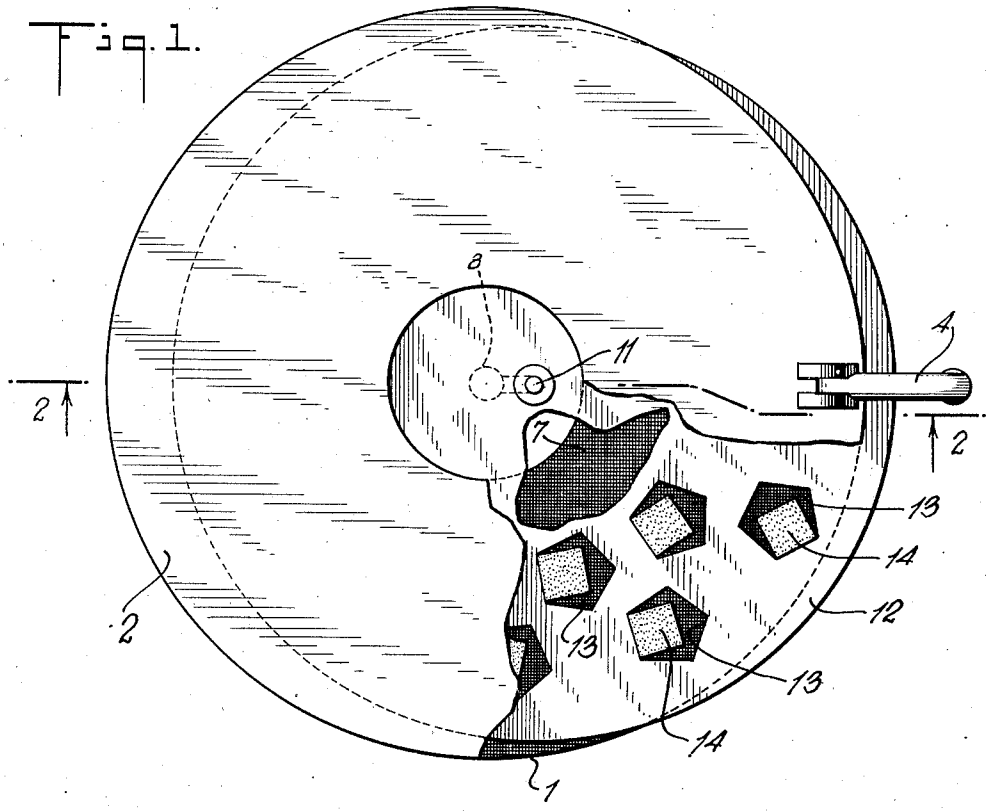
Jan. 27, 1948. H. M. BACH 2,435,118

APPARATUS FOR GRINDING CRYSTALS AND THE LIKE

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Fig. 1.



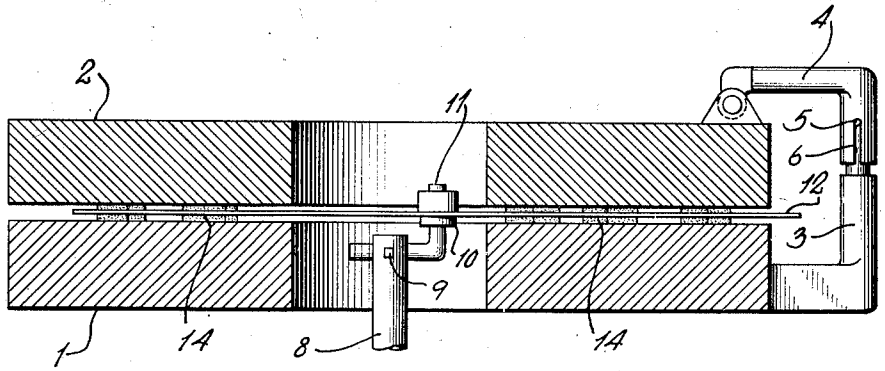


Fig. 2.

