective segments 46 projecting radially from the driving plate 45 and the lap 41 is positioned for rotation by the driving plate 45 when each pin 47 projecting radially inwardly from the lap 41 is disposed against the edge of a segment 46 which will move toward that pin 47 when the motor M is energized.

When the upper lap 41 has been positioned in its proper relationship to the respective work pieces as shown best in FIG. 7, the drive motor M may be energized to produce rotation of the output shaft 22 and thereby rotate the several rotatable elements of the lapping device including the upper lap assembly 40, the inner driving element 60, the lower lap assembly 80, and the outer driving element 100. The relative rotation of these elements as determined by the respective gear trains therefor is continued until the lapping operation is completed.

Throughout the lapping operation, an abrasive slurry consisting of abrasive particles and a suitable liquid vehicle therefor may be supplied to the work pieces being lapped by applying the abrasive slurry either manually as with a brush or automatically by means of a slurry distribution system to the upper sloping surfaces 43 and 44 of the upper lap 41. The manner in which the abrasive slurry is delivered to the work pieces during the lapping operation is best illustrated in FIG. 7 illustrating a flow of the abrasive slurry down the upper sloping surfaces 43 and 44 and thence down the vertical inner and outer side walls of the lap 41 for delivery to the upper surfaces of the respective carriers 201 for delivery to the space between the respective lapping surfaces 42 and 82 as the work piece carriers 201 are rotated therebetween.

The embodiment of the instant invention described above and illustrated in the accompanying drawings is intended to be considered exemplary only rather than limiting, particularly with respect to various structural details which may be modified within the spirit of the instant invention and within the scope of the claims appended hereto.

What is claimed is:

1. Lapping apparatus comprising a base, motor means mounted upon said base arranged to produce rotary motion, a first driving element including an annular portion rotatably supported upon said base for rotation about a predetermined vertical axis, a first lap assembly including driving means provided with an annular portion rotatably supported upon said first driving element for independent rotation about the same predetermined axis and a lower lap means supported and driven thereby, a second driving element including an annular portion rotatably supported by the first lap assembly for independent rotation about the same predetermined axis, a second lap assembly including driving means provided with a portion rotatably supported by said second driving element for independent rotation about the same predetermined axis and an upper lap means driven thereby positioned above and supported by the lower lap means, power transmission means for transmitting rotary motion from said motor means to said upper lap means, power trans-

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mission means for transmitting rotary motion from said motor means to said lower lap means, power transmission means for transmitting rotary motion from said motor means to the second driving element, power transmission means for transmitting rotary motion from said motor means to the first driving element, and a plurality of circular work piece carrier means interposed between said upper and said lower lap means in operative engagement with said first and second driving elements for rotation of the respective circular carrier means concurrently about their respective axes and about the same predetermined axis.

2. Apparatus as described in claim 1, wherein said first lap assembly further includes three symmetrically spaced supporting elements projecting upwardly from and individually adjustable vertically relative to the driving means thereof, and three symmetrically spaced recessed portions in the underside of said lower lap means so disposed as to receive the three symmetrically spaced supporting elements in supporting and driving engagement therewith.

3. Lapping apparatus comprising a base, motor means mounted upon said base arranged to produce rotary motion, an outer driving element including an annular outer driving means and supporting means therefor having an elongated annular portion rotatably supported upon said base for rotation about a predetermined vertical axis, a lap driving means including spaced vertically projecting portions arranged to support and drive an annular lap mounted thereon and an elongated annular portion rotatably supported upon said outer driving element for rotation about the predetermined axis, a lower lap means disposed concentrically of and within said outer driving element supported upon and driven by the lap driving means supported by said outer driving element, an inner driving element including a circular driving means disposed concentrically within and substantially co-planar with said annular outer driving means and supporting means therefor including an elongated annular portion rotatably supported by the lap driving means supporting said lower lap means for rotation about the predetermined axis, a lap driving means including radially projecting portions for positioning and for driving engagement with an upper lap and an elongated portion supported by the inner driving element for rotation about the predetermined axis, an upper lap means in engagement with the driving means therefor positioned above the lower lap means and concentric of the predetermined axis, power transmission means for transmitting rotary motion from said motor means to said upper lap means via the driving means therefor, power transmission means for transmitting rotary motion from the motor means to said lower lap means via the drive means therefor, power transmission means for transmitting rotary motion from the motor means to the inner driving means via the inner driving element, power transmission means for transmitting rotary motion from the motor means to the outer driving means via the outer driving element, a plurality of circular work piece carrier means interposed between said upper and said lower laps in operative engagement with said inner and outer driving means for rotation of the respective circular carrier means concurrently about their respective axes and about the predetermined axis.

