

[54] **APPARATUS FOR TREATING A SURFACE**

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51/134

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[58] Field of Search.. 51/133, 134, 120, 3, 53, 56.5,
51/57

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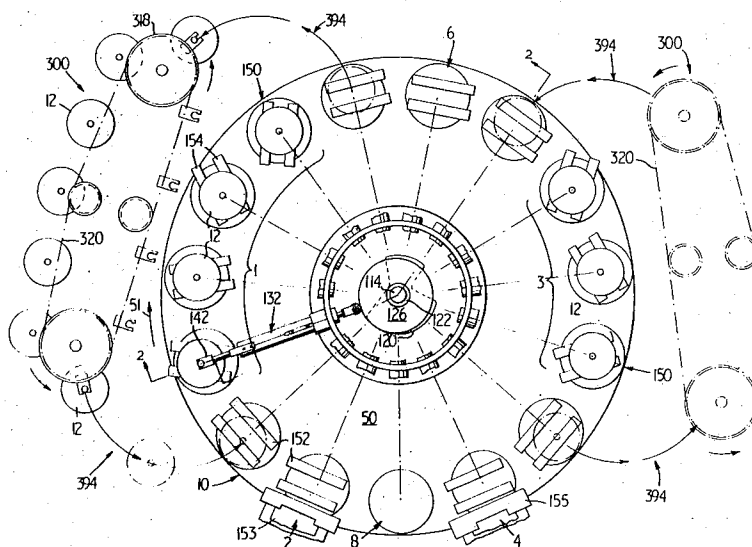
Primary Examiner—Harold D. Whitehead

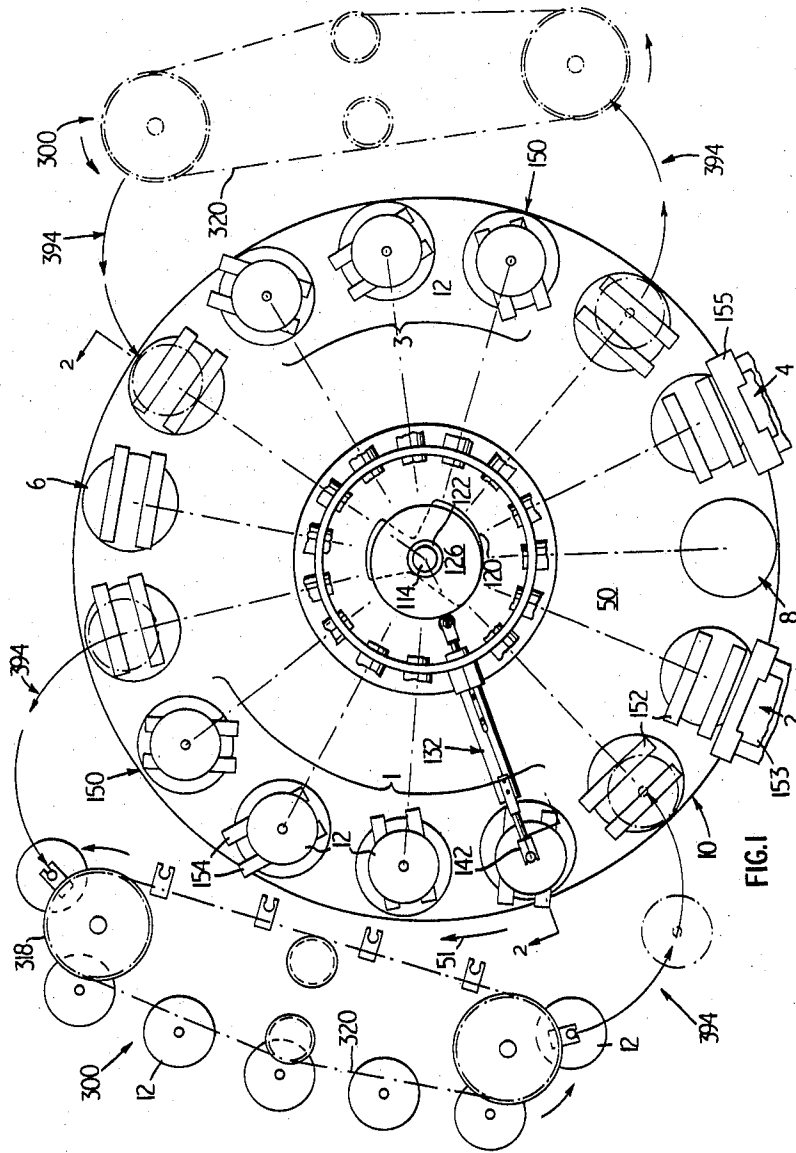
Attorney, Agent, or Firm—Cushman, Darby & Cushman

[57] **ABSTRACT**

An apparatus and process are described for finishing a surface on a workpiece. At least one workpiece is rotatably supported by a chuck assembly provided on a turntable. The turntable can be indexed to advance the workpieces through one or more treatment zones. The workpieces on each chuck assembly are preferably engaged by a corresponding lapping disc that is releasably and floatingly supported by the main turntable. A pushrod assembly is provided for reciprocally moving each lapping disc in a direction radially of the rotatable turntable. This reciprocal movement combines with rotational movement of the lapping disc as derived from the floating mounting and frictional contact with the rotating workpiece, enabling wear of the surfaces in contact to be very uniformly distributed. Extreme smoothness and flatness of the workpiece surface being treated can be obtained. Each zone is provided with a recirculating conveyor for the lapping discs and a transfer mechanism that moves such discs at a predetermined time from one of the chuck assemblies to the recirculating conveyor, and vice versa. The treatment zones are independent of one another. By initial treatment in the first lapping zone followed by final finishing in the second zone, surface flatness can be obtained to within one-half of a lightwave band width of monochromatic light, for example, obtained from a sodium source.

8 Claims, 19 Drawing Figures





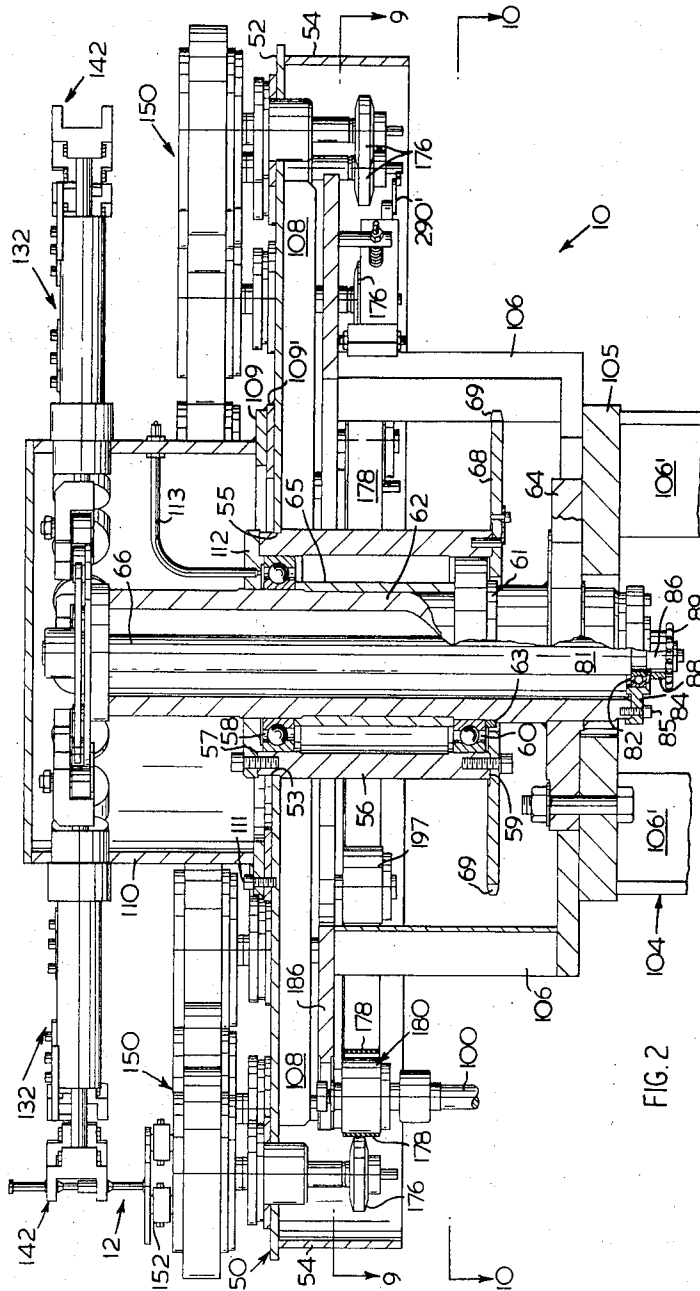
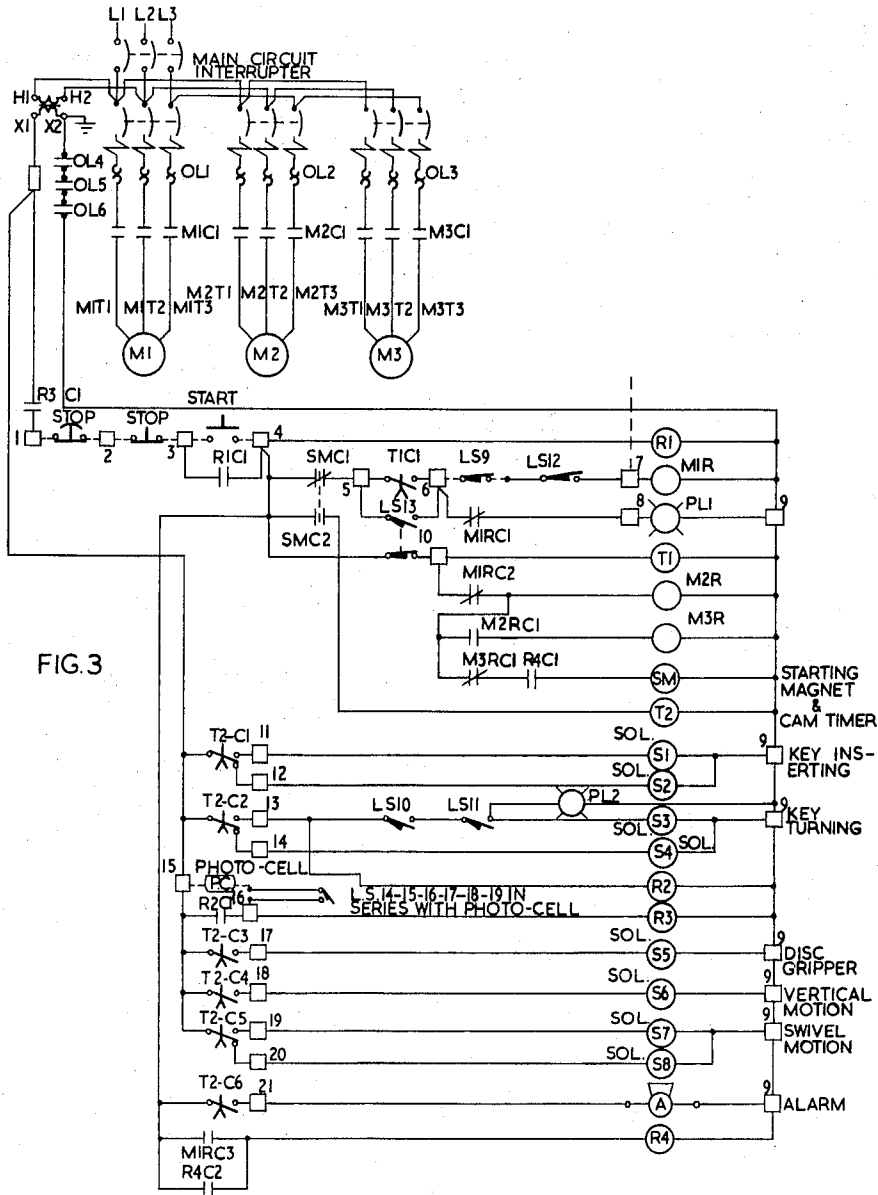


