Sept. 28, 1954 R. BALDRIDGE 2,690,036

LAPPING MACHINE

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Fig. 4.

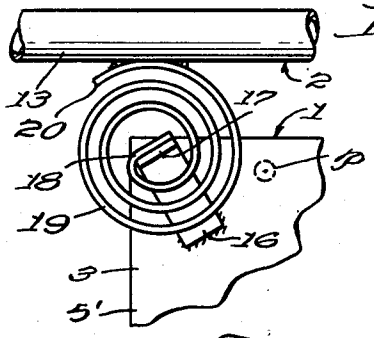


Fig. 1.

Fig. 5.

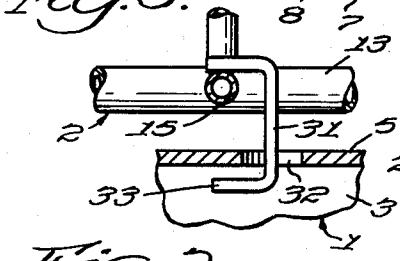


Fig. 3.

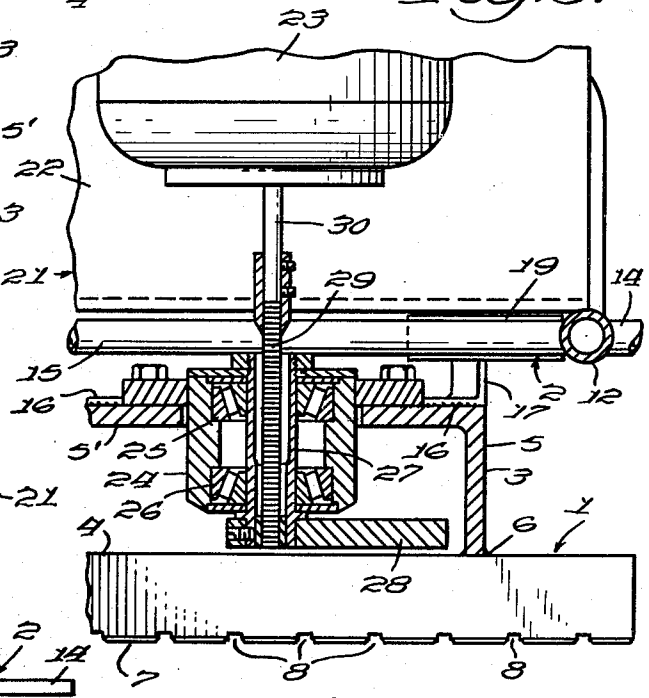
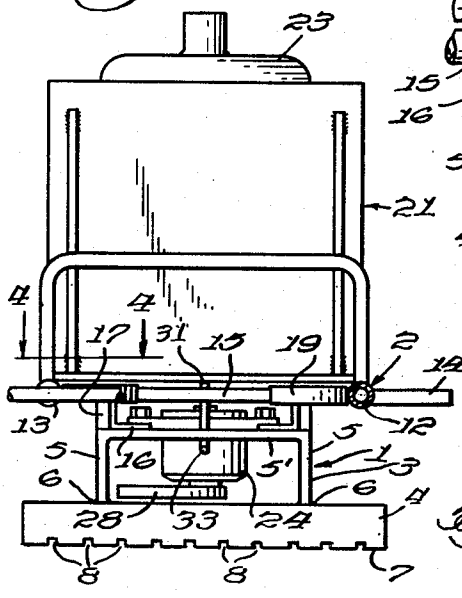


Fig. 2.



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Fig. 6.

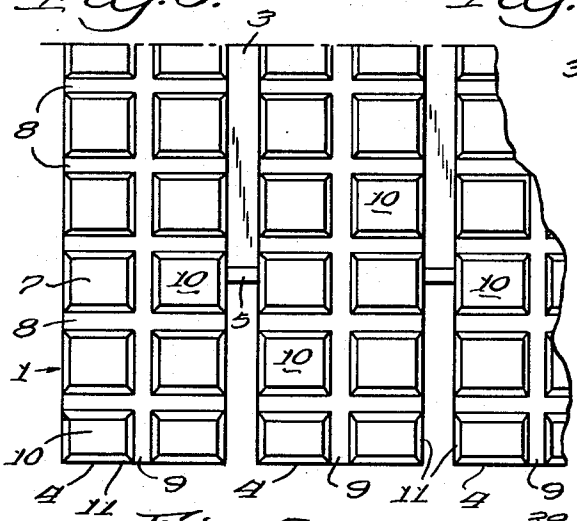


Fig. 10.

