

Feb. 9, 1954

R. F. HOLZRICHTER ET AL

2,668,397

METHOD AND APPARATUS FOR CORRECTING CRYSTAL BLANKS

Filed June 29, 1951

2 Sheets-Sheet 1

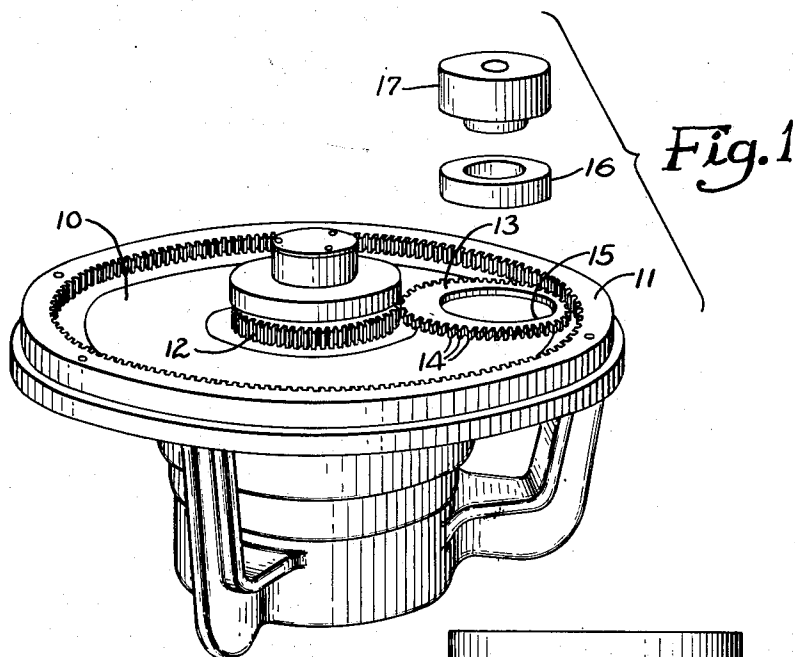


Fig. 2

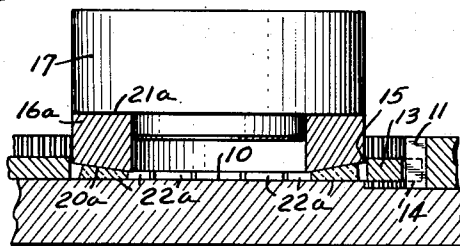
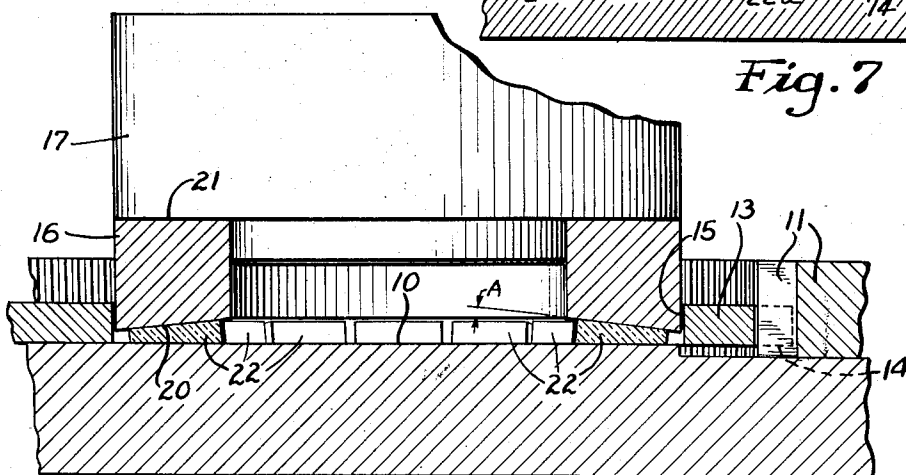


Fig. 7



Inventors
Robert F. Holzrichter
Ernest E. Overbey

by: Carlson, Pitzner, Hubbard + Asafe
Attys.