FIG. 2



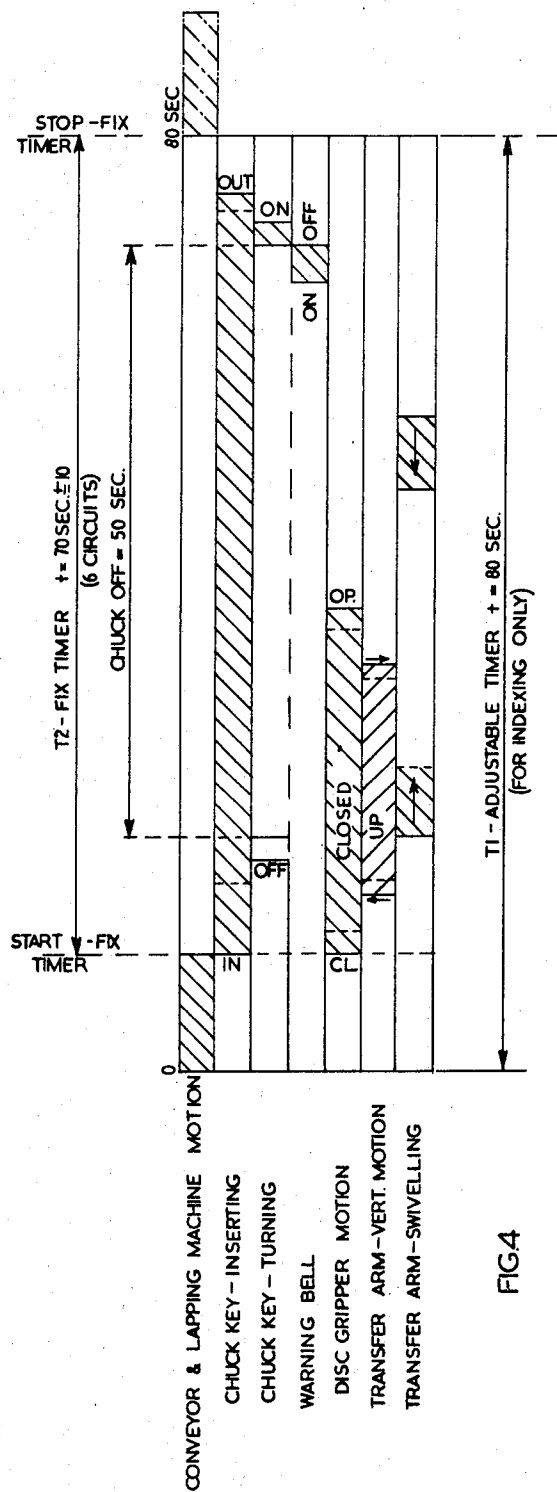
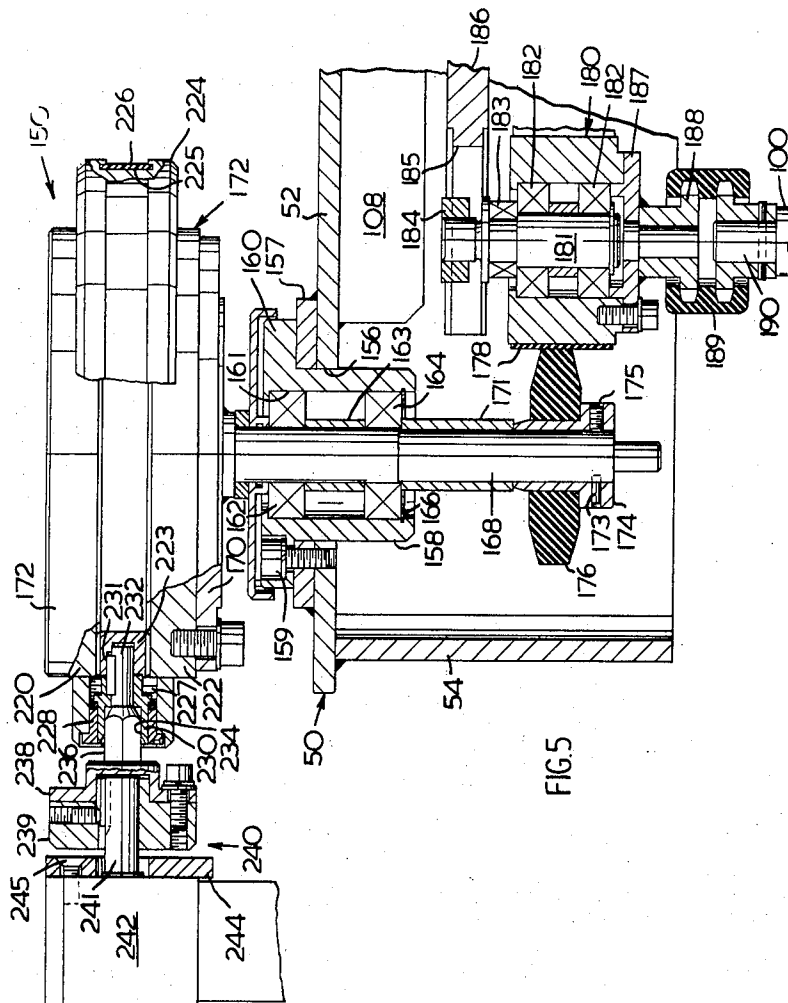


FIG4



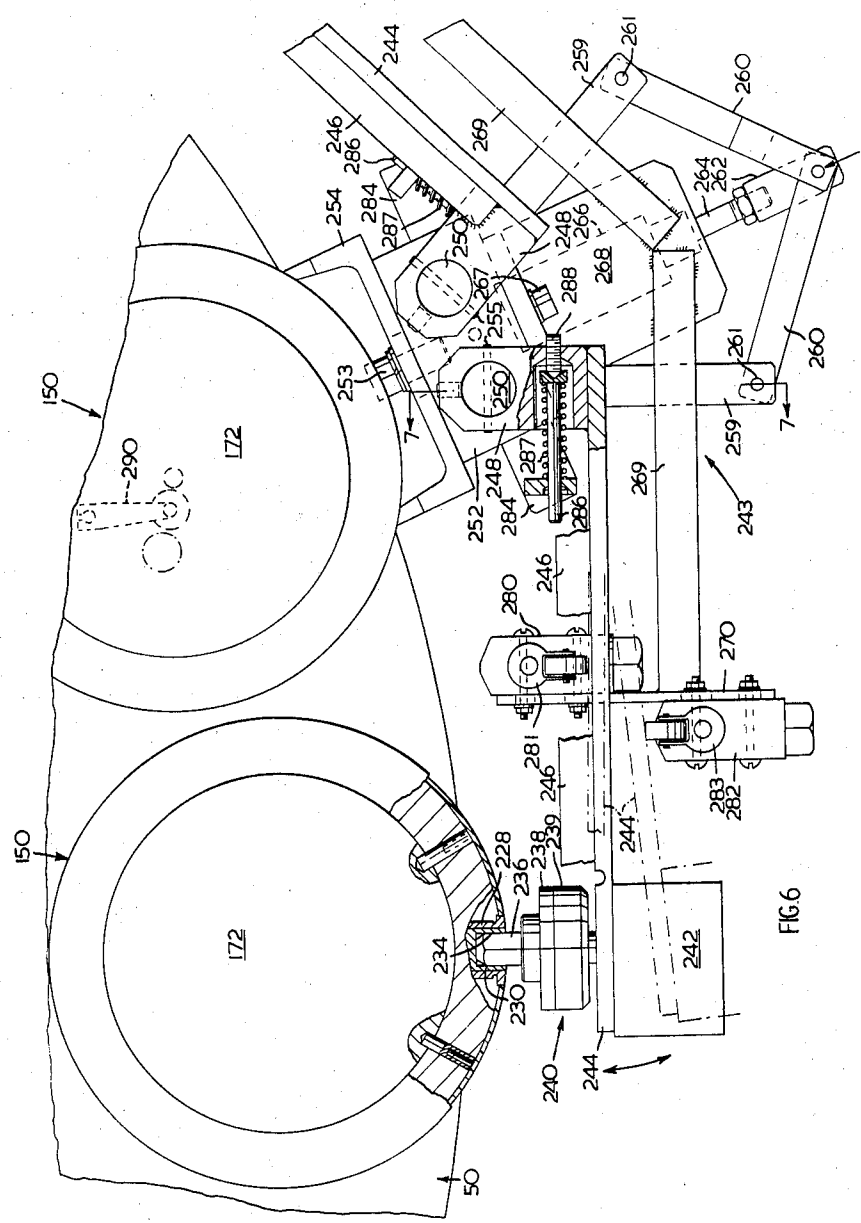
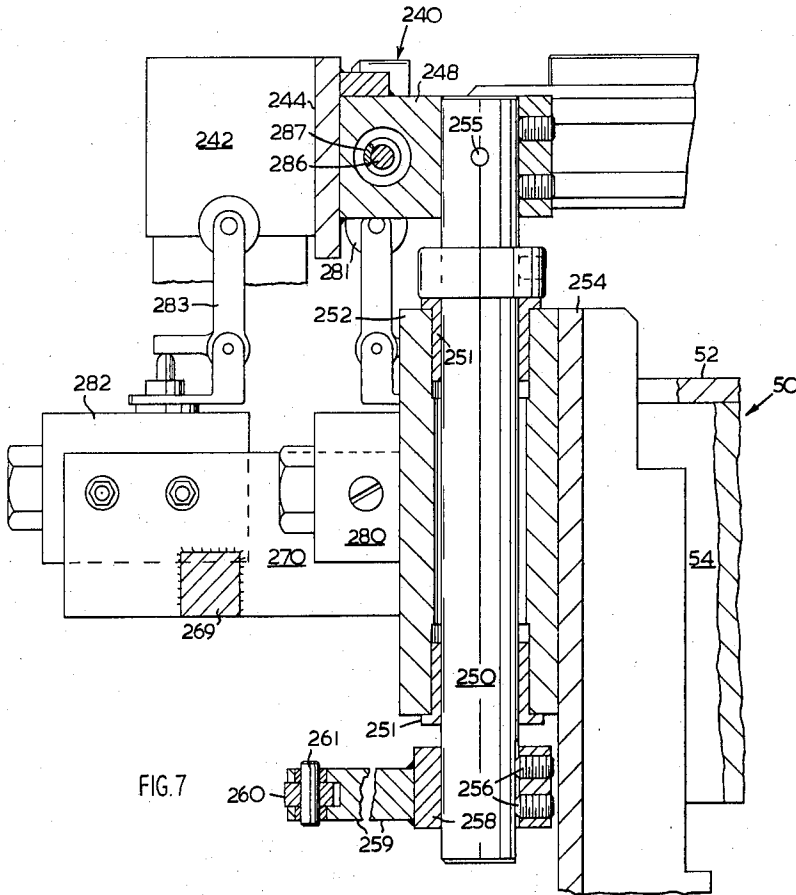