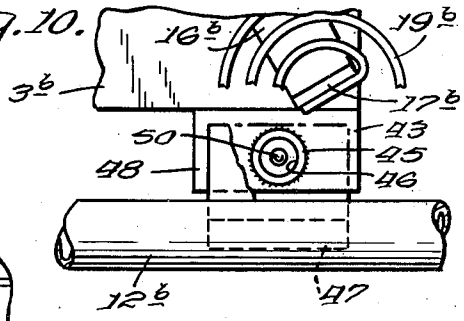


Fig. 7.

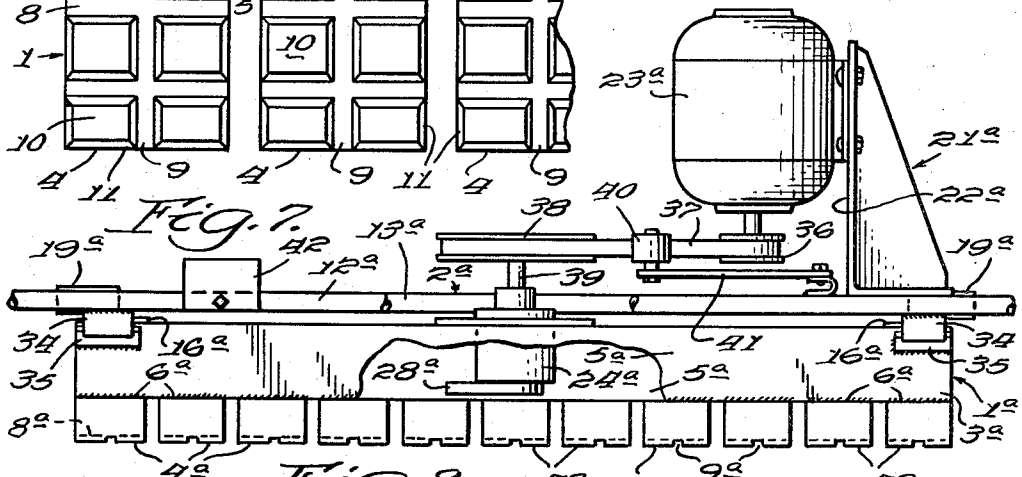


Fig. 8.

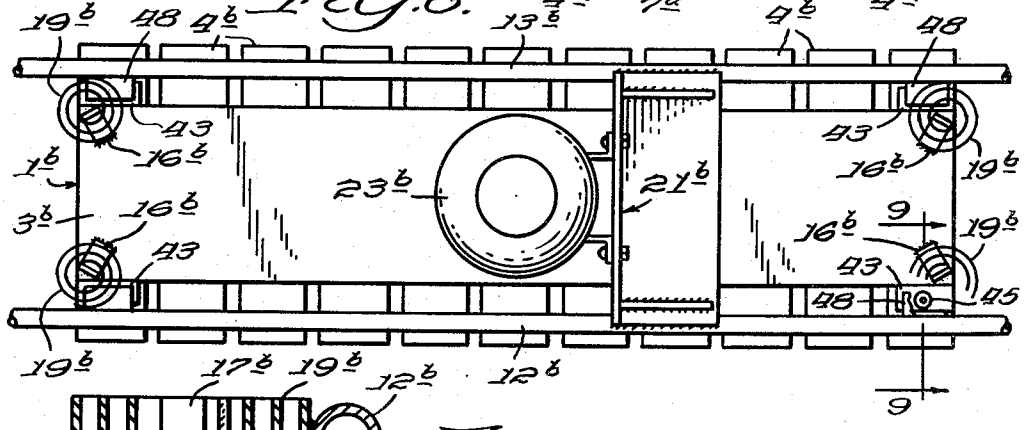
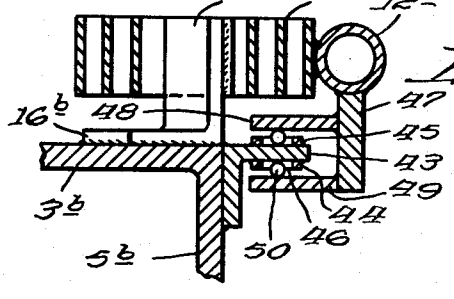


Fig. 9.



