

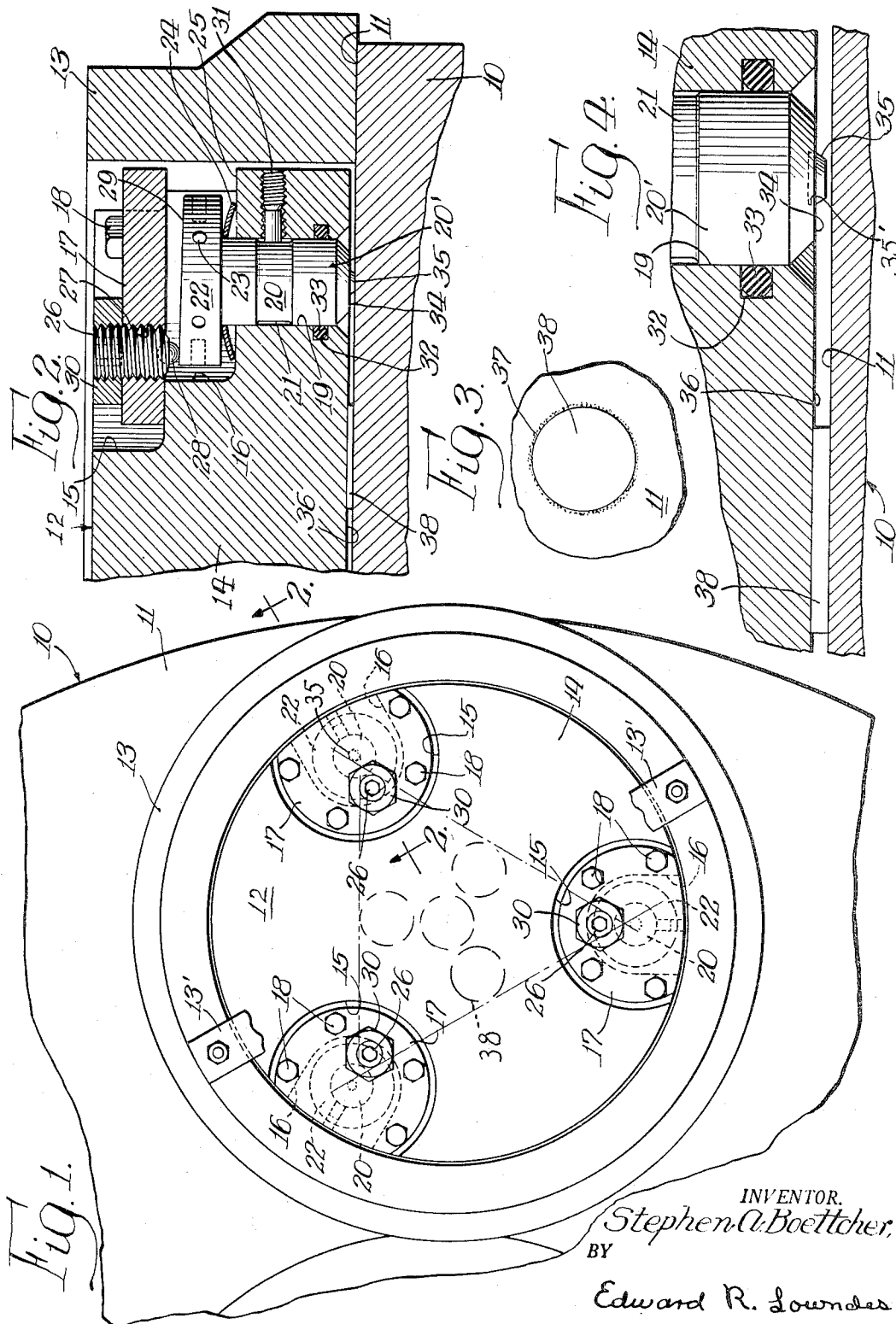
Nov. 1, 1955

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2,722,089

METHOD OF AND APPARATUS FOR LAPPING ARTICLES

Filed April 18, 1952



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METHOD OF AND APPARATUS FOR LAPPING ARTICLES

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Application April 18, 1952, Serial No. 282,960

15 Claims. (Cl. 51—131)

The present invention, in its broadest aspect, relates to a method of and apparatus for producing flat surfaces on articles by a lapping operation wherein the plane of the finished lapped face on the article assumes a definite and predetermined angularity within very fine limits with respect to the plane of some other face on the article, or to a fixed reference plane established relative to the article itself.

