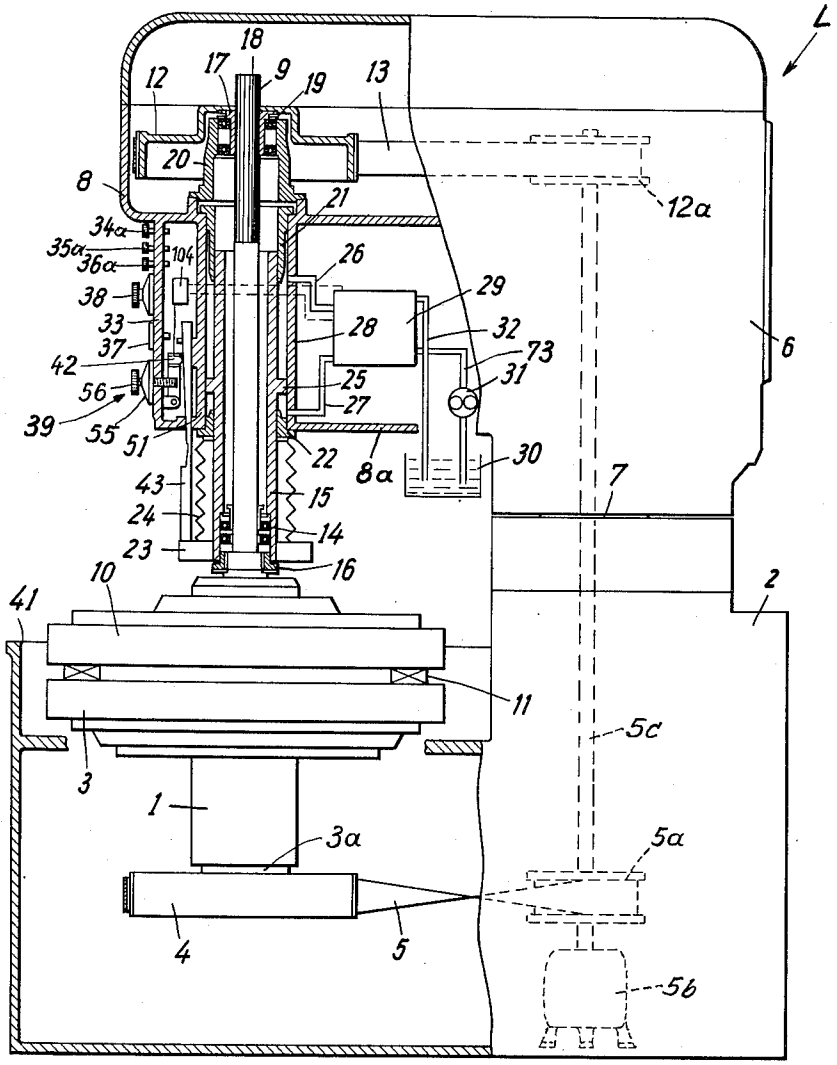
May 22, 1962 HANS-FRIEDRICH BOVENSIEPEN ETAL 3,035,377

LAPPING MACHINE

Filed Dec. 22, 1959 8 Sheets-Sheet 1

Fig. 1



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LAPPING MACHINE

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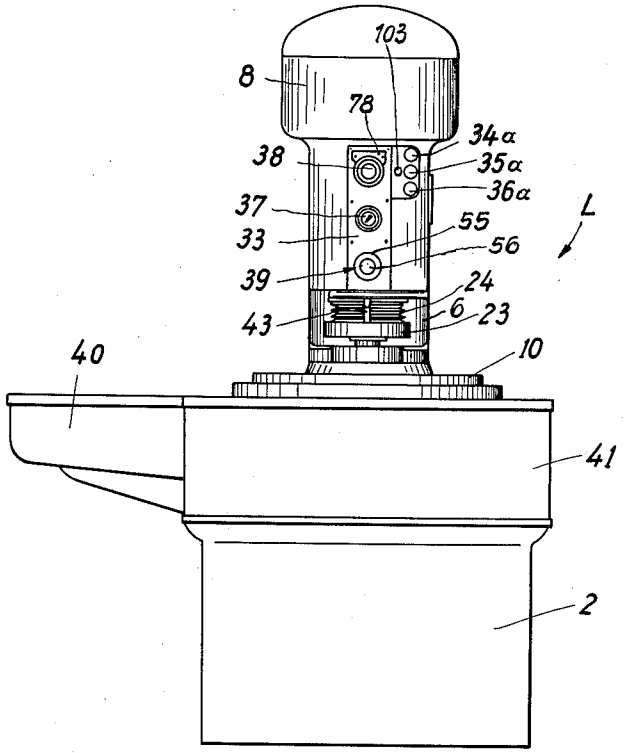

Fig. 2

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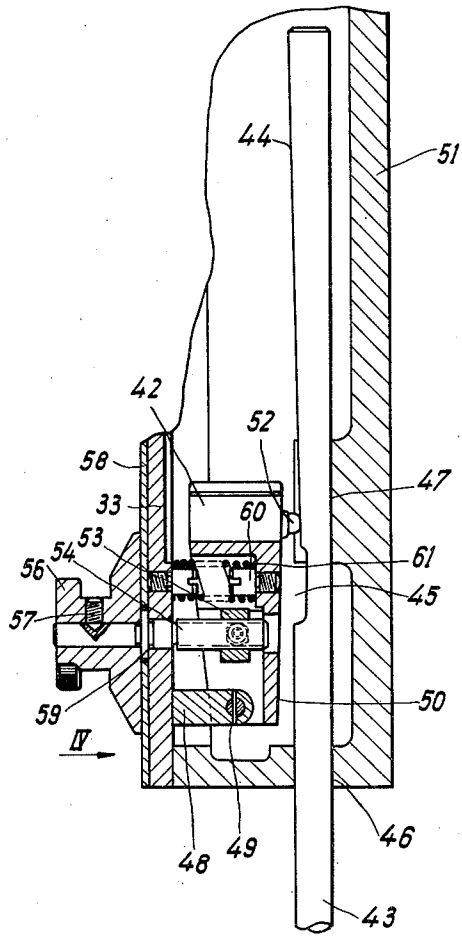

Fig. 3

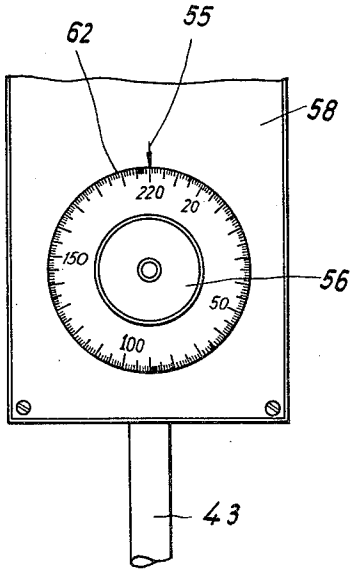

Fig. 4

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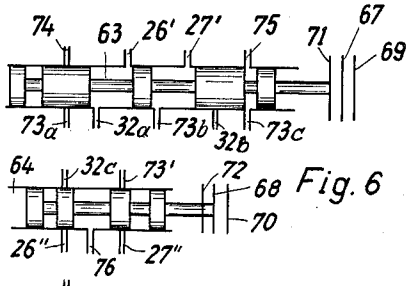

Fig. 6

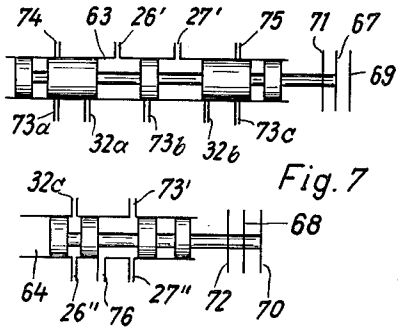

Fig. 7

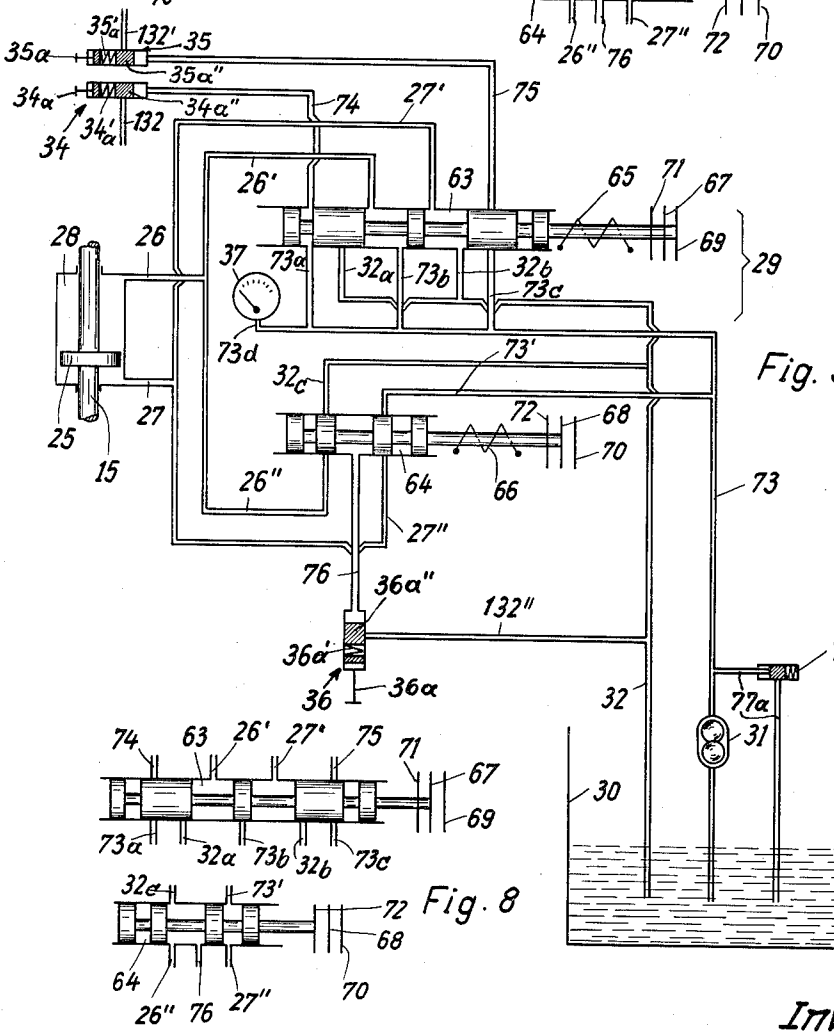

Fig. 5

Fig. 8

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LAPPING MACHINE

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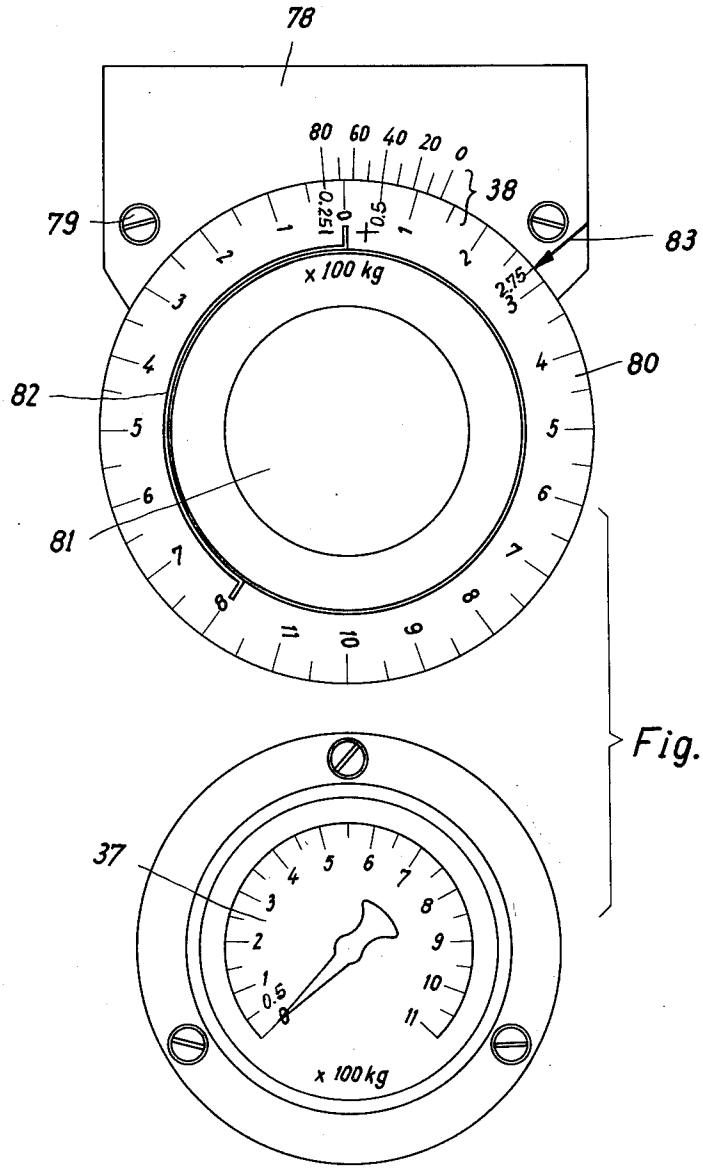