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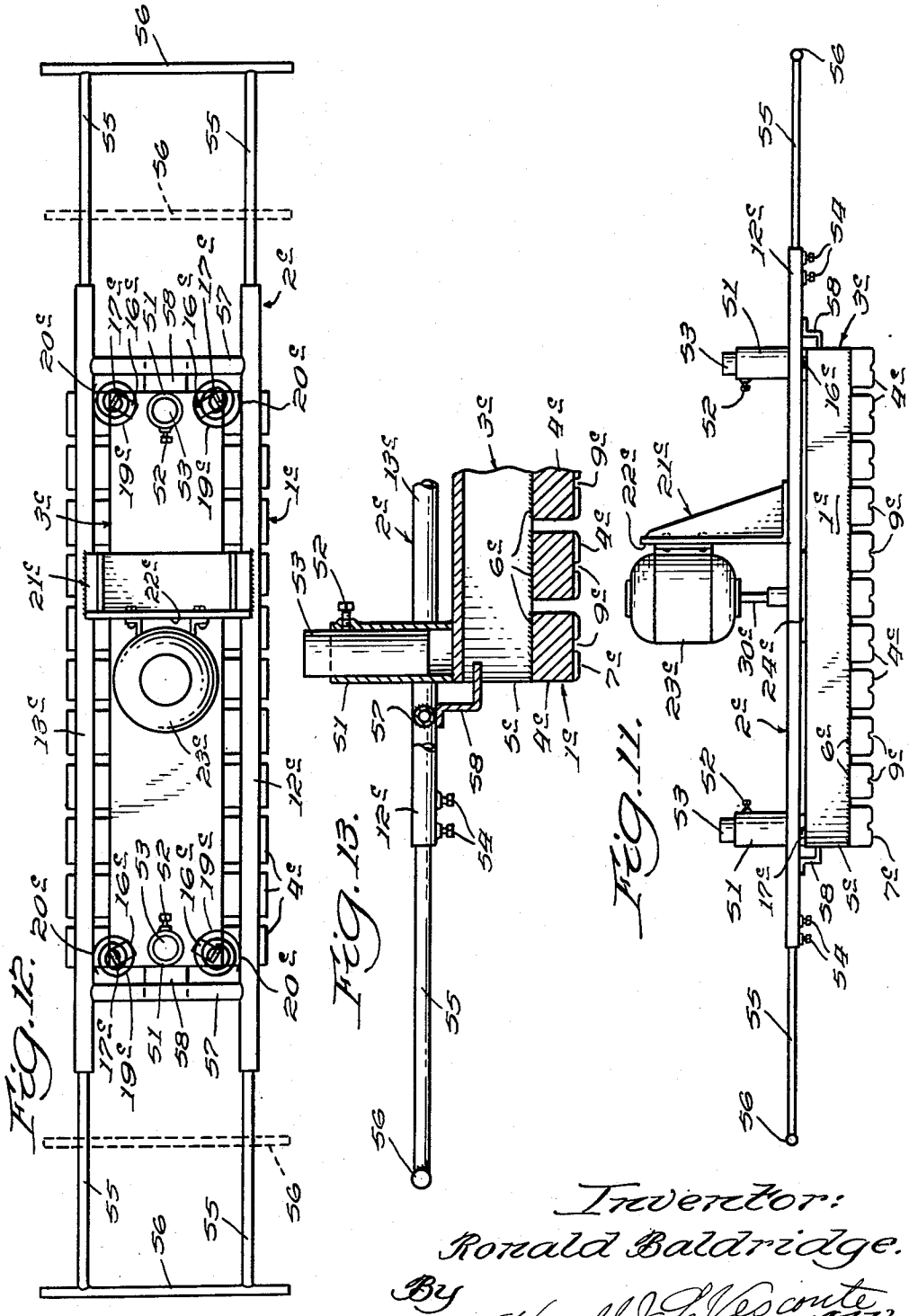


Fig. 12.

Fig. 13.

Fig. 11.

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UNITED STATES PATENT OFFICE

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LAPPING MACHINE

Ronald Baldridge, Glendale, Calif.

Application August 14, 1953, Serial No. 374,253

7 Claims. (Cl. 51—170)

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This invention relates to lapping machines and more particularly to a form thereof useful in the finishing of stone surface plates employed in extremely accurate measuring operations on machine parts and the like. Such surface plates generally range in size from about 18" x 24" to 72" x 96" although in special instances they may be even larger. The surface of such plates must be flat within a tolerance of .2^{-5}" and in some cases, even closer tolerances are required. Mechanical grinding operations produce a surface within a tolerance of about .2^{-4}" and the final surface finishing has heretofore been performed by laboriously rubbing the surface of the plate with a metal lapping block with a suitably fine abrasive powder being applied to the surface.