More specifically the invention relates to such a method and apparatus whereby the opposite faces of relatively thin articles may, by a lapping operation, be brought to a high degree of parallelism and flatness. For purposes of illustration, the invention has been described in connection with the lapping of thin quartz crystals of the type used in high frequency communication.

The invention still further relates to a fixture designed for use in holding an article in lapping position relative to the moving lapping surface associated with a lapping machine whereby the face on the article undergoing lapping may be brought to an extremely high degree of flatness and coincidence with a predetermined plane established relative to a fixed reference plane which, in the case of thin quartz crystals may be a plane parallel to a previously lapped flat face of the crystal.

The improved lapping fixture comprising the present invention has been designed primarily for use in connection with lapping machines of the type shown and described in the patent to E. J. Bullard, No. 2,565,590, dated August 28, 1951, for Lapping Machine. The invention, however, is capable of other uses and the same may, if desired, with or without modification, be employed in connection with other types of lapping machines having associated therewith a lapping surface which is movable in its own plane to produce the necessary lapping operations.

In the machine disclosed in the above mentioned patent to Bullard, a lapping plate is mounted for rotation about a vertical axis and presents a flat planar lapping surface upon which the article or articles to be lapped are placed. Lapping pressure is supplied by the weight of the articles themselves and may be augmented by the weight of a pressure plate placed on the articles directly or upon an intermediate pressure distributing member. The surface of the lap is maintained in substantially flat condition by means of a conditioning ring which bears against the lap and which is held against revolution about the axis of the lapping surface in any suitable manner. The article or articles to be lapped are placed within the conditioning ring so that the latter performs the dual function of holding the article on the lapping surface and constantly conditioning the lapping surface. Tracking of the articles on the lapping surface is minimized by rotation of the conditioning ring which is induced by contact of the ring with the rotating lapped surface. Machines of the type briefly outlined above are provided with a single lapping surface and thus difficulty is encountered in utilizing such a machine to lap

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the opposite faces of an article such as a quartz crystal to a high degree of parallelism and flatness. Articles such as quartz crystals for the electronic communications field require that the standard of parallelism between the opposite faces of the crystal be maintained on the order of from two to five millionths of an inch taper for one linear inch dimension. Similar high standards are set for variance in the thickness of the crystals.

Such high standards of precision work have necessitated the lapping of quartz crystals by a manual operation on a single lap surface and this has resulted in a large number of rejects due not only to failure to bring the faces of the crystals within such fine tolerances but also due to a high percentage of breakage. Where quantity production has been sought, the use of machines employing dual lap surfaces has been resorted to with the attendant disadvantage that conditioning of the lap surface must necessarily become a separate operation capable of being performed only when lapping operations are not in progress.

The present invention is designed to overcome the above noted limitations that are attendant upon the use of manual lapping operations as well as upon multiple face lapping machines and, toward this end, it contemplates the provision of a method and apparatus utilizing a single flat lap for lapping the opposite faces of crystals and similar articles by a machine operation wherein the faces of the article may be brought to a high degree of parallelism and flatness with a minimum of care and attention on the part of the operator.

In utilizing any machine having a single lapping surface to produce a flat face of predetermined planar orientation on an article, it has been deemed necessary to establish a fixed reference plane and to utilize this reference plane as a guide for the article holder so that when lapping operations are completed, the plane of the lapped face of the article will bear a definite relation, usually one of coincidence or parallelism, with or to the fixed reference plane. Where the fixed reference plane is established independently of the lapping surface, uneven wear of the latter will, even after the first few articles have been lapped, necessitate establishing a new reference plane, if articles of uniform shaped characteristics are to be produced. Even where uniform wear of the lapping surface maintains the same in its planar condition, such wear will lead to the production of articles of decreasing thickness, thus likewise necessitating readjustment of the reference plane.

Due to the fact that all lapping operations, whatever be their nature, involve a certain amount of wearing of the lap surface, it has been deemed impractical to utilize the constantly changing lapping surface as a reference plane capable of determining the ultimate thickness to which an article is to be lapped when bringing its opposite surfaces into parallelism. It has, however, been possible to utilize one constantly changing lapping surface as a reference plane for guiding the feeding movements of a second and cooperating lapping surface but even in such an instance the guiding means which engages the first lapping surface is itself subject to uneven wear, thus widening tolerances of parallelism as well as making it impossible to automatically establish a limit to the lapping operations so that lapping may be discontinued when the desired degree of thickness of the article has been reached.