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APPARATUS FOR GRINDING CRYSTALS AND THE LIKE

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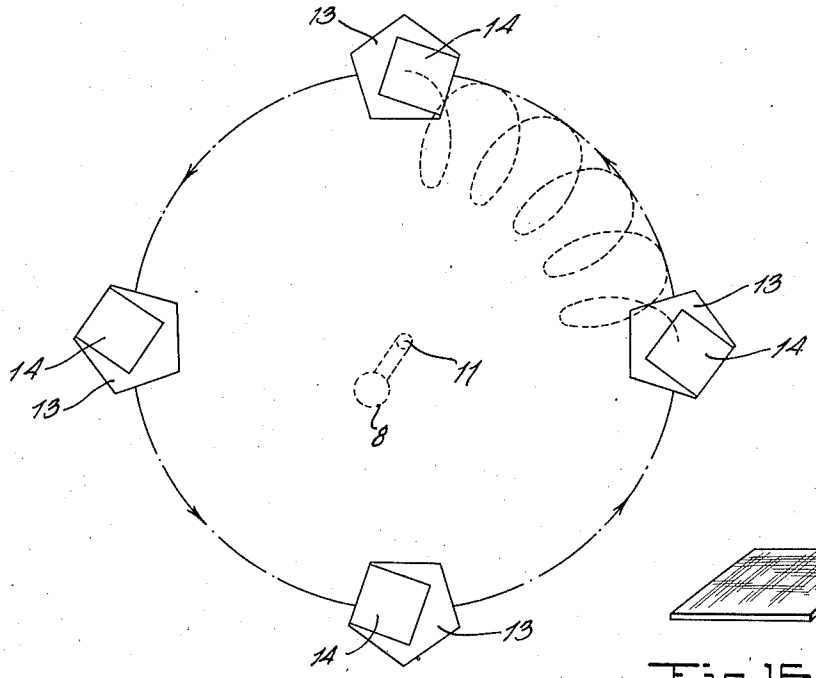


Fig. 3.

Fig. 16.

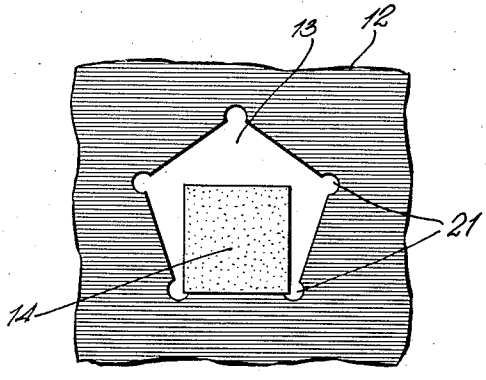


Fig. 4.

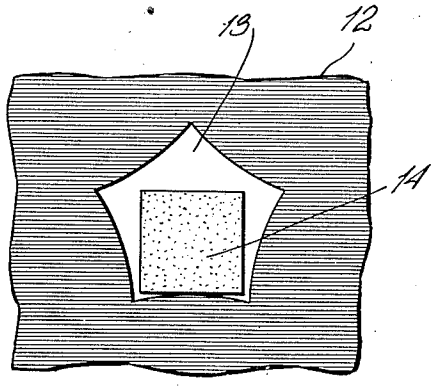


Fig. 5.

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APPARATUS FOR GRINDING CRYSTALS AND THE LIKE

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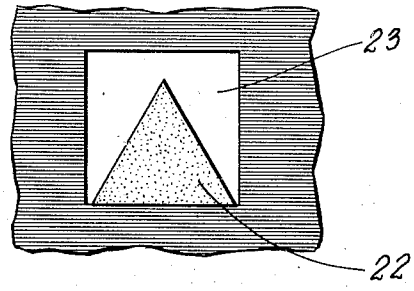


Fig. 6.