The present invention has for its principal object the provision of a device which can be moved back and forth across the surface of the stone and including power means for imparting vibratory movements thereto whereby the lapping surface of the device is caused to effect a much greater extent of abrading action than would be achieved by the mere bodily movement of the device across the surface being lapped with attendant reduction of the time required to achieve a surface of the desired character.

Another object of the invention is to provide a lapping device of the above character which embodies a rotating, unbalanced weight moving in a plane parallel to the surface to be lapped as the means for imparting the desired vibratory movement to the lapping surface.

Still another object of the invention is to provide a lapping machine for dirigible use on large surfaces including means for varying the effective position of the center of mass of the machine.

A further object of the invention is to provide a lapping machine for lapping the surface of granite surface plates comprising a frame including handle means by which the device may be guided and a lapping surface resiliently mounted on said frame for limited, spring resisted movement relative to said frame in any direction in a plane parallel to the surface to be lapped.

Still another object of the invention is to provide a lapping device in which the foregoing objectives are realized in practice and which is simple and sturdy in construction, which may be satisfactorily operated by persons having less skill than is required for the heretofore conventional method of hand lapping, and which effects an appreciable reduction in the time required and in the cost of the finished surface plate.

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With the foregoing objects in view, together with such additional objects and advantages as may subsequently appear, the invention resides in the parts, and in the construction, combination and arrangement of parts disclosed, by way of example in the following specification of certain modes of execution of the invention, reference being had to the accompanying drawings which form a part of said specification and in which drawings;

Fig. 1 is a perspective view of a lapping machine embodying one mode of execution of the invention; a portion of the machine being broken away to show interior construction,

Fig. 2 is an end elevation of the machine shown in Fig. 1, portions being broken away for clearness of illustration,

Fig. 3 is an enlarged, fragmentary view taken on the line 3—3 of Fig. 1,

Fig. 4 is an enlarged, fragmentary top plan view of one of the spring mounting means and is taken on the line 4—4 of Fig. 2,

Fig. 5 is an enlarged, fargmentary sectional view taken on the line 5—5 of Fig. 1 and showing details of the lifting means,

Fig. 6 is an enlarged, bottom plan view of a portion of the lapping surface of the machine; the illustrated portion being indicated by the line 6—6 of Fig. 1,

Fig. 7 is a side elevation of a machine embodying a second mode of execution of the invention; portions of the machine being broken away,

Fig. 8 is a top plan view of a lapping machine of the type shown in Fig. 1 but including means effective to limit the lapping action to a plane parallel to the surface being lapped; portions of the machine being broken away to permit showing on a larger scale and to disclose details of construction otherwise concealed from view,

Fig. 9 is an enlarged, fragmentary, sectional view taken on the lines 9—9 of Figs. 8 and 10,

Fig. 10 is a top plan view on the same scale of the portion of the device shown in section in Fig. 9,

Fig. 11 is a side elevation of a lapping machine of the type shown in Fig. 1 with adjustable means for varying the center of mass of the machine and for adjusting the positions of the operating handles,

Fig. 12 is a top plan view of the machine shown in Fig. 11, and

Fig. 13 is an enlarged, fragmentary sectional view taken on the line 13—13 of Fig. 12.

Referring first to the form of the invention shown in Figs. 1 to 6, inclusive, the illustrated

embodiment of the invention comprises a lapping foot portion 1 and a frame portion 2. The lapping foot portion 1 includes a backing member 3 here shown as an inverted channel section and a series of lapping members 4 spaced from each other and extending transversely of the channel member 3; said lapping members being secured rigidly to the lower ends of the depending leg portions 5 of the channel member 3 by welding as indicated at 6 to form an integral structure having a flat bottom surface 7 interrupted by longitudinally extending grooves 8 and transversely extending grooves 9 combining to form the bottom surfaces of the lapping members 4 into a pattern of lands 10 (see Fig. 6). Also, the edges of the grooves and the adjacent perimeters of the blocks 4 are beveled as at 11 and the amount of such beveling increases gradually from the center of the lapping surface 7 to the sides and ends thereof with resultant gradual decrease in the size of the areas of the lands as they are disposed away from the center of the surface of the foot portion 1.

