

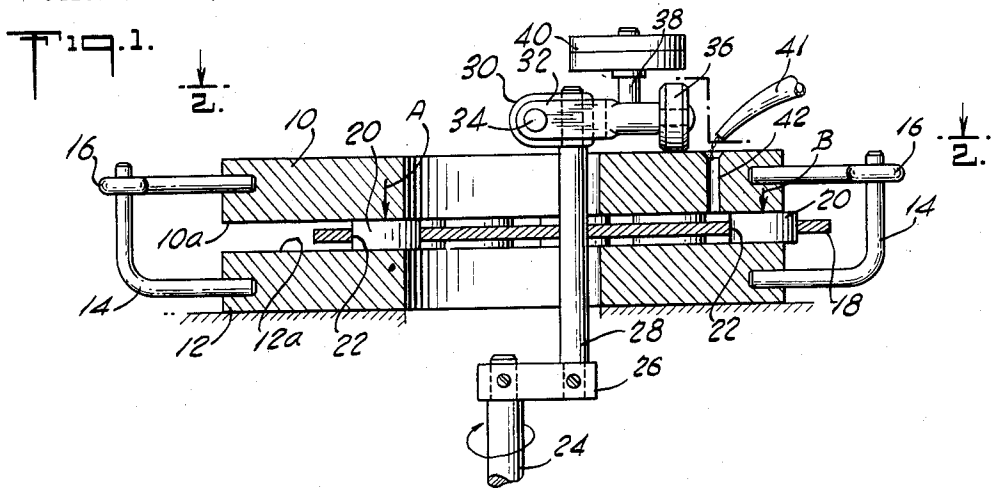
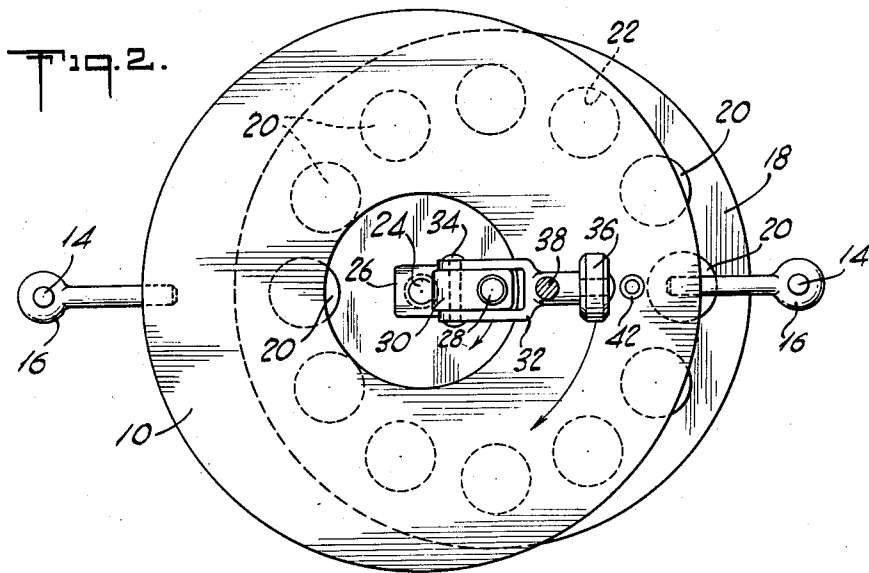
**July 12, 1960**