FIG 6



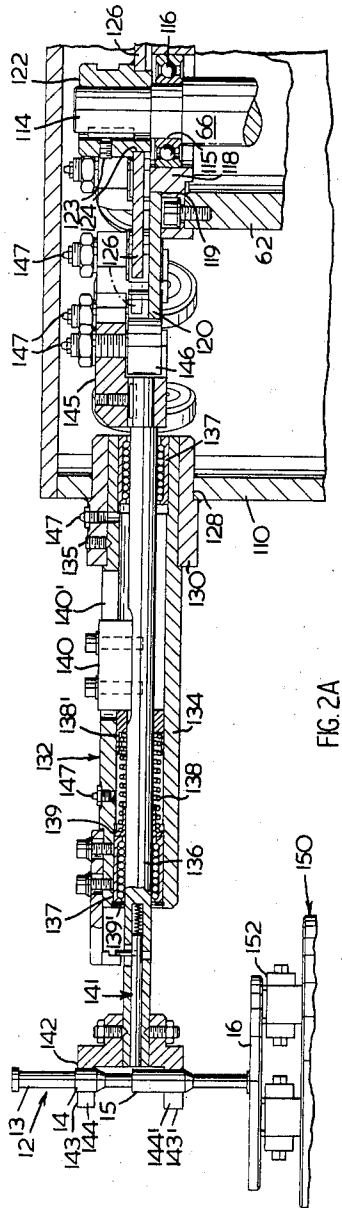


FIG. 2A

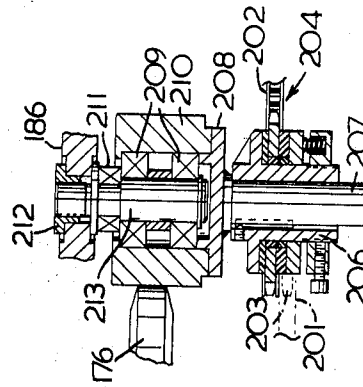
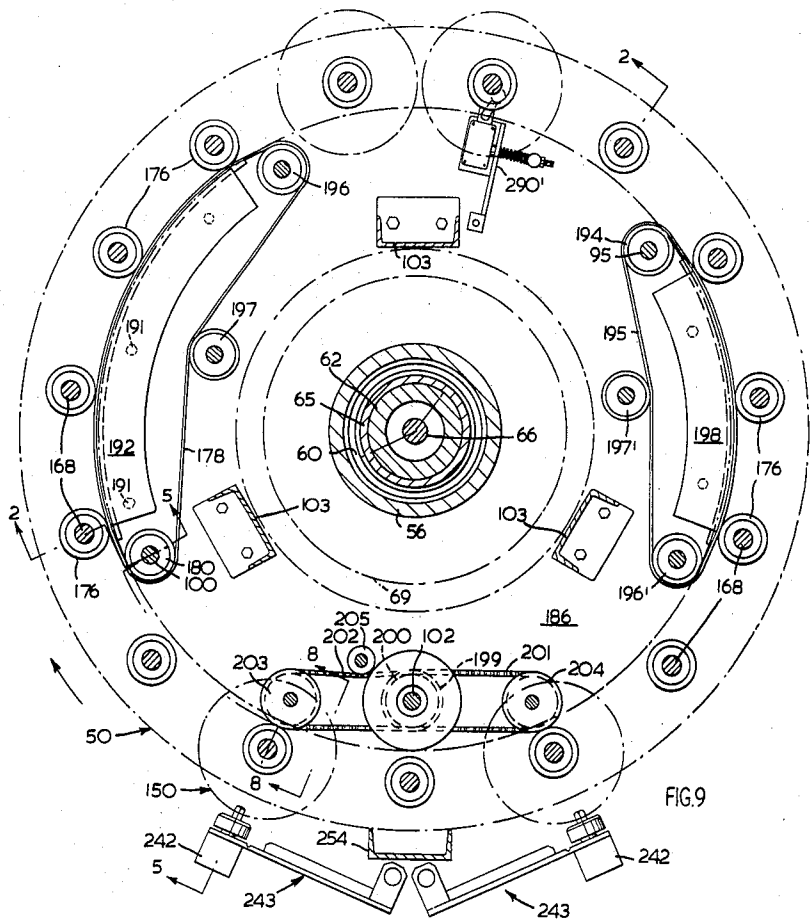
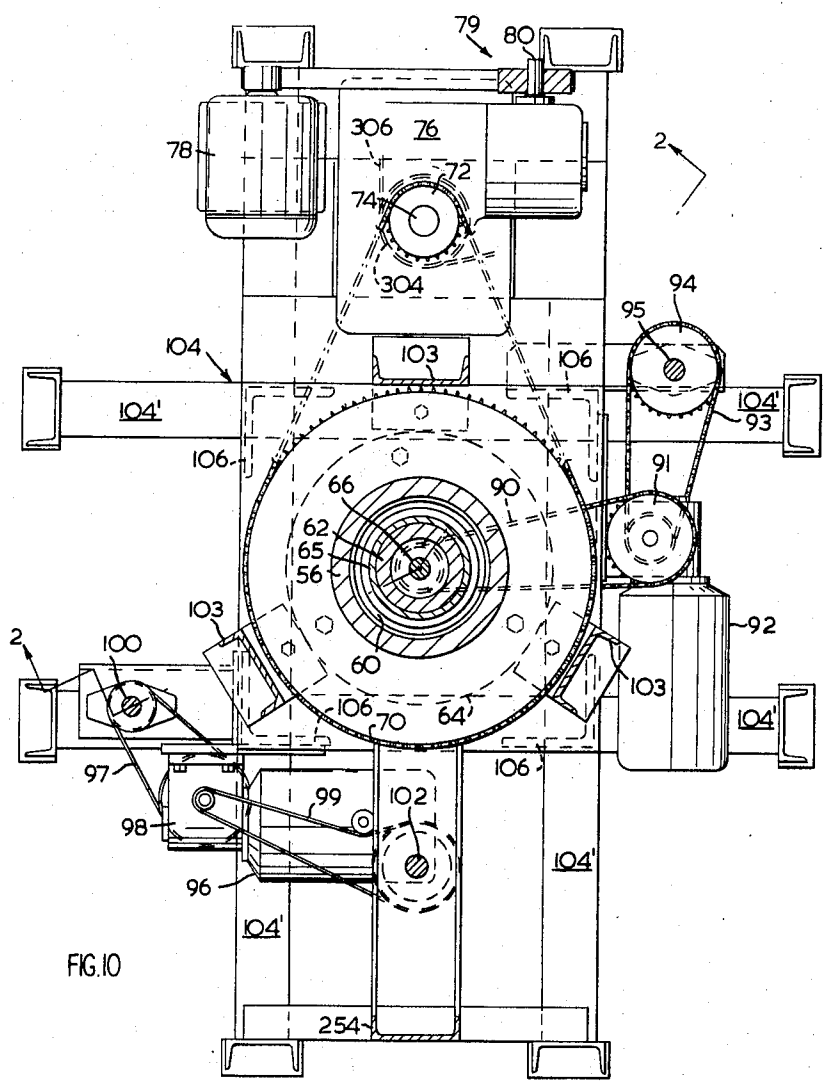
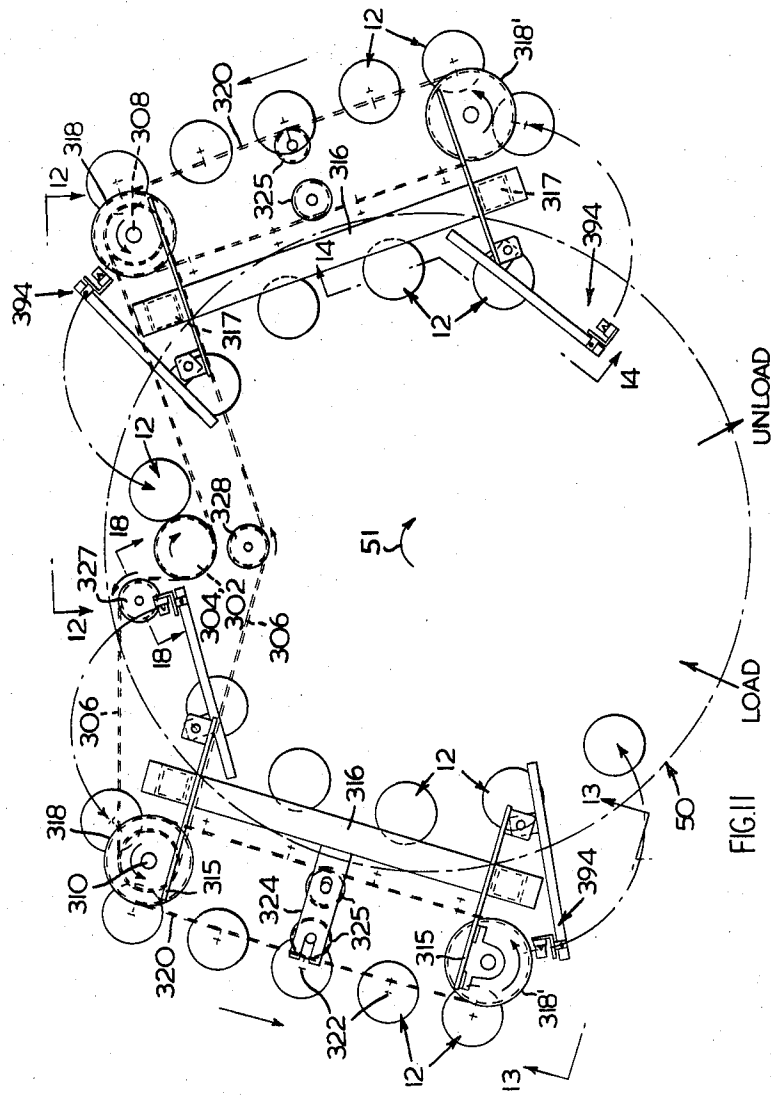
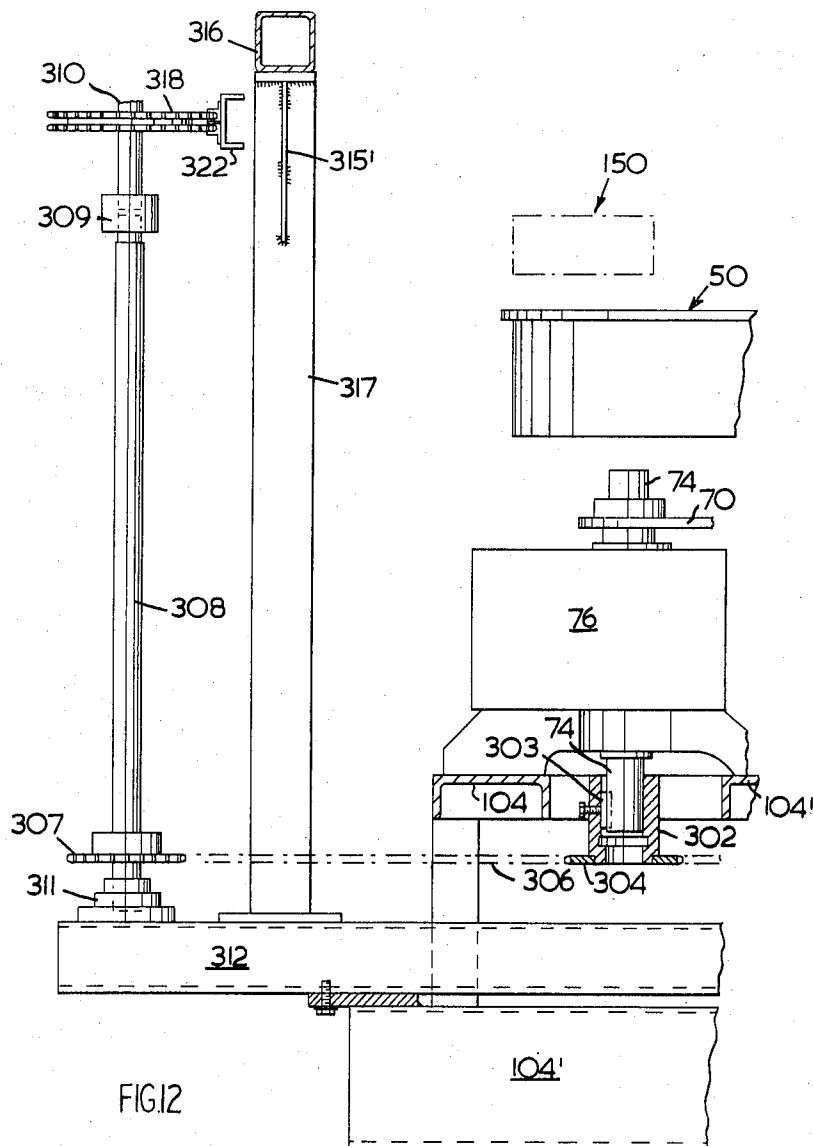