According to the principles of the present invention, it is possible, utilizing a lapping machine having a single lapping surface, to bring the opposite sides of thin articles such as quartz crystals to an extremely fine degree of parallelism and also to bring the articles as a whole to the desired degree of thickness within very fine limits and to terminate lapping operations automatically when such de-

grees of parallelism and thickness have been attained. In accomplishing these aims, briefly, the invention contemplates the provision of an article holder or fixture to which an article is adapted to be fixedly secured and by means of which the article may be applied to the lapping surface for lapping purposes with the weight of the holder resting upon the article to maintain the latter in contact with the lapping surface. During the lapping operation, and as the face of the article undergoing lapping is lapped, the article holder is caused to descend upon the lapping surface at a rate commensurate with the speed of lapping. Means are provided on the article holder establishing a fixed, non-wearing, three-point suspension for the holder on the lapping surface in such a manner that continued lapping of the face of the article will bring the individual points of suspension into coincidence with the plane of the lapping surface. Since the three-point suspension is of a non-wearing nature, movement of the suspension points into coincidence with the plane of the lapping surface as it exists at the time such coincidence takes place, will relieve the pressure of the article on the lapping surface and terminate further effective lapping operations.

According to the method and apparatus employed in carrying out the invention, means are provided for visually indicating the time at which the face of the article undergoing lapping reaches the desired degree of flatness and of parallelism which, as stated above is the time at which effective lapping operations are discontinued. By such an arrangement the work may be removed from the machine or the operation of the machine may be terminated preparatory to substitution of additional articles in the machine.

The provision of a method and the apparatus of the character briefly set forth above being the principal object of the invention, another object is to provide a novel form of fixture for applying the articles to the lapping surface of a lapping machine and having associated therewith a three-point suspension for the fixture on the lapping surface and which three-point suspension is readily adjustable by a very fine adjustment for the purpose of determining the final position which the fixture, and consequently the article or articles secured thereto, will assume when lapping operations are completed so that the desired degree of parallelism and thickness of the articles will automatically be attained.

Other objects and advantages not at this time enumerated, will become more readily apparent as the nature of the invention, is better understood.

In the accompanying single sheet of drawings forming a part of this specification, one embodiment of the invention has been illustrated.

In these drawings:

Fig. 1 is a fragmentary plan view of a lapping machine showing a rotatable lap and conditioning ring to which a fixture constructed in accordance with the principles of the present invention has been applied;

Fig. 2 is an enlarged sectional view taken substantially along the line 2—2 of Fig. 1;

Fig. 3 is a fragmentary plan view of a portion of the supporting surface of the fixture shown in Fig. 1 showing a circular quartz crystal applied thereto for lapping purposes, and

Fig. 4 is an enlarged fragmentary sectional view taken through the fixture and lap plate at the commencement of lapping operations on a crystal.

A lapping machine which may be of the type shown and described in the above mentioned patent to Bullard is fragmentarily shown and includes a circular lapping plate 10 having an upper, substantially flat, annular lapping surface 11. The lapping plate is mounted for rotation about a vertical axis so that the plane of the lap surface is substantially horizontal. Any suitable means (not shown) may be employed for continuously rotating the plate 10 about its vertical axis.

The surface 11 of the lapping plate 10 is adapted to be continuously dressed and maintained in its original flat condition by means of a conditioning ring 13, the external diameter of which is greater than the radial dimension of the lap surface 11 so that the ring will normally overhang both the inner and outer peripheral edges of the lapping surface. Such overhanging of the conditioning ring prevents the formation of shoulders or grooves in the lap surface which would render it useless for the production of flat faces on the articles undergoing lapping. The ring 13 is preferably formed of close-grained cast iron such as Meehanite, and has a cross section such as is shown in Fig. 2. The ring 13 is held against circumferential shifting movement on the lap plate 10 but is freely rotatable about its own vertical axis. The means for thus restricting the movement of the ring 13 is fully disclosed in the above mentioned Bullard patent and comprises a frame, only a portion of which has been designated herein at 13'. The details of the frame 13' are not fully disclosed herein and it is deemed sufficient to state the ring is capable of rotation about its fixed vertical axis under the influence of its frictional contact with the surface 11 of the lapping plate 10. The lapping surface 11 is adapted to have applied thereto a suitable lapping compound in the form of an oil grit which is used to assist in grinding or lapping the articles positioned on the lap surface. The means for applying and distributing such a lapping compound over the surface of the lapping plate has not been disclosed herein and reference may be had to the above mentioned Bullard patent for a full disclosure of such means.