**M. LIPKINS**  
**LAPPING MACHINE**

**2,944,375**

Filed Oct. 26, 1956

2 Sheets-Sheet 1



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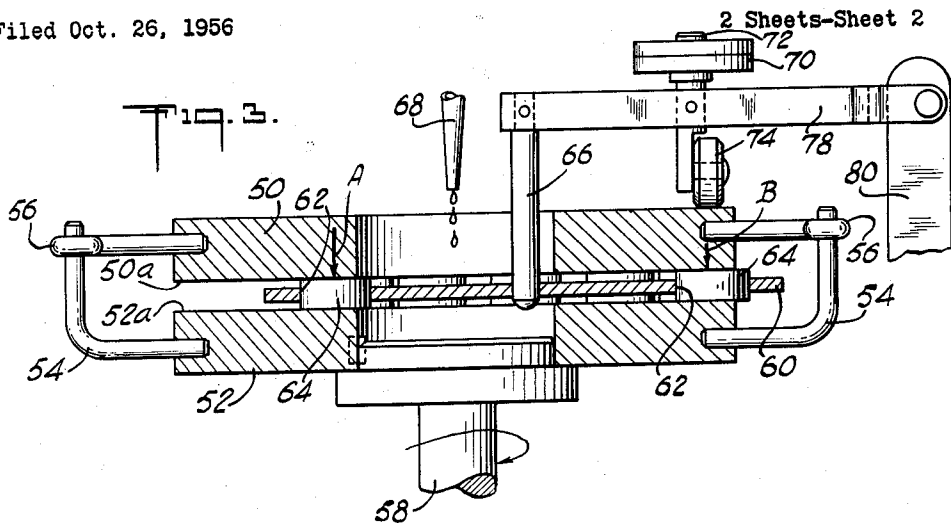
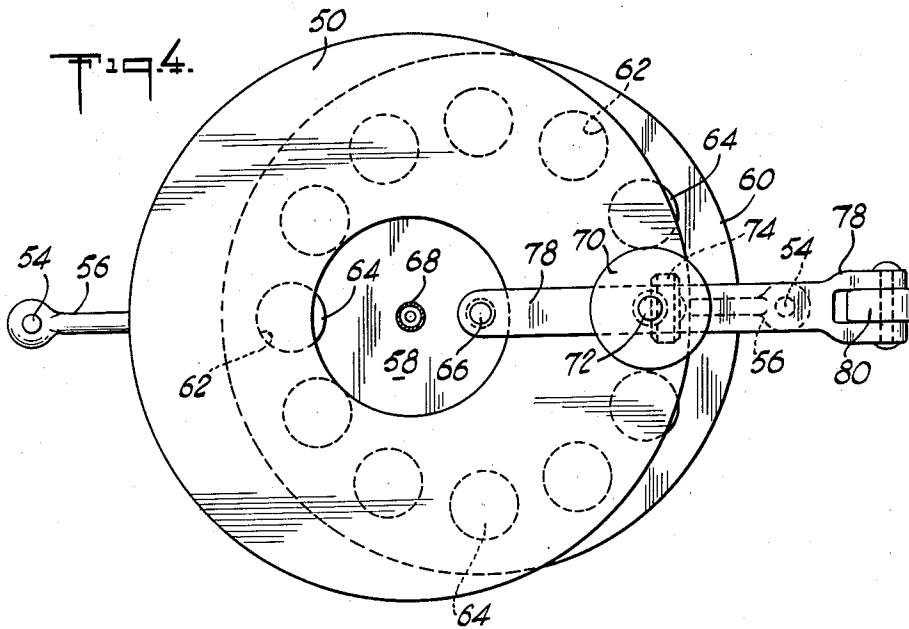
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## LAPPING MACHINE

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17 Claims. (Cl. 51—117)

The present invention relates to apparatus for performing lapping operations and, more particularly, to apparatus for performing lapping operations simultaneously on a plurality of like articles.

Lapping machines commonly include a pair of lapping plates disposed one above the other, and having flat confronting lapping faces in spaced-apart parallel horizontal planes. An article-carrier or so-called "nest" having a series of article-retaining recesses arranged in a circle is disposed between the lapping rings for holding the articles in a pattern and moving the articles between the lapping surfaces. The weight of the top plate is carried by the articles, which develops the lapping pressure at the top and bottom faces of the articles. The center of the article-retaining nest is shifted in an orbit relative to the lapping plates, and the nest is thus caused to translate in the same orbit; and in addition there is imparted a rotation of the nest about its center. The nest is free to assume this rotation. The articles carried by the nest thus move in complex paths between the lapping surfaces. A lapping compound is supplied or an abrasive is imbedded in the lapping surfaces. The top and bottom faces of the articles retained by the nest are progressively lapped to the required degree of parallelism, thickness, flatness and finish.

