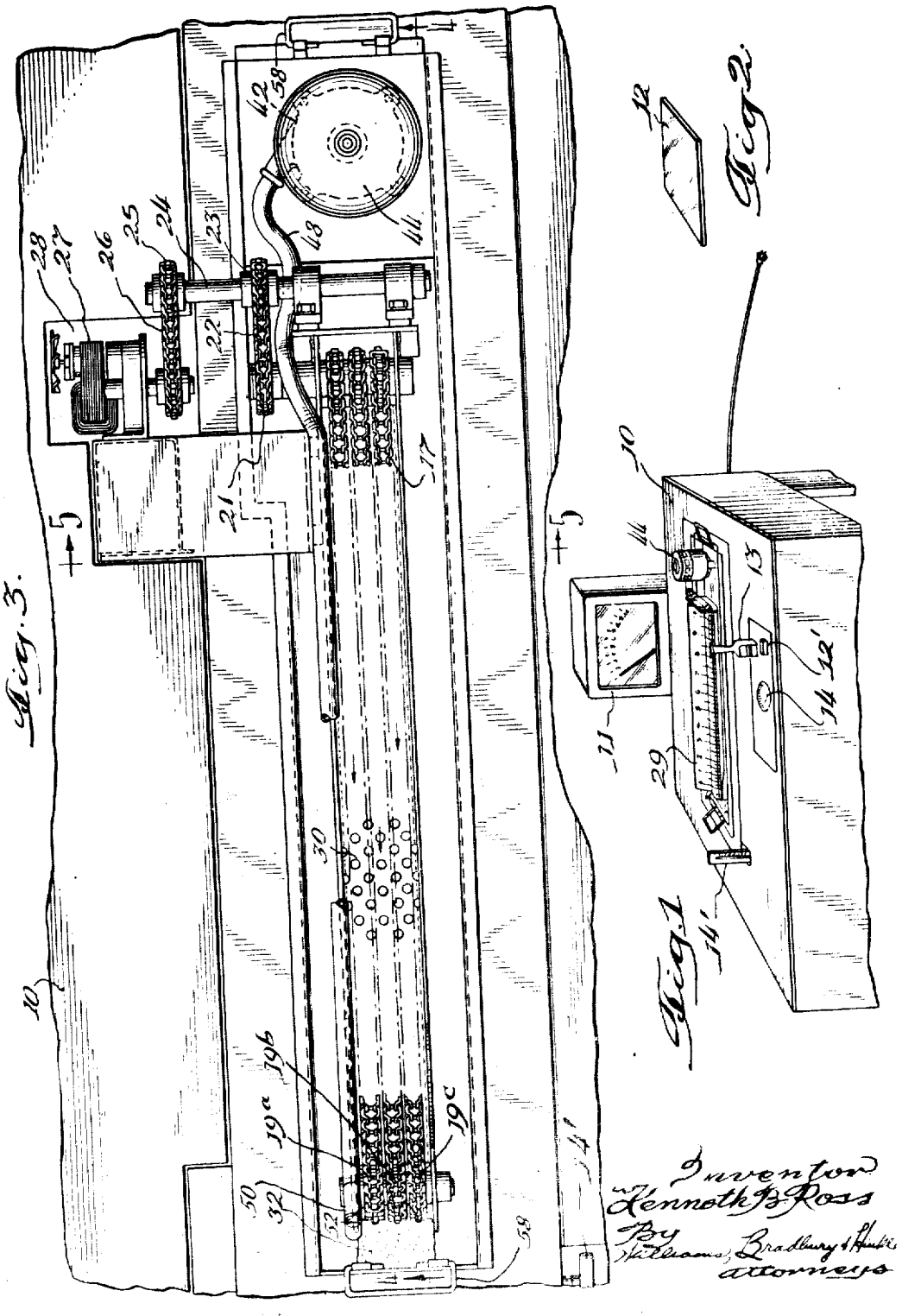
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METHOD OF FINISHING PIEZO-ELECTRIC CRYSTALS