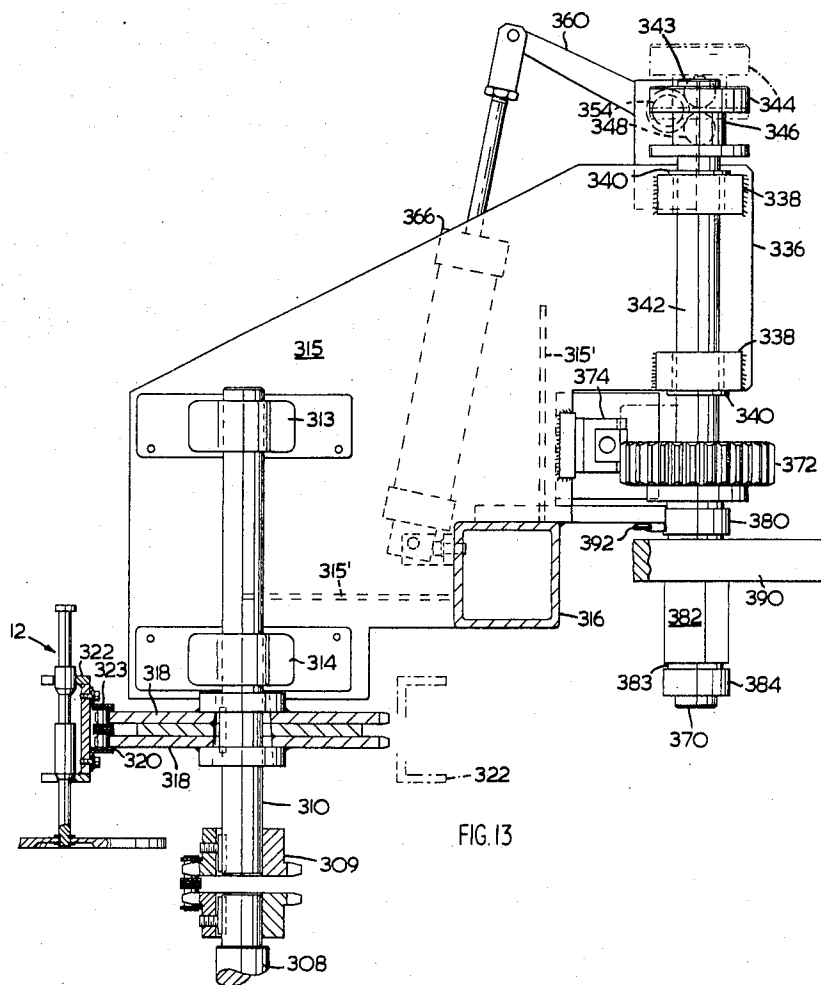
FIG. 8

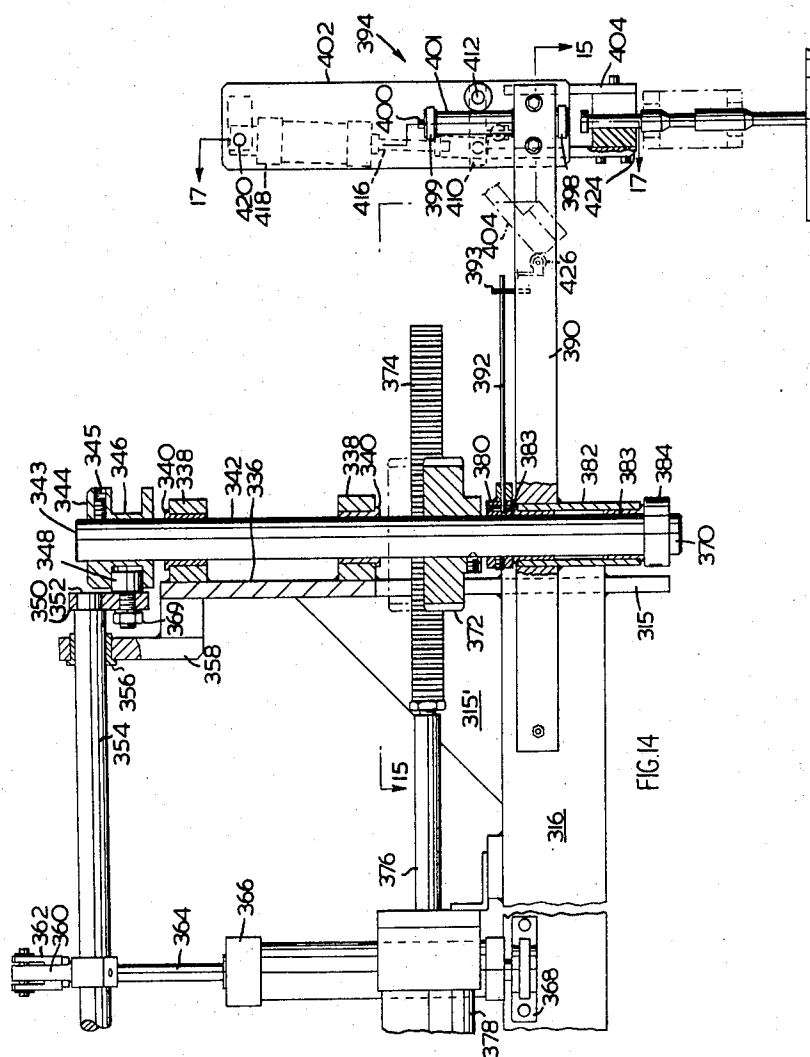












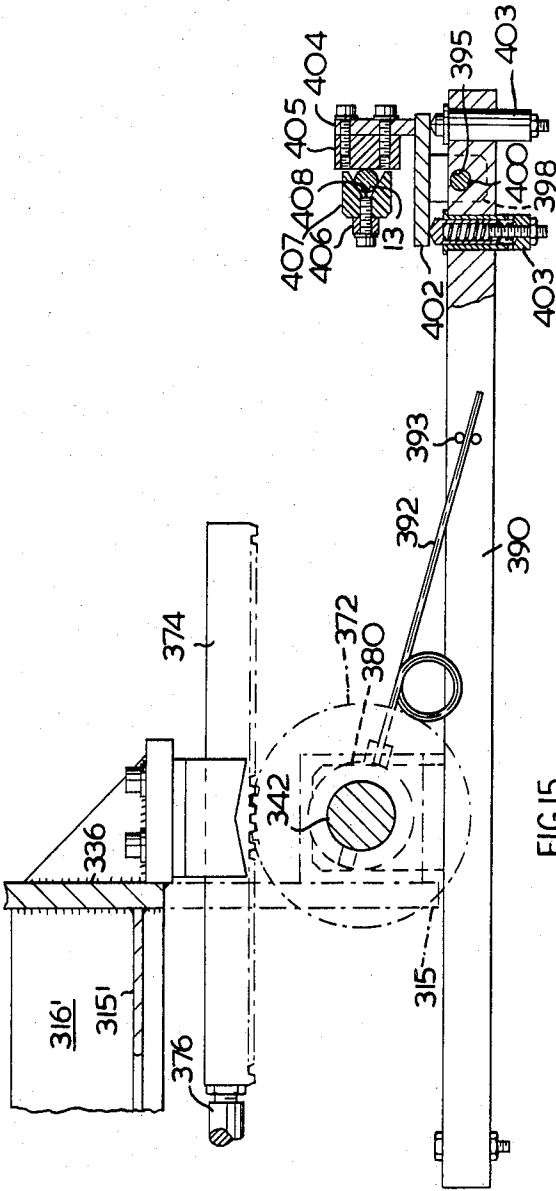
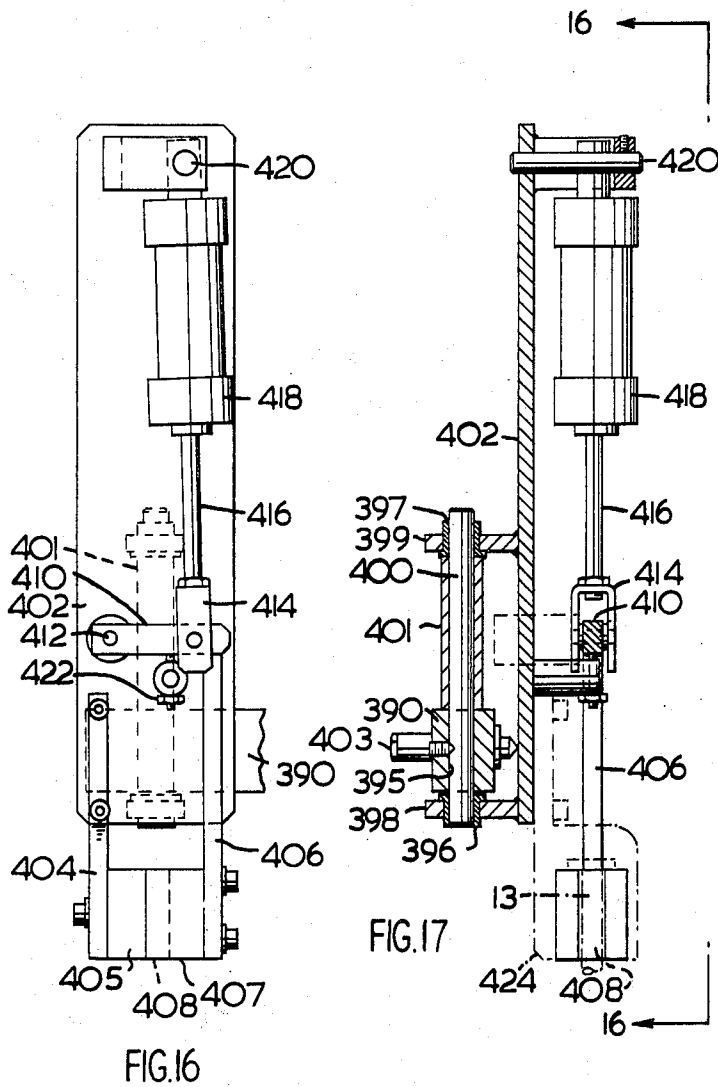


FIG. 15



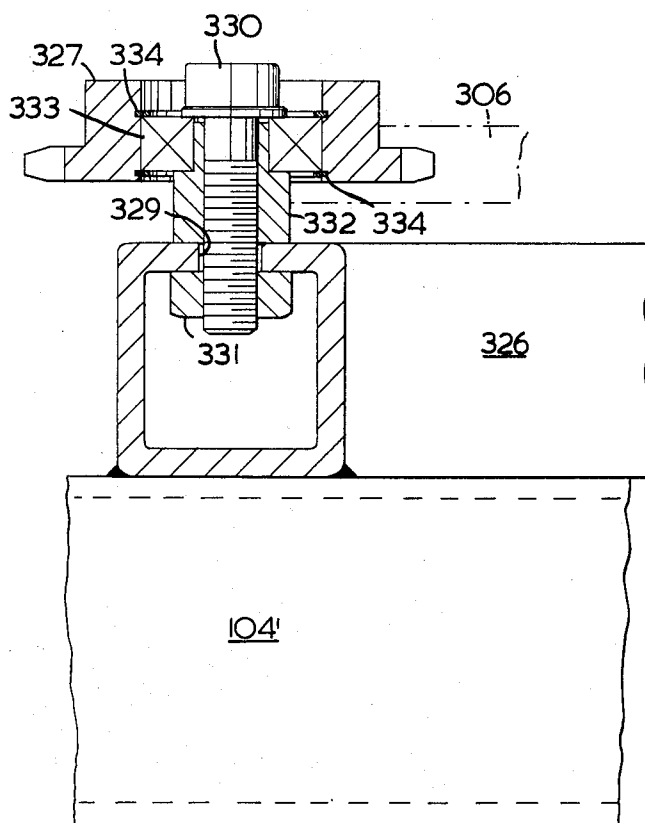


FIG. 18

APPARATUS FOR TREATING A SURFACE

This invention relates to an apparatus and process for treating a surface on a workpiece to provide an extremely smooth and flat finish of the same. More particularly, the invention relates to a lapping machine having at least one lapping zone a workpiece being rotatably supported is advanced through such zones automatically by timed indexing motion of that machine.

BACKGROUND OF THE INVENTION

It is well known in the machine-tool art that the purpose of a lapping machine and lapping operation is not to remove metal, but rather to finish the same to some size or surface finish. The lapping operation normally involves the use of loose-grain abrasive flours mixed with oil or other such lubricant. Such a mixture is applied to the workpiece whose surface is to be treated, by means of a lap which might be a disc, or the like. The lap is often made of a metal softer than the workpiece to be lapped, and can be made of soft cast iron, brass, copper, lead or soft steel. It will be recognized that the harder the lap, the slower the cut, the duller the finish, and the faster the wear on the lap. The faces of laps, say on a lapping disc, are usually serrated to enable the working surface to remain clean and free of accumulations of abrasives or dirt.

U.S. Pat. No. 2,469,563 which issued May 10, 1949 to R. K. Kinard describes one type of lapping machine. That machine includes an element which is formed with a plurality of lapping surfaces surrounded by a retaining element and co-operating with a relatively movable lapping plate to lap objects positioned on the lapping surface. The lapping plate is supported loosely upon the objects to be lapped, the workpieces, and is oscillated relative to the lapping members. In that particular patent, the lapping machine is especially adapted to enable two parallel surfaces on opposite sides of a workpiece to be lapped.

Problems that have existed in this art arise, for example, when a person attempts to lap many small workpiece surfaces simultaneously and to a high degree of accuracy. To our knowledge, conventional lapping machines using discs have not been able to achieve accuracy on a production basis better than one lightwave band width in flatness. This difficulty has persisted in some instances because of the problems associated with uneven or irregular wear of the surfaces in contact, and in others due to an accumulation of grit and the like upon the working surface of the lapping disc. It will be seen, for example, that in the above Kinard patent, a retaining element is provided for maintaining the workpieces to be lapped in place. An upper lapping plate is rotatably mounted and is moved reciprocally by an eccentrically mounted pin. Means are also provided to rotate the upper lapping plate periodically so as to reduce the possibility of continuous wear on limited parts of the gritted face of the lapping plate. It will be recognized, however, that because of the significantly large size of the upper lapping plate, as well as of the lower workpiece retaining element, considerable difficulty could be experienced in maintaining the working surfaces in proper alignment, i.e. as close to being absolutely parallel to one another as possible. Uneven wear on the mounting surfaces and bearings, thermal distortion, and the like can nevertheless dis-

able extreme flatness from being obtained of the workpiece surfaces being treated. Furthermore, it will be recognized that despite the kind of lapping compound used in the machine shown in this Kinard patent, whether it be coarse or fine in texture, a major cleanup of the working surfaces on the upper lapping plate and on the retaining element would be required to effect more than one stage of treatment to the workpiece surfaces on this one machine. In other words, the Kinard patent is wholly unsuited for the concept of more than one lapping zone in the same machine.

SUMMARY OF THE INVENTION

In decided contrast to the problems encountered in prior art lapping machines such as that noted above, the present invention provides very significant improvements both in the quality and accuracy of finishing a workpiece surface especially by lapping. A lapping machine is described herein which can lap a workpiece surface to within one-half a lightwave band width of flatness (measured using monochromatic light). In one aspect of the invention, there is afforded a technique by which a multiplicity of workpiece surfaces which are each quite small in size can be finished to extreme smoothness and a higher degree of flatness than had previously been possible. In that embodiment, individual workpieces of which a small surface is to be treated and finished are supported in a workpiece holder, such surfaces being positioned to lie in a common plane. A lap in the form of a disc is floatingly supported in contact with the surfaces to be treated. This disc is subjected to both positive reciprocal and "induced" rotational movement so as to undergo compound motion relative to the workpieces. The lapping disc is preferably made of a very hard steel that is extremely flat on its working surface. When subjected to the compound motion just mentioned, the lapping disc and workpiece surface in contact therewith wear uniformly, resulting in a surface finished to a higher order of flatness than had previously been possible.

A preferred embodiment of this invention provides two stages of lapping in two independent lapping or treatment zones, so as to enable a smooth finish to be obtained as well as one which is very flat. The lapping discs are floatingly supported in contact with the workpiece surfaces during passage of the workpieces through the particular treatment zone. The discs are then removed from contact with the workpieces and recirculated back to a starting position or point at which they are brought back into contact with new workpieces being advanced into that treatment zone. Different textures of lapping compound can therefore be used simultaneously in the separate and independent treatment zones on the one lapping machine. The first stage of treatment in finishing the workpiece surface can, for instance, be a lapping operation. This can subsequently be followed in the next treatment zone by, say, a burnishing procedure. An idle position is preferably provided intermediate the two treatment zones so as to enable inspection and/or cleaning of the workpiece surfaces prior to further treatment in the next treatment zone.

According to one aspect of the present invention, therefore, there is provided apparatus for treating a surface on a workpiece that can be placed from a load station onto a rotatable turntable and removed there-

from to an unload station, comprising: support means rotatably mounted on the turntable for carrying at least one workpiece; drive means for selectively rotating said support means; disc means for engaging the workpiece and effecting said surface treatment thereof, the disc means being floatingly supported on a support assembly provided on the turntable; actuating means operatively connected to the support assembly for reciprocally moving said disc means to cause compound relative motion between the disc means and said workpiece, this compound relative motion causing wear of the workpiece and disc means to be uniformly distributed so that maximum flatness is obtained of the surface being treated; and, driving means operative for periodically indexing said turntable and advancing the workpiece through at least one treatment zone provided intermediate the load and unload stations. Contrary to earlier machines, loading and unloading herein is performed without stopping our machine. A transfer assembly is preferably provided in operative relation to each treatment zone for transferring the disc means to and from the support assembly on the turntable which carries the disc means in operative relation to the workpieces. It is also preferable that a recirculating conveyor be provided in operative relation to these transfer assemblies for receiving and carrying the disc means from one position at which they have been transferred from the turntable support assembly to another position from which said disc means is transferred to the turntable support assembly, movement of the recirculating conveyor being in synchronism to the indexing motion of the turntable.

It is therefore an object of this invention to provide an improved apparatus by the operation of which a surface on a workpiece can be finished to a degree of smoothness and extreme flatness of an order not possible with similar devices of the prior art.

It is an object of a preferred embodiment herein to provide more than one finishing operation in a single apparatus by providing two treatment zones in which finishing steps or procedures are effected separately of one another.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and features of this invention will become apparent from the detailed description below, as read with reference to the accompanying drawings which illustrate only one preferred form of the present apparatus, and in which:

FIG. 1 is a plan view showing schematically a preferred form of apparatus according to this invention;

FIG. 2 is an elevation view taken in cross section along line 2—2 of FIG. 1 and showing the main turntable of that apparatus;

FIG. 2A is a side elevation view taken in central section to show detail of a disc-supporting and reciprocating assembly such as that illustrated at approximately the eight o'clock position in FIG. 1;

FIG. 3 is an electrical control circuit illustrating one circuit which can be used to effect automatic control and operation of a preferred embodiment of the present invention;

FIG. 4 is a graphical representation showing the timing of various steps involved in the operation of the apparatus of FIG. 1;

FIG. 5 is an elevation view taken partly in section to show detail of a chuck assembly that is rotatably mounted on the main turntable of the apparatus in FIG. 1, on which one or more workpieces are supported;

FIG. 6 is a top plan view taken partly in section showing details of one mechanism for automatically activating and deactivating the chuck assembly of FIG. 5;

FIG. 7 is an elevation view taken in cross-section along 7—7 of FIG. 6;

FIG. 8 is an elevation view taken in cross-section along line 8—8 of FIG. 9 to show details of a slipping clutch arrangement for driving the chuck assembly shown in FIG. 5, at the load and unload stations of the system illustrated in FIG. 1;

FIG. 9 is a top plan view partly in section and taken along line 9—9 of FIG. 2, to show the arrangement by which the chuck assemblies are rotated in the treatment zones of the system illustrated in FIG. 1;

FIG. 10 is a top plan view partly in section and taken along line 10—10 of FIG. 2 to show the drive means for periodically indexing the main turntable shown in FIGS. 1 and 2;

FIG. 11 is a plan view showing schematically the operative relationship of a disc-recirculating conveyor and transfer assemblies associated therewith, in operative relation to each of the treatment zones of the system illustrated in FIG. 1;

FIG. 12 is an end elevation view partly in section and showing a stand for supporting the recirculating conveyor illustrated in FIGS. 1 and 11;

FIG. 13 is also an end elevation view taken partly in section to show details of the disc-recirculating conveyor and one associated transfer assembly shown at the unload station of FIG. 11;

FIG. 14 is a side elevation view taken partly in section to show an arrangement for providing swivelling motion of the transfer assembly illustrated in FIG. 11, it being noted that FIGS. 12 13 and 14 are taken along section lines 12—12; 13—13; and 14—14 of FIG. 11;

FIG. 15 is a top plan view taken partly in section to show detail of a swivel arm forming part of the transfer assembly of FIG. 14;

FIG. 16 is an elevation view showing detail of a gripping mechanism supported by the swivel arm of FIG. 15;

FIG. 17 is an end elevation view taken partly in section and showing additional detail of the gripping mechanism of FIG. 16; and

FIG. 18 is a side elevation view taken in section along line 18—18 of FIG. 11 and showing an idler sprocket wheel in the disc-recirculating conveyor drive system.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Turning now to a detailed description of the preferred embodiments of this invention, reference should be made initially to FIGS. 1 and 2 of the accompanying illustrative drawings. In those drawings a preferred form of the present invention is embodied in a lapping machine shown overall at 10. In brief, this lapping machine 10 comprises a circular turntable 50 that is rotatably supported on a pedestal-like base assembly 104. A multiplicity of chuck assemblies shown overall at 150 and in greater detail in FIG. 5, are rotatably supported

at intervals spaced equally apart near the outer periphery of the turntable 50. Each of the chuck assemblies 150 is adapted to receive workpieces 152 either by themselves or in workholders 154. These workpieces 152 are supplied, for example from a loading conveyor illustrated schematically by the numeral 153 that is located at an "input" or "load" station 2. The workpieces 152 are subsequently advanced by a periodic indexing motion of the turntable 50 through finishing or treatment zones shown at 1 and 3 in FIG. 1. The workpieces 152 are moved either manually or automatically from the chuck assemblies 150 for removal by a discharge or delivery conveyor 155 that is positioned in operative relation to the turntable 50 at an exit or unload station shown at 4. As noted earlier, loading and unloading of workpieces 152 is performed without stopping the lapping or other finishing operations taking place in treatment zones 1 and/or 3. Prior art lapping machines have either to be stopped or run idle during load-unload operations. In the embodiment illustrated in FIG. 1, there are four index positions of the turntable 50 within treatment zone 1 where lapping of the workpieces 152 will take place. Treatment zone 3 contains three such index positions where a second stage of lapping, or alternatively, some other finishing procedure such as burnishing can take place. One idle position shown at 6 is provided intermediate the treatment zones 1 and 3 for purposes to be discussed below. A further neutral or idle index position 8 is shown at approximately the six o'clock position in FIG. 1. The input or load index position is shown at approximately six thirty; and the output or unload index position is shown at approximately the five-thirty position, again in FIG. 1.