Fig. 9

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LAPPING MACHINE

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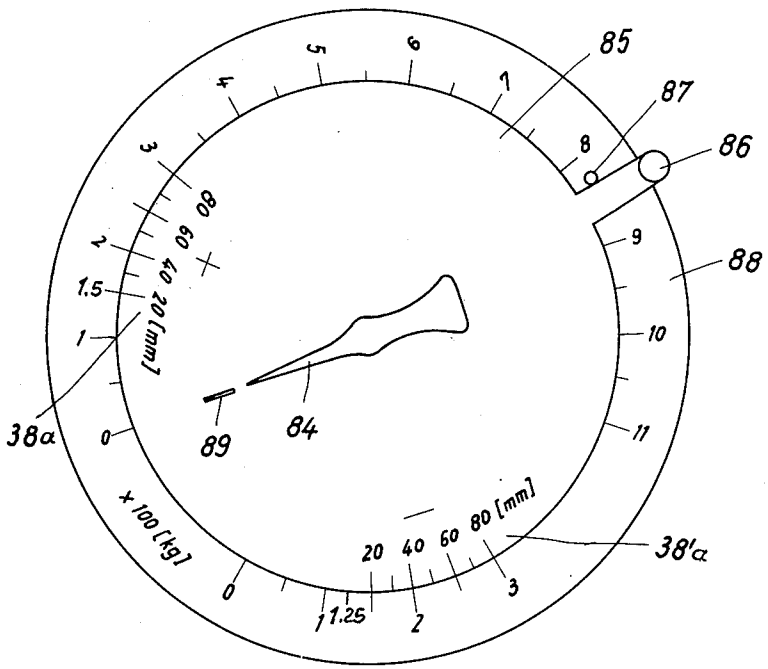

Fig. 10

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LAPPING MACHINE

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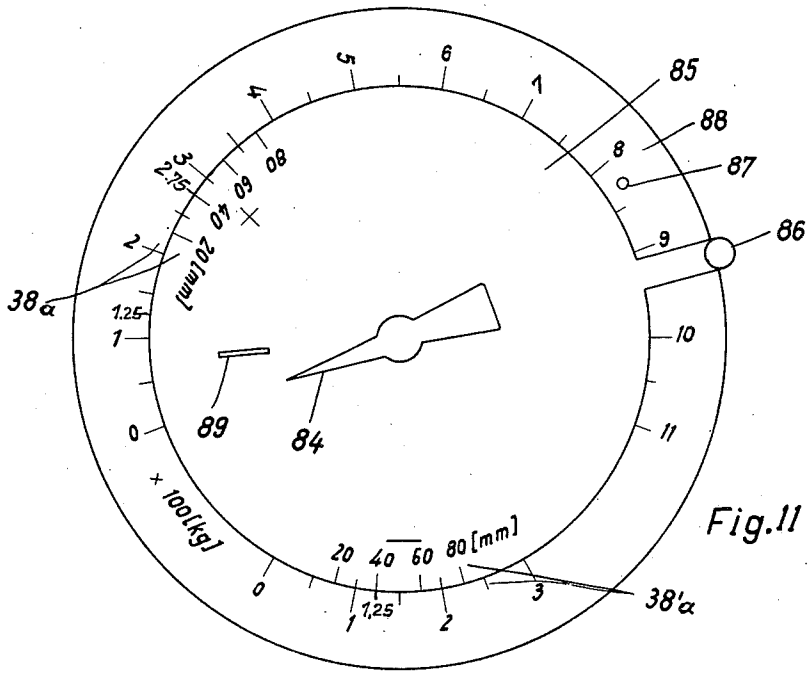

Fig. 11

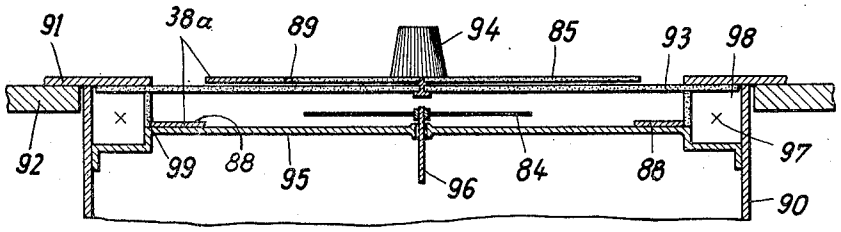

Fig. 12

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LAPPING MACHINE

Filed Dec. 22, 1959 8 Sheets-Sheet 8

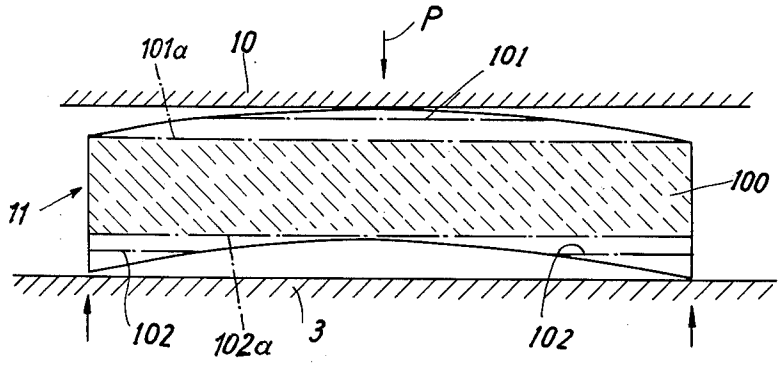

Fig. 13

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United States Patent Office 3,035,377 Patented May 22, 1962

3,035,377
LAPPING MACHINE

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Filed Dec. 22, 1959, Ser. No. 861,239
Claims priority, application Germany Dec. 22, 1958
22 Claims. (Cl. 51—111)

The present invention relates to improvements in one- and two-lap lapping or superfinishing machines. More particularly, the invention relates to improvements in lapping machines of the type wherein the overall lapping load upon the work pieces placed onto a lapping member includes the combined weight of a series of vertically reciprocable parts plus or minus the pressure of a double-acting, preferably hydraulic piston. A one-lap lapping machine utilizes a single, preferably discoid lapping member which is normally caused to perform a rotary movement to produce a highly finished surface on each work piece in contact therewith. In a two-lap lapping machine, a single work piece or a series of work pieces is placed between two normally discoid or annular lapping members which then simultaneously treat two opposing surfaces of each work piece by rotating in opposing directions or in the same direction but at different angular speeds.

In a one-lap lapping machine, the aforementioned combined weight includes the weight of the work piece or, if a series of articles is lapped in a simultaneous operation, the weight of all such work pieces. In a two-lap lapping machine which is particularly adapted to embody the features of our present invention, the overall load during the lapping operation includes the weight of the upper lapping member but not the weight of the comparatively light work piece or work pieces.

In certain presently known two-lap lapping machines wherein the load upon the lower lapping member or lap normally equals the load upon the upper lapping member, the lapping pressure or load on the work pieces can be changed and regulated only by varying the pressure of a hydraulic piston which is connected with the lower lapping member. Such arrangement renders it difficult to find and/or to maintain the optimum piston pressure for a given type of work pieces which must be treated in the lapping machine. In such constructions, the selection of optimum load for the work pieces depends solely upon the skill and experience of the operator in charge of the lapping machine, and the machine cannot furnish exact data as to existing pressures even if the operator should accidentally set the machine for optimum load. Consequently, such lapping machines cannot be operated with a desired degree of accuracy, and it is particularly difficult to set the machines in advance for optimum load in connection with different types of work pieces. As a consequence, the work pieces are frequently subjected to excessive or insufficient loads, and the quality of treated articles varies within a wide range.

The above enumerated problems are partially solved in another type of known two-lap lapping machine in which the weight of vertically reciprocable parts is equalized and compensated for by a system of counterweights, and wherein only the pressure of a hydraulic piston produces the actual operating pressure or load upon the work pieces, i.e. the weight of movable parts including the weight of the upper lapping member or lap does not contribute to the lapping pressure. Such machines normally comprise a pressure gauge which is intended to furnish readings as to the load to which the work pieces are subjected during lapping. The lapping operation is often carried out in two immediately following stages in

the first of which the work pieces are subjected to comparatively high loads and in the second of which the load is reduced considerably so that the final part of the lapping operation occurs at a much lower pressure.

An important object of the present invention is to provide a very compact, reliable and highly versatile lapping machine which is capable of furnishing accurate readings as to the momentary load upon the lapped work pieces and which can change such load within the required range without resorting to bulky counterweights and like dimensions- and weight-increasing systems.

Another important object of the invention is to provide a lapping machine of the just outlined characteristics which is constructed in such a way as to permit very simple and rapid determination of and convenient setting for optimum loads upon the work pieces before the lapping operation begins.

A further object of the invention is to provide a lapping machine of the type as above set forth which is particularly suitable for superfinishing of slightly deformed at least moderately resilient work pieces in that it performs the lapping operation in a way to prevent a finished article from recoiling into deformed condition by removing all or the major part of deformed zones from the article.

An additional object of the instant invention is to provide a lapping machine which is capable of finishing a single or a series of work pieces without causing chipping or the formation of fissures in the treated surfaces.

A concomitant object of the present invention is to provide a lapping machine which is capable of treating the surfaces of a deformed work piece without the danger of breakage even if the work piece consists of comparatively brittle material.

A further object of the invention is to provide a lapping machine of the above outlined characteristics which is capable of automatically changing the load upon the work pieces in such a way as to perform the lapping operation in more than one stage under different pressure conditions.

An additional object of the invention is to provide a lapping machine which embodies control means capable of automatically varying the load upon the work pieces in a way best suited for each specific type of treated goods, whose control system is of comparatively simple design and may be serviced by a single operator in a fully mechanical way requiring no special skill, which may be used in connection with the lapping of many articles of different configuration and of widely different materials, and which takes into full consideration the wear and tear upon the lapping members to determine with great accuracy the optimum load conditions for the work pieces.

A still further object of the present invention is to provide a lapping machine which is constructed in such a way as to afford ready access to the work pieces, which embodies suitable instruments for effecting measurements necessary after each regrinding or refinishing of the lapping members, and whose moving parts may be driven by a single power source.