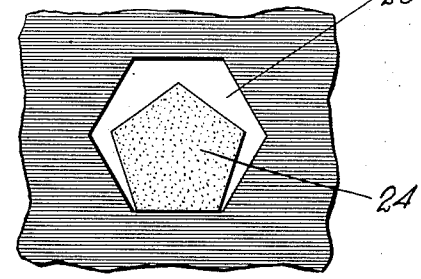


Fig. 7.

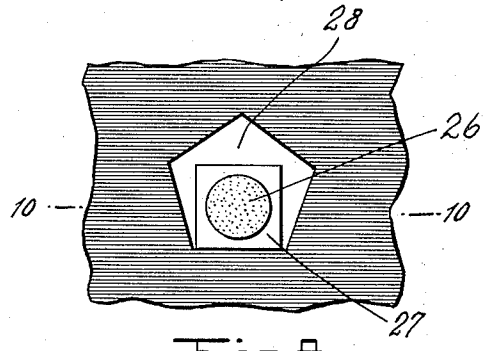


Fig. 8.

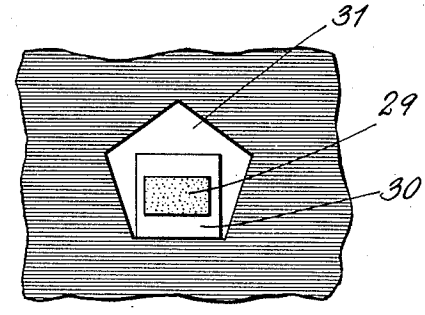


Fig. 9.

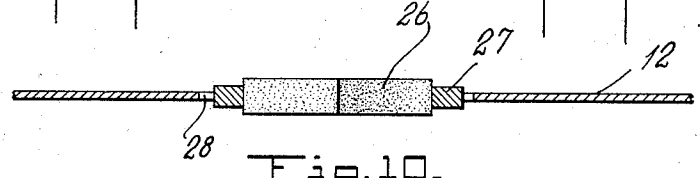


Fig. 10.

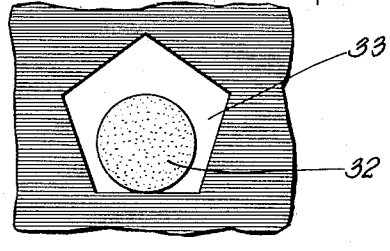


Fig. 11.

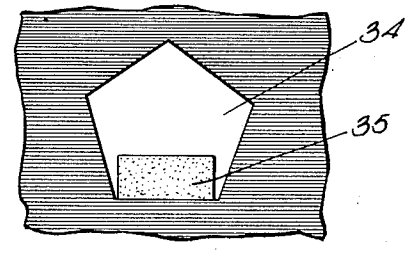


Fig. 12.

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APPARATUS FOR GRINDING CRYSTALS AND THE LIKE

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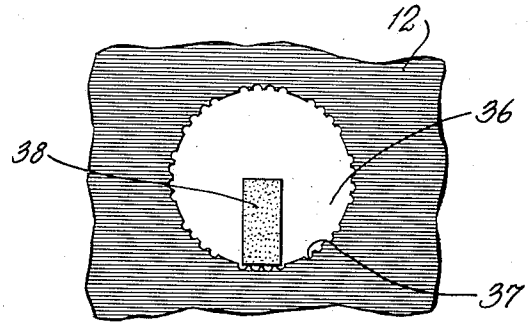


Fig. 13.

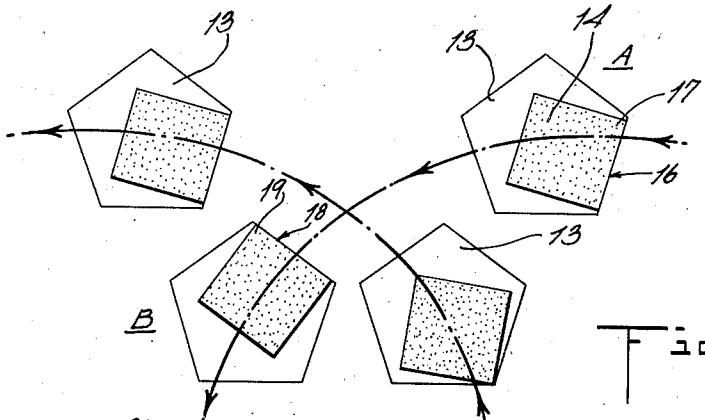


Fig. 14.