A work or article holder is designated in its entirety at 12 and involves in its general organization a circular plate 14 which is disposed within the conditioning ring 13 and which thus is held against circumferential shifting movement on the lap surface 11. The plate 14 is provided with three circumferentially spaced arcuate recesses 15 in the upper surface thereof. The bottom of each recess 15 is formed with a smaller recess 16 of general U-shape configuration and having arcuate wall portions concentric with the recess 15. A plate 17 is disposed within each recess 15 and is secured to the bottom thereof by means of a series of clamping studs 18. The bottom of each recess 16 is provided with a vertical bore 19 concentric with the recess 15 and in which there is slidably disposed the cylindrical shank portion 20' of an adjustable stop member 20. The stop member 20 is provided with an enlarged head 22 and the shank portion 20' thereof is provided with a medial annular groove 21. A plurality of radial disposed holes 23 are formed in the head 22 and are designed for selective reception therein of a suitable operating pin or lever (not shown) by means of which the member 20 may be turned in the manner of a capstan for purposes that will be made clear presently. A washer-type spring 24 is compressed between the head 22 and the bottom 25 of the recess 16 and serves to normally urge the stop member 20 upwardly as viewed in Fig. 2. Upward movement of the stop member is limited by a screw 26 mounted in an offset threaded opening 27 provided in the plate 17. A hardened ball 28 is interposed between the lower end of screw 26 and the upper surface 29 of head 22. The surface 29 is preferably inclined at a slight angle with respect to said axis of stop member 20. Thus the screw 26 provides a coarse adjustment for stop member 20 in the bore 19 and rotation of stop member 20 about its own axis will provide a fine adjustment for the stop member due to the angularity of the upper surface 29 relative to the axis of the stop member. It will be noted that in the illustrated form of the invention, the ball 28 rides on the surface 29 near the outer periphery thereof so as to secure the maximum fine adjustment. In other words, by causing the ball 28 to ride on the surface 29 near its outer periphery, the full difference in the length of the stop member 20 as between the highest and lowest part of the surface 29 is utilized for adjustment purposes.

After a particular coarse adjustment has been made, the screw 26 may be fixed relative to the plate 17 by a lock nut 30. Similarly, the stop member 20 may be locked against rotation and also against vertical movement in the bore 19 by means of a setscrew 31 which may be advanced into groove 21 to hold the stop member 20 frictionally in the bore 19.

An internal annular groove 32 is formed in the bore 19 to receive a packing ring 33 which may take the form of a standard "O" ring of rubber or the like. The packing ring 33 prevents grit from working its way into the bore 19 and causing excessive wear thereof which in time would impair the accuracy of the fixture.

The extreme end 34 of each shank portion 20' carries a point or rest 35 which is preferably a commercial diamond point and which has been flattened in the plane of the lap surface 11 to eliminate any sharp cutting edges. The rest 35 is thus harder than the lap surface 11 and hence its wear will be negligible. Any suitable means may be used to secure the diamond on the end of the shank 20', it being only required that the securing means be rigid so that the point will maintain any desired setting. One effective means for securing the diamond in place consists in the provision of a recess 35' into which the diamond may be seated and secured by brazing.

The plate 14 is provided with a substantially flat underneath surface 36 to which the articles undergoing lapping may be secured by means subsequently to be described. Three stop members are employed in connection with the fixture 12 inasmuch as the three diamond rests 35 will, when bearing against the lap surface 11 determine or establish a plane for the underneath article-supporting surface 36 of the fixture 12. An article such as the crystal 38, when secured to the surface 36 and lapped by the lap surface 11 to completion, as determined by movement of the diamond rests 35 into coincidence with the plane of the lap surface 11 will be found to have a lapped face parallel to the surface 36.