The frame portion 2 includes a pair of longitudinally extending members 12 and 13 located above and extending beyond the opposite ends of the lapping portion 1; said members being interconnected at each end by handle portions 14, 14 and by intermediate cross bars 15, 15; said handles and cross bars being welded thereto. At each corner thereof the upper surface of the web 5' of the channel member 3 is provided with an angle bracket member 16 projecting horizontally diagonally from the corner and terminating in an upwardly extending member 17. This member is secured to the center or inner end 18 of a spiral spring element 19 the outer end 20 of which is secured to the side of the adjacent frame member 12 or 13 as best shown in Figs. 1 and 4; the four springs 19 thus providing interconnection between the foot portion 1 and the frame portion 2 with capacity for resilient relative movement between said portions. As here shown the springs 19 are welded to the portions 1 and 2, but any other form of connection that will provide rigid interconnection between the respective ends of the springs and the portions of the device to which they are connected may be employed. In Fig. 4 there is shown the spring at the left hand side of Fig. 2 and it will be noted that the spring spirals outwardly in a counterclockwise direction. The spring at the right hand side of Fig. 2 will wind outwardly in the opposite direction and at the opposite end the directions of the springs will be reversed so that as relative movement in a horizontal plane between the frame and foot portions occurs, adjacent springs in the direction of such movement will tend to wind up and unwind, respectively.

Mounted on the frame members 12 and 13 at about the mid length thereof is a motor mounting bracket 21 having a vertically disposed motor mounting surface 22 carrying a vertically disposed electric motor 23 having its axis disposed in substantially the vertical center line of the foot portion 1. Mounted on the web 5' of the channel member 3 in axial alignment with the motor 23 and extending downwardly therefrom is a bearing assembly 24 comprising upper and lower roller bearings 25 and 26 which support a hollow shaft 27 which shaft below the bearing assembly and in close proximity to the upper surface of the bars 4 of the foot portion carries an unbalanced member 28. A flexible shaft 29 extends through the hollow shaft 27 and connects the motor shaft 30 to the hollow shaft 27 at the lower end of said shaft.

As the unbalanced member is rotated by the motor, the unequal centrifugal forces generated by rotation thereof will impart a gyratory movement to the foot portion relative to the frame portion against the resistance offered by the springs 19; the described path of motion being a circle relative to any fixed point in a plane normal to the axis of the member 28 as indicated by the dotted circles P in Figs. 1 and 4, and thus the foot portion is caused to gyrate in a plane parallel to the surface on which it rests. It is to be noted that the only reaction to such movement imparted to the frame portion is that transmitted through the springs 19 since none is transmitted through the driving means; the clearance between the flexible shaft 29 and hollow shaft 27 being sufficient to accommodate the movement of the foot portion and the flexible shaft 29 permitting such movement without side thrust on the motor shaft.

For lifting the machine on to and off of a surface to be finished, each cross member 15 is provided with a hook element 31 which extends downwardly through an opening 32 in the web 5' of the channel member 3 and thence longitudinally of the channel member 3 as shown in Fig. 5. Normally, the free end 33 of the hook member 31 is spaced beneath the under surface of the web member 5' but on lifting of the frame portion, the hook members engage the web member and thus relieve the springs 19 from any distortion and enable the machine to be lifted bodily by the frame portion.

It is to be noted at this point that the springs 19 are of a type having great resistance to distortion axially while being more readily yieldable in a plane normal to their axes. Their natural frequency is well below the rate of gyratory movement of the foot portion so that when the motor is operating the foot portion at its normal rate, little, if any of that movement is imparted to the frame structure and thence to the operator or operators. The result of this choice of spring mounting thus achieves two desirable advantages in that first, the operators may readily apply additional loading on the lapping foot by pressing down on the handles, and second, the movements of the foot portion are almost completely isolated from the frame structure which not only extends the entire movement imparted by the rotating weight to the lapping foot, but also prevents the operator or operators from being subjected to annoying vibration while operating the machine.

In use the granite surface plate is first finished by grinding processes to a flat surface of, say, .4–4'' smoothness. The plate is covered with an abrasive and fluid mixture of the desired fineness, the machine placed on the surface plate and the motor started. The machine is then moved back and forth in a uniform pattern over the entire surface of the plate by the operator or by two operators grasping the handles 14, 14 until, by reduction of the high spots, the desired fineness and flatness of surface finish is achieved; the operation being suspended from time to time to check the progress of the operation by suitable gauges with reference to a known surface. Any portions of the surface plate requiring additional finishing are detected in such checking and such additional lapping

treatment is given those surface portions as is found to be necessary.