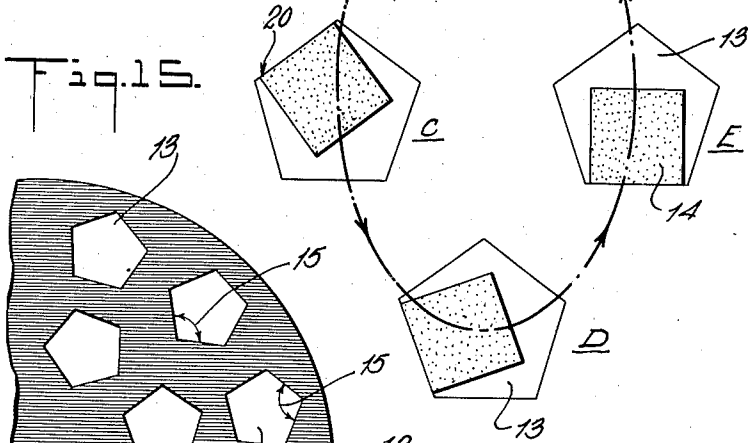


Fig. 15.

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Patented Jan. 27, 1948

2,435,118

UNITED STATES PATENT OFFICE

2,435,118

APPARATUS FOR GRINDING CRYSTALS AND THE LIKE

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Application June 10, 1942, Serial No. 446,458

2 Claims. (Cl. 51—161)

1

This invention relates to grinding devices and more especially to apparatus for grinding bodies to a very high order of accuracy.

In certain of the arts, especially in that pertaining to piezo-crystal devices and the like, ordinary grinding methods and procedures are not feasible because of the high order of dimensional accuracy required in the finished crystal. This is especially true where the crystals are required to have perfectly flat and parallel opposite faces or sides. I have discovered that with known methods of grinding, it is not possible to grind a piezo crystal with true parallel opposite faces where the crystal during the grinding operation is restrained to assume a comparatively fixed orientation with respect to the center of rotation of the carrier or of the grinding surfaces. With known prior grinding devices wherein the crystal is merely revolved about an axis or axes external to its own axis, the finished crystal possesses a wedge-like shape. This wedge-like shape is a source of disturbance when the crystal is used in certain exciting circuits and especially so in the case of ultra-high frequency crystals.

Accordingly it is a principal object of this invention to provide a method and apparatus for grinding piezo-crystals and the like, whereby both the opposed faces of the crystal are subjected to uniform grinding over substantially their entire facial areas.

Another object is to provide a method of grinding piezo-crystals and the like whereby they are subjected to a motion of rotation around their individual axes while simultaneously being subjected to a motion of revolution around a common axis.

Another object is to provide an improved method of simultaneously grinding opposite faces of articles with a high degree of accuracy of cross-section and with the utmost accuracy of parallelism between such faces.

Another object relates to a mechanism whereby a relatively thin and relatively fragile device such as a high frequency piezo crystal can be rotated around its own axis during a grinding operation without danger of chipping or otherwise disturbing the peripheral contour of the crystal.

Another object is to provide an automatic grinding machine whereby during the grinding operation the article is subjected to a compound eccentric motion and to a rotary motion about its own axis.

A further object is to provide an automatic grinding machine for piezo crystals and the like which is adaptable to grind crystals of a wide

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variety of peripheral contours with the same high degree of accuracy and uniformity.

A feature of the invention relates to a grinding machine employing a crystal guiding mask or apertured plate which is revolved bodily about an eccentric axis while it is simultaneously rotating about its own central axis. In accordance with this feature the crystal receiving apertures are so dimensioned and shaped with respect to the dimensions and shape of the crystals that the crystals are subjected to a uniform grinding force over their entire opposed faces.