Feb. 9, 1954

R. F. HOLZRICHTER ET AL

2,668,397

METHOD AND APPARATUS FOR CORRECTING CRYSTAL BLANKS

Filed June 29, 1951

2 Sheets-Sheet 2

Fig. 3

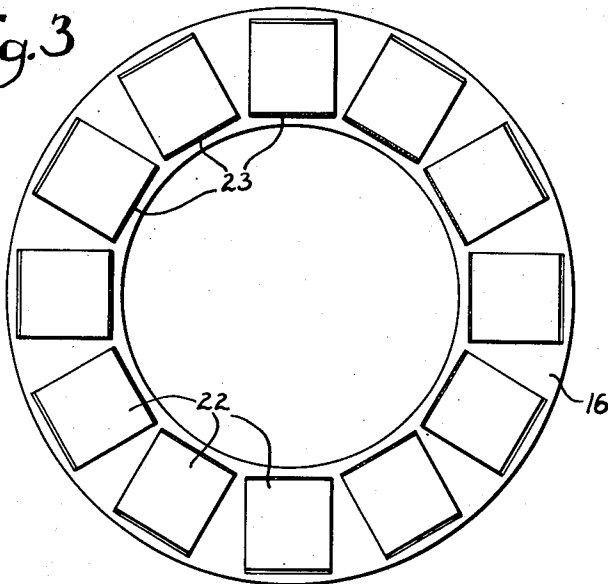


Fig. 5

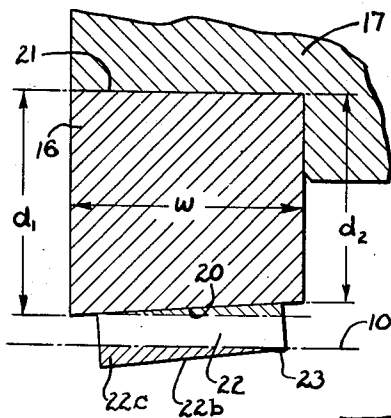


Fig. 6

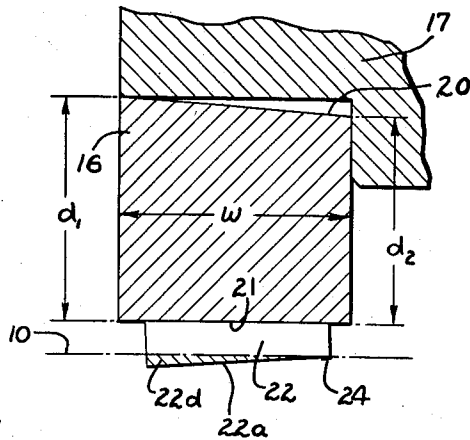
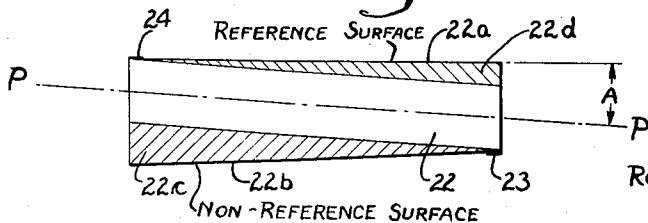


Fig. 4



Inventors
Robert F. Holzrichter
Ernest E. Overbey

by: Carlson, Pitzner, Hubbard & Solfe
Attys.

UNITED STATES PATENT OFFICE

2,668,397

METHOD AND APPARATUS FOR CORRECTING CRYSTAL BLANKS

Robert F. Holzrichter and Ernest E. Overbey,
Sandwich, Ill., assignors to The James Knights
Company, Sandwich, Ill., a corporation of Illinois

Application June 29, 1951, Serial No. 234,242

7 Claims. (Cl. 51-161)

1

The present invention relates to the manufacture of piezo-electric crystals and, more particularly, to correcting the orientation of crystal blanks during the course of manufacture.

