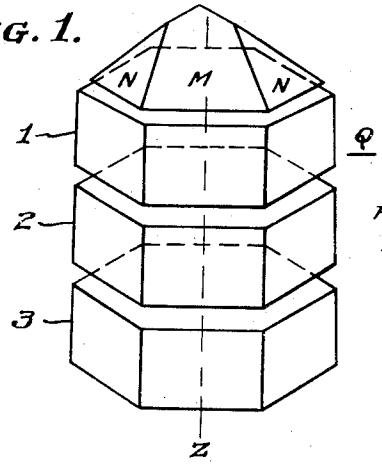
Dec. 2, 1941. C. E. JOHNSON 2,264,698

METHOD OF CUTTING QUARTZ

Filed Sept. 30, 1939

FIG. 1.



PRIOR ART

FIG. 2.

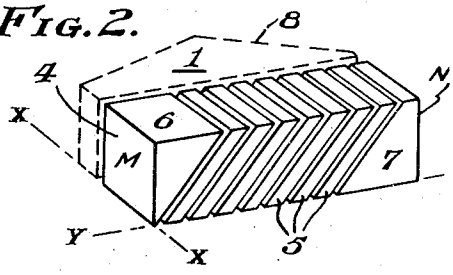


FIG. 3.

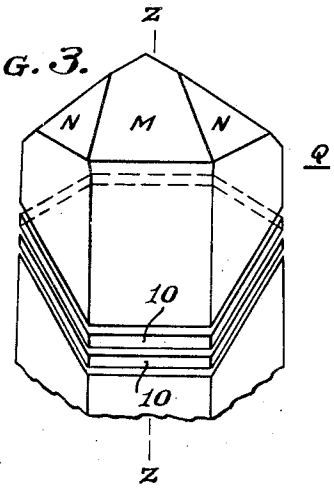
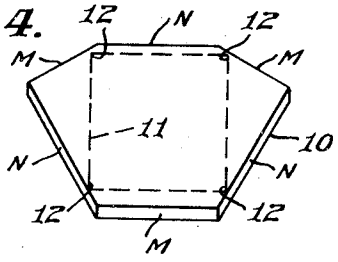


FIG. 4.



PRIOR ART

FIG. 5.

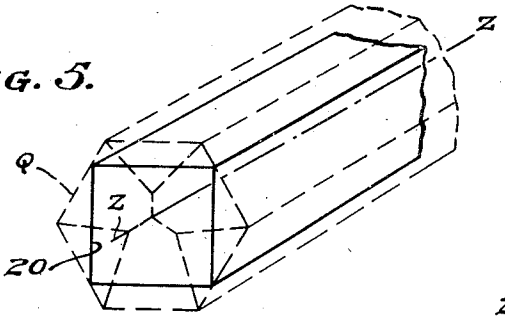


FIG. 7.

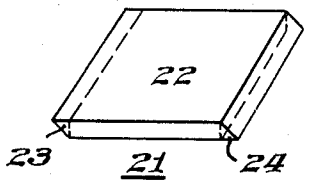


FIG. 6.

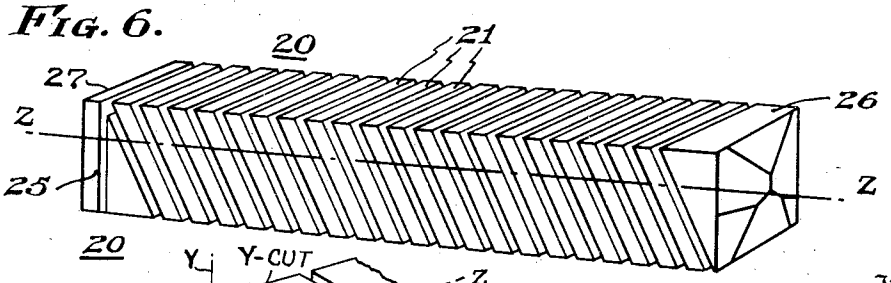
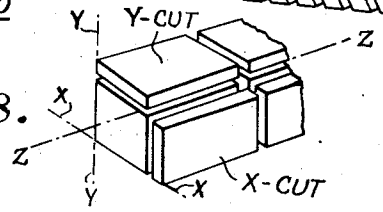


FIG. 8.



Inventor

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Patented Dec. 2, 1941

2,264,698

UNITED STATES PATENT OFFICE

2,264,698

METHOD OF CUTTING QUARTZ

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Application September 30, 1939, Serial No. 297,410

6 Claims. (Cl. 171—327)

This invention relates to the art of cutting natural quartz crystals (or "rock crystals" as they are sometimes called) and has for its principal object to provide (*a*) a simplified, inexpensive, time saving method of cutting quartz, (*b*) one which permits the use of smaller, and consequently cheaper mother crystals in the production of piezoelectric and optical elements, and (*c*) one which ensures minimum wastage of material.