4. Apparatus as described in claim 3, wherein said lower lap means is provided with three symmetrically spaced recessed portions in the under-surface thereof, and the spaced projecting portions of the lap driving means for said lower lap means consist of three symmetrically spaced supporting elements individually vertically adjustable and positioned for interfitting engagement with the respective recessed portions of said lower lap means for supporting and driving engagement therewith, whereby said lower lap means may be precisely positioned with its lapping surface in a plane perpendicular to

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the predetermined axis without distortion of said lower lap means.

5. Lapping apparatus comprising a base, variable speed motor means mounted upon said base arranged to produce rotary motion, an outer driving element including an annular outer carrier driving means and supporting means therefor including an annular portion depending therefrom rotatably supported upon said base for rotation about a predetermined vertical axis, a lap driving means for a lower lap means including spaced vertically projecting portions arranged to support and drive an annular lap mounted thereon and an elongated portion dependent therefrom rotatably supported upon said outer driving element for independent rotation about the same predetermined axis, an annular lower lap means disposed concentrically of and within said outer driving element supported upon and driven by the lap driving means supported by said outer driving element, an inner driving element including a circular carrier driving means disposed concentrically within and substantially co-planar with said annular outer driving means and an elongated annular portion dependent therefrom rotatably supported upon the driving means supporting said lower lap means for independent rotation about the same predetermined axis, a lap driving means for an upper lap means including radially projecting portions for positioning and for driving engagement with an upper lap means and an elongated portion dependent therefrom rotatably supported upon the inner driving element for independent rotation about the same predetermined axis, an annular upper lap means in engagement with the driving means therefor positioned above and supported by the lower lap means and concentric of the same predetermined axis, power transmission means for transmitting rotary motion from said motor means to said upper lap means via the dependent portion of the driving means therefor, power transmission means for transmitting rotary motion from and said motor means to said lower lap means via the dependent portion of the driving means therefor, power transmission means for transmitting rotary motion from said motor means to the inner carrier driving means via the dependent portion of the inner driving element, power transmission means for transmitting rotary motion from said motor means to the outer carrier driving means via the dependent portion of the outer driving element, a plurality of circular work piece carrier means interposed between said upper and said lower lap means in operative engagement with said inner and outer carrier driving means for rotation of the respective circular carrier means concurrently about their respective axes and about the same predetermined axis.

6. Lapping apparatus comprising a base, motor means mounted upon said base arranged to produce rotary motion, an outer driving element including an annular driving member and supporting means therefor including an annular portion rotatably supported upon said base for rotation about a predetermined vertical axis, a lap driving means including spaced projecting portions arranged to support and drive a lap mounted thereon and an elongated annular portion rotatably supported within the elongated portion of said outer driving element for independent rotation about the same predetermined axis, a lower lap disposed concentrically of and within said outer driving element supported upon and driven by the lap driving means supported by said outer driving element, an inner driving element including a circular driving member disposed concentrically within and substantially co-planar with said annular driving member and an elongated annular portion rotatably supported within the elongated portion of the driving means supporting said lower lap for independent rotation about the same predetermined axis, a driving means for an upper lap including projecting portions for positioning and for driving engagement with an upper lap and an elongated portion rotatably supported within the elongated portion of the inner driving