It will be appreciated that for best results the supporting surface 36 of the plate 14 must itself be perfectly planar. Otherwise its deviation from a plane may be submitted to the face of the article being lapped. Assuming, however, that the surface 36 is perfectly flat and smooth, error may still creep into the final product if the product is not properly mounted on plate 14. Any dirt, grit or viscous fluid lodged between the article to be lapped and the surface 36 may result in angular displacement of the article and consequent deviation of the lapped surface from the desired lapping plane.

To minimize the introduction of error insofar as particles of dirt and viscous fluid entering between the article and surface 36 is concerned, it has been found that articles such as quartz crystals having extensive generally planar surfaces to begin with can be wrung to the surface 36 if a very slight amount of moisture is first placed on one or the other of the contacting surfaces. When the article is thus wrung on the surface 36, its face makes intimate contact with the surface 36 so that the article is firmly held to the fixture plate by phenomena which is believed to be a combination of molecular adhesion and atmospheric pressure.

Although the article may be mounted on surface 36 in such a manner as to exclude dirt and fluid, the normal operation of the fixture may result in grit or fluid being forced between the article and said surface 36. This action, however, may be eliminated by sealing the contacting edges with lacquer as shown at 37 in Fig. 3. Thus a complete ring of lacquer is formed around the article 38 and no grit or fluid can then enter between the article and surface 36 to dislodge the article. At the completion of the lapping operation the lacquer may be removed by a suitable neutral solvent which will in no way harm or etch the finished surfaces of the article.

In the operation of the fixture hereinabove described

each stop member 20 is adjusted to its proper height above surface 36 by any standard measuring instrument. Instruments are available for determining the position of the rests 35 relative to the surface 36 to two millionths of an inch. With the three stop members adjusted to precisely the same height, a plane is then determined which is parallel to the plane of the surface 36. One or more articles may be secured or fixed to the surface 36 by wringing them onto the surface with the aid of a minute quantity of moisture if necessary, and then sealing as above described. The fixture is then placed within the conditioning ring 13 as previously described. At this stage the stop members 20 and rests 35 will appear as shown in Fig. 4. The full weight of fixture 12 will rest upon the articles 38, and the rests 35 will be elevated from the lapping surface 11. The lapping operation is then commenced during which the plate 10 rotates with the aid of a minute quantity of moisture if necessary, and then sealing as above described. The fixture is then placed within the conditioning ring 13 and fixture plate 14. Rotation of the plate 14 above the lap surface 11 results in an abrading action which gradually reduces the thickness of articles 38 until the diamond rests 35 of the fixture move into contact with the surface 11.

As the diamond points or rests 35 closely approach the surface 11 of the lapping plate 10 they will move into the path of the grit particles on the rotating surface and displace the same out of their normal circular path of travel and thus leave visible track marks on the lap surface which will indicate to the operator that lapping operations are approaching completion. The progress of lapping operations may thus be observed from the time the first rest thus approaches the plane of the lapping surface through such time as the second rest and finally the third rest moves into close proximity to the plane of the lap surface.

It will also be understood that no appreciable amount of lapping or wearing away of the diamond rests or of the lap surface itself will take place. In the first place, no effective lapping of the first two diamond rests to descend upon the lap surface will occur and when the third and last rest moves onto the plane of the lapping surface, lapping operations are complete and may be terminated. With careful placement of the articles on the surface 36 so as to place the composite center of the articles at or near the center of the triangular area defined by the rests or apices of the triangle, the descent of the three rests may be almost simultaneous so that the time interval between contact of the first rest and the last rest with the lap surface is of extremely short or negligible duration. More important, however, is the fact that the hardness of the diamond rests relative to the hardness of the lap surface, coupled with their relatively broad effective surface areas is such that even with the full weight of the fixture being distributed among the three rests, no noticeable wearing of the lap surface will take place.

While the physical phenomena responsible for such lack of wear of the lap surface is not exactly understood, it is believed that the failure of the diamond material to yield to wear results in actual descent of the plane face of the diamond rest into intimate contact with the lap surface. In other words, the plane supporting face of the rest actually moves below the level of the grit particles and the particles are thus "pushed aside" so to speak so that there is an absence of grit particles between the face of the diamond rest and the face of the lap surface. The rest thus "slides" on a clean lap surface and no wear of either the rest or of the lap surface takes place. At the same time the presence of circular swaths where the three rests or stops come into contact with the lap surface will indicate to the operator that lapping operations are complete so that he may terminate the operation of the machine. Thus at no time during effective lapping operations on the articles are all three diamond rests in contact with the lap surface.