Another feature relates to the novel manner whereby an eccentrically driven crystal receiving plate is designed so that the number of crystals which can be ground uniformly and simultaneously is in great degree independent of the said eccentricity.

A further feature relates to a grinding machine employing one or a pair of non-rotating grinding laps or plates between which a crystal guiding mask is rotatable, the combination being so designed that the upper lap can be more closely grooved than the lower lap. This reduces the likelihood of the crystals adhering to the upper lap when the latter is raised for any purpose, with a consequent reduction in the possibility of crystals breaking by falling off the upper lap when it is raised.

A still further feature relates to the novel organization, arrangement and relative cooperation of parts which cooperate to produce an improved machine for polishing or grinding articles generally.

Other features and advantages not specifically enumerated will become apparent after a consideration of the following descriptions and the appended claims.

While the invention finds its primary utility in the grinding of such articles as quartz or piezo crystals, it will be clear that it is capable of use in other situations where articles of different physical characteristics from piezo crystals are to be ground or polished to accuracy and uniformity.

Accordingly merely for explanatory purposes the invention will be described in connection with the grinding of piezo crystals and for that purpose,

Fig. 1 is a top plan view of a machine embodying the invention, but with certain parts broken away to show more clearly the arrangement of parts.

Fig. 2 is a sectional view of Fig. 1 taken along the line 2—2 thereof.

Fig. 3 is a diagrammatic view to explain the way in which each crystal is rotated within its individual window.

Figs. 4 and 5 show modified forms of windows in the rotating mask.

Figs. 6 and 7 show a portion of a mask for grinding triangular and pentagonal crystals respectively.

Figs. 8 and 9 show how the crystals can be placed in a closely fitting insert for achieving the objects of the invention.

Fig. 10 is a sectional view of Fig. 8 taken along the line 10—10 thereof.

Fig. 11 shows how a circular crystal can be ground without the special insert of Fig. 8.

Fig. 12 shows how a rectangular crystal can be ground without the special insert of Fig. 9.

Fig. 13 shows a modified form of mask window.

Fig. 14 is an explanatory diagram of the compound rotation and revolution of the crystal.

Fig. 15 shows a preferred embodiment of the arrangement of the mask windows when polygonal windows of an odd number of sides are employed.

Fig. 16 is a perspective view of the shape of a crystal ground without the specially designed masks according to the invention.

Referring to Figs. 1 and 2, the machine comprises a lower stationary annular lap or grinding member 1, and an annular upper lap or grinding member 2. The member 1 may be rigidly mounted on any suitable support or pedestal, while the member 2 is removable but is coupled to member 1 so that it is restrained against rotation when the crystals are being ground. For this purpose member 1 may have an upstanding arm 3 which locks with a pivoted arm 4 carried by member 2, so that member 2 can be centered and locked with respect to member 1. While the drawing shows a bayonet pin 5 carried by arm 6 and a pair of cooperating slots in the hollow end of arm 4 for centering and locking members 1 and 2 against relative movement, it will be understood that this is merely illustrative and any other suitable latching or locking means may be employed. Likewise, if desired, the members 1 and 2 may be locked at more than one point around their peripheries and in certain cases an adjustable spring coupling may be provided to supplement gravity in acting as a pressure on the crystal surfaces.

The upper face of member 1 is grooved or undercut with a series of intersecting lines or grids 7, and the lower face of member 2 is likewise grooved or undercut but with a coarser mesh or spacing of the grooves. Member 1 is centrally mounted with respect to driving shaft 8 which is driven at the desired speed by a suitable motor (not shown). Adjustably fastened to the upper end of shaft 8 by a bolt 9 is a dog 10 the vertical arm 11 of which passes through a central opening in the apertured mask 12. Arm 11 has a peripheral shoulder to support the mask 12 for free rotation around arm 10 as a center. Thus mask 12 is revolved, as distinguished from rotation, around a fixed axis through the center of shaft 8, while at the same time it can be independently rotated around the center of arm 11 as an axis. The speed of bodily revolution of the mask is fixed by that of shaft 8, but the rotational speed of the mask around arm 11 will be controlled by the frictional drag on the mask.