Experiments disclosed a tendency for the outer portions of the lapping foot to wear less rapidly than toward the center. This derives from the fact that during a portion of the lapping, the outer edges of the lapping foot necessarily momentarily overhang the edges of the plate being lapped as the machine is moved back and forth. This concavity was slight, but was objectionable. By reducing the extent of the bevels 11 at the edges of the blocks 4 and of the grooves 8 and 9 as they are located nearer to the center of the lapping surface and by locating the blocks 4 in closer proximity to each other as they approach the center of the lapping surface, the tendency to concavity is opposed by providing more working surface towards the center of the surface 7 with consequent tendency to delay the wearing of the inner portions of such surface and resultant more even wearing down of the lapping surface 7 and formation of a slight convexity in that surface; said slight convexity being of the order of about .001'' in 36'' and found to be of material aid in sliding the machine back and forth across the surface plate while the motor is running.

Prior to the above invention, the preferred method of manufacturing granite surface was to bodily drag a lapping block of great size and weight back and forth by hand comparable to the method of handlapping gauge surfaces; the resultant speed of the operation being very slow and the cost of such plates being greatly increased. By the use of the present machine with its moving foot portion, much more lapping action can be achieved in a given time due to the additional movement imparted to the foot portion as it is thus bodily moved over the surface being finished with resultant important reduction in the manufacturing cost; such reduction becoming more pronounced as the degree of desired flatness is increased.

For some operations, a slower rate of vibratory movement than is afforded by the first described form of the invention is desirable and a modification of the invention in which that objective is achieved is shown in Fig. 7. In this figure all similar parts are identified by the same numerals as in the preceding figures with the additional of the exponent *a*. The lapping foot construction is the same as described above as is the frame portion with certain exceptions. The frame side members 12*a* and 13*a* adjacent the opposite ends of the channel member 3*a* are provided with downwardly and thence laterally extending hook elements 34 which extend beneath laterally extending lugs 35 projecting from the sides of the channel member and which are normally out of contact with the under face of the lugs but which when the machine is to be lifted off the surface on which it rests, engage said under surface and take the load occasioned by such lifting off the corner springs 19*a*. The motor mount 21*a* is mounted on the frame members 12*a* and 13*a* toward one end of the foot member and carries a vertical motor 23*a* having a small pulley 36 connected by a belt 37 to a larger pulley 38 carried by the upper end of a shaft 39 which is journalled in the bearing assembly 24*a* and which at its lower end carries an unbalanced weight 28*a* which upon rotation imparts the lapping movement to the foot portion in the same manner as previously described in connection with the preceding figures. A spring biased idler pulley 40 carried by a pivoted arm 41 engages the run of the belt travelling to the motor pulley 36 and provides compensation for changes in the center distance between the belt pulleys deriving from the movement of the foot portion relative to the frame portion. To compensate for the unequal load imposed on the foot portion by the unequal load of the frame portion, a weight 42 is secured to the frame portion at a distance from the end thereof supporting the motor sufficient to provide substantially equal bearing pressure at opposite ends of the foot portion. In practice, the position of the weight is best made adjustable so that the finer adjustment thereof can be made when the machine is first placed in operation. This form of the invention is especially desirable for further finishing plates previously surfaced by a machine of the type shown in Figs. 1 to 5 in that the slower rate of lapping movement contributes less vertical components to the foot action and, while slower, the machine is able to lap the surface of a granite surface plate to a surface smoothness of the order of .1^{-6}'' with greater assurance of attaining that extreme degree of accuracy. Few uses of surface plates require that extreme accuracy but for those uses where it is desired, plates can now be furnished at prices which are within the reach of those in need of such precision in measuring.

Referring next to Figs. 8, 9 and 10, there is shown a further modification of the invention, in which the motion of the lapping foot portion is further confined to a plane parallel to the surface being lapped by the machine. The modification is shown applied to the first described form of the invention but it can be equally readily applied to the forms shown in Figs. 7 and 12.