In the production of piezo-electric crystals it is a well known fact that the temperature-frequency characteristics of the crystal may vary considerably, depending upon the precise angle of cut. For example, in the case of an AT cut crystal to be operated at room temperature, orienting the crystal at an angle of 35 degrees, 13 minutes relative to the Z axis produces a satisfactory temperature characteristic. However, where a crystal of AT cut is to be employed in a crystal oven and operated at a substantially constant temperature, preferred characteristics are obtained when the angle is on the order of 35 degrees, 26 minutes. But where the crystal is to be employed in aircraft or for military purposes where wide temperature swings are to be encountered, for example, from minus 55 degrees C. to plus 90 degrees C., the performance characteristics require that the angle of cut lie between the above limits; for example, at 35 degrees 19 minutes. It is apparent, therefore, that changing the angle of cut only a few minutes of arc has a radical effect on the operating characteristics, and such angle must be maintained within extremely close tolerances where military specifications are to be met.

When crystal blanks are produced from a rough crystal, the crystal axes are determined by X-ray measurement, and the individual blanks are formed by a series of parallel cuts made at the appropriate angle employing a diamond saw. Unfortunately, sawing is an inherently inaccurate operation, and it is practically impossible to control conditions closer than plus or minus seven minutes of arc. The accuracy desired in the final crystal, by contrast, is on the order of plus or minus one or two minutes. In order to prevent a high rate of rejection, therefore, it is desirable to correct the angle of orientation of a large portion of the crystal blanks resulting from the sawing operation. Correction has, in the past, been time consuming and expensive. Where crystals are to be produced in quantity for a competitive market, many manufacturers have preferred to throw away a large proportion of the blanks rather than to bother with individually correcting them. In a number of instances efforts have been made to correct orientation of a number of crystal blanks at the same time, but the schemes which have been devised have suffered from various drawbacks; for example, the grinding away of too much face material from at

2

least a portion of the crystal undergoing correction.

Accordingly, it is an object of the present invention to provide a method and apparatus for correcting orientation which enables crystal blanks to be corrected to an extremely high degree of accuracy, and which may be employed with equal effectiveness regardless of whether the amount of correction which is required is large or small. It is another object to provide a method and apparatus for crystal angle correction which enables crystals of any type of cut to be corrected quickly in a high quantity production line and at an extremely small cost per crystal. It is a related object to provide a procedure and apparatus for correcting crystal blanks which may be efficiently and safely employed by relatively unskilled help.

It is another object to provide a method and apparatus for crystal angle correction which is capable of treating a relatively large number of crystals at the same time yet which removes only a minimum amount of quartz from each of them, thereby having especial application to crystals which are extremely thin and fragile. It is a related object to provide a method and apparatus for crystal correction which leaves the faces of the crystal blank smooth and active and which avoids the necessity for extensive subsequent lapping for the purpose of restoring activity and avoiding "twinning."

It is a further object to provide an apparatus which, although of high accuracy, may be easily and inexpensively constructed and which may be employed in various types of conventional lapping machines.

Other objects and advantages of the invention will become apparent as the discussion proceeds in connection with the following drawings:

Figure 1 shows a general view of a setup for correcting crystal blanks in accordance with the present invention and in connection with a standard type of lapping machine, the correction ring employed herein being illustrated in exploded relation to the machine.

Fig. 2 is a cross-sectional view showing the correction ring and the crystal blanks attached thereto during the correcting operation.

Fig. 3 shows the underside of the correction ring with crystals closely spaced around the periphery thereof.

Fig. 4 shows a crystal blank before and after correction with the removed portions emphasized by shading.

Fig. 5 is a fragmentary view of the correction

ring and attached crystal showing the manner of correcting the first crystal face.

Fig. 6 is a similar view showing the correction of the remaining crystal face, and

Fig. 7 shows an alternative construction of correction ring used in practicing the present invention.

While the present method and apparatus are subject to various modifications and alternative constructions, it will be understood that only the preferred embodiment is disclosed herein and that the invention is not limited thereto, but includes the various modifications and alternative constructions falling within the spirit and scope of the appended claims.