The invention will be better understood from the following description considered in connection with the accompanying drawing and its scope is indicated by the appended claims.

In the drawing wherein like reference characters designate the same or corresponding parts in all figures,

Figure 1 is a view in outline and in perspective of a quartz mother crystal cut, in accordance with the prior art, in planes normal to its optic (Z) axis, to provide a plurality of sections,

Figure 2 is an elevational view of one of the sections of Fig. 1 showing subsequent cutting operations dictated by the later described prior art method of producing so-called "V-cut" piezoelectric quartz elements,

Figure 3 is a view in perspective of a quartz mother crystal which is marked to indicate another prior art method of cutting "V-cut" piezoelectric elements therefrom,

Figure 4 is a view in perspective illustrating subsequent cutting operations required by this prior art method,

Figure 5 is a view in perspective of a quartz mother crystal having cut therefrom (in accordance with the present invention) a single bar whose long dimensions are substantially parallel to the optic axis,

Figure 6 is a view in perspective of the bar of Fig. 4 removed and cut into a number of semi-finished "V-cut" piezoelectric blanks,

Fig. 7 is a view in perspective of one of the blanks of Fig. 6, and

Fig. 8 is a view in perspective of the bar of Fig. 4 removed and cut into a number of semi-finished X-cut and Y-cut piezoelectric blanks.

The term "V-cut" as used herein designates any crystal element whose thickness dimension is inclined at other than a right angle with respect to the optic (Z) axis of the mother crystal. The orientation of V-cut crystals of both the "thickness mode" and "contour mode" types are described in considerable detail in British Patent 457,342 (1936).

The term "X-cut" or "Curie cut" as herein used designates any crystal element whose thickness dimension lies along an X axis of the mother crystal.

The term "Y-cut" or "Tillyer-cut" as used herein designates any crystal element whose thickness dimension lies along a Y-axis of the mother crystal.

The term "Z-cut" as used herein designates any crystal whose thickness dimension lies along the optic (Z-axis) of the mother crystal. As is known in the art, Z-cut crystals exhibit substantially no piezoelectric effect, but may, when suitably ground and finished, be employed as optical lenses and the like.

In accordance with one widely used method of cutting V-cut, X-cut, Y-cut, and Z-cut crystal elements, the practice has been to cut as many slabs from the mother crystal in planes normal to the optic axis as the length of the crystal and the ultimate desired size of the finished element will permit. This is indicated in Fig. 1 of the drawing, wherein three sections **1**, **2** and **3**, respectively, each, say, one-inch thick are shown cut from a mother crystal Q, whose optic axis is marked Z—Z. From these sections **1**, **2** and **3**, bars **4** (Fig. 2) whose short dimensions may be parallel to an X-axis or to an $X+\theta$ axis are cut. From the bars **4**, the crystal elements **5** are cut at an angle determined by the particular characteristic desired. Thus, referring to Fig. 2, if a V-cut crystal element having a zero or some low temperature coefficient of frequency is required, the elements **5** may have their electrode faces inclined not only with respect to the Z axis and with respect to the major (M) and minor (N) apex faces but also with respect to the X-axes, all as described in detail in the above-mentioned British Patent 457,342.

One very real objection to the above described prior art method of cutting quartz is that it can not be practiced economically with mother crystals of small size (e. g. "quartz candles" up to, say, 2½'' diameter) and, in the case of larger mother crystals will result in the production of numerous useless fragments unless the mother crystal is carefully selected with a finished element of particular size in mind. In the case of the mother crystal here illustrated, the fragments **6**, **7** and **8**, or some of them, may be used in the production of very small piezoelectric elements (e. g. "filter crystals") but are usually discarded in commercial production because of the difficulties incident to the identification of the natural axes of such fragments. Another objection to this method of the prior art resides in

the fact that the wastage at the areas 6, 7 and 8, Fig. 2, is duplicated in each central section 1, 2 and 3. Further, each section and each bar 4 must be separately set up in the cutting machine before the separate semi-finished elements 5 can be realized.

Referring to Figs. 3 and 4, in accordance with another prior art method of cutting "V-cut" blanks the mother crystal Q is first "sliced," at the desired angle with respect to the Z-axis, into as many as possible slabs 10 of a thickness approximating that of the finished elements. The principal objection to this method is that each thin slab 10 must be separately set up in the cutting machine in the manufacture of the semi-finished blanks 11 (Fig. 4). Another difficulty which is especially apparent in the cutting of blanks of the indicated orientation is that in attempting to practice this method economically the corners 12 of the blanks may extend to the side faces M and N of the mother crystal where imperfections (such as "twinning") in the crystalline structure are most pronounced. This may result in the production of a number of non-usable elements.