As seen schematically in FIG. 1, each of the treatment zones 1 and 3 has a disc-recirculating conveyor 300 in operative relation to the rotatable turntable 50. Each of these recirculating conveyors 300 has an upstream end and a downstream end, taken relative to the clockwise indexing motion shown by arrow 51 of the turntable 50. At each of the upstream ends, there is provided a disc transfer mechanism which is illustrated schematically at 394 in FIG. 11, these upstream transfer mechanisms functioning to transfer lapping discs shown at 12 from the recirculating conveyors 300 to the turntable 50. In an analogous manner, downstream transfer mechanisms 394 function to remove lapping discs 12 one at a time from the turntable 50 and place the same onto the recirculating conveyor 300. A more detailed description of both the recirculating conveyors 300 and the disc transfer mechanisms 394 is set forth below in connection with FIGS. 11-16. It will suffice at this time to indicate that in a timed operation, upstream transfer mechanisms 394 will pick up and transfer lapping discs 12 one at a time from the recirculating conveyor 300 and bring such discs 12 into engagement with a disc-supporting head 142 of a disc-supporting and reciprocating assembly 132 of which only one is shown in top plan view at approximately the eight o'clock position in FIG. 1.

These disc-supporting and reciprocating assemblies 132 are described in detail below, with particular reference to FIG. 2A. It will be adequate for present purposes to indicate that each of the heads 142 will floatingly support a lapping disc 12, and by a method of actuation to be described below, cause reciprocation of the same within the treatment zones 1 and 3. The lap-

ping disc 12 is floatingly supported by the disc-supporting head 142 in each instance, and the friction is generated by the weight of the same contacting the surface of workpiece 152 being treated as the latter is supported and rotated by chuck assemblies 150. This frictional contact induces rotary motion of the lapping disc 12. The "induced" rotary motion of the lapping discs 12 combines with the positive linear reciprocating motion derived from disc-supporting and reciprocating assemblies 132 to effect compound motion of the lapping discs 12 relative to the workpiece surfaces. This compound relative motion enables wear of either the surface of workpieces 152 or of lapping discs 12 to be distributed uniformly, thereby enabling extremely smooth and flat surface finishes to be obtained. It is also important to note here that the laps involved have a relatively small surface area. This, coupled with being floatingly supported means that alignment problems arising from uneven wear of bearing surfaces, of thermal distortion, or the like which could arise in the above-mentioned Kinard patent, do not present major problems in our apparatus. Indeed, it is expected that because of the floating mounting of the lapping discs 12 when in use, combined with their relatively light weight and lack of any biasing forces other than that of gravity, means sufficiently accurate alignment can be obtained simply by following normal engineering tolerances in manufacturing and constructing the present apparatus. With such an arrangement, we have consistently obtained significantly improved results in the smoothness and flatness of a workpiece surface being finished. Indeed, as previously mentioned surface flatness in the order of one-half a lightwave band width has been obtained, as measured by using monochromatic sodium light.

It will become apparent below that the present invention is readily capable of being modified for highly automated operation, as illustrated by the preferred embodiment described here. On the other hand, the principles encompassed in that preferred embodiment can also be used successfully in an apparatus involving manual operations to a much greater extent than in this particular instance. To the extent that the lapping machine 10 is a highly automated machine, FIGS. 3 and 4 illustrate, respectively, a control circuit and timing diagram which enable such automated operations to be obtained. A more detailed description and further reference will be made to the control circuit of FIG. 3, below.

At this point, however, reference should be made in particular to FIGS. 2 and 5 which illustrate construction details of the turntable 50 of lapping machine 10, and of the chuck assemblies 150. The turntable 50 is made of structural steel and is shown in FIG. 2 as comprising a top 52 to which a dependent skirt 54 is welded. The top 52 of turntable 50 is centrally apertured at 53 in order to enable the same to be received and positioned on an upwardly facing shoulder 55 of a tubular support housing 56. The top 52 of turntable 50 will normally be welded in place upon shoulder 55.

The support housing 56 has upper and lower ends 57 and 59 with the inner surface adjacent these ends serving to mount the outer race of a pair of ball bearings 58 and 60, say, by an interference fit. The inner race of each of these bearings 58 and 60 is in turn closely received over the exterior surface of a fixed column 62 that is itself welded to a reinforcing plate 64. The latter

is bolted or otherwise secured to a top plate 105 of the pedestal-like base assembly 104, (See FIG. 10 also). The inner race of bearing 58 abuts against the upwardly facing end of a spacer sleeve 65. The inner race of bearing 60 also abuts that spacer sleeve 65, and is maintained in place by a retaining ring 61 that is seated on an upwardly facing shoulder 63 provided on the lower portion of the fixed column 62. It will be noted that such an arrangement enables the main turntable 50 to be rotated about an axis that is coaxial with a central drive shaft 66 mounted interiorly of the fixed column 62. To enable the main turntable 50 to be rotated with a periodic indexing motion, the end 59 of tubular support housing 56 is provided with a main sprocket wheel 68 having teeth 69 thereon and being screw-fastened or otherwise fixedly secured to the end of this supporting housing. The teeth 69 of sprocket wheel 68 are engaged by a chain 70 (FIG. 10) that is driven by a driving sprocket wheel 72. The sprocket wheel 72 is secured by a key and keyway arrangement to the upwardly extending end portion of an output shaft 74 of a gear-reducing unit 76. This gear-reducing unit 76 is operatively coupled by a 400:1 gear ratio to a main drive motor 78. The coupling together of the main drive motor 78 and the gear-reducing unit 76 is, in this instance, accomplished by means of a belt and pulley arrangement 79 and another drive shaft 80 which is connected by the intermediary of gears not shown to the output drive shaft 74.

The downwardly extending end 81 of shaft 66 is rotatably supported by bearings 82 and a retaining plate 84 which serves to support such bearings on the lower end 85 of the fixed tubular column 62. Retaining plate 84 is connected to the end of column 62 by means of suitable screw fasteners 85 or the like. As seen in FIG. 2, the lower end of shaft 66 is provided with a stub portion 86 to which a collar 88 is fixedly secured by means of a key and keyway arrangement. The collar 88 is in turn provided with a radially outwardly extending flange on which teeth 89 are provided. Teeth 89 are engaged by a drive chain 90 (see FIG. 10) which is driven through the intermediary of sprocket wheel and intermediate shaft 91 from a second drive motor 92. It should also be noted that the drive motor 92 drives a second sprocket wheel and chain 93 which, through a further sprocket wheel 94 fixedly secured to a generally vertically extending drive shaft 95, ultimately effects rotation of the chuck assemblies 150 within treatment zone 3 (of FIG. 1). A third drive motor 96 (seen in FIG. 10) functions through the intermediary of continuous belts 97 and 99 and associated pulleys to drive shafts 100 and 102. See FIGS. 5 and 9 also. It will be seen from the control circuit of FIG. 3 that for convenience, each of the driving motors 78, 92 and 96 is electrically driven from one common source of electrical power. Other alternative arrangements would, of course, also be possible. Returning to FIG. 2, it will be seen that a coverplate 112 is screw-fastened to the end 57 of support housing 56. This coverplate 112 is of course provided with a large central aperture so that it can be closely received over the tubular column 62. The coverplate 112 is further apertured in order to enable adequate lubrication to be introduced by conduit means 113 to the main bearings 58 and 60.

The upper end portion of the fixed tubular column 62 is contained within a cylindrical enclosure or top housing 110. This housing 110 is welded to a retaining ring

109 which is itself fixedly secured by screw fasteners 111 or the like to the top 52 of the main turntable 50. If necessary, or desired, a re-inforcing ring 109' can also be provided, being welded to the top plate 52.

It will be seen from FIGS. 2 and 2A, in particular, that the top end of shaft 66 also has a stub portion shown at 114 and a two-stage reduction in cross-sectional area. The first stage of reduction forms a seat and shoulder 115 over which the inner race of ball bearings 116 is closely received. The outer race of bearing 116 is in an interference fit with the interior surface of a positioning collar 118 that is screw-fastened or otherwise secured to the top end of the tubular fixed column 62. The upper face of positioning collar 118 is provided with a shoulder 119 that enables a fixed cam 120 to be secured thereto. As seen in FIG. 1, the shape of the fixed cam 120 is approximately that of an elongated, double headed keyhole. The reason for the shape of the fixed cam 120 will become apparent shortly. The outermost part of the stub portion 114 has a retaining collar 122 fixedly secured thereto by means of a set screw and Woodruff key and keyway arrangement 123. The inwardly facing end of this collar 122 is provided with a shoulder 124 on which a "moving" or driven cam 126 is secured, as by welding. Since the driven cam 126 is fixedly secured to the shaft 66, driving that shaft with rotary motion will cause corresponding rotary motion of the driven cam 126. It is to be noted from FIGS. 1, 2, and 2A that the driven cam 126 is approximately circular in shape, and is eccentrically mounted upon the retaining collar 122. It should also be noted that the maximum radius of the fixed cam 120 slightly exceeds the maximum radius of the driven cam 126. This is a feature whose value will be described below. It will suffice at this stage to state that rotation of the driven cam 126 does, through the intermediary of the disc-supporting and reciprocating assembly 132 cause linear reciprocal motion of the lapping discs 12 radially of the main turntable 50, and only within the lapping zones 1 and 3. That is to say, at those index positions of the turntable 50 intermediate lapping zones 1 and 3, no reciprocal motion of the assemblies 132 of discs 12 occurs. In the first place, such motion is not required since those locations are idle positions. Secondly, it is also desirable that no reciprocating motion of the assemblies 132 occurs intermediate the lapping zones 1 and 3 since placement or removal of workpieces onto the chuck assemblies 150 is taking place. Alternatively, inspection and/or cleaning of the workpieces prior to the second stage of treatment in zone 3 is to be performed. It would therefore be difficult and hazardous to carry out those operations if the assemblies 132 were reciprocating at the same time that other work was to occur.

It will be seen from FIGS. 2 and 2A that the cylindrical top housing 110 is provided with a series of openings 128 spaced uniformly apart circumferentially of the upper portion of this housing. A support sleeve 130 is welded into each of the openings 128 and serves in each instance to mount one of the disc-reciprocating assemblies 132 in proper alignment. A tubular and cylindrical housing 134 is force-fitted into each support sleeve 130 and locked in place by means of a set screw 135. A push rod 136 is mounted interiorly of the housing 134 by means of bearings 137 mounted at either end of that housing. It will be seen from FIG. 2A that each end of the housing 134 is recessed in order to re-

ceive the bearings 137. It will also be seen that the bearings 137 at the outer end of housing 134 are retained in position abutting against a sleeve bushing 139 on one side that is biased by a compression spring 138, and on the other side abutting against a retaining ring 139'. One end of the compression spring 138 is seated over the sleeve bushing 139, while the other end of the spring is received within the recessed end of a cup-like bushing 138'. The bushing 138' abuts against a stop member 140 which is screw-fastened to the push rod 136 and is slideably guided within a slot 140' provided in the upwardly facing surface of the tubular housing 134. It will be recognized, therefore, that the radially innermost and outermost ends of the slot 140' serve as positive limits for the linear reciprocal travel of the push rods 136. In reality, the length of the slot 140' will be sufficient to allow compression spring 138 to provide a degree of spring loading of the push rod 136 relative to the driving cam 126. An L-shaped stop member is screw-fastened to the free end of the cylindrical housing 134 and is operatively associated with a spring-loaded tensioning pin assembly shown at 141. This spring-loaded tensioning pin assembly 141 is housed within an axial borehole provided in the outermost end of each push rod 136. More will be said on this shortly. The disc-supporting heads 142 are in the form of a yoke that is screw-fastened to the free end of each push rod 136. Each yoke-like disc-supporting head 142 has an upper and lower arm 143 and 143' in which there is respectively provided keyhole-shaped slots 144 and 144'. It will be recognized that because each lapping disc 12 is floatingly supported within the keyhole slots of each disc-supporting head 142, there is a relatively loose fit of the lapping disc seated in each of the slots 144 and 144'. FIG. 2A shows that the tensioning pin assembly 141 is axially movable a slight distance relative to each push rod 136. Hence, this tensioning pin assembly 141 can project outwardly and by virtue of the small compression spring provided in the blind end of the borehole, engage the enlarged portion 15 of the stem of the lapping disc 12 and cause the latter to be seated in position by virtue of the force of the small compression spring.