With the above objects in view, the invention resides essentially in the provision of a lapping machine which is constructed and assembled in such a way that the load upon a single work piece or a series of work pieces during a lapping operation equals the combined weight of all parts movable toward and into contact with the work pieces plus or minus the positive or negative pressure exerted against a double-acting piston by a preferably hydraulic pressure medium whose flow into and from the cylinder of said piston is controlled by a novel system of adjustable control valves which may be set in such a way as to produce a given load upon the work pieces. The aforemen-

tioned piston is connected to and reciprocates with the parts which are movable toward and away from the work pieces and, depending upon the direction of the fluid pressure acting thereagainst, either contributes to the action of the gravitational force of such parts or acts against the gravitational force.

Among others, the invention is based on the recognition that a balancing of the weight of all such parts which are movable toward and away from the work pieces and eventually also the weight of the work pieces by the provision of bulky counterweights and like devices in order to insure that a pressure gauge will furnish accurate readings regarding the lapping pressures would unduly affect the design and weight of the machine. A very important feature of the invention resides in that the improved lapping machine operates without counterweights but is nevertheless capable of being adjusted to any desired operating pressure for the work pieces to the same extent as, and in an even simpler manner than, the presently utilized much bulkier lapping machines with counterweights.

An important advantage of the conduit and valve system which controls and adjusts the fluid pressure upon the double-acting piston is that, once the desired load upon the work pieces is established, an operator can subject the work pieces to such desired load in a fully mechanical way without exercising any particular skill beyond that necessary for adjusting certain valves and starting the power drive for the lapping machine. The control system is provided with suitable pressure gauges of novel design which furnish accurate readings as to the pressures to which the work pieces are to be subjected as well as continuous information regarding the actual operating pressures. Certain graduated component parts of such gauges may be readily exchanged if the operator desires to utilize a different lapping member for a particular lapping operation.

An additional very advantageous feature of the improved lapping machine is that it takes into full consideration eventual deformation of work pieces before a lapping operation begins, as well as the characteristics of the material of which the work pieces are made, and thus prevents breakage, formation of fissures in or any chipping of the work pieces. For example, it is a rather frequent occurrence that a comparatively long but thin work piece enters the lapping machine in a somewhat deformed, e.g. bent, condition which may be brought about in a number of ways, such as during the hardening of metallic articles. If a deformed work piece is immediately subjected to a full load exerted thereagainst by an upper lapping member which presses it against the lower lapping member of a two-lap lapping machine, the normally at least slightly elastic work piece is straightened or flattened out before the lapping operation begins but immediately recoils into its original deformed condition as soon as the lapping pressure ceases. This phenomenon is also observable in conventional one-lap lapping machines in which a work piece is merely moved against a single lapping member of discoid or annular shape. In addition, the danger that a comparatively brittle deformed work piece may break during lapping is always present if full operating pressure is applied against a deformed article.

The novel lapping machine, particularly when utilizing two lapping members, is capable of fully preventing elastic deformation of resilient work pieces or breakage of brittle work pieces. To that end, the valve system for the aforementioned double-acting piston of the reciprocable lapping member preferably causes said lapping member to rapidly descend toward the work piece; to thereupon reduce its speed sufficiently to enter into contact with the work pieces without any shock or sudden impact such as could cause damage to the treated articles; to subsequently subject the work pieces to an initial load which is a fraction of the total operating load so as to partially treat the work pieces and to increase the area of their contact with the lapping members; and to finally apply the full operating pressure at a time when the surface-to-surface contact of partially lapped work pieces with the lapping members is sufficient to prevent breakage or eventual resilient deformation of treated articles. The means for automatically operating the control valve system in a way to subject the piston of the movable lapping member to pressures in a sequence as described hereinabove may embody a suitable trailing or make-before-break contact assembly, an electrically operable system of valve switches and electromagnets, and a time-lag relay which latter controls the timing of one or more switching and contact devices.

It will be noted that, contrary to the operation of presently known lapping machines which utilize counterweights, the improved lapping machine subjects the work pieces to a lower pressure in the first stage of the lapping operation and thereupon subjects the partially lapped work pieces to increased pressures which are maintained to the very end of the treatment. By dispensing with the counterweights, the improved machine may be manufactured at a lower cost with greatly reduced weight and dimensions. It also operates with lower fluid pressures since the weight of all movable parts can contribute to the lapping pressures.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following detailed description of certain specific embodiments when read in connection with the accompanying drawings, in which:

FIG. 1 is in part side elevational and in part vertical sectional view of a two-lap lapping machine embodying the present invention;

FIG. 2 is a somewhat reduced front elevational view of the lapping machine shown in FIG. 1;

FIG. 3 illustrates in section the housing and adjusting means of a trailing switch assembly including a limit switch as well as a tripping device therefor, the purpose of this switch being to prevent sudden impact of the vertically reciprocable upper lapping member against the work pieces;

FIG. 4 is a front elevational view of the structure shown in FIG. 3 as seen in the direction of arrow IV, showing the operating knob for controlling the exact timing of the action of the tripping device against the limit switch and a dial for facilitating the setting of the knob;

FIG. 5 is a schematic view of the conduit and valve system which controls the double-acting piston of the upper lapping member, the system being shown in a position in which it subjects the piston and the upper lapping member to positive pressure tending to move or actually moving the latter in downward direction;

FIG. 6 illustrates a pair of slide valves forming part of the valve system shown in FIG. 5, the slide valves being illustrated in a position enabling the hydraulic fluid to exert a negative upwardly directed pressure upon the piston and the upper lapping member;

FIG. 7 illustrates the slide valves of FIG. 6 in a position they assume when the work pieces are subjected to a partial load at the outset of a lapping operation;

FIG. 8 shows the slide valves in a position in which the hydraulic fluid is free to cause upward movement of the piston with the upper lapping member in a direction away from the work pieces when the lapping operation is completed;

FIG. 9 illustrates a pressure gauge for the hydraulic fluid and an adjacent second gauge which indicate the optimum load during a lapping operation;

FIG. 10 illustrates a modified system of two concentric gauges which may be utilized as a substitute for the gauges shown in FIG. 9;

FIG. 11 shows the gauges of FIG. 10 in a different position;

FIG. 12 is an axial section through the system of gauges shown in FIGS. 10 and 11; and

FIG. 13 illustrates in vertical section a deformed work piece between a pair of lapping members at the beginning of a lapping operation, the deformation of the work piece being exaggerated for the sake of clarity.

Referring now in greater detail to the drawings, and first to FIGS. 1 and 2, there is shown a lapping or superfinishing machine L which comprises a frame consisting of a lower frame member or base 2 and an upper frame member 6. The base 2 supports a bearing 1 for the annular or discoid lower lapping member or lap 3, the latter being mounted in the bearing 1 for rotation about a vertical axis and being driven by a pulley 4 which is mounted at the lower end of the lap shaft 3*a* below the bearing 1. The pulley 4 is rotated by an endless belt 5 which receives motion from a driving pulley 5*a* driven by the shaft 5*c* of an electric or like motor 5*b*. It will be readily understood that the motor 5*b* may rotate the driving pulley 5*a* through a speed-reducing gearing of any known design which forms no part of this invention and, therefore, is not shown in the drawings.

The upper frame member 6 is mounted for rotation with or about the vertical axis of a center support or journal 7 which is installed in the base 2 and is preferably coaxial with the upright shaft 5*c* of the motor means 5*b*. The upper frame member 6 comprises a hollow head 8 which may be swung about the support 7 into a position above or laterally away from the upper side of lapping surface or the lower lap 3. The head 8 rotatably supports a vertical shaft 9 for an annular or discoid upper lapping member or lap 10, also called weight plate, which latter is coaxially carried by the lower end of the shaft 9 and is axially shiftable with the latter toward and away from the upper side of the lower lap 3. In FIG. 1, the laps 3, 10 are shown in operative position with a number (only two shown) of work pieces 11 therebetween. When the lapping machine L is put to actual use, its laps 3, 10 usually act upon a large number of work pieces 11 which are held in requisite position by suitable retaining means, such as one or more retaining or truing rings (not shown) which are caused to circle in the space between the lapping members 3, 10 .

The upper lap 10 is rotated by a pulley 12 which is driven by a second endless belt 13. It is often preferred to mount the driving pulley 12*a* for the belt on the shaft 5*c* of the motor 5*b* as is shown in broken lines in the righthand half of FIG. 1. Of course, the drive for the upper pulley 12 normally embodies means for reversing the direction in which the upper lap 10 rotates, as well as means for rotating the laps 3, 10 at different speeds. Such means are not shown because they form no part of the instant invention. The lower end of the shaft 9 is rotatably mounted in an antifriction bearing 14 provided at the lower end of a vertical tube or shell 15. The bearing 14 is installed between an internal shoulder in the shell 15 and a ring nut 16 which latter is screwed into the internally threaded lower end of the tubular member 15.

The hollow hub 17 of the upper pulley 12 is formed with axially parallel internal ribs extending into axially parallel peripheral grooves 18 formed in the upper end portion of the shaft 9. Thus, the latter is axially shiftable with respect to the pulley 12 and may move with the upper lap 10 downwardly toward or upwardly away from the upper side of the lower lap 3. At the same time, the just described ridges in the hub 17 and the grooves 18 on the shaft 9 enable the pulley 12 to impart rotation to the parts 9, 10 regardless of the momentary axial position assumed by the shaft 9. The hub 17 is rotatably mounted in an antifriction bearing 19 which is carried by an upwardly extending internal collar 20 forming an integral part of, or connected to, the head 8 of the upper frame member 6. The upper end of the tube or shell 15 is

guided in a second cylindrical collar 21 which extends downwardly from and is coaxial with the member 20. The shell 15 is also slidable in a stuffing box 22 which is inserted into an aperture formed in the bottom plate 8*a* of the head 8. The lower end of the shell 15 carries an external annular flange 23 which supports the lower end of a siphon or bellows 24, the latter's upper end being fixed to the member 22. The stuffing box 22, the flange 23 and the bellows 24 constitute a sealing means also known as a siphon gland. The flange 23 is non-rotatably fixed to the shell 15 and is held against rotation by a rod 43 which latter is secured to the head 8 of the upper frame member 6. Another function of the rod 43 will be described in connection with FIGS. 3 and 4.

Between the collar 21 and the stuffing box or packing gland 22, the shell 15 is formed with an external annular flange 25 which constitutes a double-acting piston and is axially reciprocable in vertical direction together with the shell 15 within a cylinder 28 whose chambers above and below the piston 25 are connectable to a source of preferably hydraulic fluid. The interior of the cylinder 28 above the piston 25 communicates with a first conduit 26, and a second conduit 27 is connected with the lower cylinder chamber at a point below the piston. The cylinder 28 preferably forms part of or is rigidly connected to the head 8. The collar 21 and the stuffing box 22 seal the upper and lower ends, respectively, of the cylinder 28.

As is shown in FIG. 1, the conduits 26, 27 lead to a schematically represented valve system 29 which is illustrated in full detail in FIGS. 5 to 8. Fig. 1 also shows a schematically represented source 30 of a suitable hydraulic fluid, e.g. oil, which is caused to circulate in various conduits in the valve system 29 and in the cylinder 28 by a pumping device 31, preferably a gear pump, mounted in a supply conduit or line 73. Spent hydraulic fluid flows from the valve system 29 and back into the tank 30 through a discharge line 32.

The head 8 of the upper frame member 6 is formed with or removably supports a vertical front plate or instrument panel 33 which is shown somewhat distorted in the view of FIG. 1 but is illustrated in its preferred form in FIG. 2 of the drawings. This plate supports the actuating or setting members 34*a*, 35*a* and 36*a* of adjustable control valves 34, 35 and 36, respectively, which latter are shown in greater detail in FIG. 5. The knob-shaped actuating member or handgrip means 34*a* of the valve 34 is adjusted by an operator when it is necessary to impart to the piston 25 and to the upper lap 10 a positive force, i.e. a force which will tend to move the lap 10 in downward direction toward the lower lap 3 so as to assist the gravitational force of the member 10 in its action upon the work pieces 11. The actuating member 35*a* of the valve 35 is adjusted when the operator desires to impart a negative force to the double-acting piston 25 so as to tend to move the latter and the upper lap 10 upwardly and away from the member 3, i.e. to either partially or completely counteract the weight of the upper lap 10 and of the parts connected thereto. The device 34 also acts as an overflow valve to return excess hydraulic fluid when the latter is permitted to flow through the line 26 and into the upper chamber of the double-acting cylinder 28 above the piston means 25, i.e. the valve 25 maintains the fluid pressure in the upper cylinder chamber at a given value which may be varied by operating its handgrip means 34*a*. The second conduit 27 then permits discharge of hydraulic fluid from the lower cylinder chamber back into the tank 30.