It will be noted that the point at which the bearing assembly 24 is attached to the foot portion is well above the blocks 4 and that the rotating mass 28 is in close proximity to the upper surface of the blocks 4. Because of this, the forces derived from the rotation of the mass 28 tend to impart a very slight pendulum like component of movement to the lapping foot, which while being almost unnoticeable is found to be sufficient to require some added skill in the manipulation of the machine to get the best results from the use of the machine. To resist the tendency of the lapping foot in this manner, guiding means tending to confine the movement of the lapping foot to a plane parallel to the surface being lapped is provided. Since the structure shown is the same as in Figs. 1 to 6, the like parts have been identified by the same numerals with the added exponent *b*. The four corners of the channel 3*b* are each provided with a laterally projecting bracket portion 43 having secured to the upper and under faces thereof a pair of discs 44 and 45 each having a large, centrally disposed hole 46 therein. Each of the frame members 12*b* and 13*b* opposite each of the brackets 43 carries a depending member 47 having a pair of laterally inwardly extending arms 48 and 49 respectively disposed above and below the bracket 43 as best shown in Fig. 9. Mounted in each of the holes 46 in the discs 44 and 45 is a plurality of ball bearings 50 which are engaged by the opposed faces of the bracket 43 and the arms 48 and 49; the holes 46 being of such size that as the balls 50 are moved by the relative movements of the foot and frame portions, they will not contact the sides of the holes.

The discs 44 and 45 serve only as retainers for the balls 50. By this bearing arrangement, the foot portion is free to move to the extents permitted by the springs 19b, but the tendency to include a vertical component of movement is resisted and the foot portion is more completely confined to a plane containing the four guiding means, and the said guiding means being disposed in a plane parallel to the surface of the lapping portion, wherefore, the machine is better enabled to produce a surface that is both flat and smooth within extremely close tolerances.

Figs. 11, 12 and 13 illustrate still another modification and refinement of the form of the invention shown in Fig. 1. The tendency of the machine foot to achieve a slight convexity in use has been referred to above and this appears to be due to a lesser mass above the plane above the horizontal plane containing the point at which the forces developed by the unbalanced and rotating weight are received than below said plane. In these figures all essential corresponding parts have been given the identifying numerals applied in Fig. 1 with the added exponent c. Fixed to the center of each end of the channel member 3c is a vertical sleeve 51 carrying a set screw 52 at the upper end thereof by means of which a cylindrical weight 53 may be held in adjustably variable vertical elevations within the sleeve. If the tendency of the machine is to oscillate slightly, the weights 53, 53 may be adjusted vertically until a point is reached at which the center of the mass of the foot is coincident with the plane in which the inertia of the rotating weight is expanded whereby the said oscillating tendency is overcome and the bottom surface of the foot moves in a strictly horizontal plane.

This form of the invention includes still another modification in the provision of adjustment of the handles longitudinally of the frame to permit the machine to be used on varying sizes of plates with the operators positioned as close to the machine as may be possible. To this end the hollow side bars 12c and 13c are each provided with setscrews 54, 54 at each end thereof and the side bars each slidingly receive the spaced shank portions 55, 55 of the handles 56 which shanks are secured in the desired adjusted positions by the setscrews 54, 54. To provide means for lifting the machine by the handles, the side bar elements 12c and 13c are connected at each end thereof by a cross bar 57 disposed beyond the opposite ends of the member 3c and each cross bar 57 carries a downwardly and thence laterally extending hook portion 58 normally disposed slightly beneath the undersurface of the channel member 3c as best shown in Fig. 13. Upon lifting of the frame structure by the handles, the springs 19c will yield sufficiently to allow the hook portions 58, 58 to engage the member 3c and thus relieve the springs 19c from any distorting strain incident to lifting the machine.

While in the foregoing specification, there have been disclosed certain modes of execution of the invention, such disclosure is by way of illustration and the invention is not to be deemed to be limited to the exact forms so disclosed, and it is to be understood that the invention embraces all such modifications in the parts, and in the construction, combination and arrangement of parts as shall come within the purview of the appended claims.

I claim:

1. In a machine for high precision lapping of flat, horizontal surfaces, a rigid lapping foot having a work contacting lower surface divided into a plurality of lands, a motor supporting frame structure disposed above said lapping foot and connected to said frame member by a plurality of spiral springs formed of flat metal strip and having greater resiliency radially of their axes than parallel to said axes, a motor carried by said frame structure, a rotatable, unbalanced mass journalled on said lapping foot and disposed in a horizontal plane containing the center of mass of said lapping foot, and means operatively connecting said motor and said rotatable unbalanced mass constructed and arranged to compensate for variations in the relative positions of said lapping foot and said frame structure deriving from forces developed by the rotation of said unbalanced mass.