The inner end of each push rod 136 is of a reduced diameter and has an L-shaped supporting bracket 145 fixedly secured thereto by a Woodruff key and set screw arrangement or the like. Each of the brackets 145 functions to rotatably support a roller follower 146 which is in rolling contact, depending upon the index position, with one of the cams 120 or 126. In order to provide for adequate lubrication of these roller followers 146, as well as the bearings 137 a number of grease nipples 147 are provided on each push rod assembly 132.

It will be seen, therefore, that indexing motion of the main turntable 50 will cause relative movement between the roller followers 146 and the fixed cam 120, at least so far as the roller followers 146 are positioned in one of the index positions where no reciprocal movement of the lapping disc is to take place. In other words, so long as a particular disc-reciprocating assembly 132 is located at an index position outside of either the lapping zone 1 or 3, the roller follower 146 provided therein will engage the periphery of the fixed cam 120. The lapping disc 12 thereon will hence be reciprocally driven. In each of the index positions within lapping zones 1 and 3, however, the roller followers

146 will be in engagement with the periphery of the driven cam 126. This can also be seen by referring to FIG. 1. As stated earlier, the maximum radial distance of the fixed cam 120 is slightly larger than the maximum radial distance of the driven cam 126. Consequently, in those positions outside of the lapping zones 1 and 3, the fixed cam 120 will override the potential effect of the driven cam 126.

It will be recognized that the axis about which the main turntable 50 rotates (with periodic indexing motion of the same) is coaxial with shaft 66. It will also be seen that pushrods 136 will have their axes disposed generally in a common plane that is at about 90° to the axis of shaft 66. As previously mentioned, each lapping disc 12 is floatingly supported by the heads 142 in respective ones of the disc-supporting and reciprocating assemblies 132. That floating mounting subsequently allows a degree of pivotal movement of the lapping discs 12 relative to heads 142. Also, as seen in the left side of FIG. 13, the disc element 16 is loosely connected to stem 13 so as to allow for pivotal motion therebetween. The floating condition of each disc 16 is based especially on this pivotal motion being possible. Hence, absolute parallelism of the stem 13 of the lapping discs to the axis of shaft 66 is not essential. Moreover, it is not absolutely essential to have the surface of the workpieces on different chuck assemblies 150 exactly coplanar and perpendicular to the axis of shaft 66. Some misalignment can readily be compensated by the floating mounting of the lapping discs 12. It is necessary only that, in the case of a plurality of workpieces being supported, say, in one or a pair of workholders 154 as shown in FIGS. 1, 2 and 2A, that the workpiece surfaces engaged by any one lapping disc 12 be themselves in a common plane. That is to say, the workpiece surfaces being treated at say the eight o'clock position shown in FIG. 1 will each be in a common plane, but not necessarily in the same plane as other workpieces supported upon chuck assembly 150 in the nine o'clock position. Each lapping disc 12 has a disc 16 which is manufactured of hardened steel, for instance, and is extremely flat on its working surface. The disc 16 is pivotally connected to stem 13, as described above. Those features coupled with the floating mounting in each head 142 enable the lapping discs 12 to finish the workpiece surfaces to the extremely high order of flatness mentioned earlier.

It has been noted above that the main turntable 50 is provided at equally spaced apart intervals with a series of rotatable chuck assemblies 150. These chuck assemblies 150 are preferably magnetically operated and serve to fixedly support a workpiece with or without a workpiece holder in operative relation to the lapping discs 12. Referring now to FIGS. 2 and 5, it will be seen that the top 52 of the turntable 50 is provided with openings 156, such openings being spaced equally apart and slightly radially inwardly of the skirt 54. The area surrounding openings 156 is provided with a reinforcing ring 157 that is welded to the top plate. A bearing sleeve 158 is subsequently mounted in the opening 156. This bearing sleeve 158 is provided with a radially outwardly extending flange 160 which is apertured in order to fixedly secure the sleeve to the re-inforcing ring 157 and top plate 52 by means of bolts or screw fasteners 159, or the like. A radially inwardly extending shoulder or seat 161 is formed interiorly of the sleeve 158, opposite the flange 160. One ball bearing

162 is seated against the shoulder 161 and spaced from a second bearing 164 by means of a spacer sleeve 163. A retaining ring 166 serves to secure both bearings 162 and 164 in position within the interior of bearing sleeve 158.

A chuck drive shaft 168 is rotatably supported interiorly of the bearings 162 and 164. The upper end of the drive shaft 168 is fixedly secured to a disc-like plate 170 which serves to support thereon a magnetic chuck 172. The lower end of the drive shaft 168 is housed within a spacer sleeve 171, and a support collar 174 is fixed to the shaft. A locking pin 173 and set screw 175 serve this purpose. A rubber drive wheel 176 is carried by the support collar 174, being fixed against any rotational movement relative to that collar. It will therefore be seen that rotation of the rubber drive wheel 176 will transmit rotary motion through the support collar 174 into drive shaft 168 which in its turn causes rotation of the chuck assembly 50. Each of the chuck assemblies 150 is mounted upon the main turntable 50 in the same way, and is constructed identically. The various chuck assemblies 150 are not, however, each driven and rotated in exactly the same way as will be apparent from the description below.

With reference still to FIGS. 2 and 5, and also to FIGS. 9 and 10, it will be seen that the rubber drive wheels 176 of those chuck assemblies 150 which are positioned at any given time within lapping zones 1 and 3, will be in driven engagement with a driving belt shown at 178. With respect to lapping zone 1, the belt 178 is entrained around a pulley 180 that is carried on the drive shaft 100, against a backing surface or shoe 192 and around idling and tensioning pulleys 196 and 197. With respect to lapping zone 3, a continuous drive belt 195 is similarly entrained around a drive pulley 194 that is fixedly secured to the drive shaft 95. The drive belt 195 is also in contact with a backing surface or shoe 198 and idling and tensioning pulleys 196' and 197'. It will be recognized that the backing surfaces or shoes 192 and 198 are fixedly secured to an annular plate 186 that is supported by three upstanding columns 106 made from steel channels having C-shaped cross sections. These can be seen in FIGS. 2, 9 and 10. The columns 106 are, of course, part of the base assembly 104.

It is to be noted from FIG. 5 in particular that drive pulleys 180 and 194 that are, respectively, carried by drive shafts 100 and 95 have a stub or pulley shaft 181 supported by suitable bearings within those pulleys. In each case, the pulley shaft 181 is connected by splined coupling element 189 to its respective drive shaft, 100 or 95. It will be seen from FIG. 10 that drive shaft 100 is driven from the drive motor 96 while drive shaft 95 is driven from the drive motor 92. It will also be seen that drive motor 96 effects rotation of the drive shaft 102 which, in FIG. 9, carries lower and upper sprocket wheels 199 and 200. The top end of shaft 102 is supported in journal bearings that are anchored on the underside of the annular plate 186. Furthermore, as seen from FIGS. 8 and 9 upper sprocket wheel 200 engages a chain 202 and through the intermediary of a further sprocket wheel and slipping clutch 204 (illustrated in FIG. 8) drives a clutch shaft 204. It should be noted that the view seen in FIG. 8 is taken along section line 8-8 of FIG. 9, and is identical to the drive arrangement at the unload station of FIG. 9. In either instance the clutch shaft 207 is welded to a supporting plate 208

that serves to carry a drive pulley 210. This pulley 210 is supported for rotation on bearings 209 carried on a stub shaft 213. The end of stub shaft 213 exteriorly of the pulley 210 is supported by alignment bearings 211 and bushings 212 from the annular plate 186. The drive pulley 210 can be seen (in FIG. 8) to engage the rubber drive wheel 176 provided on the chuck assembly 150 when the latter is positioned at either the load or unload station. In a similar manner, the lower sprocket wheel 199 drives chain 201 which engages sprocket wheel 203 and through the intermediary of the slipping clutch previously mentioned drives the corresponding shaft 207 at unload station 4.

It might be noted at this time that there is some initial rotation of the chuck assemblies 150 in both the load and unload stations. That initial rotation continues until such time as the chuck activate and deactivate mechanism illustrated in FIG. 6 engages the two chucks 172 preventing them from rotating any further. In that condition, the slipping clutch 204 comes into operation enabling the pulley 210 to remain stationary. The slipping clutch 204 simultaneously allows rotational movement of the sprocket wheels being driven through chains 201 and 202 from the main drive shaft 102 for the load-unload stations 2 and 4.

We have described thus far how the main turntable 50 is rotatably supported from the pedestal base assembly 104, how the chuck assemblies 150 are both supported in the main turntable 50 and how they are rotatably driven either in the two lapping zones 1 and 3, or at the load and unload stations 2 and 4. We have, moreover, described how rotation of the central drive shaft 66 and driving cam 126 activate the disc-supporting and reciprocating assemblies 132, thereby providing positive reciprocating motion to the lapping discs 12, within lapping zones 1 and 3.

It is also to be noted that when a chuck assembly 150 passes beyond the lapping zone 3 and is brought by indexing motion of the turntable 50 into unload station 4, that same chuck assembly is deactivated by a mechanism shown overall at 243 and a technique to be described shortly. Deactivation of the chuck assembly 150 in unload station 4 enables an operator to take any workpieces supported thereon for subsequent removal to some other work area, for instance, final inspection. As the main turntable 50 is further indexed, that deactivated chuck assembly 150 will advance in a clockwise direction as shown by arrow 51 in FIG. 1, to the load station 2. Here, the operator places fresh workpieces upon that chuck assembly. In a timed sequence which will also be described below, that same chuck assembly is now activated causing the magnetic chuck to securely hold the workpieces in place. In summary, therefore, the chuck assemblies 150 are in an activated condition securely holding workpieces properly in place when passing through lapping zone 1, idle position 6 and through lapping zone 3. The chuck assemblies are deactivated at unload station 4 and remain so until activated again when they reach load station 2.

In order to see how the chuck assemblies 150 are activated and deactivated, let us now refer to FIGS. 5, 6 and 7. With reference initially to FIG. 5, the magnetic chuck 172 which is preferably used herein, comprises two body portions 220 and 222. These two parts 220 and 222 are operatively interconnected by means of a gear element 223. As stated previously, parts 220 and 222 are supported upon a plate 170, and are retained

by a collar 224. This collar 224 is provided with a recess 225 extending circumferentially thereof, this recess serving to contain and support a strip 226 of material such as tetrafluoroethylene which has very low frictional characteristics. It will also be seen from FIG. 5 that the retaining collar 224 is provided at one position with a borehole 227 that is internally threaded to receive a mating and externally threaded sleeve or bushing 228. The bushing 228 in turn carries with it a cylindrical sleeve insert 230 that has a larger "diameter" recess at one end that is hexagonal in cross-section. The other end of insert 230 is provided with a connecting pin 232 secured thereto by means of a Woodruff key and keyway arrangement 231. The pin 232 is also fixed to the gear element 223 by means of the same key and keyway arrangement 231.

The hexagonal recess in insert 230 is adapted to receive an Allen key 236 that is operatively coupled to a rotary cylinder 242 by means of a coupling arrangement 240. More particularly, coupling device 240 comprises two parts 238 and 239. Part 238 receives key 236 while the part 239 is connected to an output shaft 241 of the cylinder 242. The rota-cylinder 242 is screw-fastened at 245 (FIG. 5) to a lever arm 244. A reinforcing bar 246 is welded to arm 244 which is itself welded to the free end of a pivotally mounted bracket 248 (FIG. 6). Bracket 248 is pivotally mounted on a main pivot pin shown at 250 which is itself journaled in bushings 251 that are seated in the recessed ends of a borehole in mounting bracket 252. The bracket 252 is a block of steel or similar metal which is bolted at 253 to an upstanding channel member 254 itself connected to the main base assembly 104. The mounting bracket 248 and pivot pin 250 are locked together by means of a shear or locking pin 255. A first crank arm 259 is welded to a connecting collar 258 that is fixedly secured to the lower end of pivot pin 250 by means of a pair of set screws 256. The free end of crank arm 259 is pivotally connected at 261 to a second crank arm 260 which is itself pivotally connected to a clevis 262 that is fixed to the free end of a piston rod 264 of a pneumatic cylinder 266. A support bracket 268 is also fixedly secured to the upstanding channel 254 and has welded to its free end a pair of support members 269 that are square in cross section. Welded to the free end of each support member 269 is a vertically-extending plate 270, on each of which there is screw-fastened a pair of limit switches 280 and 282. Each of these limit switches 280 and 282 has an associated sensing element or actuator 281 and 283 respectively, connected thereto. The actuator 281 or 283 is contacted by the support arm 244. Actuation of the limit switch 280 by contact between support arm 244 and actuator 281 indicates that the Allen key 236 has been fully seated in the insert 230 of the magnetic chuck assembly 150. When that has happened, a solenoid switch is energized to actuate rotary cylinder 242 and thereby rotate the Allen key, and with it, the gear element 223. When that happens, relative rotary motion of the parts 220 and 222 of the magnetic chuck takes place causing magnetic elements therein to be coupled together thereby generating a magnetic force which holds the workpieces securely on the chuck 172.

In a corresponding manner, contact between the support arm 244 and sensing element 283 of the limit switch 282 causes the latter to be "tripped" thus indicating that the Allen key 236 has been fully extracted

from contact with the magnetic chuck assembly 150. It should be noted here that actuation of the activate-deactivate mechanism shown overall at 243 is effected by operation of the pneumatic cylinder 266. Inward motion of cylinder piston rod 264 causes the Allen keys 236 to be biased into contact with the low friction strip of material 266 on the chuck assemblies 150 which are located in either the load station 2 or the unload station 4 (referring to FIG. 1). In order to extract the Allen keys 236 from inserts 230 and deactivate the mechanism 243, the return spring shown at 287 is provided. This spring 287 is supported in place in a recess in the mounting bracket 248 by means of an L-shaped supporting bracket 284 and pin means 286 carried by the latter. Compression spring 287 is seated to surround the pin 286 and is in operative engagement with a threaded adjusting screw 288 which is operative the tension in the return spring 287. Since deactivation of the mechanism 243 takes place by the operation of the mechanical compression spring 287 which overrides the effect of the pneumatic cylinder 266 when the latter is de-energized, this extraction operation takes place automatically. Moreover, as will be explained further, below, the limit switches 282 which sense the extracted condition of the Allen keys 236 must be activated before indexing motion of the main turntable 50 can take place. Lastly, FIG. 6 also shows a limit switch 290 associated with the main turntable 250. This limit switch 290 is operative for sensing the correct positioning of the turntable 50. When actuated, the limit switches 290 290' (seen also in FIG. 9) will indicate to the main control circuit of FIG. 3, that main turntable 50 is adequately indexed and in a position wherein other operations such as that of the activate-deactivate mechanism 243, or transferring of a lapping disc 12 onto workpieces about to enter lapping zones 1 or 3 can be allowed to take place.