As shown in Fig. 1 the mask is provided with two rows of openings or windows 13 which may be pentagonal in shape. The mask is formed of thin sheet metal and its thinness is less than the thickness of the crystals 14 before grinding takes place. The windows 13 are much larger dimensions than the crystals so that when the parts are in position for grinding, the crystals rest freely and directly on the lower lap 1, while the upper lap 2 rests directly on the crystals. In the case of square crystals, as shown in Fig. 1 the length of each polygonal side of the window 13 should be preferably slightly greater than the length of the crystal edge. Consequently when the parts are in the relation shown in Figs. 1 and 2 and the shaft 8 is set in rotation, the several crystals are carried bodily around between the grinding faces of members 1 and 2. However, because of the combined motion of revolution of the crystal around shaft 8 as a center and the rotational movement of the mask 12 around arm 11 as a center, the resultant path of movement of the center of the window 13 is represented by the dot-dash arrowed lines of Figs. 3 and 14.

If the windows 13 were of substantially the same dimensions as the crystals, then regardless of the fact that the windows follow a multiple elliptical path, the crystals would be restrained against independent movement or rotation within their respective windows, and there would result an uneven grinding effect on the crystal faces and the production of a wedge-like shape in the crystal as illustrated in Fig. 16. I have found that by making the windows 13 much larger than the crystals and by properly designing the contour of the window with respect to the contour of the crystal the compound movement of the windows causes the several crystals to undergo independent movement in the nature of rotation around their own axes, or in the nature of a progressive movement around the center of the window, with the result that the crystals are ground perfectly flat over substantially the entire area of the opposed faces of each crystal. In the case of windows with an odd number of sides such as a pentagon, there may be a tendency to uneven grinding near the corners of the crystal resulting from unequal wear over the surface of the laps because of lack of symmetry. I have discovered that this can be overcome by arranging successive windows with different orientations. Thus as shown in Fig. 1, alternate windows 13 are disposed so that the corresponding angles 15 point outwardly towards the circumference of the mask, while the intervening alternate windows have the corresponding angles 15 pointing toward the center. However it is not entirely necessary to have this 180 degree displacement of the windows, as beneficial results are obtained provided all the windows are not oriented the same way with respect to the axis of rotation.

Referring to Fig. 14 there is shown one explanation of how each crystal is independently rotated or moved around within its individual window. This figure shows a series of successive positions of the same crystal and its window during a single complete cycle. In position A, the crystal 14 is in engagement with the side 16 of the window. As the mask performs its compound rotation and revolution along the dotted dash line, because of the frictional drag on the crystal by the grinding faces of members 1 and 2, the crystal starts to pivot in a clockwise direction around the corner 17 so that by the time window 13 reaches position B the crystal is flat against the side 18 of the window. Likewise as the window starts to move from position B to position C the crystal engages the corner 19 and

pivots therearound to position C where it engages the side 20. As the window assumes different positions the crystal continues to be turned clockwise with respect to the center of the window so that during each cycle of rotation of the mask the crystal has been turned at least 360 degrees around an axis through itself, while it is being subjected to the grinding action of members 1 and 2. In other words each crystal undergoes three components of movement, one of revolution around shaft 8 as a center, one of revolution around member 11 as a center, and one of rotation with respect to an axis through the crystal itself.

It is not necessary that the side dimensions of the crystal be the same as the side dimensions of window 13 since the crystal may first undergo a slight sliding movement along one side, e. g. side 16, until the corner of the crystal engages the next angle of the window whereupon it is rotated. It is understood therefore, that the invention is not limited to a simple rotation of each crystal but also covers a compound sliding and rotating movement of the crystal within its window so long as the crystal progressively changes its orientation with respect to the center of the window.