Referring now to Figure 1, a lapping machine base is disclosed, which will be recognized as being of Hunt-Hoffman type extensively employed in this art. It includes a lap plate 10, having an outside rack or gear 11, and an inside gear 12. The lap plate and outside rack are stationary while the inside gear is rotatable by any suitable power source. Meshing with the inside and outside gears is a carrier 13, having a series of gear teeth 14, to impart orbital rotation movement to the carrier as the inside gear 12 is rotated.

Eccentrically arranged in the carrier 13 is an opening 15. In accordance with the present invention, a novel correction ring 16 is provided which fits freely within the opening 15 and which is held in place by a weight 17. The parts are assembled as set forth in the sectional view in Figure 2. As shown in detail in the latter figure, the correction ring 16 has a frusto-conical face 20 machined on one side thereof, and a flat face 21 machined on the remaining side. The conical angle or slope is indicated at A in Fig. 2 and is generally very small, on the order of one to forty-five minutes, depending upon the exact amount of correction which is desired.

Arranged side-by-side around the bevelled or undersurface of ring 16 are a plurality of crystal blanks 22 (see also Fig. 3). These blanks are fastened to the surface 20 by means of paraffin wax or the like.

In order to understand the manner in which correction is achieved, it will be helpful to refer to Fig. 4 which shows a typical rough crystal blank greatly enlarged and with the amount of correction exaggerated. The crystal blank has two faces which have been designated 22a, 22b. Face 22a will be assumed to be the reference surface. It is desirable to designate a selected one of the surfaces as a reference surface since normally the faces of the blank will not be exactly parallel to one another upon completion of the sawing operation. It will be further assumed that the proper plane of orientation of the crystal blank is denoted by the line P—P which is located at the desired angle relative to the Z axis. It will be seen that the desired orientation can be achieved by removing the wedge-shaped portions which have been cross-hatched in the figure and indicated at 22c, 22d. The resulting blank, indicated by the unshaded portion in Fig. 4, therefore, has an angle of orientation which is related to the reference surface by a small angle A. It is this angle A which is referred to as the angle of correction. As the discussion proceeds it will be apparent that a single reference surface is sufficient and that it is unnecessary to know the relative angle of orientation of the opposite or non-reference surface.

The angle of correction A between the reference surface and the plane of orientation of the crystal is established by employing X-ray techniques known to one skilled in this art. Employing such techniques, the crystal is mounted in the X-ray analyzer with the reference surface away from the operator. A reading is made of the number of minutes of arc between the reference surface and the desired plane of orientation of the crystal, in other words, the amount by which the reference surface is in error. To preserve the direction that the cut is to be taken, and in carrying out the present invention, a pencil mark is applied to one of the faces of the crystal, preferably while the crystal is still in the X-ray analyzer. For a purpose which will become clear as the discussion proceeds, such pencil mark is applied, not to the reference surface, but to the non-reference surface 22b, the surface which faces the operator. This pencil mark, which is indicated at 23 of Fig. 4, is preferably in the form of a line which is placed on the non-reference surface 22b along the edge which is diagonally opposite from the portion of the reference surface which requires minimum correction. Since the error in parallelism is usually rather small, the mark 23, as a result, denotes that portion of the reference surface which requires minimum correction. The pencil employed for the purpose is preferably hard so as to resist ordinary cleaning and handling and to be removable only as a result of the later lapping of the crystal face.

In a quantity production run of crystal blanks there will, of course, be a considerable variation in the degree of correction required. In the case of some of the blanks it will be necessary to remove material to correct the orientation of the reference surface by, say, two minutes of arc. Other blanks will require the reference surface to be corrected by three minutes of arc, still others four minutes, and so on. In carrying out the present invention, all of the blanks requiring the same amount of correction are segregated to form a three-minute lot and four-minute lot, and so on.

After all of the crystals have been analyzed and segregated, they are given an additional pencil marking on the opposite face which is, as stated, the reference surface. Preferably such marking is applied with a red pencil at a region of the reference surface which lies diagonally opposite from the first mark 23. The new mark has been designated at 24 in Fig. 4. Preferably the mark is one which is non-symmetrical and therefore not subject to reading from the reverse side of the crystal. In practice, the numeral "4" is used.