A serious difficulty in the operation of this well known type of machine results from the action of the lapping compound on the lapping faces in addition to the abrasion of the articles being finished. That is to say, the operation of the machine not only laps the articles being processed, but the compound also acts on the lapping surfaces themselves. The lapping surfaces progressively depart from their initially flat condition and are deformed. Much effort has been devoted to meet the problem of preserving the original substantially flat condition of the lapping surfaces, but so far as I know, this type of lapping machine is commonly regarded as having the inherent characteristic of causing deformation of the lapping surfaces after even moderate periods of operation.

Accordingly, an object of this invention is to improve the foregoing type of lapping machine, by greatly reducing the deformation of the lapping faces incidental to the lapping operation. Expressed otherwise, an object of this invention is to improve such machines, for greatly prolonging the period of operation without requiring shutdown for refacing the lapping surfaces of the lapping plates.

As an approach to the problem, I considered the pressures that are developed between the articles and the plates at different regions through which the articles move in complex paths. At any instant, the articles near the center of the lapping plates have more pressure applied to them and they, in turn, apply more pressure to the lapping plates, than the articles momentarily near the periphery of the lapping plates. When the articles interchange their relative positions later in the lapping operation, the relative amounts of pressure also reverse, as to

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the articles. I found the differences in pressures account for virtually all of the uneven wear of the plates. A further object of the invention, accordingly, is to devise mechanisms for improving the uniformity of pressure applied to each article by the top plate and thereby to the bottom plate as each article moves to its various positions in its complex path, particularly with regard to the extreme positions nearest to and farthest from the center of the lapping plates. This phase of the problem involved special difficulties because of the complex motions traveled by the articles in the known lapping machines.

In achieving the foregoing purposes, I devised ways of applying a supplementary off-center pressure or weight to that part of the top lapping plate which at each instant was applying a relatively light force to the outermost article in the article-carrying nest, constantly shifting the point of application of force in dependence on the travel of each successive article in the series of articles reaching the position farthest from the center of the lapping plates.

Such mechanisms yielded great gain in respect to the useful life of the lapping surfaces in the improved machines. The article holder or "nest" has a rotation relative to the lapping plates in the improved machine (in addition to the orbital motion of the center of the nest). I discovered that this rotation can be controlled by the amount of supplementary force applied to the top lapping plate. With greater or less applied off-center force, it is possible to control the speed and direction of progressive rotation of the article carrier or "nest" relative to the lapping plates and with a critical, empirically determined force, that relative rotation can be arrested. Optimum results are obtained with slow rotation of the nest relative to the lapping plates.

By applying a supplementary force to the top lapping plate in the embodiments of the invention hereinafter described in detail, I am able to greatly extend the useful life of an initially flat lapping surface on each of the lapping plates, before it becomes necessary for its surface to be refinished and corrected. Additionally, I am able to obtain more perfect products by greatly retarding the relatively rapid progressive deformation of the lapping surfaces in known machines.

Certain other objects and features of novelty will be noted in the following description of two illustrative embodiments of the invention shown in the accompanying drawings forming part of the present specification. In the drawings:

Fig. 1 is a vertical cross section of an illustrative embodiment of the invention, and Fig. 2 is a top plan view, partly in section, of the embodiment in Fig. 1;

Fig. 3 is a vertical cross-section of another embodiment of the invention, and Fig. 4 is a top plan view thereof.

Referring now to Fig. 1 there are shown a pair of lapping plates in the form of rings 10 and 12 having lapping surfaces 10a and 12a that are flat, to a close approximation. These lapping rings are stationary, and they are held against relative rotation by a pair of L-shaped arms 14 extending from the lower ring 12 and into a pair of diametrically opposite eyes 16 extending radially from the upper lapping ring 10. An article carrier or so-called "nest" 18 is disposed between the confronting parallel spaced-apart lapping faces of lapping rings 10 and 12, nest 18 acting to hold a series of articles 20 distributed in a circular pattern. The articles 20 are received in recesses 22 formed in nest 18, the center of the nest being off-set from the center of the rings. In Fig. 1, a drive shaft 24 is shown, which is disposed along the common axis of rings 10 and 12. A crank arm 26 carries a shaft 28 that extends through and defines the location of the center of nest 18, and of the center of the circle formed by the series of article-retaining recesses 22.