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element for independent rotation about the same predetermined axis, an upper lap in engagement with the driving means therefor positioned about the lower lap and concentric of the same predetermined axis, power transmission means for transmitting rotary motion from said motor means to said upper lap via the driving means therefor, power transmission means for transmitting rotary motion from the motor means to said lower lap via the driving means therefor, power transmission means for transmitting rotary motion from the motor means to the inner driving member via the inner driving element, power transmission means for transmitting rotary motion from the motor means to the outer driving member via the outer driving element, a plurality of circular work piece carrier means interposed between said upper and said lower laps in operative engagement with said inner and outer driving elements for rotation of the respective circular carrier means concurrently about their respective axes and about the same predetermined axis, the relationship between the power transmission means for said upper lap and the power transmission means for said lower lap being such that the upper and lower laps are rotated simultaneously in opposite directions about the predetermined axis at substantially the same but not identical relatively high rates, and the differential relationship between the power transmission means for said outer driving member and said inner driving member being such that the carrier means are rotated about their respective axes and about the predetermined axis at relatively very low rates as compared to the rates of rotation of the respective laps.

7. Lapping apparatus comprising an upper lap supported for rotation about a predetermined vertical axis, first lap driving means disposed in operative engagement with said upper lap and including an elongated dependent portion thereof disposed and supported for rotation about the predetermined axis, a first driving element disposed adjacent said upper lap, a first supporting means connected to said first driving element including an elongated annular dependent portion thereof disposed and supported for rotation about the predetermined axis, means supporting said first driving means rotatably upon said first supporting means, a lower lap mounted below said upper lap for rotation about the predetermined axis, a second lap driving means supporting and driving said lower lap by engagement therewith and including an elongated annular dependent portion thereof disposed and supported for rotation about the predetermined axis, means supporting said first supporting means rotatably upon said second driving means, a second driving element disposed adjacent said upper lap and spaced from said first driving element, a second supporting means connected to said second driving element including an elongated annular dependent portion thereof disposed and supported for rotation about the predetermined axis, means supporting said second driving means rotatably upon said second supporting means, a base, means supporting said second supporting means rotatably upon said base, a plurality of generally planar work piece carrier means interposed between said upper lap and said lower lap and positioned in operative engagement with said first and second driving elements, motor means mounted upon said base and connecting means supported upon said base operatively connecting said motor means to said upper lap through said first driving means, to said first driving element through said first supporting means, to said lower lap through said second driving means, and to said second driving element through said second supporting means, whereby rotation of said motor means produces rotation of said upper lap, said lower lap, said first driving element, and said second driving element in predetermined directions at predetermined relative rates.

8. Lapping apparatus comprising an annular upper lap supported for rotation about a fixed predetermined vertical axis, first lap driving means disposed in operative engagement with said upper lap and including an elon-

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gated portion dependent therefrom disposed and supported for rotation about the predetermined axis, a first driving element disposed concentrically of said upper lap, a first supporting means connected to said first driving element including an elongated annular portion dependent therefrom disposed and supported for rotation about the predetermined axis, an annular lower lap mounted beneath and adjacent said upper lap for rotation about the predetermined axis, a second lap driving means supporting and driving said lower lap by engagement therewith and including an elongated annular portion dependent therefrom disposed and supported for rotation about the predetermined axis, a second driving element disposed concentrically of said upper lap, a second supporting means connected to said second driving element including an elongated annular portion dependent therefrom disposed and supported for rotation about the predetermined axis, a base, first bearing means supporting said first driving means upon said first supporting means, second bearing means supporting said first supporting means upon said second driving means, third bearing means supporting said second driving means upon said second supporting means, fourth bearing means supporting said second supporting means upon said base, a plurality of generally planar work piece carrier means interposed between said upper lap and said lower lap and positioned in operative engagement with said first and second driving elements, motor means mounted upon said base and power transmission means supported upon said base operatively connecting said motor means to said upper lap through said first driving means, to said first driving element through said first supporting means, to said lower lap through said second driving means, and to said second driving element through said second supporting means, whereby rotation of said motor means produces rotation of said upper lap, said lower lap, said first driving element, and said second driving element in predetermined directions at predetermined relative rates.