In accordance with the present invention, a group of crystal blanks from the same lot and requiring the same reference correction are mounted side-by-side in ring formation upon the conical face of a correction ring having a corresponding angle. The crystal blanks are mounted on such correction ring with their reference surfaces in contact with the ring and with the reference marks 23 on all of the blanks facing inwardly, as shown in Fig. 3. With the crystals thus mounted, it will be apparent that the desired orientation is defined by a plane which passes symmetrically through all of the crystal blanks. The portions bearing the reference marks 23 will be the last to be removed during the lapping process.

As illustrated in the fragmentary view of Fig.

5; the correction ring is then placed in the carrier 13 with the weight 17 thereon. The lap plate is coated with an abrasive of fine lapping grade suspended in oil, water or similar vehicle. The weight is such as to produce efficient cutting action for the particular grade of lapping material employed, the selection being a matter well within the skill of the art.

The correction ring and its load of crystals are rotated with a compound orbital movement until the wedge-shaped portion indicated at 22c in Figs. 4 and 5 is removed. The orbital movement is compound since the carrier is moved orbitally with respect to the lapping plate and the ring is moved eccentrically with respect to the carrier. Complete removal of the unwanted portion 22c of the crystals is indicated by the lapping off of all of the pencil marks on the entire series, and the progress can be checked from time to time during the lapping process to determine when this point has been reached. Upon completion of the lapping step it is found that the lapped faces lie in a plane which is precisely parallel to the plane of desired orientation of each of the crystals. This is the desired result. Its achievement, however, is rather surprising considering the fact that the correction ring is only loosely guided by the carrier and the fact that the correction ring is positioned in the lapping machine solely by the non-reference surfaces of the crystal blanks, the orientation of which is not only undetermined but varies somewhat from blank to blank.

After the material 22c has been lapped away, the crystal blanks are removed from the tapered surface 20, for example, by heating the paraffin which has been used as a cement. As a next step in the correction, the surfaces which have been lapped are cemented to the opposite or flat surface 21 of the correction ring as indicated in Fig. 6, and the reference surfaces are exposed for lapping. Proper orientation is assured by placing the red pencil mark toward the inside of the ring and a final check is made to see that the crystal is right side up by noting whether all of the marks are "readable." The weight 17 is again applied and the lapping machine turned "on." The work is inspected from time to time until it is noted that the marks 24 have all been removed. The time required for the lapping of the first face serves as a rough guide for lapping the second.

Upon completing the lapping of the second face of the crystal blank, the faces will be substantially parallel to one another and the crystal will be ready for additional lapping, as required to bring it to the desired frequency. Such additional lapping is conveniently carried beyond the desired frequency point and the faces are, as a final operation, loaded by plating them with silver or the like in order to adjust the frequency of the crystal to a high degree of accuracy.

It will be apparent that the above procedure enables a large number of crystals, for example fourteen or more, to be treated simultaneously. The amount of quartz removed from each of the crystals during the correction thereof is substantially the same. It will be apparent that the amount removed is the very minimum amount necessary in order to establish the desired degree of correction. It is to be noted that the crystals during correction acquire a lapped finish, as contrasted with a "diamond" finish. As is well known to one skilled in this art, a lapped finish is highly desirable since it insures a high

degree of activity, insures frequency stability over a long period of time, and prevents the phenomenon known as "twinning." Furthermore, the production of a lapped finish greatly simplifies the subsequent finishing operations and makes it completely unnecessary to perform extensive lapping to repair the damage done by the heavier abrasives commonly employed in crystal correction. It has been necessary in the past to lap as much as .010 inch from the face of a crystal in order to correct the damage done by rough grinding operations and to insure a high degree of accuracy and stability. It will be apparent, therefore, that the present procedure is particularly applicable to high frequency crystals which are extremely thin and which may not have sufficient quartz available to permit the use of conventional correction techniques.