Referring to Figs. 5, 6 and 7, the present invention contemplates and its practice dictates the sawing or otherwise cutting from a mother crystal Q of a single bar 20 whose long dimensions are parallel to the optic axis, and the subsequent "slicing" of this bar into semi-finished "V-cut" blanks 21 whose length, breadth and thickness dimensions each closely approximate those of the finished elements 22 (Fig. 7). Since but little material need be removed from these semi-finished blanks to provide finished piezoelectric elements of the desired dimensions the finishing operation may be accomplished by grinding or lapping and without setting up the separate blanks in a saw or other cutting machine.

It will be observed that the principal wastage in material resulting from the practice of this method is that which occurs at 23, 24, Fig. 7, adjacent the side faces of the mother crystal where, as above pointed out, imperfections in the quartz are most likely to be present. It will also be noted that there are but two end portions 25 and 26 (Fig. 6) to be discarded instead of six as in the case of the method of Figs. 1 and 2.

There is another very real saving incident to the practice of the present method in that it permits the economical use of mother crystals whose diameter is substantially no greater than the diameter of the elements to be cut therefrom. The importance of this feature of the invention will be appreciated by a reference to the current price of quartz. The price of raw quartz "candles" of a size suitable for the cutting of blanks 1'' square in accordance with the present invention is currently about $4.00 per lb.; the larger pieces usually employed in practicing prior methods cost up to $16.00 per lb.

While the invention has thus far been described as applied to the cutting of a "V-cut" piezoelectric element, the electrode faces of which are substantially parallel to an X-axis and inclined at an angle (the actual angle of the "V-cut" blanks of Figs. 2, 3, 6 and 7 is substantially 49°) with respect in the optic axis in a direction toward parallelism with a major (M) apex face of the mother crystal, it will be apparent the invention is not limited to the cutting of crystal elements of this particular orientation. Obviously, the long bar of Figs. 5 and 6 may be circular or of any other desired shape and cut with its edges inclined at an angle with respect to all or any of the side faces of the mother crystal if desired.

It will likewise be apparent that Z-cut crystal elements, useful for optical purposes, may be obtained from the elongated bar of Fig. 5 by cutting it in planes normal to the optic axis, instead of askew with respect to it, as in the case of the "V-cut" elements 21 shown in Fig. 6. Such a Z-cut element is shown at 27, Fig. 6.

Referring to Fig. 8. In applying the invention to the cutting of X-cut and Y-cut blanks, the bar 20 is cut in a direction parallel to the Z-axis so that, in the case of an X-cut blank, its thickness dimension is parallel to an X-axis and, in the case of a Y-cut blank, the thickness dimension is parallel to a Y-axis.

Other modifications of the invention will suggest themselves to those skilled in the art. It is to be understood therefore that the foregoing is to be interpreted as illustrative and not in a limiting sense except as required by the prior art and by the spirit of the appended claims.

What is claimed is:

1. Method of cutting a quartz crystal element from natural quartz which comprises cutting directly from a mother crystal a bar whose long dimensions are substantially parallel to the optic axis and then cutting said element from said bar.

2. Method of cutting a quartz element from natural quartz which comprises cutting directly from a mother crystal a bar whose long dimensions are substantially parallel to the optic axis and then cutting said element from said bar in planes which are transverse with respect to said optic axis.

3. Method of cutting a quartz piezoelectric element from natural quartz which comprises cutting directly from a mother crystal a bar whose long dimensions are substantially parallel to the optic axis and then cutting said piezoelectric element from said bar at a desired angle with respect to said optic axis.

4. Method of cutting a "V-cut" quartz piezoelectric element from natural quartz which comprises cutting directly from a mother crystal a bar whose long dimensions are substantially parallel to the optic axis and then cutting said element from said bar at an acute angle with respect to said optic axis.

5. Method of cutting a quartz piezoelectric element from natural quartz which comprises cutting directly from a mother crystal a bar whose long dimensions are substantially parallel to the optic axis and whose short dimensions are only slightly greater than is required to produce a finished element of the required dimensions, then cutting a slab from said bar at a desired angle with respect to said optic axis, and finally reducing the dimensions of said slab to the desired dimensions of said element.

6. Method of cutting a "Z-cut" crystal element from natural quartz which comprises cutting directly from a mother crystal a bar whose long dimensions are substantially parallel to the optic axis and then cutting said element from said bar at a right angle with respect to said optic axis.

CHARLES E. JOHNSON.