It is evident from an inspection of Fig. 1, as it has so far been described, that as shaft 24 rotates, it carries shaft 28 in a circular path about the center of rings 10 and 12; and in so doing it shifts each of the article-retaining recesses 22. Each recess 22 moves from an innermost position when it is relatively close to the axis of rings 10 and 12, progressively to an outermost position at its radially extreme separation from the common axis of rings 10 and 12 or, viewed otherwise, at the remote position relative to the center of the orbit. This outermost position may be considered the "projected" position, as a term of reference.

The machine thus far described is of a known form. In operation, the center of the nest moves in a circular orbit, and this carries the articles through a complex path. The nest rotates at a fairly high speed incidental to the orbital shifting of its center. This type of machine suffers from the difficulty that, after a period of operation, the lapping surfaces become deformed or distorted and no longer have their initial, desirable, essentially flat surfaces. When they are no longer flat, the articles being lapped can no longer be expected to emerge from the lapping process with flat parallel faces. It may be significant to note here that the order of dimensions and deviations from flatness involved may be as little as a few millionths of an inch.

It is highly to be desired that the lapping faces should retain their initial configuration for as long a period of lapping time as can reasonably be achieved. In carrying out certain objects of the invention, there has been provided a means for applying a weight to the top lapping ring, as one form of supplementary force additional to the weight of the ring itself, and means is also provided for moving this weight relative to the articles being lapped so as always to be at the side of the lapping ring that is nearest to the outermost article and nearest each successive outermost article during the travel of the nest in its orbit.

Shaft 28 is seen to have a crank arm 30 thereon to which a forked arm 32 is pivoted at 34. At the end of arm 32 remote from pivot 34 there is a roller 36 that bears on the top face of the upper lapping ring 10. A shaft 38 carries a series of weights 40, these weights acting on arm 32 about pivot 34 to apply the supplementary force via roller 36 to a portion of ring 10. This portion is in line radially with the outermost recess 22 of nest 18.

Crank arm 26 shifts the center of nest 18 in a circular path, thereby projecting successive article-retaining recesses 22 to their respective outermost or projected positions relative to the center of the lapping rings. Crank arm 30 and forked arm 32 cause roller 36 to follow along, and at all times roller 36 remains in line with the outermost or projected article as the successive articles assume that position. Roller 36 applies a supplementary force to the upper ring 10 in the region of the outermost or projected article-retaining recess of nest 18, this force being proportional to the amount of weight on shaft 38.

Before devising the supplementary force applying means just described, I was convinced that the unequal wear on the lapping plates was caused by the following circumstances: As seen from Fig. 1, a force is applied by ring 10 to the innermost article 20, due to the weight of the ring, which force may be represented by the long arrow A. The total weight of ring 10 is distributed, but not evenly, among all the articles 20. The force applied to the innermost article is relatively large because that article 20 is relatively near to the center of gravity of ring 10. In contrast to this force A, a force represented by the smaller arrow B is applied by ring 10 to the outermost article 20 at the right in Fig. 1. This force is a relatively small one, because, compared with force A, the portion of ring 10 that bears on the right-hand article 20 is far from the center of mass of the ring.

The weight 40 operates on arm 32 as a lever and applies a force via wheel 36 to the top of the ring 10. This force is not applied directly above the outermost article 20; but it is applied off-center to ring 10, along the same radius where outermost article 20 is disposed. If ring 10 be regarded as very nearly an ideal rigid body, then the force applied by wheel 36 to ring 10 and transmitted to all articles 20 is divided unequally among those articles. The force of wheel 36 is applied in only small measure to the innermost article 20 and the largest share of the force applied by wheel 36 and distributed over the entire series of articles is carried by the outermost (right-hand) article 20. The inequality of force transmitted from wheel 36 to the series of articles 20 in their different positions is designed to compensate to a close approximation for the inequality of the shares of the weight of ring 10 which the articles 20 are caused to support. Ring 10 is designed to be rigid. The analysis is somewhat complicated when it is realized that ring 10 is necessarily not perfectly rigid, recalling the extremely small dimensional variations that are significant here. In any event the addition of the supplementary off-center force-applying means together with means for relatively shifting it continually so as to be opposite the successive outermost or projected articles 20 does yield very great increase in the useful life of a pair of lapping surfaces and, correspondingly, the lapped articles are more nearly perfect with the improved machine.