It has been found that a wide range of correction is possible employing the present procedures. As little as one minute of correction may be effected, or, if desired, the correction may be as much as one degree or more. Regardless of the degree of correction, the fabrication of the correction rings therefor is an extremely simple procedure and one which may be accomplished with precision while using only an ordinary degree of care. A correction ring may be chucked in a conventional lathe and an angle cut taken to form the tapered surface 20. The angle need not be measured directly but may be ascertained indirectly with a high degree of accuracy simply by calipering the inner and outer edges of the ring and measuring the distances d_1 and d_2 (Fig. 5). The difference between these two distances divided by the width w of the ring is the tangent of the angle. In the event that the angle produced by a given cut is not sufficiently accurate, a very slight tool adjustment may be made and a second cut taken. This process may be repeated until the desired angle is achieved. If desired, the tapered surface may be made using a grinding wheel instead of a cutting tool in the tool holder.

A graded set of rings may be made up in this manner for the various amounts of correction, for example, with intervals of one minute or two minutes of arc. Each of such rings should preferably have the same inside and outside diameter to enable use of a single carrier and single auxiliary weight. Only one such set of rings is required regardless of whether the correction is plus or minus, assuming the pencil marking procedure is uniformly followed as described above.

In operation, use of the rings is so simple and mechanical that a relatively unskilled operator may be employed, even where the degree of correction is extremely slight and maximum accuracy essential. The operator need merely be told to use a ring having a designated number for all of the crystal blanks in the container having the corresponding number. Several lapping machines equipped with the present correction rings can easily be tended at the same time.

It will be apparent to one skilled in the art that the invention is not limited to the use of a ring and separable weight. If desired, the ring may be made of heavier cross section so that the desired weight is incorporated therein. The present arrangement enables a single weight to be used with a complete set of rings.

It will also be apparent that the invention is not limited to a correction ring having an internally conical surface but is equally applicable to rings in which the conical surface 20 faces

outwardly. The crystal blanks in such case would be similarly oriented with respect to the lapping surface so that the marked portion of each blank is "low" and therefore the last to be removed. This is shown in Fig. 7, corresponding parts being indicated by corresponding reference numerals with subscript "a." While the arrangement of Fig. 2 is preferred, either construction enables the same amount of material to be lapped from a group of diametrically arranged blanks.

In the following claims the term "ring" shall be understood to mean a crystal lapping mount in which there is provision for arranging crystals in ring formation and is not limited to carriers which have a hole or opening at the center.

We claim as our invention:

1. Apparatus for correcting the angle of orientation of a plurality of piezoelectric crystal blanks comprising in combination a correction ring having a frusto-conical surface on one side thereof which is coaxial with respect to the ring, said frusto-conical surface being of such width as to accommodate a plurality of crystal blanks arranged side by side in ring formation thereon and with the slope of said surface equal to the angular correction to be imparted to the first face of each of said crystal blanks, said correction ring having a plane face on the opposite side thereof for the mounting of said crystal blanks in ring formation for corrective lapping of the remaining faces of said crystal blanks when the ring is in inverted position, a lap plate having an extensive flat surface, a carrier having a flat apertured face through which extends the said correction ring, said flat face lying on the lap plate, and means operatively engaging the carrier for translating the same with orbital movement on the lap plate.

2. Apparatus for correcting the angle of orientation of a plurality of piezoelectric crystal blanks comprising in combination a correction ring having a frusto-conical surface on one side thereof which is coaxial with respect to the ring, said frusto-conical surface having a plurality of crystal blanks arranged symmetrically side by side in ring formation on such conical surface and cemented thereto, the slope of said surface being equal to the angular correction to be imparted to the presented faces of each of said crystal blanks, said correction ring having a plane face on the opposite side thereof, a lap plate having an extensive flat surface, a carrier having a flat apertured face through which extends the said correction ring, said flat face lying on the lap plate, and means operatively engaged in the carrier for translating the same with orbital movement on the lap plate.