In the lapping of crystals such as are shown at 38, the articles will first be lapped on one side to provide a per-

fectly flat surface which may or may not be parallel with its opposite surface. The lapped surface will then be wrung on the surface 36 of the late 14 as described above and the unlapped surface then operated upon in accordance with the above procedure to cause it to be lapped perfectly flat and parallel with the first surface. Obviously, if the lap is not perfectly flat, then the surfaces of the article 38 likewise will not be flat so that it is imperative for high precision work to maintain the surface of the lapping plate 10 as flat as possible.

In the placement of crystals such as those shown at 38 in Fig. 1 on the underneath surface 36 of the lapping plate 14, it has been found that generally good lapping will take place if the crystals are mounted on the face 36 so as to lie completely within the triangular area bounded by a series of straight lines passing through the effective rest points of the diamond rests 35. Such a triangle is designated by broken lines in Fig. 1, and these lines are drawn tangential to the small circles which represent the rest areas on the inner sides thereof as shown. A group of four crystals thus placed on the surface 36 are shown within the triangle. While it may be possible to obtain proper lapping of a crystal mounted on the surface 36 which lies partially or wholly outside of the triangle, such effective lapping will take place, however, only when the adjustment of the diamond rests is such as to cause them to descend simultaneously upon the lap surface. Such a condition would ordinarily be dependent upon chance since it would be difficult to predict the wearing qualities of a particular crystal and effect an adjustment of the rests accordingly. It will be understood, of course, that where precision lapping is not essential, the areas of the circle 36 outside of the triangle are available for placement of articles undergoing lapping.

While the three diamond rests designated in the drawings at 35 have been referred to herein and in the claims as "a three-point suspension for the article on the lap surface," this definition should be construed somewhat loosely inasmuch as a definite measurable area has been illustrated in the drawings for the bottom surface of each of the diamond rests. The invention may better be appreciated when it is pointed out that when the three areas just mentioned ultimately move into contact with the lap so that lapping operations may be terminated, theoretically the articles will then be supported at three points, namely the three points on the three rests 35 respectively which are microscopically at the lowest elevation. It should be remembered that any article having a flat surface resting on another flat surface by gravity is theoretically supported only by three points since it requires but three points to establish a plane. Although an infinite number of increments on the flat surface of the article may contact the supporting surface, actually only three points, namely the three microscopically lowest points, actually perform the supporting function. Thus, in connection with each of the three rests 35 a single point on each of these rests will serve as the support for the article after it has touched the lap surface. It is therefore within the contemplation of the present invention to utilize a three-point suspension for the articles or for the holders which serve to carry the articles which have apparently more than three points of suspension but which in reality, due to the fact that it requires only three points to establish a plane, is a true three-point suspension when it has descended upon the lap plate and rests freely thereon.

Although this invention has been described with reference to its application to the lapping of relatively thin quartz crystals, the fixture 12 might likewise be used with articles of any thickness and initial shape. Thus the invention could be used for lapping gauge blocks or other measuring devices. Furthermore, fixtures other than the specific fixture 12 illustrated are contemplated within the scope of the present invention. The invention is therefore not to be limited to the exact arrangement of parts

shown in the accompanying drawings or described in this specification as various changes in the details of construction may be resorted to without departing from the spirit of the invention. Only insofar as the invention has particularly been pointed out in the accompanying claims is the same to be limited.

What is claimed is:

1. The method of lapping an article on an abrasive lap surface which comprises, establishing a fixed three-point suspension for the article on the lap surface, applying the article to the lap surface so that said points are supported by the article and maintained out of contact with the lap surface, creating relative movement between the article and lap surface to effect lapping operations on the article while allowing said points of suspension to approach and ultimately successively engage the lap surface, and, after all of the points have engaged the lap surface terminating the lapping operations.

2. The method of simultaneously lapping articles on a moving lap surface which moves in its own plane, said method comprising affixing the articles to an article holder, applying the articles to the moving lap surface with the weight of the holder resting upon the articles, restraining the holder against movement bodily with the moving lap surface and allowing the holder to move toward the lap surface at a rate commensurate with the speed of lapping of the articles, limiting the movement of the holder by establishing a three-point suspension therefor on the lap surface, the points of which suspension define a common plane intersecting all of the articles, whereby said points of suspension will successively engage the lap surface so as to determine the plane of the faces lapped upon the articles when all of said points have engaged the moving lap surface.