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METHOD OF FINISHING PIEZO-ELECTRIC CRYSTALS

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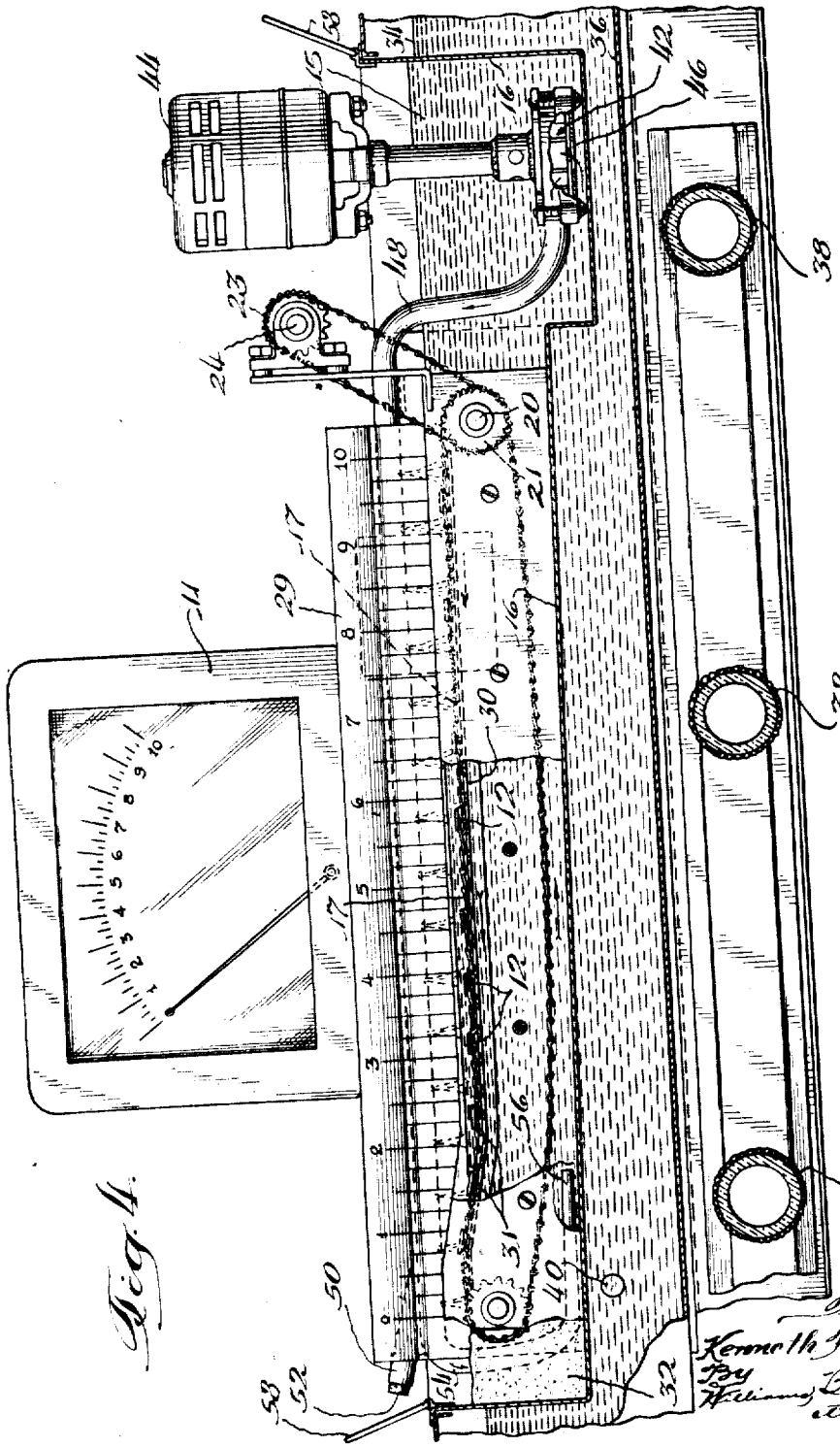


Fig. 4.