The actuating member 36*a* of the third control valve 36 is operated when it is desired to subject the work pieces 11 to an initial or partial load less than the full working load. When the work pieces are under such initial load, the valve 36 allows the hydraulic fluid to subject the piston to a negative pressure, i.e., in a direction upwardly and away from the lower lap 3 in order to reduce the pressure caused by the combined weight of the

shell 15, shaft 9 and upper lap 10 upon the work pieces 11.

The front plate 33 further supports a pressure gauge or manometer 37 and a second gauge 38 which latter comprises a system of dials and pointers for indicating the desired or rated value of pressures to which the work pieces 11 are to be subjected during a lapping operation. In addition, the front plate 33 also supports the adjusting knob 56 of a trailing or make-before-break switch assembly 39 including a limit switch 42 which will be described in greater detail in connection with FIG. 3.

FIG. 2 shows an extension 40 which projects laterally from the trough-shaped receptacle 41 forming part of the machine base 2 and surrounding the lower lap 3. The purpose of the extension 40 is to protect the upper lap 10 when the latter is swung in a horizontal plane amout the pivot axle 7 and away from alignment with the lower lap 3, e.g. when the work pieces are placed onto or removed from the lower lap 3.

Referring now to FIG. 3, the trailing switch assembly 39 therein shown comprises a limit switch 42 and the aforementioned rod-shaped switch actuating or tripping member 43 which latter participates in axial movements of the upper lap 10 because it is rigidly fixed to the flange 23 at the lower end of the shell 15. The lower part of the rod 43 is of circular cross-sectional contour; its upper half is formed with a wedge surface 44 which tapers downwardly and inwardly toward the vertical axis of the member 43 and terminates at a recess or cutout 45. The rod 43 is guided in a bore 46 formed in the bottom plate 51*a* of a switch housing 51. The latter forms part of the head 8 and comprises a grooved internal half bush or guide member 47 for slidably supporting an intermediate zone of the rod 43 but providing access to the wedge surface 44. The housing 51 releasably supports the front plate 33 which latter carries a stud 48 for a horizontal pivot pin 49 of a swingable bracket member 50. The aforementioned limit switch 42 is mounted on the bracket 50 and is swingable with the latter in a vertical plane within the housing 51 about the horizontal axis of the pivot pin 49. The pin-shaped sensing or scanning element 52 of the limit switch 42 extends rearwardly toward and, in the view of FIG. 3, abuts against the wedge surface 44 of the rod 43.

The bracket 50 carries a nut 53 which is pivotable about a horizontal shaft 53*a* and meshes with an externally threaded spindle 54. The latter projects through the front plate 33 and has its outer end portion non-rotatably fixed to a turning knob 56 by means of a radial machine screw 57. The knob is connected with a dial 55 (see FIG. 4). The outer side of the front plate 33 is connected with a comparatively thin plate member 58 made of sheet metal or a suitable synthetic plastic material, this plate member having a circular cutout for a small retaining ring 59. The member 59 is located between a smaller-diameter outer portion of the spindle 54 which is received in the turning knob 56 and its dial 55, and a larger-diameter portion of the spindle 54 which is freely rotatable in a coaxial bore of the front plate 33. Thus, the ring 59, together with the parts 55, 56, prevents axial movements of the spindle 54. When the knob 56, by means of the screw 57, causes the spindle 54 to rotate in the plates 33, 58, the nut 53 and the bracket 50 with the limit switch 42 are caused to swing in clockwise or anticlockwise direction about the pivot pin 49 in order to move the scanning pin 52 toward or away from the wedge surface 44 of the tripping rod 43.

The bracket 50 and the front plate 33 carry a pair of substantially aligned studs 60 whose purpose is to properly support a helical expansion spring 61, the latter acting between the inner side of the front plate 33 and the adjacent face of the bracket 50 and tending to pivot the latter in a direction to move the pin 52 into abutment with the wedge surface 44.

As is shown in FIG. 4, the dial 55 carries an annular scale which surrounds the knob 56 and is divided into 220 increments. These increments indicate the distance of the upper lap 10 from the lower lap 3 (in mm.). The outer side of the plate member 58 carries a marker 62 which facilitates the setting of the dial 55.

Referring now to FIG. 5, the valve system 29 therein shown comprises two slide valves 63, 64. The shiftable member or rod of the slide valve 63 is reciprocable by an electromagnet 65 between a neutral or median position 67 and a pair of extreme or end positions 69, 71 at the opposing sides of the neutral position. A similar electromagnet 66 is adapted to move the shiftable member or rod of the second slide valve 64 from a first extreme or end position 70 into a neutral or median position 68 and thereover into a second end position 72.

The conduit 26 which leads to the upper chamber of the double-acting cylinder 28 branches into a line 26′ communicating with the housing of the slide valve 63, and into a second line 26″ which is connected with the housing of the second slide valve 64. The other conduit 27 which is connected to the lower pressure chamber of the cylinder 28 branches into lines 27′, 27″ communicating with the housings of slide valves 63, 64, respectively. The conduit 73 which conveys the hydraulic fluid from the tank 30 under the action of the pumping device 31 branches into lines 73*a*, 73*b*, 73*c*, 73*d* and 73′. Branch lines 73*a*, 73*b* and 73*c* communicate with the housing of the slide valve 63, and the line 73*d* is connected to the pressure gauge 37. The fifth branch line 73′ is connected to the housing of the second slide valve 64.

The control valves 34, 35 are connected with the housing of the slide valve 63 by means of conduits 74, 75, respectively. The third control valve 36 is connected with the housing of the slide valve 64 by means of a line 76. The control valves 34 to 36 are also connected with the discharge line 32 by means of conduits 132, 132′, 132″, respectively, the line 32 conveying spent fluid pressure medium back into the tank 30. The line 32 further comprises three branches 32*a*, 32*b*, 32*c* the latter of which is connected with the housing of the slide valve 64. The lines 32*a*, 32*b* are connected with the housing of the valve 63.

A pressure relief valve 77 is installed in an overflow line 77*a* which is connected with the conduit 73 at a point above (i.e. at the pressure side of) the pumping device 31 and extends with its lower end into the fluid tank 30. The valve 77 permits return flow of hydraulic fluid from the line 73 through the conduit 77*a* and into the tank 30 when the pump 31 is in operation but the shiftable members of the slide valves 63, 64 seal the discharge ends of branch lines 73*a*, 73*b*, 73*c* and 73′.

FIG. 5 shows the slide valve 63 in its right-hand end position 69 while the valve 64 remains in the neutral position 68. In FIG. 6, the slide valve 63 is in its left-hand end position 71 and the second slide valve 64 is in its neutral position 68. In FIG. 7, the valve 63 is in its neutral position 67 but the second slide valve 64 is moved into its right-hand end position 70. In FIG. 8, finally, the slide valve 63 assumes the neutral position 67 of FIG. 7, but the other valve 64 is in its left-hand end position 72.

FIG. 9 shows the gauges 37 and 38 in the position of FIGS. 1 and 2, i.e. closely adjacent to each other with the gauge 38 located above the gauge 37. These gauges may be combined to constitute a composite instrument as will be fully explained in connection with FIGS. 10 to 12. The gauge 38 of FIG. 9 is calibrated to the weight of the piston 25 and of all parts movable therewith; it comprises a rotary dial disc 80 and a stationary segment-shaped dial 78 which latter is fixed to the outer side of the front plate 33 by a pair of screws 79 or by like readily releasable means. The dial disc 80 is coaxially connected with a turning knob 81 and carries a circular scale including a first group of graduations or increments (0 to +11) which constitute the positive portion of the scale, and a second group of increments (0 to −8) which constitute the negative portion of the scale. In order to facilitate the determination whether a reading furnished by the

scale on the dial disc **80** is positive or negative, the negative scale portion is bounded by a heavier line **82**. Each increment on the scale portions of the dial disc **80** is indicative of a certain pressure divided by one hundred, i.e. the increment adjacent to a numeral **4** indicates a load of +400 kg. or −400 kg.

The readily exchangeable stationary segment-shaped dial **78** carries a scale formed with increments "0 to 80" and a marker in the shape of an arrow **83**. The segment **78** also carries an inscription "700 x 180" which identifies the segment for use with a specific upper lap **10**. If a lap **10** of different dimensions is installed in the lapping machine of the present invention, a different segment must replace the segment **78** of the gauge **38**, i.e. each segment **78** can be utilized only with an upper lap of predetermined dimensions such as are indicated by the inscription on the segment. The inscription "700 x 180" indicates that the upper lap has a diameter of 700 mm. and an annular lapping surface whose width equals 180 mm. The graduations "0 to 80" on the scale of the segment **78** indicate the thickness of the upper lap **10**, i.e. the thickness of an unused upper lap **10** equals 80 mm. Owing to the wear in actual use and also to intermittent regrinding, the thickness of the upper lap **10** is gradually reduced from the initial thickness of 80 mm. The gauge **38** indicates the optimum pressure upon the work pieces **11** during a lapping operation.

The pressure gauge **37** carries a series of graduations numbered "0 to 11" each of which must be multiplied by one hundred to obtain the exact reading in kg. as to the actual pressure exerted by the hydraulic pressure medium against the upper or lower side of the piston **25**. Thus, when the tip of the pointer is adjacent to the increment numbered "4" on the scale of the pressure gauge **37**, the piston **25** is subjected by the fluid to and transmits a pressure of 400 kg. in upward or downward direction.

FIGS. 10 to 12 illustrate a modified instrument which is a combination of two gauges and may be utilized as a substitute for the gauges **37**, **38**. Referring first to FIG. 10, the axis of a pointer **84** is concentric with and is rotatable relative to a circular inner dial disc **85**. The pointer **84** is connected to the conduit which conveys fluid under pressure into the cylinder **28** and furnishes readings on the outer dial **88** indicative of the total lapping load upon the work pieces. The dial disc **85** carries a radial handgrip member or lever **86** which, in the position of FIG. 10, abuts against a zero stop **87**. The stationary annular outer dial plate **88** of larger diameter concentrically surrounds the dial disc **85** and is fixed to a component part of the manometer housing **90** which may form part of the frame and is illustrated in FIG. 12. The dial disc **85** carries a marker **89** which is aligned with the tip of the pointer **84** when the combined gauge is not in use, i.e. when the pressure reading of the gauge is zero.

The larger-diameter dial plate **88** carries a series of graduations "0 to 11" corresponding to the graduations on the scale applied to the dial disc of the gauge **37** shown in FIG. 9. The dial disc **85** is provided with a first set of graduations **38***a* covering the range between "20 and 80 mm." preceded by the plus symbol, and with a second group of graduations **38***a'* also covering the range of between "20 and 80 mm." but preceded by a minus symbol. The outer dial **88** also carries a second set of graduations covering the range of between "0 and 3" and an inscription "×100 (kg.)" which latter means that each value shown on the dial plate **88** must be multiplied by one hundred to obtain the actual reading. A more detailed description of FIG. 11 will be made hereinafter in connection with the explanation of the manner in which the lapping machine operates. The scale portion **38***a* and the scale "0 to 11" form a first pair of scales, and the graduations **38***a'* and the scale "0 to 3" form a second pair of scales on dials **85**, **88**.