In operation of the machine, the amount of weight used in applying supplementary force (additional to that applied by the top ring 10) can be varied, and will control the actual rotation of nest 18 in relation to rings 10 and 12, apart from the orbital shifting of the center of nest 18. With a critical amount of weight, the nest rotation can be stopped, leaving only the orbital shifting motion. Best results have been obtained when the amount of weight is adjusted to produce gradual rotation of nest 18.

It would serve the broad purpose of present invention if the roller 36 were disposed directly above the center of the outermost article 20, illustrated at the right of Fig. 2. However, the arrangement as actually shown makes possible a convenient arrangement for feeding a supply of lapping compound or sludge to the articles and to the lapping surfaces, this compound being a fine abrasive carried in a liquid vehicle. A nozzle 41 is shown almost directly above hole 42 in the upper lapping ring or plate 10. Lapping compound drips from nozzle 41 and passes via hole 42 to the nest 18, and is then distributed everywhere in the course of the lapping operation. Additional holes 42 (not shown) may conveniently be disposed about ring 10, at the same or other radial distances from the axis of ring 10 but at different angular positions about that axis, and additional nozzles 41 may be employed. Nozzle 41 and hole 42 are disposed in a position of clearance, so as not to interfere with the circular travel of arm 32 and wheel 36.

A further embodiment of various aspects of the invention is illustrated in Figs. 3 and 4, this embodiment having certain of its own special advantages. In Figs. 3 and 4, a pair of lapping rings 50 and 52 are disposed with the flat confronting lapping surfaces 50a and 52a in spaced-apart parallel planes. Lapping ring 52 is rotated (as will be seen) and lapping rings 50 and 52 are constrained to rotate in unison by virtue of L-shaped arms 54 that extend from lower ring 52 and eyes 56 extending from ring 50, eyes 56 slidably receiving arms 54. Shaft 58 rotatably supports ring 52, and actually rotates rings 50 and 52 during the lapping process. Shaft 58 has its axis in line with the common axes of rings 50 and 52. A nest 60 is disposed between surfaces 50a and 52a, and has a series of article retaining recesses 62 therein which carry a series of articles 64 through various motions between lapping surfaces 50a and 52a during operation of the apparatus. Recesses 62 are distributed in a circle

about a fixed shaft 66, which is displaced laterally from the common axis of rings 50 and 52.

It will be recognized that, as shaft 58 rotates and causes rotation of rings 50 and 52, nest 60 will also rotate about its fixed shaft 66. The rotation of rings 50 and 52 and of nest 60 causes each article-retaining recess to move from the innermost position represented at the left of Fig. 3 to the outermost position represented at the right of Fig. 3, that is, in the same type of combined orbital and rotational path relative to the plates 50 and 52 as was achieved by the different mechanism in Figs. 1 and 2.

The rotation of the system of elements 50, 52 and 60 in Figs. 3 and 4 gives rise to certain important advantages. For example, it is now quite easy to apply a supply of lapping compound by means of a nozzle 68 directed inside ring 50, the compound reaching a spinning portion of nest 60 to be thereby distributed centrifugally all over the nest 60 and the lapping surfaces.

Similar to the condition existing in Fig. 1, it is clear that in Fig. 3 a relatively large force A is applied to the innermost article 64 in contrast to the relatively small force represented by the smaller arrow B and applied to the outermost article 64, at the right of Fig. 3. This is because article 64 at the left of Fig. 3 is considerably nearer to the center of gravity of ring 50 than article 64 at the right of Fig. 3 which is relatively remote from the center of mass of ring 50. Similarly, progressively decreasing forces developed by the weight of ring 50 are applied to the circular series of articles between the innermost article 64 and the outermost article 64 of the circular series.