2. In a machine for high precision lapping of flat, horizontal surfaces, a rigid lapping foot having a flat, work engaging lower surface of generally rectangular form in plan outline; said surface being divided into a plurality of rectangular lands, a motor supporting frame structure disposed above and resiliently connected to said lapping foot, handle means on said frame structure for manual movement of said machine over the surface of the work, a motor on said frame structure, and motor operated means on said lapping foot disposed in a horizontal plane containing the center of mass of said lapping foot operatively connected to said motor effective to impart vibratory movement in a horizontal plane to said lapping foot; said lands decreasing in individual area as they are disposed at greater distances from said vibratory movement imparting means.

3. In a machine for high precision lapping of flat, horizontal surfaces, a rigid lapping foot structure of substantial weight and rotary, unbalanced weight means mounted on said lapping foot structure for rotation about a vertical axis and effective to impart vibratory movement thereto in a horizontal plane substantially at the center of mass of said lapping foot, a motor supporting frame structure resiliently connected to said lapping foot structure and provided with handles for moving said machine over the surface being lapped, a motor on said frame structure operatively connected to said rotary, unbalanced weight means, and vertically adjustable weights at each end of said lapping foot structure disposed above the plane of rotation of said rotary, unbalanced weight means and by adjustment being effective to bring the center of mass of said lapping foot structure into exact coincidence with the horizontal plane containing the center of mass of said rotary, unbalanced weight means and resultant maintenance of said vibratory movement in a horizontal plane.

4. In a machine for high precision lapping of flat, horizontal surfaces, a rigid lapping foot structure of substantial weight having a flat work engaging bottom surface comprising a plurality of lands; the lands adjacent the edges of said surface each being of lesser area than any of said lands disposed inwardly of said edges, vertical axis, rotary means carried by said lapping foot structure effective to impart a vibratory movement in a horizontal plane only, a motor and supporting means therefore disposed above and supported by said lapping foot structure, means operatively connecting said motor and said rotary means, spiral spring means interconnecting said lapping foot structure and said motor supporting means, and other means interconnecting said lapping foot structure and said mo-

tor supporting means effective to prevent movement therebetween in any direction not in a horizontal plane.

5. In a machine for high precision lapping of flat, horizontal surfaces, a rigid lapping foot structure of substantial weight and of generally rectangular form in plan outline and having a work engaging bottom surface comprising a series of lands, a vertical axis, rotary, unbalanced weight means for imparting vibratory movement to said lapping foot mounted thereon, a motor operatively connected to said rotary means, and vertically adjustable weights carried by said lapping foot effective on adjustment to bring the center of mass of said lapping foot structure into a plane coinciding with the effective center of mass of said rotary, unbalanced weight means.

6. In a machine for high precision lapping of flat horizontal surfaces, a rigid lapping foot of substantial weight having a flat, work engaging face, a motor support disposed above said lapping foot and connected thereto by interengaging means confining relative movement between said motor mount and said lapping foot to a plane parallel to the plane of said work engaging face, a plurality of vertical axis spiral springs interposed at spaced points in a horizontal plane between said motor mount and said lapping foot, means for vibrating said lapping foot comprising a rotatable, vertical axis, unbalanced weight journalled on said lapping foot and disposed in a horizontal plane containing the center of mass of said lapping foot, a motor fixed to said motor mount, a flexible shaft interconnecting said motor and said rotatable, unbalanced weight, and handle means rigidly fixed to said motor mount for manual direction of said machine over a surface being lapped thereby; said spring means having a natural frequency lower than the rate of vibration imparted to said lapping foot by said unbalanced weight with resultant substantial isolation of the vibrations of said lapping foot from said motor mount and said handle means during operation of the machine.

7. In a machine for high precision lapping of flat, horizontal surfaces, a rectangular rigid lapping foot structure comprising a plurality of metal bars having coplanar bottom surfaces and having said surfaces divided into a plurality of rectangular lands and a frame member extending transversely to and rigidly interconnecting said bars, means for imparting vibratory movements to said lapping foot structure including a rotatable, unbalanced weight journalled on said frame member and disposed substantially at the center of mass of said lapping foot, means for rotating said unbalanced weight including a motor carried by said lapping foot structure and resiliently isolated from the vibrations thereof, and means for effecting an adjustment of the center of mass of said lapping foot structure vertically relative to the plane of rotation of said rotatable, unbalanced weight.

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