As is shown in FIG. 12, the combined manometer and rated pressure gauge comprises a housing **90** which is formed with an annular flange **91** and is installed in the cutout of a modified front plate **92** or in the instrument board of a non-represented attachment for the lapping machine. The exposed side of the manometer housing **90** is sealed by a preferably removable transparent or translucent pane **93** which removably supports the aforementioned rotary circular dial disc **85**. The latter is made of a suitable synthetic plastic material, such as "Plexiglas" (trademark) or the like. The dial disc **85** is rotatable by a concentric knob **94** and is transparent to permit observation of the pointer **84**. This disc may be mounted at the inner or at the outer side of the transparent pane **93**.

Within the manometer housing **90**, there is provided a plate-like partition or panel **95** which supports the shaft **96** of the pointer **84**. Between the pane **93** and the panel or partition **95**, the manometer housing **90** receives an annular receptacle **98** which contains a series of schematically indicated signal lamps **97**. The inner side of the receptacle **98** is sealed by a short transparent cylinder **99**. The purpose of lamps **97** is to alternately illuminate the scale portion **38***a* or **38***a'*, depending upon which of these scale portions furnishes readings when the machine L is in use. The signal lamps are preferably connected with the electromagnets **65**, **66** to light up automatically when the rods of valves **63**, **64** are shifted.

The annular dial plate **88** is affixed to the upper side of the panel **95** and is observable through the transparent pane **93**. As stated hereinabove, the dial plate **88** carries two scales which are disposed in mirror reverse, namely, "0 to 11" and "0 to 3," as is shown in FIGS. 10 and 11. The two sets of positive and negative graduations "20 to 80" are also disposed in mirror reverse and are applied to the underside of the dial disc **85**; the latter also carries the aforementioned marker **89**. The dial **85** is readily removable from the pane **93** if a different upper lap **10** is used in the machine L, i.e. this dial corresponds to the segment **78** and carries indicia "700×180" and scales **38***a*, **38***a'* indicative of the dimensions of one of the parts (upper lap **10**) which are movable with the piston **25** toward and away from one or more work pieces **11** on the lapping member **3**. Thus, while the gauge **38** of FIG. 9 comprises a removable stationary dial **78**, the system of FIGS. 10–12 uses a readily removable rotary dial **85** and a permanently installed non-rotatable dial **88**.

FIG. 13 illustrates one of two serious problems solved by the lapping machine of the present invention. It shows schematically in vertical section the laps **3** and **10** with a work piece **11** therebetween. For one or another reason, e.g. during hardening, the elongated but comparatively thin work piece is assumed to have been deformed into an arcuate form. In a conventional lapping machine, the deformed work piece would be immediately subjected to the full working pressure or load P. Owing to such a load which often reaches a considerable magnitude, the arcuate work piece **11** is flattened out by being subjected to bending stresses which tend to move its ends into the plane of its central portion. Thus, during the lapping operation, the originally deformed and subsequently flattened work piece tends to reassume its deformed state shown greatly exaggerated in FIG. 13 because the construction of conventional lapping machines does not take into consideration that a work piece may be deformed at the beginning of a lapping operation. Therefore, as soon as the laps are moved apart, a finished work piece immediately recoils into the shape of FIG. 13, i.e. it reassumes the arcuate form which results in a poorly lapped product.

In accordance with the present invention, the initial

load upon the work piece **11** of the type shown in FIG. 13 constitutes only a fraction of the total load P, i.e. the initial load is sufficiently small to avoid any, or at least any appreciable, elastic deformation of the work piece. While the work piece is subjected to such comparatively small initial load, the laps **10** and **3** remove its central portion above the horizontal phantom line **101** and its end portions below the horizontal phantom lines **102**. When the partially lapped work piece is subjected to the full load P in the immediately following lapping step, the work piece is either incapable of elastic deformation or any elastic deformation thereof under the full load P is negligible. Moreover, upon removal of the portions above and below the phantom lines **101**, **102**, respectively, the area of contact between the partially treated work piece **11** and the laps **3**, **10** is increased to such an extent that any formation of fissures or any chipping of the treated surfaces on the work piece due to excessive pressure is not possible. This last mentioned advantage of subjecting a work piece to successive loads of increasing magnitude is often more important than the prevention of recoiling of a lapped work piece back into its original deformed state.

When the preliminary lapping step is completed, i.e. when the zones of the work piece **11** above and below the lines **101**, **102** are removed by the action of the laps **10**, **3**, respectively, the problem to be solved resides in proper selection of full loads P to which the partially lapped work piece should be subjected. Of course, the likelihood of fissures, chipping and/or deformation of the work piece is already avoided by the initial treatment under partial load. For each type and shape of work pieces, there exists an optimum maximal load, i.e. a maximal load which will insure most satisfactory grinding action and will produce a lapped surface of extremely fine and accurate finish. The optimum maximal load P to which a single work piece **11** should be subjected is multiplied by the total number of work pieces which are treated simultaneously in a single operation in order to obtain the rated value of the load for which the laps **10**, **3** must be set. In the following description, it is assumed that the optimum maximal load for a single work piece is already determined, i.e. that the operator in charge of the improved lapping machine knows what the load upon the work pieces **11** between the laps **3** and **10** should be.

When the lapping operation under full load P is completed, there remains only the median zone **100** of the work piece **11**, i.e. in the second stage of the operation, the laps **10**, **3** remove the portions between phantom lines **101**, **101***a* and **102**, **102***a*, respectively. The final product is a completely flat article **100** whose thickness equals the distance between the phantom lines **101***a*, **102***a*.

It is assumed in the following description of the manner in which the improved machine L operates that the optimum load equals 275 kg. It is also assumed that the lapping machine is equipped with a pair of pressure gauges **37**, **38** of the type shown in FIG. 9. In the first step, the operator turns the knob **81** to set the dial **80** in the position of FIG. 9 (upper half) in which the marker **83** is aligned with that increment on the positive scale portion on the dial **80** which is adjacent to the numeral +2.75. The latter, multiplied by one hundred, indicates the rated optimum load of 275 kg. Of course, the operator is also assumed to have checked and to know that the segment **78** may be used with the selected upper lap **10**, i.e. with that lap **10** which is about to be used in the lapping machine. Thus, the diameter of the member **10** must equal 700 mm., the width of its annular lapping surface equals 180 mm., and it is assumed to consist of e.g. cast iron which is the material required for satisfactory lapping of the selected work pieces **11**.

In the next step, the operator measures the thickness of the upper lap and, by way of example, finds that this thickness equals 40 mm. Subsequently, he determines that value on the positive scale portion on the dial **80** which is aligned with the increment numbered "40" on the scale of the stationary segment **78**. As shown in FIG. 9, the sought-for value is +0.5 which, multiplied by one hundred, indicates a positive load of 50 kg. Thus, the operator knows that, in addition to the weight of the uper lap **10** and of all parts which are connected for movement therewith, the member **10** must be subjected to a pressure of 50 kg. in downward direction, i.e. toward the lower lap **3**. Such positive pressure of 50 kg. must be applied by the piston **25** which latter, by means of the shell **15** and nut **16**, is connected for movements with the shaft **9** of the upper lap **10**. The operator then turns the actuating member **34***a* of the control valve **34** in a closing direction until the pointer of the manometer **37** indicates a load of 50 kg. (i.e. when the pointer is aligned with the graduation indicating the value "0.5" between the graduations "0" and "1" in the lower half of FIG. 9. Multiplied by one hundred, the graduation numbered "0.5" indicates a positive load of 50 kg.

Alternately, and assuming that the operation is carried out with a new lap **10**, i.e. with a lap whose thickness equals 80 mm., the upper half of FIG. 9 clearly shows that the initial pressure would then exceed the optimal maximum pressure because the graduation numbered "80" on the scale of the segment **78** is aligned with a graduation "—0.25" in the negative portion of the scale on the dial **80**. Thus, even if the plunger **25** were under no load whatever, the intial pressure exerted by the upper lap **10** upon the work pieces **11** would exceed the optimum value. In such instances, the operator turns the actuating member **35***a* of the control valve **35** in order to subject the piston **25** to a negative pressure in upward direction by permitting the flow of fluid pressure medium through the line **27** and into the lower chamber of the cylinder **28** with simultaneous discharge of fluid from the upper cylinder chamber, i.e. through the line **26**. As is shown in the upper half of FIG. 9, the graduation numbered "80" on the scale of the segment **78** is aligned with the value "—0.25" in the negative portion of the scale on the dial **80**. Thus, again multiplied by one hundred, the scales on the members **78**, **80** then indicate a negative pressure of —25 kg. Consequently, the valve **35** must be adjusted in such a way that the manometer **37** indiactes a pressure of 25 kg. The underside of the piston **25** is then acted upon by the hydraulic fluid entering through the conduit **27** with a pressure of exactly 25 kg. As can be observed in FIG. 5, the actuating members **34***a*, **35***a* of the control valves **34**, **35**, respectively, control the tension of resilient elements **34***a'*, **35***a'*. These resilient elements act upon the rear sides of valve pistons **34***a''*, **35***a''*, respectively.

When the lapping operation is carried out with a positive piston pressure, e.g. when the thickness of the upper lap **10** equals 40 mm. which requires a positive pressure of 50 kg., the valve system **29** assumes the position of FIG. 5 in which the rod of the first slide valve **63** is in its righthand end position **69** but the rod of the second slide valve **64** remains in the neutral position **68**. Assuming that the pump **31** is in operation, the shiftable member or rod of the slide valve **64** then prevents the discharge of hydraulic fluid from the conduit **73'** into the line **27''** and through the line **27** into the lower chamber of the cylinder **28**. Thus, no negative pressure in upward direction is exerted upon the piston **25**, and the conduit **27**, through the conduit **27'**, the housing of slide valve **63**, the line **32***b* and conduit **32**, returns the hydraulic fluid from the lower cylinder chamber back into the tank **30**. The pressure side of the pump **31** delivers hydraulic fluid through the conduit **73**, line **73***b*, the housing of the valve **63**, line **26'** and conduit **26** into the upper chamber of the cylinder **28** to exert upon the piston **25** a positive pressure in downward direction. At the same time, the shiftable member of the second slide valve **64** seals the conduit **26''** from the conduit **32***c* to prevent discharge of hydraulic fluid from the upper cylin-

der chamber above the piston 25. The shiftable member of the valve 63 permits communication of hydraulic fluid between the conduits 73*a* and 74 which maintain the control valve 34 under pressure. The latter maintains the pressure in the upper chamber of cylinder 28 at a constant value in that it permits the excess fluid delivered by the pump 31 to flow through the discharge line 132 back to the tank 30.

When the piston 25 is actually lifted upwardly and away from the work pieces 11, the rods of slide valves 63, 64 assume the position of FIG. 8 in which the rod of the valve 63 is in its neutral position 67 but the rod of the other slide valve 64 assumes the end position 72. The valve 63 then seals the lines 73*a*, 73*b* from the conduits 74, 27', respectively, whereas the line 73' communicates with the conduit 27'' over the housing of the slide valve 64. Thus, the hydraulic fluid is free to flow from the line 73 into the line 27 and thence into the lower chamber of the cylinder 28 to lift the pitson 25 with the lap 10, but the line 27' cannot discharge fluid into the line 32*b* and thence back into the tank 30. At the same time, the line 26'' communicates with the line 32*c* to permit discharge of hydraulic fluid from the upper cylinder chamber above the piston 25 back into the tank 30. The valves 34, 35 remain inactive.