Using reasoning developed in connection with Fig. 1 a supplementary weight is applied in Fig. 3. Weight 70, carried by shaft 72 and bearing on wheel 74, applies the supplementary force at an off-center portion of lapping ring 50, along the radius through the outermost article 64 of the circular series of articles carried by nest 60. This supplementary force has the effect of compensating for the unequal weight distribution of ring 50 alone, and acts to achieve prolonged life of the lapping surfaces.

Shaft 72 is vertically fixed in an arm 78 that is pivoted to a fixed support 80 disposed at one side of the lapping rings 50 and 52. This arm 78 also provides a fixed support for shaft 66. Arm 78 is formed with a fork at its right-hand extremity so that it resists any tendency that there might be for shafts 66 and 72 to shift, and additional supplementary stiffening structure (not shown) may be provided.

Detailed description of the operation of the apparatus in Figs. 3 and 4 appears to be unnecessary. Briefly, shaft 72 remains stationary and wheel 74 is at all times off center, in the direction of that article 64 which is in the outermost position relative to the axis of lapping rings 50 and 52, regardless of which article 64 assumes that position. This is true whether nest 60 rotates as fast as or at a different rate than this rotary speed of rings 50 and 52. Each of the articles is caused to move in its own complex path so as to be lapped during the rotation of lapping discs 50 and 52. The paths of articles 64 may be almost simple radial strokes relative to the lapping rings, back and forth over the lapping faces, or they may be similar to cycloidal paths relative to the lapping surfaces. The particular path that results is controlled in large measure by the amount of weight employed on shaft 72; and the optimum amount of weight, empirically determined, will produce the longest useful life of the lapping surfaces without requiring corrective resurfacing thereof.

The nature of the invention and its various details will naturally be found subject to a latitude of variation and varied application by those skilled in the art. Consequently, it is appropriate that this invention should be broadly construed in a manner consistent with its full spirit and scope.

What I claim is:

1. In combination, an upper plate and a lower plate having confronting lapping surfaces in spaced-apart horizontal planes, a nest between said lapping surfaces, said nest having means for holding articles to be lapped in a circle extending to opposite sides of the center of said upper plate and at different distances from the periphery thereof, means for effecting relative motion between the nest and the pair of plates such that the center of the nest has relative shifting motion in an orbit, carrying the articles successively to relatively retracted and relatively projected positions, and a supplementary force applying means disposed to act continuously on the upper plate toward the lower plate at the side thereof adjacent to the successively projected portions of the nest.

2. A lapping machine including a lapping ring having a flat lapping surface, a nest having a series of recesses arranged in a circle for retaining articles at distributed positions in engagement with the lapping surface of said ring, means enforcing orbital shifting of the center of the nest in relation to the ring so that certain of the recesses in the nest move inward radially relative to the ring while others move to relatively projected positions radially, said ring being heavy and its weight inherently applying unequal pressures to the articles at their respectively different distances from the center of the ring, and means disposed at a fixed distance from the center of said circle for applying a supplementary pressure to the successively different portions of the ring adjacent the successively radially projected nest recesses during the orbital motion of the nest relative to the lapping ring.

3. A heavy lapping machine including a lapping ring having a flat bottom face, a nest having a series of recesses extending in a circle for retaining articles in distributed positions in engagement with the lower lapping surface of said ring, said circle extending about the center of said ring, means enforcing a relative orbital shifting of the nest relative to the ring so that certain of the recesses in the nest move radially inward relative to the ring while others move to relative radially projected positions, and means for applying a supplementary downward force to a portion of the ring adjacent the radially projected nest recesses during the orbital motion of the nest relative to the lapping ring.

4. In combination a lapping ring having a substantially flat horizontal bottom lapping surface, a nest having a series of recesses for retaining articles, said article-retaining recesses being disposed in a circle about a center, a crank for shifting the nest in a circular orbital path about the center of the lapping ring, and the orbital shifting motion causing certain of the recesses gradually to move from intermediate positions toward radially inward positions relative to the center of the ring while at the same time causing other recesses to move progressively outward relative to the center of the ring, and means rotated with and by said crank for applying a supplementary force to the lapping ring continuously at the side thereof where the outermost article-retaining recesses are shifted.