In order to reduce likelihood of damage to the crystal corners and to control more definitely the pivoting of the crystal at its corners, the angular corners of the window may be smoothly recessed or notched as indicated by numeral 21 in Fig. 4. Alternatively instead of employing a window with straight sides, these sides may be curved as shown in Fig. 5.

It will be understood that the invention is not limited to grinding crystals of any particular shape so long as the windows are designed to cooperate with the crystal contour to effect the bodily rotation of the crystal in its window. Thus as shown in Fig. 6 the crystal 22 may be triangular and window 23 square or rectangular. Likewise in Fig. 7 the crystal 24 may be pentagonal while the window 25 is hexagonal. In order to achieve the best results the crystal, if polygonal, should be provided with a window which is also polygonal but of $n+1$ sides where n is the number of crystal sides. In some cases it may be desired to employ much smaller crystals than the windows, in which event the crystal may be first mounted in a closely fitting insert. Thus as shown in Fig. 8 the circular crystal 26 is fitted into a polygonal metal member 27 whose dimensions are correlated with the side dimensions of the pentagonal window 28 as described in connection with Fig. 14.

Fig. 9 shows a rectangular crystal fitted into a metal insert 30 for cooperation with the pentagonal window 31. In Figs. 8 and 9 the insert should be thicker than the mask 12 but thinner than the crystal before grinding, and if desired the members 27 and 30 may be used as gauges to limit the amount of grinding to which the crystal is subjected. It will be clear that the crystal which is used within the insert may be square or any other shape, furthermore the insert may be of any polygonal formation which cooperates with the window to cause rotation of the insert and crystal as described.

It is not necessary to employ the special insert where larger circular or polygonal crystals are to be ground. Thus as shown in Fig. 11 the circular crystal 32 may be placed in a pentagonal or other polygonal window 33, and preferably the side dimensions of the polygonal window are slightly greater than the diameter of the crystal. Likewise in Fig. 12 the side dimensions of the window 34 are slightly greater than the longer side of the crystal 35.

In the case of any polygonal crystal, a circular window may be employed as shown in Fig. 13, and if desired the inner edge of the circular window 36 may be provided with a series of notches 37 to accommodate the corners of the rectangular crystal.

While in the foregoing, certain particular shapes of crystals have been disclosed, it will be clear that the invention is capable of use in grinding any regular or irregular shaped crystal, but the best results are obtained where the dimensions of the window are correlated with the dimensions of the crystal to produce what may be termed a "quasi-gearing" between the mask and the crystal. Furthermore, the invention can be used not only for grinding but also for polishing articles generally, it being understood that in the machine of Figs. 1 and 2 a suitable grinding or polishing powder is applied to the grinding faces of members 1 and 2, and, if desired, a quantity of cooling or lubricating liquid may be maintained between members 1 and 2 to insure a more uniform distribution of the powder over the surfaces.

Various changes and modifications may be made in the disclosed embodiments without departing from the spirit and scope of the invention. Thus while in the foregoing the upper and lower laps are stationary with respect to mask 12, it will be understood that either of the laps may be rotated with respect to the other. Furthermore while the drawing shows the crystal as thicker than the mask, if desired, the mask may be initially thicker than the crystal so that the mask is lapped or ground down to the crystal thickness. Thus the thickness of the mask at any given instant will determine the final thickness of the crystal. Since the mask protrudes out beyond the upper and lower laps because of its eccentricity, this protruding edge may be gauged or calipered to determine when the crystal has been ground the desired amount.

While the drawing shows a mask with a double row of windows, the preferred form employs a single circumferential row so as to obtain the utmost accuracy and flatness of grinding. Thus each window 13 is located on a radius from the center of the mask so that as member 11 makes one complete revolution each crystal moves radially from the outside circumference of the annulus of the lap to the inside circumference of that annulus. This has been found desirable in order to insure equal wear on the annular laps while obtaining maximum flatness of the crystal faces.