When the operator desires to return the upper lap 10 with the shaft 9 and piston 25 in downward direction toward the lower lap 3, the valve system 29 assumes the position of FIG. 5 and operates in the same manner as described hereinabove in connection with the application of positive load to the piston 25. Since the upper side of the piston exerts no counterpressure against the hydraulic fluid entering into and filling the upper chamber of the cylinder 28 (because the line 27' is then open to line 32*b*), the valve 34 remains inactive whenever the upper lap 10 moves in downward direction until the underside of the lap 10 abuts against a nonyielding body, i.e. one or more work pieces 11.

When the lapping operation is carried out with an upwardly oriented (negative) fluid pressure acting against the underside of the piston 25, the shiftable members of slide valves 63, 64 assume the position of FIG. 6. Thus, the shiftable member of the valve 63 is in its left-hand end position 71 and the shiftable member of the second valve 64 assumes its neutral position 68. The valve 64 seals the conduit 73' from the line 27'' but the valve 63 permits communication of fluid between the lines 73*c*, 73*b* and conduits 75, 27', respectively. Thus, the line 27' can convey hydraulic fluid under pressure into the line 27 and into the lower chamber of the cylinder 28 to exert a lifting force against the underside of the piston 25. At the same time, the conduit 26' is free to communicate with the conduit 32*a* which latter returns the fluid from the upper cylinder chamber back to the tank 30. Thus, the upper side of the piston 25 is not subjected to fluid pressure. Valve 63 also permits communication of fluid between the lines 73*c* and 75 to subject the valve 35 to fluid pressure. As mentioned hereinabove, the valve 35 is adjusted whenever it is desired to exert a negative pressure upon the piston 25; this valve controls the magnitude of negative pressure and permits excess fluid to return through its discharge line 132' back to the fluid tank 30. While the piston 25 is subjected to a negative pressure, the total load upon the work pieces 11 during the lapping operation equals the overall weight of the upper lap 10 and of the parts movable therewith minus the negative fluid pressure against the underside of the piston 25.

When the work pieces are subjected to a mere partial load at the beginning of a lapping operation, the shiftable members of slide valves 63, 64 assume the position of FIG. 7. Thus, the shiftable member of valve 63 is moved into its neutral position 67 and the shiftable member of the valve 64 is caused to move into the extreme right-hand position 70. During the initial lapping step under partial load, the piston 25 of a two-lap machine is always subjected to a negative fluid pressure because the overall weight of the upper lap 10 and of the parts movably connected therewith is greater than the maximum permissible load for initial lapping. Such initial load need not be calculated with a very high degree of accuracy, i.e. it is not necessary to measure the thickness of the upper lap 10 before the initial lapping operation begins. The shiftable member of slide valve 63 is in sealing position and, consequently, the conduits 74, 26', 27' and 75 cannot communicate with the conduits 73*a*, 32*a*, 73*b*, 32*b* and 73*c*. The other slide valve 64 permits communication of fluid between the lines 73' and 27'', and the latter conveys the fluid through the line 27 into the lower chamber of the cylinder 28 to exert upwardly oriented pressure against the underside of the piston 25. Also, the line 76 is free to communicate with the conduit 73' to transmit fluid under pressure to one side of the plunger 36*a*'' in the control valve 36. For example, by actuating the handle 36*a*, the operator sets the valve 36 for an initial lapping load of 50 kg. Thus, if the overall weight of the upper lap 10 and of all parts connected for movements therewith is 275 kg. the upper lap then exerts only a pressure of 50 kg. against the upper sides of the work pieces 11 while the fluid in the lower chamber of the cylinder 28 must act against the underside of piston 25 with a pressure equal to 225 kg. It will be understood that, throughout this description, the pressure expressed in kg. is intended to denote a pressure per unit area, i.e. kg./cm.^{2}. The valve 36 maintains the pressure in the lower chamber of the cylinder 28 at a constant value in that its spring 36*a*' permits return flow of fluid through the line 132'' whenever the fluid pressure in the line 76 and hence in the lower cylinder chamber exceeds 225 kg.

If the upper lap 10 is still out of contact with the work pieces 11 at the beginning of a lapping operation under partial load, the difference between the weight of downwardly movable parts and the negative fluid pressure against the underside of piston 25 (275 kg. —225 kg.) will cause the member 10 to descend slowly in the direction toward the lower lap 3 because the overall weight (275 kg.) of the movable parts exceeds the fluid pressure (225 kg.) set by the control valve 36. Thus, the latter's spring 36*a*' will permit gradual escape of fluid through the line 132'' and into the discharge line 32 until the upper lap 10 comes into actual contact with the work pieces. The state of equilibrium begins only after a contact is established between the work pieces 11 and the lap 10, the load difference of 50 kg. being taken up by the work piece during the initial lapping operation.

Having described all four positions and the purpose of the valve system 29, we will now proceed to describe a complete operating cycle of the improved lapping machine.

While the operator loads a new set of untreated work pieces 11 onto the lower lap 3 (the head 8 is then preferably swung into a position above the lateral extension 40), the piston 25 assumes its uppermost position in which it abuts against the lower end of the collar 21. If the pump 31 is already in operation, the pressure relief valve 77 allows the fluid to return from the line 73 back into the tank 30 while the slide valves 63, 64 assume the position of FIG. 8. The selection of necessary initial load (valve 36) and of the full lapping load (valve 34 or 35) is already made, the pump 31 is also in full operation, and the motor 5*b* continuously rotates the laps 3 and 10. In the next step, the operator swings the head 8 back into the position of FIG. 2 and depresses a starting button 103 (FIG. 2) on the instrument panel 33 of the machine L to energize the magnet 65 and to thereby move the shiftable member of the slide valve 63 from the neutral position 67 (FIG. 8) into the right-hand end position 69 of FIG. 5. The simultaneously energized magnet 66 causes the shiftable member of slide valve 64 to move from the left-hand end position 72 into the neutral position 68 of FIG. 5. As soon as the shiftable mem-

bers of valves 63, 64 are in the position of FIG. 5, the upper lap 10 is caused by the hydraulic fluid to move at a considerable speed in a direction toward the lower lap 3 and the untreated work pieces 11 on the latter's upper surface. However, the wedge surface 44 of the tripping rod 43 (the latter participates in the movements of the upper lap 10) acts against the sensing element 52 of limit switch 42 in a given intermediate position of the upper lap, preferably when the latter is already close to the work pieces. The exact time when the element 52 trips the switch 42 of the assembly 39 is set by the knob 56 and spindle 54 and may be read on the scale of the dial 55 (see FIGS. 3 and 4). The limit switch 42 arrests the upper lap 10 shortly before the latter comes into contact with the work pieces 11 in that it again energizes the electromagnets 65, 66 in order to move the shiftable members of slide valves 63, 64 from the positions 69, 68 (FIG. 5) into the positions 67, 70, respectively (FIG. 7). The upper lap 10 is now free to descend gradually and without shock into contact with the work pieces 11 because it is caused to move only under the difference in its weight (plus the weight of all parts movably associated therewith) and the negative upward pressure of hydraulic fluid in the lower chamber of the cylinder 28, such as is set by the control valve 36. Because the laps 3 and 10 rotate, the work pieces 11 are now subjected to partial lapping action at a predetermined pressue of say 50 kg.

The electric circuit of the limit switch 42 and electromagnets 65, 66 is illustrated only schematically in the drawings. This circuit includes a time-lag relay 104 (FIG. 1) of any known design which is energized when the rod 43 trips the limit switch 42. The purpose of the time-lag relay 104 is to again energize the electromagnets 65, 66 after the laps of a given period of time necessary for completion of the initial or parallel lapping operation. The newly energized magnets 65, 66 then move the shiftable members of slide valves 63, 64 from the positions 67, 79 (FIG. 7) into the positions 69, 68, respectively (FIG. 5). The position of the valves constituting the valve system 29 then remains unchanged until the lapping operation under optimum load is completed. When the work pieces 11 are ready for removal from the machine L, the electromagnets 65, 66 are energized again to move the shiftable members of the slide valves 63, 64 from the positions 69, 68 (FIG. 5) into the positions 67, 72, respectively (FIG. 8). The hydraulic fluid is then free to enter the lower chamber of the cylinder 28 and moves the piston 25 with the lap 10 in upward direction and away from the work piece 11.

In the above example describing the operation of the lapping machine, it was assumed that the piston 25 is under a positive load as soon as the initial lapping step under partial load is completed. Thus, the above example presupposes that the total load upon the work pieces during the actual lapping operation equals the combined weight of parts 9—10, 15—16, 23—25 and 43 plus a certain pressure of hydraulic fluid in the upper chamber of the cylinder 28. If the initial lapping operation should be followed by an actual lapping step under a load which is less than the combined weight of parts 9—10, 15—16, 23—25 and 43, the electromagnets 65, 66 cause the shiftable members of slide valve 63, 64 to move into the positions 71, 68 (FIG. 6), i.e. instead of assuming the position of FIG. 5, the rods of valves 63, 64 are shifted from the position of FIG. 7 into that of FIG. 6.

We will now describe the application of the combined manometer shown in FIGS. 10 to 12 which is not shown in the machine of FIGS. 1 and 2, and which is adapted to replace the gauges 37, 38 of FIG. 9. Referring to FIG. 11, the position of the turnable dial disc 85 is analogous to the position of the knob 81 shown in the upper half of FIG. 9. The value corresponding to the thickness of the upper lap 40 (+40 mm. on the positive upper scale portion 38*a* of the dial disc 85) is aligned with the desired maximum load reading (2.75×100 kg.) on the upper scale "0 to 11" of the annular dial plate 88. It will be noted that the increment identified by the numeral "+40 mm." on the upper scale portion 38*a* of the dial disc 85 is aligned with the increment adjacent to the numeral 2.75 on the upper scale of the dial plate 88. The marker 89 is not aligned with the tip of the pointer 84 because the handle 86 of the dial disc 85 is moved away from its zero stop 87 (compare FIG. 11 with FIG. 10). The pointer 84 is operatively connected with the control valve 34 and the latter's actuating member 34*a* is turned by an operator until the pointer 84 returns into alignment with the marker 89 on the face of the dial disc 85. The signal lights 97 illuminate the scale portion 38*a*.

If the desired maximum load upon the work pieces 11 is as low as 125 kg., the zero stop 87 prevents the handle 86 from turning the dial disc 85 into such position in which the increment numbered "+40" on the latter's positive scale portion 38*a* comes into alignment with the increment numbered "1.25" on the upper scale "0 to 11" of the dial plate 88 (compare the zero position of dial disc 85 in FIG. 10 in which the increment numbered "+20" on the scale portion 38*a* is aligned with the increment numbered "1.5" on the upper scale "0 to 11" of the dial plate 88). In such instances, the value "40" is selected on the lower (negative) scale portion 38*a'* of the disc 85 and the latter is turned about the axis of pointer 84 until the increment numbered "—40" comes into alignment with the increment numbered "1.25" on the lower scale "0 to 3" of the dial plate 88. This position of the disc 85 is also shown in FIG. 11. The actuating member 35*a* of the control valve 35 is then turned until the pointer 84 moves into alignment with the marker 89. The signal lights 97 illuminate the scale portion 38*a'*.

It will be readily understood that the control valves 34, 35 may be equipped with suitable electric switch means (not shown) which control the electromagnets 65, 66 of the slide valves 63, 64, respectively, in such a way as to move the shiftable members in the valve system 29 either into the position of FIG. 5 (valve 34) or into that of FIG. 6 (valve 35). Of course, such shifting of the valves 63, 64 may be brought about by hand, if desired.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can, by applying current knowledge, readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic and specific aspects of this invention and therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. A lapping machine comprising, in combination: a frame; a lapping member mounted in said frame and adapted to support at least one work piece; a double-acting cylinder mounted in said frame; a piston having two opposing sides and reciprocably received in said cylinder for movements in directions toward and away from said lapping member; a plurality of parts operatively connected with said piston for movements toward and away from the lapping member for subjecting the work piece to a lapping load including the weight of said parts and of said piston; a source of fluid pressure medium; conduit means for connecting said cylinder with said source; pump means for circulating the fluid medium in said conduit means; and a system of valves in said conduit means for controlling the flow of the fluid medium into said cylinder and for controlling the pressure of said medium against the selected side of said piston whereby to either increase or reduce said lapping load.