9. Lapping apparatus comprising a base, an upper lap supported for rotation about a fixed predetermined axis, first lap driving means disposed in operative engagement with said upper lap and including an elongated portion disposed and supported for rotation about the predetermined axis, a first driving element disposed adjacent said upper lap and a coaxing lower lap, a first supporting means connected to said first driving element including an elongated annular portion disposed and supported for rotation about the predetermined axis, a lower lap mounted adjacent said upper lap for rotation about the predetermined axis, a second lap driving means supporting and driving said lower lap by engagement therewith and including an elongated annular portion disposed and supported for rotation about the predetermined axis, a second driving element disposed adjacent said upper and lower laps and spaced from said first driving element, a second supporting means connected to said second driving element including an elongated annular portion disposed and supported for rotation about the predetermined axis, first spaced bearing means supporting said first driving means upon said first supporting means, second spaced bearing means supporting said first supporting means upon said second driving means, third spaced bearing means supporting said second driving means upon said second supporting means, fourth spaced bearing means supporting said second supporting means upon said base, a plurality of generally circular work piece carrier means interposed between said upper lap and said lower lap and positioned in operative engagement with said first and second driving elements, motor means mounted upon said base, power transmission means supported upon said base operatively connecting said motor means to said upper lap through said first driving means and to said lower lap through said second driving means so as to rotate said upper and lower laps in opposite directions at substantially the same but not identical rates, and power

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transmission means supported upon said base operatively connecting said motor means to said first driving element through said first supporting means, and to said second driving element through said second supporting means so as to rotate said first and second driving elements in opposite directions at different rates relatively much slower than the rates of rotation of said laps.

10. Lapping apparatus comprising a relatively fixed base, first and second lap assemblies, first and second work carrier driving elements, each lap assembly and each driving element including one of four generally cylindrical depending portions all rotatably supported upon said base for independent rotation about a common vertical axis, and a single drive means operatively connected separately to each of said depending portions so as to produce rotation of each of said lap assemblies and each of said driving elements in a predetermined direction at a predetermined rate, so that a plurality of circular work piece carrier means interposed between said first and said second lap assemblies and in operative engagement with said first and said second driving elements are rotated concurrently about their respective axes and about the common vertical axis.

11. Lapping apparatus comprising a relatively fixed base, upper and lower opposed annular lap assemblies, inner and outer spaced opposed generally coplanar work carrier driving elements, each lap assembly and each driving element including one of four generally cylindrical concentrically disposed depending portions all rotatably supported upon said base for independent rotation about a common vertical axis, a drive means fixedly mounted relative to said base, and first, second, third and fourth power transmission means all operatively coupled to said drive means and each connected to one of said four depending portions to produce rotation of the upper and lower lap assemblies in opposite directions at similar but not identical rates and rotation of the inner and outer driving elements in opposite directions at respective rates such that circular work carriers engaged therebetween are advanced slowly about the common vertical axis as they are rotated about their respective central axes.

12. Lapping apparatus as described in claim 11, wherein said upper lap assembly includes an annular lap member provided on its underside with an uninterrupted annular horizontal lapping surface intersected at at least one

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edge thereof by a vertical surface extending upwardly therefrom, and having at least one truncated conical upper surface intersecting the upper edge of each vertical surface, so that an abrasive slurry deposited at one or more points on each truncated conical upper surface of said annular lap member is distributed over each truncated conical upper surface and the intersecting vertical surface and thence into the space between the respective lap assemblies.

13. Lapping apparatus as described in claim 11, wherein said upper lap assembly includes an annular lap member provided on its underside with an uninterrupted annular horizontal lapping surface intersected at each edge thereof by a vertical surface extending upwardly therefrom, and having an upper surface including truncated conical portions intersecting the upper edge of each vertical surface, so that an abrasive slurry deposited at one or more points on each truncated conical portion of the upper surface of said annular lap member is distributed over each truncated conical portion of the upper surface and the intersecting vertical surface and thence into the space between the respective lap assemblies.

14. In lapping apparatus including a relatively fixed base, and drive means mounted fixedly relative to said base, a lower lap assembly including a lap driving means mounted upon the base for rotation about a fixed predetermined vertical axis and operatively connected to the drive means, three symmetrically spaced lap supporting elements projecting upwardly from and individually adjustable vertically relative to said lap driving means, and a lower lap means having a planar lapping surface and provided with three symmetrically spaced recessed portions in the underside thereof so disposed as to receive said three symmetrically spaced lap supporting elements in supporting and driving engagement therewith, whereby said lower lap means may be precisely positioned by said lap supporting elements with its lapping surface in a selected plane perpendicular to the predetermined vertical axis without distortion of said lower lap means.

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