5. Lapping apparatus including a lapping ring, means for rotating the lapping ring about its center, said lapping ring having a flat-bottom lapping surface disposed horizontally, a nest having a circular series of article-retaining recesses disposed below said lapping ring and with the center of the circle of recesses being offset relative to the center of the ring and the circle of recesses extending about the center of the lapping ring eccentrically thereof, said lapping ring causing said nest to rotate, a fixed bearing for the nest disposed at a position displaced from the center of the lapping ring, whereby the circular series of recesses move progressively from the innermost position relative to the center of the lapping ring to an outermost position, and means for applying an off-center force to said lapping ring at the side thereof nearest said

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outermost article-retaining recess and farthest from the innermost article-retaining recess.

6. A lapping machine including a lapping ring having a central hole and a flat-bottomed lapping surface disposed horizontally, means for rotating said lapping ring about its center, a nest having a circular series of article-retaining recesses disposed below said lapping ring, the center of the series of article-retaining recesses being fixed at a position radially displaced from said center of said lapping ring and the circle of recesses extending about the center of the lapping ring eccentrically thereof, the rotation of the lapping ring in engagement with articles in the article-retaining recesses of the nest causing the nest both to rotate and to shift in an orbit relative to the lapping ring, means for depositing on the nest a supply of lapping compound, and means fixed in position along the line through the centers of the ring and the orbit for applying a supplementary force to said ring, additional to the weight of said ring.

7. A lapping machine including a lapping ring having a central hole and a flat-bottomed lapping surface disposed horizontally, means for rotating said lapping ring about its center, a nest having a circular series of article-retaining recesses disposed below said lapping ring, the center of the series of article-retaining recesses being fixed at a position radially displaced from said center of said lapping ring and the circle of recesses extending about the center of the lapping ring eccentrically thereof, the rotation of the lapping ring in engagement with articles in the article retaining recesses of the nest causing the nest both to rotate and to move relative to the lapping ring in an orbital shifting-path; means for depositing on the nest a supply of lapping compound, and means for applying to the lapping ring a supplementary force at the radial extremity of the lapping ring at the portion thereof which overlies the outermost recess in the article-retaining nest.

8. In combination a pair of coaxial lapping rings having confronting lapping surfaces in spaced-apart horizontal planes, a nest between said lapping surfaces, said nest having means for holding articles to be lapped in a circle, means for moving the center of the nest in an orbit about the center of the plates, carrying the article holding means to relatively protracted and relatively projected positions, and a supplementary force applying means arranged to travel on the upper plate at the side thereof and to remain adjacent to the projected nest recess.

9. In combination a pair of coaxial lapping rings having confronting spaced-apart flat horizontal surfaces, a nest having a series of recesses for retaining articles, said article-retaining recesses being disposed in a circle about a center, a crank for shifting the center of the nest in a circular orbital path about the center of the lapping rings, and the orbital shifting motion causing certain of the recesses gradually to move from intermediate positions toward radially inward positions relative to the center of the rings and at the same time causing other recesses to move progressively outward relative to the center of the rings, and means rotated with and by said crank for applying a supplementary force to the lapping ring at the side thereof where the outermost article-retaining recesses are successively shifted.

10. Lapping apparatus including a pair of coaxial lapping rings, means for rotating both the lapping rings in unison about their center, said lapping rings having spaced-apart confronting lapping surfaces disposed horizontally, a nest having a circular series of article-retaining recesses disposed between said lapping rings and with the center of the circle of recesses being offset relative to the center of the ring and the circle of recesses extending about the center of the lapping ring eccentrically thereof, said lapping rings when in operation causing said nest to rotate, a fixed bearing for the nest disposed at a position displaced from the center of the lapping rings, whereby the recesses move progressively from the innermost positions

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relative to the center of the lapping rings to the outermost position, and progressively return to the innermost position, and means for applying to the top lapping ring a force at the side thereof nearest said outermost article-retaining recess and farthest from the innermost article-retaining recess.