2. A lapping machine comprising, in combination: a frame; a driven lower lap having an upper side constituting a lapping surface adapted to support at least one work piece; a stationary vertical double-acting cylin-

der mounted in said frame above said lower lap; a piston having an upper side and a lower side and reciprocably received in said cylinder for movements toward and away from said lapping surface; a plurality of parts including a driven upper lap connected to and reciprocable with said piston for subjecting the work piece to a lapping load including the weight of said piston, and of said parts; a source of fluid pressure medium; conduit means for connecting said cylinder with said source; pumping means for circulating the fluid medium in said conduit means; and a system of valves in said conduit means for controlling the flow of the fluid medium into said cylinder and for controlling the pressure of said medium against the selected side of said piston whereby to either increase the lapping load when the fluid medium acts against the upper side of the piston or to decrease the lapping load when the fluid medium acts against the lower side of said piston.

3. A lapping machine comprising, in combination: a frame; a lapping member mounted in said frame and adapted to support at least one work piece; a double-acting cylinder mounted in said frame; a piston having two opposing sides and reciprocably received in said cylinder for movements in directions toward and away from said lapping member; a plurality of parts operatively connected with said piston for movements toward and away from the lapping member for subjecting the work piece to a lapping load including the weight of said parts and of said piston; a source of fluid pressure medium; conduit means for connecting said cylinder with said source; pump means for circulating the fluid medium in said conduit means; a system of valves in said conduit means for controlling the flow of the fluid medium into said cylinder and for controlling the pressure of said medium against the selected side of said piston whereby to either increase or reduce said lapping load; a first pressure gauge connected with said conduit means for indicating the pressure of said fluid medium in said cylinder; and a second pressure gauge calibrated to the weight of said piston and said parts for indicating the lapping load to which the work piece is subjected.

4. A lapping machine comprising, in combination: a frame; a lapping member mounted in said frame and adapted to support at least one work piece; a double-acting cylinder mounted in said frame; a piston having two opposing sides and reciprocably received in said cylinder for movements in directions toward and away from said lapping member; a plurality of parts operatively connected with said piston for movements toward and away from the lapping member for subjecting the work piece to a lapping load including the weight of said parts and of said piston; a source of fluid pressure medium; conduit means for connecting said cylinder with said source; pump means for circulating the fluid medium in said conduit means; a system of valves in said conduit means for controlling the flow of the fluid medium into said cylinder and for controlling the pressure of said medium against the selected side of said piston whereby to either increase or reduce said lapping load; a first pressure gauge connected with said coduit means for indicating the pressure of said fluid medium in said cylinder; and a second pressure gauge calibrated to the weight of said piston and said parts for indicating the lapping load to which the work piece is subjected, said second gauge comprising a rotary dial having first scale means and a stationary second dial having second scale means and releasably connected with said frame.

5. A lapping machine comprising, in combination: a frame; a lapping member mounted in said frame and adapted to support at least one work piece; a double-acting cylinder mounted in said frame; a piston having two opposing sides and reciprocably received in said cylinder for movements in directions toward and away from said lapping member; a plurality of parts operatively connected with said piston for movements toward and away from the lapping member for subjecting the work piece to a lapping load including the weight of said piston and said parts; a source of fluid pressure medium; conduit means for connecting said cylinder with said source; pump means for circulating the fluid medium in said conduit means; a system of valves in said conduit means for controlling the flow of the fluid medium into said cylinder and for controlling the pressure of said medium against the selected side of said piston whereby to either increase or reduce said lapping load; a first pressure gauge connected with said conduit means for indicating the pressure of the fluid medium in said cylinder; and a second pressure gauge calibrated to the weight of said piston and said parts for indicating the lapping load to which the work piece is subjected, said second gauge comprising a rotary dial having an actuating knob and provided with first scale means, and a stationary segment-shaped second dial releasably connected with said frame and provided with second scale means, said second scale means indicative of the dimensions of one of said parts.

6. A lapping machine comprising, in combination: a frame; a lapping member mounted in said frame and adapted to support at least one work piece; a double-acting cylinder mounted in said frame; a piston having two opposing sides and reciprocably received in said cylinder for movements in directions toward and away from said lapping member; a plurality of parts operatively connected with said piston for movements toward and away from the lapping member for subjecting the work piece to a lapping load including the weight of said piston and said parts; a source of fluid pressure medium; conduit means for connecting said cylinder with said source; pump means for circulating the fluid medium in said conduit means; a system of valves in said conduit means for controlling the flow of the fluid medium into said cylinder and for controlling the pressure of said medium against the selected side of said piston whereby to either increase or reduce said lapping load; a first pressure gauge connected with said conduit means for indicating the pressure of the fluid medium in said cylinder; and a second pressure gauge calibrated to the weight of said piston and said parts for indicating the lapping load to which the work piece is subjected, said second gauge comprising a rotary dial having an actuating knob and provided with first scale means, a stationary segment-shaped second dial provided with second scale means, said second scale means indicative of the dimensions of one of said parts, and means for releasably connecting the second dial to said frame.

7. A lapping machine comprising: in combination: a frame; a lapping member mounted in said frame and adapted to support at least one work piece; a double-acting cylinder mounted in said frame; a piston having two opposing sides and reciprocably received in said cylinder for movements in directions toward and away from said lapping member; a plurality of parts operatively connected with said piston for movements toward and away from the lapping member for subjecting the work piece to a lapping load including the weight of said piston and said parts; a source of fluid pressure medium; conduit means for connecting said cylinder with said source; pump means for circulating the fluid medium in said conduit means; a system of valves in said conduit means for controlling the flow of the fluid medium into said cylinder and for controlling the pressure of said medium against the selected side of said piston whereby to either increase or reduce said lapping load; a first pressure gauge connected with said conduit means for indicating the pressure of the fluid medium in said cylinder; and a second pressure gauge calibrated to the weight of said piston and said parts for indicating the lapping load to which the work piece is subjected, said second gauge comprising a rotary circular dial connected to said frame, having a turning knob, and provided with first scale means, a segment-shaped second dial ad-

jacent to and surrounding a portion of the rotary dial, said second dial provided with scale means indicative of the dimensions of one of said parts, and means for releasably connecting the second dial to said frame.

8. A lapping machine comprising, in combination: a frame; a lapping member mounted in said frame and adapted to support at least one work piece; a double-acting cylinder mounted in said frame; a piston having two opposing sides and reciprocably received in said cylinder for movements in directions toward and away from said lapping member; a plurality of parts operatively connected with said piston for movements toward and away from the lapping member for subjecting the work piece to a lapping load including the weight of said parts and of said piston; a source of fluid pressure medium; conduit means for connecting said cylinder with said source; pump means for circulating the fluid medium in said conduit means; and a system of valves in said conduit means for controlling the flow of the fluid medium into said cylinder and for controlling the pressure of said medium against the selected side of said piston whereby to either increase or reduce said lapping load, said valve system comprising means for permitting such flow of the fluid medium into said cylinder that the piston and said parts are rapidly advanced toward but short of the work piece on said lapping member, are thereupon gradually moved into load-transmitting contact with the work piece, are subsequently caused to subject the work piece to an initial comparatively low lapping load less than said weight, and are finally caused to subject the work piece to a higher lapping load to complete the treatment of the work piece.

9. A lapping machine comprising, in combination: a frame; a lapping member mounted in said frame and adapted to support at least one work piece; a stationary double-acting cylinder mounted in said frame; a piston having two opposing sides and reciprocably received in said cylinder for movements in directions toward and away from said lapping member; a plurality of parts operatively connected with said piston for movements toward and away from the lapping member for subjecting the work piece to a lapping load including the weight of said piston and said parts; a source of fluid pressure medium; conduit means for connecting said cylinder with said source; pump means for circulating the fluid medium in said conduit means; a system of valves in said conduit means for controlling the flow of the fluid medium into said cylinder and for controlling the pressure of said medium against the selected side of said piston whereby to either increase or reduce said lapping load; and a combined pressure gauge comprising a circular first dial mounted on and rotatable with respect to said frame, said first dial having scale means indicative of the dimensions of one of said parts, a pointer concentric with said first dial, operatively connected with said conduit means for indicating the fluid pressure prevailing in said cylinder, and movable by the fluid pressure along said first dial, a marker carried by said first dial and aligned with said pointer when the fluid pressure equals zero, and a stationary second dial concentrically surrounding said first dial and having scale means indicative of the lapping load, said pointer providing readings on said last mentioned scale means as to the momentary lapping load when a fluid pressure prevails in said cylinder.

10. A lapping machine comprising, in combination: a frame; a lapping member mounted in said frame and adapted to support at least one work piece; a stationary double-acting cylinder mounted in said frame; a piston having two opposing sides and reciprocably received in said cylinder for movements in directions toward and away from said lapping member; a plurality of parts operatively connected with said piston for movements toward and away from the lapping member for subjecting the work piece to a lapping load including the weight of said piston and said parts; a source of fluid pressure medium; conduit means for connecting said cylinder with said source; pump means for circulating the fluid medium in said conduit means; a system of valves in said conduit means for controlling the flow of the fluid medium into said cylinder and for controlling the pressure of said medium against the selected side of said piston whereby to either increase or reduce said lapping load; and a combined pressure gauge comprising a housing, a circular first dial removably mounted on and rotatable with respect to said housing, said first dial having scale means indicative of the dimensions of one of said parts, a pointer rotatably mounted in said housing and concentric with said first dial, said pointer operatively connected with said conduit means for indicating the fluid pressure prevailing in said cylinder and movable by the fluid pressure along said first dial, a marker carried by said first dial and aligned with said pointer when the fluid pressure equals zero, and a stationary second dial mounted in said housing, said second dial concentrically surrounding said first dial and having scale means indicative of the lapping load, said pointer providing readings on said last mentioned scale means as to the momentary lapping load when a fluid pressure prevails in said cylinder.

11. A lapping machine comprising, in combination: a frame; a lapping member mounted in said frame and adapted to support at least one work piece; a stationary double-acting cylinder mounted in said frame; a piston having two opposing sides and reciprocably received in said cylinder for movements in directions toward and away from said lapping member; a plurality of parts operatively connected with said piston for movements toward and away from the lapping member for subjecting the work piece to a lapping load including the weight of said piston and said parts; a source of fluid pressure medium; conduit means for connecting said cylinder with said source; pump means for circulating the fluid medium in said conduit means; a system of valves in said conduit means for controlling the flow of the fluid medium into said cylinder and for controlling the pressure of said medium against the selected side of said piston whereby to either increase or reduce said lapping load; and a combined pressure gauge comprising a housing having a transparent pane, a transparent circular first dial removably mounted on and rotatable with respect to said pane, said first dial having scale means indicative of the dimensions of one of said parts, a pointer rotatably mounted in said housing beneath said first dial, said pointer concentric wth said first dial, operatively connected with said conduit means for indicating the fluid pressure prevailing in said cylinder and movable by the fluid pressure along said first dial, a marker carried by the first dial and aligned with said pointer when the fluid pressure equals zero, and a stationary second dial mounted in said housing beneath said pane and having scale means indicative of the lapping load and disposed in surrounding relationship about the scale means on said first dial, said pointer providing readings on the scale means of said second dial as to the momentary lapping load when a fluid pressure prevails in said cylinder.