As pointed out hereinabove the polygonal window should have one side more than the crystal in order that the angles of the window sides be larger, in degrees, than the angles made by the sides of the crystal. Following is a generalized explanation of the mode in which the rotation of the crystal occurs, and assuming a pentagonal window and a square crystal. As the crystal rotates inside the pentagon it will move for each complete revolution of 360 degrees of shaft 8, an angular distance of 90 degrees, i. e. 5(108°—90°), and it will require four revolutions of shaft 8 to effect a 360 degree movement of the crystal. Generally speaking, when the crystal is a regular "N-gon" of N_c sides, and the window is a regular "N-gon" of N_w sides, then the angular rota-

tion of the crystal per 360 degrees rotation of shaft 8 is determined as follows:

$$N_w\left[\left(\frac{180°.N_w-360°}{N_w}\right)-\left(\frac{180°.N_c-360°}{N_c}\right)\right] \quad (1)$$

which upon simplification becomes,

$$360°\left(\frac{N_w-N_c}{N_c}\right) \quad (2)$$

Thus it will be seen that the greater the value of N_w, the greater the ratio of the rotation of the crystal per rotation of the main drive shaft.

The circular window may be represented by an "equivalent" "N-gon" of a certain definite number of sides with respect to the crystal. The greater the radius of the circular window with a given crystal size, the greater is the effective size of the "equivalent" "N-gon" and the greater the number of revolutions of the crystal per revolution of the shaft 8. If the circular window has a radius of R, then

$$\frac{180°}{\sin^{-1}\frac{L}{2R}}=N \quad (3)$$

where L is the length of the crystal side, and N is the effective number of sides of the "equivalent" "N-gon" of the circle. If N is not an integer then the "N-gon" may be considered as having the integer component as the number of sides and the fractional component as a fractional rotation of the "N-gon" about its center. This is advantageous when it is desirous of insuring an overall crystal motion wherein the crystal never returns to the same position at the end of each complete revolution of the crystal per rotation of shaft 8. Thus the number of revolutions of the crystal per revolution of shaft 8 can be varied by varying the radius of the circular window. For example using a one-inch square crystal which is to be given one revolution per 360° rotation of shaft 8, the radius of the desired circle would be calculated as follows; substituting the value 4 for N_c in the above Equation 1 then N_w equals 8, i. e. an octagon. Substituting this value in Equation 3 we find

$$\sin^{-1}\frac{1}{2R}=22.5°$$

from which the value of R is calculated as 1.3 inches. Hence a circle of 1.3 inches radius will effect one revolution of a one-inch square crystal per 360° revolution of shaft 8.

What I claim is:

1. In a grinding machine of the type having a pair of opposed grinding laps between which a rotatable apertured article carrier is mounted, said carrier having its apertures of polygonal shape, a polygonal insert in each carrier, said insert being sufficiently smaller than the aperture to allow the insert to change its orientation within the aperture through an angle of 360°, and an opening in each insert into which is fitted the article to be ground.

2. A device for grinding crystals and the like of polygonal peripheral contour, comprising at least one grinding lap, a crystal carrier mounted for rotation in a plane adjacent the grinding surface of said lap and having a plurality of crystal receiving apertures of larger size than the crystal to allow the crystal to change its orientation through an angle of 360° inside the aperture, a main driving shaft for the carrier, said carrier being mounted on and eccentrically with relation to said shaft and capable of independent rotation about its center, the edge of each of said apertures having a plurality of indentations cooperating with the crystal corners to positively change the orientation of each crystal in its aperture as the carrier is rotated, the apertures being circular and of a radius related to the length of the polygonal sides of the crystal in accordance with the formula

$$N=\frac{180°}{\sin^{-1}\frac{L}{2R}}$$

wherein N is the number of polygonal sides of the crystal and R is the radius of the aperture.

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