FIG. 6 shows primarily one half of the chuck activate-deactivate mechanism 243, the other half being a mirror image of structure shown to the left of, say, a longitudinal plane taken through the axis of the pneumatic cylinder 266. It will also be noted that rotation of the pneumatic rotary cylinder 242 will be in one direction to activate or energize the magnetic chuck 172, in the load station 2, while the corresponding rotary cylinder in the unload station 4 will necessarily rotate in the opposite direction, thereby deactivating the magnetic chuck positioned there.

As noted previously, whenever a new workpiece has been placed by an operator onto the chuck assembly 150 then at load station 2, the chuck assembly is turned ON. This magnetically secures that workpiece to the magnetic chuck. Subsequently the main turntable 50 can be indexed with rotary motion in accordance with a timed sequence. In so moving, the fresh workpiece is now moved into the position shown at approximately seven-thirty in FIG. 1, where, a fresh lapping disc 12 can be transferred from the recirculating conveyor 300 to the turntable 50. It should also be noted that the recirculating conveyor 300 moves with a periodic indexing motion, in synchronism with indexing of the turntable 50, as seen from FIG. 11.

Let us now turn to a description of the structure and operation of the recirculating conveyor shown overall at 300 in FIG. 1 and now more particularly with reference to FIGS. 11 through 18, where, the disc-transferring assembly is also illustrated. The indexing

motion for each recirculating conveyor 300 associated with the lapping zones 1 and 3 is derived from the main motor 78, shown in FIG. 10. As noted earlier, there is a gear-reducing unit 76 associated with the drive motor 78 and this unit has an output drive shaft 74. As seen in FIG. 10, the upper end of drive shaft 74 provides the torque needed to index the main turntable 50. The lower end of that drive shaft 74 provides the torque used to rotate recirculating conveyors 300 periodically and in synchronism with indexing motion of the main turntable 50. To achieve that, the lower or bottom end of the drive shaft 74 is provided with a collar 302 secured thereto by a Woodruff key and set screw arrangement 303. A sprocket wheel with teeth 304 is welded or otherwise secured to this mounting collar 302 and drives a chain 306. The drive chain 306 is itself entrained about a driven sprocket wheel 307 provided on the lower end of a vertically extending drive shaft 308 seen best in FIGS. 11 and 12. The drive shaft 308 is connected through a coupling 309 to a stub shaft 310. The lower end of drive shaft 308 is rotatably supported in thrust bearings 311 which are fixedly secured to a horizontal frame member 312 that forms part of the base assembly 104. The stub shaft 310 is supported in a pair of trunnion bearings 313 and 314 which are fixedly supported on a generally vertically positioned end plate 315 of sheet metal. Gusset plates 315' aid in securing the end plates 315 to a horizontally extending frame member 316 as a rigid structure. The frame member 316 is itself welded at each end to vertically extending frame members 317 that are supported from the lower horizontal members 312. Upper and lower driving sprocket wheels 318 are provided on the stub shaft 310, intermediate the bearing 313 and coupling 309. Corresponding upper and lower idler sprocket wheels 318' are provided on the stub shaft 310 at the opposite end of the recirculating conveyor assembly 300, and a conveyor chain 320 is entrained about the sprocket wheels 318 and 318'. A plurality of disc-supporting cradles 322 are secured to the conveyor chains 320 by screw-fastened bracket retaining means 323. A bracket arm 324 extends horizontally from the frame member 316 and functions to rotatably support a pair of idler sprocket wheels 325 which can be seen in FIG. 11. The outermost sprocket wheel 325 is slidably adjustable in the slotted free end of the bracket arm 324 in order to vary the tension in conveyor chains 320.

As noted previously, the drive chain 306 which effects indexing movement of the conveyor chain 320 is itself driven from the output shaft 74 of the main gear-reducing unit 76. The drive chain 306 is, as seen in FIG. 11, entrained about a number of idler sprocket wheels which are supported from rotation as shown in FIG. 18. There, a generally horizontally extending support bar 326 is shown welded to one of the channels 104' that forms part of the main base assembly 104. A pair of idler sprocket wheels shown at 327 and 328 in FIG. 11 are mounted on the support bar 326. As seen in FIG. 18, the outermost end of support bar 326 is slotted at 329 in order to allow for adjustably positioning the sprocket wheel 327 and hence vary the tension in the drive chain 306. A mounting bolt 330 extends through the slot 329, and through a mounting collar 332. This bolt 330 is secured in place by a lock nut 331. A ball bearing 333 is provided on the collar 332 in order to rotatably mount the sprocket wheel 327. These ball

bearings 333 are secured in place by retaining rings 334 provided interiorly of the centrally apertured sprocket wheel 327.

Turning now to FIGS. 13 and 14 in particular, the end plates 315 can be seen as being provided with nose or forward portions 336 to which a pair of apertured mounting blocks 338 are welded. The mounting blocks 338 are so positioned as to receive oil-bronze bushings 340 to rotatably support a generally vertically oriented swivel shaft 342. The top end 343 of the swivel shaft 342 is provided with a driving collar 344 which is secured thereto by a fastening set screw 345. A recess or channel way 346 is provided exteriorly and circumferentially of the collar 344 and is adapted to receive a roller follower 348. The follower 348 is rotatably mounted by a pin 349 in the free end of a crank 350. The other end of this crank 350 is fixedly secured to the stub end 352 of an actuator shaft 354. The actuator shaft 354 is rotatably supported at either end in sleeve bushings 356 that are provided in mounting brackets 358. These mounting brackets 358 are themselves welded to the forward portion 336 of the end plates 315. With reference to FIG. 14, the actuator shaft 354 is provided with a piston crank arm 360. This crank arm 360 is secured to the actuator shaft 354 closer to the end adjacent the idler sprocket wheels 318' (of FIG. 11). Moreover, the crank arm 360 is pin-connected to a cleavis 362 provided on the free end of a piston rod 364. The piston rod 364 is moved reciprocally by the operation of a pneumatic cylinder 366. The cylinder 366 is pivotally supported by a mounting bracket 368 that is screw-fastened or otherwise secured to the horizontally extending frame element 316. It will be recognized that operation of the pneumatic cylinder 366 will cause rotary motion of the actuator shaft 354 to be translated into linear reciprocating motion of the swivel shaft 342. This vertical reciprocating movement is required in order to enable the lapping discs 12 to be picked up from cradles 322 in the recirculating conveyor assemblies 300 and transferred to the disc-supporting head 142 of the disc-reciprocating assemblies 132 and vice versa. As noted earlier, each of the stems 13 on the lapping discs 12 has a pair of diametrically enlarged portions 14 and 15. Hence, these lapping discs must be moved up and down in order to either seat or remove a disc 12 from one of the cradles 233 of supporting heads 142.

The other and lower end 370 of the swivel shaft 342 has a pinion gear 372 fixedly secured thereto by means of a set screw or the like. Pinion gear 372 is adapted to operatively engage a rack 374 which is carried by one end of a piston rod 376 of a pneumatic cylinder 378. The cylinder 378 is secured by suitable mounting brackets to the horizontally extending frame element 316. For smoothness of operation in effecting reciprocal movement of the rack 374 and the consequent smooth rotation of swivel shaft 342, the pneumatic cylinder 378 is augmented by a hydraulic cylinder (not shown). It will be recognized that a hydraulic cylinder involves the use of a basically incompressible fluid as compared to air, and hence, any tendency for erratic movement of the rack will be reduced and possibly eliminated entirely.

Beyond the pinion gear 372, there is a first collar 380 fixedly secured to the swivel shaft 342 which rests upon oil-bronze bushing 383 carried upon a tubular support sleeve 382. At the lower end of the support sleeve 382

there is a further bushing 383 which abuts against a retaining collar 384. A swivel arm 390 is welded to the tubular sleeve 382, with an over-travel spring 392 being fixed at one end to the collar 380 and at its other end slideably retained by mounting pins 393 in the swivel arm 390. A disc-gripping mechanism shown overall at 394 is supported by the free end of swivel arm 390. Accordingly, a borehole 395 is provided at the free end of swivel arm 390, this borehole being adapted to receive a support pin 400. The ends of support pin 400 are mounted in bushings 396 and 397 that are carried by support brackets 398 and 399. A spacer sleeve 401 is seated on the top surface of swivel arm 390 and functions to transfer part of the load generated by the weight of the assembly 394 through bracket arm 399 to the swivel arm 390.

As best seen in FIGS. 16 and 17 the support brackets 398 and 399 are welded to the back face of a supporting plate 402. A pair of spring loaded pin assemblies 403 are mounted in the free end of arm 380, on opposite sides of the borehole 395. Pin assemblies 403 allow for some pivoting of gripping assembly 394 as it is being moved, and for some misalignment of the stems 13 of disc assemblies 12 when the latter are being picked up. A fixed gripper arm 404 including a gripper pad 405 and a pivotally movable gripper arm 406 including notched gripper pad 407 are supported from the front face of the plate 402. A notch 408 is provided in gripper pad 407 in order to accommodate the smaller diameter stem 13 of each lapping disc 12, with a loose fit having slight play. This is desirable to avoid any excessive bending stresses in the stem of the lapping discs 12 as the latter are moved rather quickly from the recirculating conveyor 300 to the main turntable 50 or vice versa. It will be recognized that most of the weight of each lapping disc 12 is in the actual disc element 16 and not in the stem 13. Hence, it is desirable to allow some slight play or pivotal movement of the disc assembly 12 when gripped between pads 405 and 407.

The movable gripper arm 406 includes a crank arm 410 which is pivotally mounted at 412 on the plate 402. A cleavis connector 414 is connected to the "free" end of the crank arm 410 and is in turn securely attached to the free end of a piston rod 416. The latter is actuated for reciprocal motion by operation of a pneumatic cylinder 418. The pneumatic cylinder 418 is itself pivotally mounted as shown at 420 on the plate 402. As seen in FIG. 16, an adjustable stop 422 is provided for positively limiting the amount of clockwise travel of crank arm 410. It will be noted that the movable gripper arm 406 in some instances swings in a direction outwardly, i.e., away from the main turntable 50; while in other instances, such swinging motion is towards the turntable. This can be picked up from FIG. 11 by keeping in mind the fact that the notched pad 407 is on the movable gripper arm 406 and is the one which swings away from the other gripper pad 405. The moving gripper arm 406 is beveled as shown at 424 in order to enable contact with an actuator 425 associated with a microswitch 426. It is to be noted that microswitch 426 must be actuated in order to signal a condition to the control circuit of FIG. 3 that will allow indexing motion of the turntable 50 to take place. The microswitch 426 is one of a number of similar "condition-sensing" microswitches which all must be actuated before indexing motion can occur. The normally open position of the

moving gripper arms 406 and pad 407 thereon are shown in ghosted lines in FIG. 14.

The lapping machine 10 constructed according to the present invention is, in its preferred form, highly automated. As a result, turning of the magnetic chuck assemblies 150 on or off will be done in a timed sequence, as will the picking up of lapping discs 12 from recirculating conveyor assembly 300 transferring the same in a generally horizontal plane across to subsequently be lowered for engagement with and support by heads 142 of disc-supporting and reciprocating assemblies 132. Furthermore, it will be apparent that once a lapping disc 12 has been transferred from the conveyor assembly 300 onto the lapping machine 10, (and vice versa) the control circuit shown in FIG. 3 will operate to energize the main driving motor 78 which causes indexing motion of the turntable 50. Such indexing motion will, however, only occur when certain microswitches are closed. These microswitches are associated, for example, with a sensed indication of the complete retraction of the key element which turns magnetic chucks 172 on and off; a return of the swivel arms 390 with gripping mechanisms 394 to their normal rest positions; and the return of each gripping mechanism 394 to its normally open position, sensed by microswitch 426 shown in FIG. 14. It should be noted that relative to the direction of indexing motion of the turntable 50, the "upstream" transfer assembly will be in the normal rest position when its swivel arm 390 is retracted to a position ready to pick up a lapping disc from the recirculating conveyor 300. In contrast to that, the downstream transfer assembly is in a normal rest position when its swivel arm 390 is in its extended position with gripping mechanism 394 positioned over one of the chuck assemblies 150 and ready to pick up and remove lapping disc 12 from the lapping machine 10.

The electrical control circuit which governs the operation of a preferred form of the present invention as described herein, is illustrated in FIG. 3. In addition, the following tabulation of items designated in FIG. 3 follows below with a brief reference to the description of each item.

LEGEND FOR FIGURE 3

Item	Description
L1, L2, L3	power lines 3 ϕ , 460 v, 60 cps
H1, H2	high voltage transformer contacts
X1, X2	low voltage transformer contacts
OL1, OL2, OL3	overload relay coils — part of manual motor starter with thermal overload trip
OL4, OL5, OL6	overload relay contacts n.o.
M1, M2, M3	electric motors
M1C1, M2C1, M3C1	Motor contacts n.o.
MIT1 to M3T3	motor terminals from power supply L1 to L3
M1R, M2R, M3R	motor relays
M1RC1	motor 1 relay contact n.c.
M1RC2	motor 1 relay contact n.c.
M1RC3	motor 1 relay contact n.o.
M2RC1	motor 2 relay contact n.o.
M3RC1	motor 3 relay contact n.c.
R1, R2, R3, R4	relays to be energized
K1C1	relay 1 contact n.o.
R2C1	relay 2 contact n.o.
R3C1	relay 3 contact n.o.
R4C1	relay 4 contact n.o.
R4C2	relay 4 contact n.o.
SM	starting magnet for timer
SMC1	starting magnet contact n.c.
SMC2	starting magnet contact n.o.
S1 to S8	solenoids to be actuated
LS9 to LS19	limit switches
PL1, PL2	pilot lights

A
T1, T2
T1C1
T2C1 to T2C6
PC

alarm bell
timers, T1 is adjustable
timer 1 contacts
timer 2 contacts
photo cell

It should be noted that the electric drive motor designated M1 in FIG. 3 is the main drive motor which effects indexing motion of the main turntable 50, and is shown at 78 in FIG. 10. There, the motors designated by M2 and M3 in FIG. 3 are shown at 92 and 96, respectively.