3. The method of lapping an article on a flat horizontal lap surface which is continuously movable in its own plane to provide a flat surface on the article which comprises, affixing the article to an article holder, applying the article to the lap surface with the total weight of the holder resting thereupon to maintain the article in contact with the moving lap surface, restraining the holder and article applied thereto against lateral shifting movement relative to the lap surface to effect lapping operations while at the same time allowing the holder to descend upon the lap surface at a rate commensurate with the speed of lapping, and limiting the downward movement of the holder by establishing a three-point suspension therefor directly on the lap surface the points of which define a common plane existing above the level of the bottom regions of the unlapped article whereby continued relative movement between the article and lap surface will bring the plane of the finished lap surface on the article into coincidence with the points of said three-point suspension.

4. In a machine for lapping a face on an article, means providing a lap surface, an article holder to which the article is adapted to be affixed for movement bodily therewith and by means of which the article is applied to the lap surface with the weight of the holder resting upon the article, means establishing relative movement between the holder and lap surface to effect lapping operations on the face of the article, and means for limiting the extent of movement of the holder toward the lap surface to thus limit the extent of lapping operations, said means comprising three limit stop members mounted on the holder and designed for ultimate contact with the lap surface to thus determine the extent of lapping operations performed upon the article, said stop members defining a three-point suspension for the holder and article affixed thereto.

5. In a machine for lapping a face on an article, means providing a flat horizontal lap surface movable in its own plane, an article holder to which the article is adapted to be affixed for movement bodily therewith and by means of which the article is applied to the lap surface with the weight of the holder resting upon the article, means for

moving said lap surface to effect lapping operations on a face of the article, means for maintaining the holder and article affixed thereto against lateral shifting movement relative to the lap surface, and means for limiting the extent of movement of the holder toward the lap surface to thus limit the extent of lapping operations, said means comprising at least three limit stop members mounted on the holder and designed for ultimate contact with the lap surface to thus determine the extent of lapping operations performed upon the article, said stop members defining a three-point suspension for the holder and article affixed thereto.

6. In a machine for lapping a face on an article, means providing a lap surface, an article holder to which the article is adapted to be affixed for movement bodily therewith and by means of which the article is applied to the lap surface with the weight of the holder resting upon the article, means establishing relative movement between the holder and lap surface to effect lapping operations on the face of the article, and a plurality of limit stop members mounted on the holder and extending forwardly therefrom in the direction of the lap surface, a rest formed of a material which is harder than the material of the lap surface secured to the forward end of each limit stop member and designed for ultimate contact with the lap surface to thus determine the extent of lapping operations performed upon the article, said rest defining a suspension on the lap surface for the holder and article affixed thereto.

7. In a machine for lapping a face on an article, means providing a flat horizontal lap surface movable in its own plane, an article holder to which the article is adapted to be affixed for movement bodily therewith and by means of which the article is applied to the lap surface with the weight of the holder resting upon the article, means for moving said lap surface, means for maintaining the holder and article affixed thereto against lateral shifting movement relative to the lap surface, three limit stop members mounted on the holder and projecting forwardly therefrom in the direction of the lap surface, and a rest formed of a material having a Mohs hardness greater than that of the lap surface mounted on the end of each limit stop and designed for ultimate contact with the lap surface to thus determine the extent of lapping operations performed upon the article, said rests defining a three-point suspension on the lap surface for the holder and article affixed thereto.

8. In a machine for lapping a face on an article, means providing a flat horizontal lap surface movable in its own plane, an article holder to which the article is adapted to be affixed for movement bodily therewith and by means of which the article is applied to the lap surface with the weight of the holder resting upon the article, means for moving the lap surface, means for preventing lateral shifting of the holder and article affixed thereto relative to the lap surface, a plurality of limit stop members adjustably secured to the holder and capable of adjustment in a direction toward and away from the lap surface when the article is applied to the latter, a diamond rest mounted on the end of each stop member and designed for ultimate contact with the lap surface to thus determine the extent of lapping operations performed upon the article, said rests defining a three-point suspension on the lap surface for the holder and article affixed thereto.