12. A lapping machine comprising, in combination: a frame; a lapping member mounted in said frame and adapted to support at least one work piece; a stationary double-acting cylinder mounted in said frame; a piston having two opposing sides and reciprocably received in said cylinder for movements in directions toward and away from said lapping member; a plurality of parts operatively connected with said piston for movements toward and away from the lapping member for subjecting the work piece to a lapping load including the weight of said piston and said parts; a source of fluid pressure medium; conduit means for connecting said cylinder with said source; pump means for circulating the fluid medium in said conduit means; a system of valves in said conduit means for controlling the flow of the fluid medium into

said cylinder and for controlling the pressure of said medium against the selected side of said piston whereby to either increase or reduce said lapping load; and a combined pressure gauge comprising a housing including a panel, a transparent pane removably mounted in said housing above said panel, a circular first dial removably mounted on and rotatable with respect to said pane, said first dial having scale means indicative of the dimensions of one of said parts, a pointer rotatably mounted in said panel, said pointer concentric with said first dial, operatively connected with said conduit means for indicating the fluid pressure prevailing in said cylinder and rotatable by the fluid pressure with respect to said first dial, a marker carried by said first dial and aligned with said pointer when the fluid pressure equals zero, and a stationary annular second dial mounted on said panel and having scale means indicative of the lapping load and disposed in surrounding relationship about the scale means on said first dial, said pointer providing readings on the scale means of said second dial as to the momentary lapping load when a fluid pressure prevails in said cylinder.

13. A lapping machine comprising, in combination: a frame; a lapping member mounted in said frame and adapted to support at least one work piece; a stationary double-acting cylinder mounted in said frame; a piston having two opposing sides and reciprocably received in said cylinder for movements in directions toward and away from said lapping member; a plurality of parts operatively connected with said piston for movements toward and away from the lapping member for subjecting the work piece to a lapping load including the weight of said piston and said parts; a source of fluid pressure medium; conduit means for connecting said cylinder with said source; pump means for circulating the fluid medium in said conduit means; a system of valves in said conduit means for controlling the flow of the fluid medium into said cylinder and for controlling the pressure of said medium against the selected side of said piston whereby to either increase or reduce said lapping load; and a combined pressure gauge comprising a housing including a panel, a transparent pane removably mounted in said housing in spaced relation with respect to and having an outer side turned away from said panel, a circular first dial removably mounted on the outer side of and rotatable with respect to said pane, said first dial having scale means indicative of the dimensions of one of said parts, a pointer rotatably mounted in said panel, said pointer concentric with said first dial, operatively connected with said conduit means for indicating the fluid pressure prevailing in said cylinder and rotatable by the fluid pressure with respect to said first dial between said pane and said panel, a marker carried by said first dial and aligned with said pointer when the fluid pressure equals zero, and a stationary annular second dial mounted on said panel and having scale means indicative of the lapping load and disposed in surrounding relationship about the scale means on said first dial, said pointer providing readings on the scale means of said second dial as to the momentary lapping load when a fluid pressure prevails in said cylinder.

14. A lapping machine comprising, in combination: a frame; a lapping member mounted in said frame and adapted to support at least one work piece; a stationary double-acting cylinder mounted in said frame; a piston having two opposing sides and reciprocably received in said cylinder for movements in directions toward and away from said lapping member; a plurality of parts operatively connected with said piston for movements toward and away from the lapping member for subjecting the work piece to a lapping load including the weight of said piston and said parts; a source of fluid pressure medium; conduit means for connecting said cylinder with said source; pump means for circulating the fluid medium in said conduit means; a system of valves in said conduit means for controlling the flow of the fluid medium into said cylinder and for controlling the pressure of said medium against the selected side of said piston whereby to either increase or reduce said lapping load; and a combined pressure gauge comprising a circular first dial mounted on and rotatable with respect to said frame, said first dial having scale means indicative of the dimensions of one of said parts, said scale means comprising two groups of scales disposed in mirror reverse with respect to each other, a pointer concentric with said first dial, operatively connected with said conduit means for indicating the fluid pressure prevailing in said cylinder, and movable by the fluid pressure along said first dial, a marker carried by said first dial and aligned with said pointer when the fluid pressure equals zero, and a stationary second dial concentrically surrounding said first dial and having scale means indicative of the lapping load, said last mentioned scale means comprising two groups of scales disposed in mirror reverse with respect to each other, the pointer providing readings on said last mentioned scale means as to the momentary lapping load when a fluid pressure prevails in said cylinder.

15. A lapping machine comprising, in combination: a frame; a lapping member mounted in said frame and adapted to support at least one work piece; a stationary double-acting cylinder mounted in said frame; a piston having two opposing sides and reciprocably received in said cylinder for movements in directions toward and away from said lapping member; a plurality of parts operatively connected with said piston for movements toward and away from the lapping member for subjecting the work piece to a lapping load including the weight of said piston and said parts; a source of fluid pressure medium; conduit means for connecting said cylinder with said source; pump means for circulating the fluid medium in said conduit means; a system of valves in said conduit means for controlling the flow of the fluid medium into said cylinder and for controlling the pressure of said medium against the selected side of said piston whereby to either increase or reduce said lapping load; and a combined pressure gauge comprising a circular first dial mounted on and rotatable with respect to said frame, said first dial having scale means indicative of the dimensions of one of said parts, said scale means comprising two groups of scales disposed in mirror reverse with respect to each other, handgrip means for rotating the first dial, a pointer concentric with said first dial, operatively connected with said conduit means for indicating the fluid pressure prevailing in said cylinder and rotatable by the fluid pressure with respect to said first dial, a marker carried by the first dial and aligned with said pointer when the fluid pressure equals zero, a stationary second dial concentrically surrounding the first dial and having scale means indicative of the lapping load, said last mentioned scale means comprising two groups of scales disposed in mirror reverse with respect to each other and each alignable with one group of scales on said first dial, the pointer providing readings on said last mentioned scale means as to the momentary lapping load when a fluid pressure prevails in said cylinder, and a zero stop for said handgrip means on the second dial.

16. A lapping machine comprising, in combination: a frame; a lapping member mounted in said frame and adapted to support at least one work piece; a stationary double-acting cylinder mounted in said frame; a piston having two opposing sides and reciprocably received in said cylinder for movements in directions toward and away from said lapping member; a plurality of parts operatively connected with said piston for movements toward and away from the lapping member for subjecting the work piece to a lapping load including the weight of said piston and said parts; a source of fluid pressure medium; conduit means for connecting said cylinder with said source; pump means for circulating the fluid medium

in said conduit means; a system of valves in said conduit means for controlling the flow of the fluid medium into said cylinder and for controlling the pressure of said medium against the selected side of said piston whereby to either increase or reduce said lapping load, said valve system comprising a pair of slide valves having shiftable members for varying the flow of said fluid medium in the conduit means and electromagnet means for operating said shiftable members; and a combined pressure gauge comprising a circular first dial mounted on and rotatable with respect to said frame, said first dial having scale means indicative of the dimensions of one of said parts, said scale means comprising two groups of scales disposed in mirror reverse with respect to each other, handgrip means for rotating the first dial, a pointer concentric with said first dial, operatively connected with said conduit means for indicating the fluid pressure prevailing in said cylinder and rotatable by the fluid pressure with respect to said first dial, a marker carried by the first dial and aligned with said pointer when the fluid pressure equals zero, a stationary second dial concentrically surrounding the first dial and having scale means indicative of the lapping load, said last mentioned scale means comprising two groups of scales disposed in mirror reverse with respect to each other and each alignable with one group of scales on said first dial, the pointer providing readings on said last mentioned scale means as to the momentary lapping load when a fluid pressure prevails in said cylinder, a zero stop for said handgrip means on the second dial, and signal lamp means in the circuit of said electromagnet means for selectively illuminating the groups of aligned scales on said dials.

17. A lapping machine comprising, in combination: a frame; a driven lower lap having an upper side constituting a lapping surface adapted to support at least one work piece; a stationary vertical double-acting cylinder mounted in said frame above said lower lap; a piston having an upper side and a lower side and reciprocably received in said cylinder for movements toward and away from said lapping surface; a plurality of parts including a driven upper lap connected to and reciprocable with said piston for subjecting the work piece to a lapping load including the weight of said piston and of said parts; a source of fluid pressure medium; conduit means for connecting said cylinder with said source; pumping means for circulating the fluid medium in said conduit means; a system of valves in said conduit means for controlling the flow of the fluid medium into said cylinder and for controlling the pressure of said medium against the selected side of said piston whereby to either increase the lapping load when the fluid medium acts against the upper side of the piston or to decrease the lapping load when the fluid medium acts against the lower side of said piston; and an electric circuit including switch means and time-lag relay means for operating the system of valves in a given sequence.

18. A lapping machine comprising, in combination: a frame; a driven lower lap having an upper side constituting a lapping surface adapted to support at least one work piece; a stationary vertical double-acting cylinder mounted in said frame above said lower lap; a piston having an upper side and a lower side and reciprocably received in said cylinder for movements toward and away from said lapping surface; a plurality of parts including a driven upper lap connected to and reciprocable with said piston for subjecting the work piece to a lapping load including the weight of said piston and of said parts; a source of fluid pressure medium; conduit means for connecting said cylinder with said source; pumping means for circulating the fluid medium in said conduit; a system to valves in said conduit means for controlling the flow of the fluid medium into said cylinder and for controlling the pressure of said medium against the selected side of said piston whereby to either increase the lapping load when the fluid medium acts against the upper side of the piston or to decrease the lapping load when the fluid medium acts against the lower side of said piston; and an electric circuit comprising switch means including a limit switch and tripping means therefor for controlling the movements of said upper lap toward the work piece, and time-lag relay means combined with electromagnet means for operating said system of valves in a given sequence.

19. A lapping machine comprising, in combination: a frame; a driven lower lap having an upper side constituting a lapping surface adapted to support at least one work piece; a stationary vertical double-acting cylinder mounted in said frame above said lower lap; a piston having an upper side and a lower side and reciprocably received in said cylinder for movements toward and away from said lapping surface; a plurality of parts including a driven upper lap connected to and reciprocable with said piston for subjecting the work piece to a lapping load including the weight of said piston and of said parts; a source of fluid pressure medium; conduit means for connecting said cylinder with said source; pumping means for circulating the fluid medium in said conduit means, a system of valves in said conduit means for controlling the flow of the fluid medium into said cylinder and for controlling the pressure of said medium against the selected side of said piston whereby to either increase the lapping load when the fluid medium acts against the upper side of the piston or to decrease the lapping load when the fluid medium acts against the lower side of said piston, said system of valves comprising a pair of slide valves each having a shiftable member and electromagnet means for moving the respective member, a first control valve for varying and maintaining the pressure of fluid medium at the upper side of said piston, a second control valve for varying and maintaining the pressure of fluid medium at the lower side of said piston, a third control valve for varying and maintaining the lapping load upon the work piece at a magnitude less than maximum load, and an electric circuit including switch means and time-lag relay means for operating said electromagnet means in a given sequence.

20. A combined pressure gauge for indicating the pressure exerted by a movable part of a lapping machine against the workpieces which are being treated in the lapping machine, said gauge comprising, in combination, housing means; a circular first dial mounted on and rotatable with respect to said housing means, said dial having scale means indicative of the dimensions of the movable part of the lapping machine; a pointer adjacent to said dial and having a zero position; pressure responsive means for moving said pointer from said zero position and along said dial; a marker connected with said dial and alignable with said pointer; and a second dial connected with said housing means and surrounding said first dial, said second dial having scale means indicative of the lapping load and said pointer providing readings on said last mentioned scale means as to the momentary pressure exerted by the movable part against the workpieces.

21. A pressure gauge as set forth in claim 20, wherein each of said dials has two groups of scales and each group of scales on one of said dials in alignable with a group of scales on the other dial.

22. A gauge as set forth in claim 20, further comprising means for removably connecting said first dial with said housing means, and means connected with said first dial and said housing means for arresting said first dial in an angular position in which said marker is aligned with the pointer in the latter's zero position.

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