Returning now to FIGS. 3 and 4, it should be noted that timer T1 is adjustable and governs the time allowable between indexing motions. Timer T2 comprises a number of rotationally driven cam wheels which close timer contacts T2C1 to T2C6 in a predetermined sequence. This will become apparent from the description below. With reference then to FIG. 3, operation of the lapping machine 10 as controlled by the circuit of FIG. 3 will be as follows.

It should initially be assumed that any previous operation of the lapping machine 10 was completed and that the portion of the electrical control circuit involving the photo cell PC in series with limit switches LS14 through LS19 is completed through the relay R3. Relay R3 is therefore energized and consequently the normally open relay contact R3C1 is closed. Consequently, pressing the start button will effect energization of the relay R1, and that circuit remains open because of closing of the normally open relay contact R1C1. At this point in time, various electrical functions are taking place together. These are as follows: energization of timer T1 through the normally closed contacts of LS13 (which have to be in actuated position) causes the normally open timer contact T1C1 to be closed. This in turn allows motor relay M1R to be energized through the normally closed starting magnet contact SMC1 and the normally closed limit switches LS9 and LS 12. Operation of motor M1 causes indexing of turntable 50 while energization of relay M1R prevents operation of motors M2 and M3 through opening of the relay contact M1RC2 (n.c.). Upon completion of the indexing motion, motor relay M2R is energized through terminal point 10 (adjacent limit switch LS12 in FIG. 3) and the normally closed motor relay contact M1RC2. Energization of the motor relay M2R subsequently allows the normally open motor relay contact M2RC1 to be closed and motor relay M3R to be energized. Since motor relay M1R has been energized, it will be seen from the bottom of FIG. 3 that closing the normally open motor relay contact M1RC3 will allow relay R4 to be energized, and normally open relay contact R4C2 to close, and be held in. Energization of the relay R4 also pulls in and closes relay contact R4C1, thereby allowing the starting magnet SM to be energized through the normally closed motor relay contact M3RC1, through to the return line terminal point 9. Energization of the timer T1 has pulled in and closed the normally open timer contact T1C1. Pilot light PL1 detects if either of limit switches LS9 or LS12 is open prior to indexing. Motor relay contact M1RC1 (n.c.) is opened by energization of motor relay M1R. If either LS9 or LS12 is open relay contact M1RC1 is closed and light PL1 comes on. Energization of the starting magnet SM will subsequently allow the normally open starting magnet contact SMC2 to be closed and timer T2 which is a cam timer to be energized.

All of the operations just mentioned occur more or less together although it will, of course, be seen that certain relays and contacts must be closed before some other part of the circuit can be completed. These various functions will occur virtually immediately after pressing the start button. The left-hand vertical line shown in FIG. 4 represents the starting point in time when the start button is pushed. Some time will elapse before timer T2 is energized, as shown by the next vertical line in FIG. 4. It will also be realized that energization of the motor relays M1R, M2R, and M3R will in turn effect closing of the normally open motor contacts M1C1, M2C1 and M3C1.

Following pushing of the start button, if the photo cell PC and limit switches LS14 through LS19 are closed relay R3 can be energized, (and this is subsequently held energized by pulling in of the relay contact R2C1 which follows energization of relay R2 caused by closing of timer contact T2C2) the first motion which takes place is that of indexing of the main turntable 50 by means of motor M1 shown at 78 in FIG. 10. This indexing motion of the main turntable 50 will cause actuation of the limit switch shown at 290 in FIG. 6. Since motor relays M2R and M3R have been energized at about the same time as energization of the cam timer T2, those motor relays will cause driving motors M2 and M3 (92 and 96 in FIG. 10) to cause rotation of the drive shafts 95, 100 and 102 (also shown in FIG. 10). When that happens, the chuck assemblies 150 which are now positioned within lapping zones 1 and 3 of FIG. 1 will begin to rotate, as will those chuck assemblies 150 which are located at the index positions at load station 2 and unload station 4. Starting of the cam timer T2 will, after a predetermined interval of time, cause timer contact T2C1 to be closed. This causes solenoid S1 to be actuated which will in turn operate pneumatic cylinder 266 of FIG. 6, causing the Allen keys 236 to be brought into engagement with the (nylon) strip 226 on the retaining collar 201 of each of the chuck assemblies 150 currently occupying the index position at load station 2 and unload station 4. These two chuck assemblies 150 will continue to rotate until such time as the recess 234 in insert 230 comes into alignment with the Allen key 236. When that happens, the biasing pressure causes the Allen keys to be inserted into the recesses 234 until such time as they are fully seated. The fully seated condition is sensed by contact of the support arms 244 with sensor 281 on limit switches LS10 and LS11 shown at 280 in FIG. 6. Rotation of the cams in cam timer T2 will subsequently allow timer contact T2C2 to be closed, hence energizing solenoid S3 which in turn will cause actuation of the rotary cylinders 242 which turn Allen keys 236. Such motion of the Allen keys 236 will cause the magnetic chucks 172 at load station 2 and unload station 4 to be turned OFF. Pilot light PL2 will also be illuminated to indicate that turning of the Allen keys 236 has taken place, and that the chucks 172 are in a "safe", i.e., non-magnetized condition. Both chucks 172 will subsequently be turned ON before retraction of keys 236. As noted also from the control circuit of FIG. 3, following closing of the timer contact T2C2 onto terminal point 13 the relay R2 will subsequently be energized. When that happens, the normally open relay contact R2C1 is closed and relay R3 can be maintained energized despite, for instance, interruption of the photo cell beam and circuit as caused by the presence of an operator close to the ma-

chine such as when moving a workpiece from the chuck assembly 150 at the unload station 4. On the other hand, when timer contact T2C2 switches back to terminal point 14, relay R3 is controlled only by the photo cell PC and limit switches LS14 through LS19. Relay R3 must remain energized in order to allow the normally open relay contact R3C1 in the upper left-hand portion of FIG. 3 to remain closed and allow motors M2 and M3 to continue operating because of the energization of motor relays M2R and M3R.

Next in the timing sequence, timer contact R2C3 is closed causing solenoid S5 to be energized and this in turn will actuate the pneumatic cylinders 418 associated with each of the disc-gripping mechanisms shown overall at 394 in FIG. 14. Next, timer contact T2C4 is closed with energization of solenoid S6 causing actuation of pneumatic cylinders 366 which in turn will cause vertical lifting movement of the swivel shafts 342, and with it, picking up of a lapping disc 12 from a cradle 322 on the conveyor chain 320, and supporting head 142 on lapping machine 10. Subsequently, timer contact T2C5 is closed and with it, solenoid S7 is energized. That causes actuation of the pneumatic cylinders 378 which will effect linear movement of the racks 374 and with it rotation of pinion gears 372 and swivel shafts 342. That rotation of swivel shafts 342 will, in the case of the upstream transfer assemblies cause swivel arms 390 to swing the lapping disc 12 which has just been picked up from the recirculating conveyor assembly 300 to be transferred across to the lapping machine 10. That swiveling motion continues until the lapping discs 12 at the upstream stations (relative to indexing movement of the turntable 50) has been fully seated within disc-supporting heads 142 of the disc-reciprocating assemblies 132. There will be a mechanical stop provided to limit the extent of swinging travel possible by the swivel arm 390. The over-travel spring 392 is provided to absorb some of the shock loads generated by contact of the transfer mechanism and swivel arm carrying the same with such mechanical stops. Simultaneously with the transfer of lapping discs 12 to the lapping machine 10, of the upstream station, there will also be a simultaneous pickup and transfer of a lapping disc 12 from a downstream index position of the turntable 50 back to be seated in the disc-supporting cradle 322 being carried by conveyor chain 320. It should again be noted that since indexing motion of the turntable 50 and driving motion of the conveyor chains 320 in recirculating conveyor assemblies 300 are derived from a common drive shaft, output shaft 74 of the main gear-reducing unit 76, those movements will be in complete synchronism. This is of course necessary in order to ensure that a disc-supporting cradle 322 which has previously been empty is advanced to such a position that it can accept a disc 12 being transferred from the lapping machine back to the recirculating conveyor assembly 300. The same holds true at the upstream position as well, where a lapping disc being carried forward in one of the cradles 322 must be so positioned as to enable retrieval of that lapping disc 12 by the disc-gripping mechanism 394 and subsequent transfer to the lapping machine 10.

The last cam in cam timer T2 effects closing of the timer contact T2C6 and causes an alarm, usually in the form of a bell or buzzer, to sound. This alarm sounds a few seconds before timer contact T2C2 switches back to terminal point 14, and indicates that in a few seconds

the chucks 172 at stations 2 and 4 will be turned ON (therefore in an "unsafe" condition). Following sounding of the alarm, lapping of the discs carried by chuck assemblies 150 located within lapping zones 1 and 3 will continue for a time period which represents the difference in setting of the fixed timer T2 relative to the adjustable timer T1.

The foregoing description has disclosed one particular form of a lapping machine, and has suggested some modifications thereto. Other modifications and alternative structures will also be possible within the scope of this invention. It is contemplated, therefore, that all such changes and alternatives are to be comprehended within the spirit of the invention, as defined by the appended claims.

I claim:

1. In apparatus for treating a surface on a workpiece movable from a load station onto a rotatable turntable and removable therefrom to an unload station, including support means rotatably mounted on the turntable for carrying at least one workpiece, the improvement comprising: disc means engageable with the workpiece to cause said surface treatment thereof, the disc means having a stem portion; a support assembly provided on and movable with said turntable, being adapted to floatingly support said disc means by arranging the stem portion of the disc means to be pivotable in said support assembly.

2. Apparatus as defined in claim 1 wherein said disc means comprises a lapping disc that has a substantially flat working surface, the stem portion of the disc means being pivotally connected by one end thereof to the lapping disc, and also being provided with shoulder means at another end thereof, floatingly engageable by said support assembly on the turntable.

3. Apparatus as defined in claim 2, wherein said support assembly causes reciprocal movement of the disc means in a direction radially of the turntable.

4. Apparatus for treating a surface on a workpiece movable from a load station onto a rotatable turntable and removable therefrom to an unload station, including support means rotatably mounted on the turntable for carrying at least one workpiece, the improvement comprising: disc means; a plurality of support assemblies on the turntable, operable to support the disc means for engaging the workpiece and effecting said surface treatment thereof; a plurality of treatment zones in said apparatus; means for periodically and automatically placing fresh workpieces onto said support means, and means for correspondingly removing treated workpieces from the support means automatically; and a conveyor and transfer system operable for recirculating said disc means from each of the support assemblies at a disc-releasing position in each treatment zone back to another of the support assemblies at a disc pick-up position in said treatment zone on the turntable.

5. Apparatus as defined in claim 4, wherein said conveyor and transfer system comprises the combination of disc transfer means and recirculating conveyor means positioned adjacent the turntable, said conveyor means including a conveyor chain on which there is carried a plurality of disc-engaging cradles; said disc transfer means having disc-supporting fingers thereon operable for transferring said disc means from the disc-supporting cradles to the support assemblies, and vice

versa; said disc-supporting cradles being adapted for receiving and releasably supporting said disc means.

6. In apparatus for treating a surface on a workpiece movable from a load station onto a rotatable turntable and removable therefrom to an unload station, the improvement comprising the combination of a base assembly for rotatably supporting the turntable; support means in the form of a plurality of chuck assemblies rotatably mounted on the turntable for carrying a plurality of workpieces, the workpieces carried by a chuck assembly having surfaces to be treated disposed in a common plane; a plurality of treatment zones; drive means in the base assembly for selectively causing independent rotation of the chuck assemblies in each of the treatment zones; a support assembly on the turntable and movable therewith, having a disc-supporting head and a tubular body section, the body section housing a push rod connected to said disc-supporting head and adapted to the reciprocally movable to cause a corresponding reciprocal movement of the disc-supporting head; disc means engageable with the workpiece surfaces and causing said finishing treatment thereof; the disc means being adapted to be floatingly supported by said disc-supporting head in contact with the surfaces of the workpieces supported on each chuck assembly; actuating means causing reciprocal movement of the push rod and disc-supporting head, such reciprocal movement combining with rotational movement of each chuck assembly to cause compound rotation of the disc means relative to the workpiece surface being treated by engagement therewith, thereby uniformly distributing wear of the disc means and workpiece surface to obtain maximum flatness of said surface; and driving means in the base assembly actuatable in a timed sequence for indexing the turntable and advancing the workpieces through the treatment zones provided between the load and unload stations.

ing the workpieces through the treatment zones provided between the load and unload stations.

7. In apparatus for treating a surface on a workpiece movable from a load station onto a rotatable turntable, and removable therefrom from an unload station, including support means mounted on the turntable for carrying at least one workpiece; the improvement comprising:

a plurality of treatment zones through which the workpiece is advanced by rotation of the turntable; disc means arranged in each treatment zone for engaging the workpiece to cause said surface treatment thereof; a plurality of support assemblies mounted on the turntable and movable therewith, each support assembly being operable to support the disc means in engagement with said surface to be treated, each of said support assemblies being constructed to provide reciprocal movement to disc means supported thereon, radially of the turntable during passage of the workpiece through one of the treatment zones; the arrangement of said treatment zones and support assemblies which carry disc means being such that lapping, burnishing or other such treatments can take place in one of said zones independently of any such treatment taking place in another zone.

8. The apparatus defined in claim 7, wherein each support assembly comprises a head section for pivotally supporting the disc means, and a body section including shaft means movably mounted therein and connected to said body section; and wherein cam means are provided on said turntable to generate period reciprocation of the shaft means and said head section.

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