9. In a machine for lapping a face on an article, means providing a flat horizontal lap surface movable in its own plane, an article holder to which the article is adapted to be affixed for movement bodily therewith and by means of which the article is applied to the lap surface with the weight of the holder resting upon the article, means for moving the lap surface, means for preventing lateral shifting of the holder and article affixed thereto relative to the lap surface, a plurality of limit stop members adjustably secured to the holder and capable of ad-

justment in a direction toward and away from the lap surface when the article is applied to the latter, a diamond rest mounted on the end of each stop member and designed for ultimate contact with the lap surface to thus determine the extent of lapping operations performed upon the article, said rests defining a three-point suspension on the lap surface for the holder and article affixed thereto, means for effecting a coarse adjustment of each individual stop member relative to the holder, and means for effecting a fine adjustment of each individual stop member relative to the holder.

10. In a lapping machine having a flat horizontal lap surface movable in its own plane and of a material having a predetermined hardness, a fixture for application of an article to said lap surface comprising a member having a face to which the article is adapted to be affixed and applied to said lap surface with the weight of the member resting upon the article, there being three spaced vertical bores formed in said member, a limit stop member disposed in each bore and axially adjustable therein and capable of projection outwardly of the member downwardly in the direction of the lap surface, a rest formed of a material harder than the predetermined hardness of said lap surface mounted on the projecting end of each limit stop member, and means for adjusting the axial position of each stop member in its respective bore.

11. In a lapping machine, a fixture of the character set forth in claim 10 in which said rests are in the form of diamonds each having a flat face of substantial area designed for contact with said lap surface when a predetermined amount of lapping has been conducted on the face of the article undergoing lapping.

12. The method of lapping an article on a lap surface having a free abrasive disposed thereon which comprises, establishing a fixed three-point suspension for the article on the lap surface with the weight of the holder resting upon the article, applying the article to the lap surface, creating relative movement between the article and lap surface to effect lapping operations while allowing said points of suspension to approach the lap surface, observing the lap surface for displacement of the free abrasive by said points of suspension, and terminating the lapping operations when such displacement of abrasive becomes apparent.

13. The method of lapping an article on a flat lap surface having a free abrasive disposed thereon which comprises, utilizing an article holder having a three-point suspension for the holder on the lap surface, affixing the article to the article holder in such a manner that the article lies wholly within the confines of three planes normal to the flat lap surface and passing through the three points of suspension, applying the article to the lap surface with the weight of the holder resting thereupon to maintain the article in contact with the lap surface, moving the lap surface in its own plane while restraining the holder and article applied thereto against lateral shifting movement bodily relative to the lap surface to effect lapping operations, while at the same time allowing the holder to descend upon the lap surface at a rate commensurate the speed of lapping, and terminating lapping operations when said three points of suspension approach the lap surface and displace the free abrasive thereon.

14. In a lapping machine having a flat horizontal lap surface movable in its own plane, a fixture for application of an article to said lap surface comprising a plate having a flat underneath surface onto which the article is adapted to be wrung and thus fixedly secured thereto with the article being adapted to being applied to said lap surface with the weight of the plate resting upon the article, there being a plurality of spaced vertical bores formed in said plate, a limit stop member disposed in each bore and axially adjustable therein and capable of projecting outwardly of the plate below the level of the underneath surface thereof, a rest mounted on the lower end of each limit stop member and designed for contacting with the

lap surface when lapping operations are completed, and means for adjusting the axial position of each stop member in its respective bore.

15. In a lapping machine having a flat horizontal lap surface movable in its own plane, a fixture for application of an article to said lap surface comprising a plate having a flat underneath surface onto which the article is adapted to be wrung and thus fixedly secured thereto with the article being adapted to being applied to said lap surface with the weight of the plate resting upon the article, there being a plurality of spaced vertical bores formed in said plate, a limit stop member disposed on each bore and axially adjustable therein and capable of projecting outwardly of the plate below the level of the underneath surface thereof, a rest mounted on the lower end of each limit stop member and designed for contacting with the lap surface when lapping operations are completed, the upper surface of each limit stop member being inclined slightly relative to the axis of the bore in which the member is disposed, a reaction member mounted on said plate

and bearing against the inclined upper surface of each limit stop member and offset from the axis thereto, and means for individually turning said limit stop members about their respective axes to cause camming engagement between the upper surfaces thereof and the reaction members to thus locate the position of the limit stop members axially in their respective bores.

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