11. The method of lapping articles, including the steps of moving a series of articles in an orbital path between and relative to a pair of lapping surfaces of horizontal upper and lower lapping plates, subjecting the articles to the weight of the upper plate, the articles in the orbital path moving to opposite sides of the upper plate and to different distances from the periphery thereof and being thereby subjected unequally to the weight of the upper lapping plate, and further imposing on the upper plate a supplemental downward force at the side thereof where each successive relatively lightly loaded article is passing.

12. In combination, a pair of lapping plates having confronting lapping surfaces in spaced-apart horizontal planes, a nest between said lapping surfaces, said nest having means for holding articles to be lapped in a circle, means for effecting relative motion between the nest and the pair of plates such that the center of the nest has relative shifting motion in an orbit, carrying the articles successively to relatively retracted and relatively projected positions, and a supplementary force applying means disposed to act continuously at a fixed distance from the center of said circle and on the upper plate toward the lower plate at the side thereof adjacent to the successively projected portions of the nest.

13. A lapping machine including a lapping plate in the form of a ring having a flat lapping surface, a nest having a series of recesses arranged in a circle for retaining articles at distributed positions in engagement with the lapping surface of said ring, means enforcing orbital shifting of the center of the nest in relation to the ring so that certain of the recesses in the nest move inward radially relative to the ring while others move to relatively projected positions radially, said ring being heavy and its weight inherently applying unequal pressures to the articles at their different distances from the center of the ring, and means fixed in relation to the center of said circle for applying a supplementary downward pressure to the successively different portions of the ring adjacent the successively radially projected nest recesses during the orbital motion of the nest relative to the lapping ring.

14. In combination, a pair of lapping members having confronting substantially horizontal lapping surfaces in spaced-apart horizontal planes, a nest between said lapping surfaces, said nest having article confining means formed therein and exposing opposed article surfaces to said lapping surfaces, means for moving the center of the nest in a circular orbit relative to said lapping members while leaving the nest free to rotate relative to said lapping surfaces, and means fixed relative to said center of said circle for applying a constant downward force against the upper lapping member at the portions thereof that are successively opposed to the portions of the nest that successively move to outermost positions relative to said lapping surfaces.

15. A lapping machine having a heavy lapping plate and means for moving a series of articles with respect to said plate, while remaining in lapping engagement therewith, through a path including retracted and projected positions relative to the periphery of said plate, said plate being arranged to rest on said articles and distributing its weight unequally among the articles in dependence on their retracted and projected positions, means for applying a supplementary downward force to said plate effective to compensate approximately for the disparity in the weight distribution of said plate, and means coordinating said supplementary force applying means with said article moving means, said coordinating

means being effective to maintain said force applying means continuously in position required to compensate as aforesaid.

16. The method of lapping articles, including the steps of producing relative movement in an orbital path between the bottom lapping surface of a lapping member and a series of articles in contact therewith, subjecting the articles to the weight of the lapping member, the orbital path of relative movement causing the articles to shift in position to opposite sides of said lapping member and to different distances from the center thereof and the articles being thereby subjected unequally to the weight of the lapping member, and further imposing supplemental downward force on the lapping member at the side thereof where the successive relatively lightly loaded articles pass, for compensating approximately for the disparity of weight distribution of the lapping member against the articles.

17. A lapping machine including a heavy lapping plate having a lower lapping surface, means for maintaining a series of articles in contact with said lower lapping surface, means producing relative movement between said lapping plate and the first-mentioned means, the path

of relative movement including positions of the articles that are relatively retracted and relatively projected with respect to the center of the lapping plate, said plate being arranged to rest on said articles, and said plate distributing its weight unequally among the articles in dependence on their relative retracted and projected positions, means for applying supplementary downward force to said plate arranged to compensate approximately for the disparity in the distribution of the weight of the plate among the articles, and means coordinating the application of supplementary force with said means for producing relative movement, said coordinating means maintaining the application of supplementary force by said applying means in position to effect compensation as aforesaid.

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