3. The method of correcting the angle of orientation of piezoelectric crystal blanks having a reference surface having a predetermined angle to the desired plane of orientation which comprises the steps of arranging a plurality of blanks requiring the same amount of correction side by side in ring formation with the reference surface on each of the crystal blanks symmetrically inclined in the locus of a cone having a slope equal to the magnitude of the desired correction, lapping said arranged crystal blanks simultaneously until the presented faces of the blanks form a plane surface, arranging said crystal blanks in similar ring formation but with the lapped surfaces coplanar and with the remaining faces presented for lapping, and then lapping said remaining faces of the crystal blanks simul-

taneously until such remaining faces form a plane surface.

4. The method of correcting the angle of orientation of piezoelectric crystal blanks which comprises the segregating a plurality of blanks each having a reference surface which is in error relative to the desired plane of orientation by the same angle of correction, mounting said blanks side by side in ring formation on a frusto-conical surface having a slope equal to the angle of correction, said crystal blanks being so symmetrically arranged that the desired orientation of said crystal blanks is defined by a plane passing symmetrically through all of the blanks, subjecting the presented faces of said crystal blanks to relative lapping movement on a flat lapping surface, continuing such lapping movement until all of the lapped faces of the crystal blanks lie in a common plane which is parallel to the plane of desired orientation, and then lapping the remaining faces of the crystals into parallelism with the faces which have been previously lapped.

5. The method of correcting the angle of orientation of piezoelectric crystal blanks which comprises the steps of selecting a plurality of crystal blanks each having a reference surface which is in error relative to the desired plane of orientation by the same angle of correction, marking the non-reference of each crystal blank adjacent the edge thereof which does not require lapping away of material, mounting said blanks side by side in ring formation with their reference surfaces in contact with a frusto-conical surface having a slope equal to the magnitude of the desired correction, said crystal blanks being so arranged that the marks are all exposed on the innermost edges of the crystals respectively, subjecting said crystal blanks to simultaneous lapping movement on a flat lapping surface, continuing such lapping movement until all of the marks on said crystals are obliterated indicating that the lapped faces of the crystal blanks lie in a common plane of desired orientation, and then lapping the remaining faces of the crystals into parallelism with the faces which have been previously lapped.

6. The method of correcting the angle of orientation of piezoelectric crystal blanks which comprises the steps of segregating a plurality of blanks each having a reference surface which is in error relative to the desired plane of orientation by the same angle of correction, mounting said blanks side by side on a mounting block in a two-dimensional pattern with each crystal blank being angled with respect to the mounting block by an angle equal to the desired angle of correction and with said crystal blanks being so symmetrically arranged that the desired orientation of said crystal blanks is defined by a plane passing symmetrically through all of the blanks, subjecting the presented faces of said crystal blanks to relative lapping movement on a flat lapping surface, continuing such lapping movement until all of the lapped faces of the crystal blanks lie in a common plane which is parallel to the plane of desired orientation, and then lapping the remaining faces of the crystals into parallelism with the faces which have been previously lapped.

7. The method of grinding piezoelectric crystal blanks on a flat abrasive coated lap plate which comprises selecting a plurality of crystal blanks requiring the same amount of angular correction, cementing the blanks side by side in ring formation on a symmetrically weighted

mounting member having a frusto-conical surface, said frusto-conical surface having a slope equal to the desired angle of correction and said crystal blanks being symmetrically arranged on the frusto-conical surface for corrective removal of a wedge-shaped face portion on each of the blanks, and then transporting the mounting member across the lap plate with the presented faces of the crystal blanks in contact with the lap plate and with the mounting member free to press downwardly on said crystal blanks under the force of gravity.

ROBERT F. HOLZRICHTER.
ERNEST E. OVERBEY.

15

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
5 689,933	Underwood	Dec. 31, 1901
1,662,672	Hoke	Mar. 13, 1928
2,309,080	Hunt	Jan. 19, 1943
2,369,107	Indge	Feb. 6, 1945
2,378,243	Penberthy	June 12, 1945
10 2,408,496	Watkins	Oct. 1, 1946
2,495,600	Ramsay	Jan. 24, 1950
2,538,620	Heinrich	Jan. 16, 1951
2,539,561	Wolfskill	Jan. 30, 1951

OTHER REFERENCES

American Machinist, June 26, 1924, page 973.