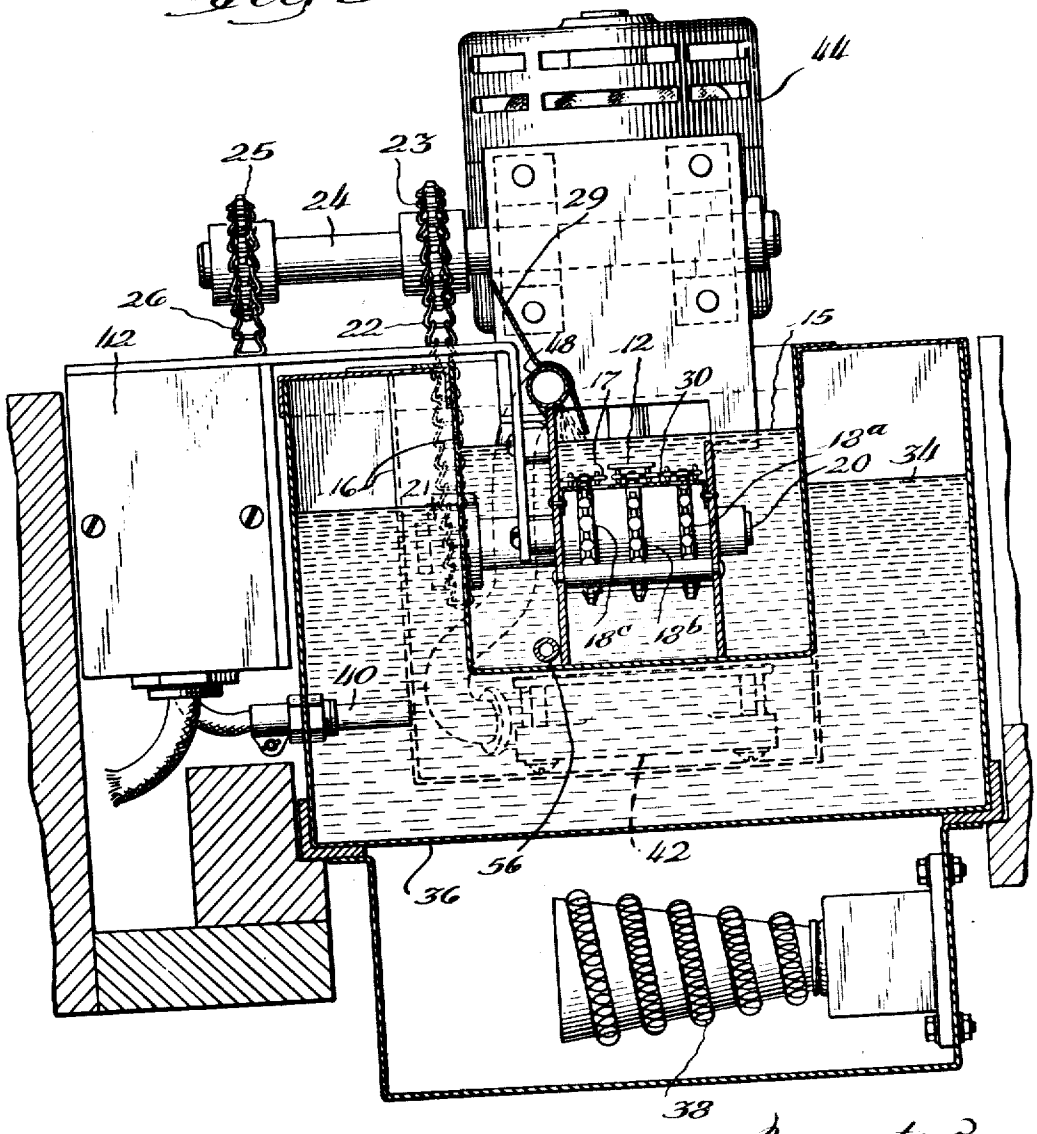
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Fig. 5.



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METHOD OF FINISHING PIEZOELECTRIC CRYSTALS

Kenneth B. Ross, Chicago, Ill.

Application November 25, 1943, Serial No. 511,725

1 Claim. (Cl. 171—327)

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My invention relates to resonators in the form of piezo-electric crystals. It has more particularly to do with a process or method of bringing large quantities of such cyrstals to a size such that within permissible tolerances they will all have a given oscillation frequency.

In general, it is the object of my invention to produce large quantities of piezo-electric crystals, all of which will oscillate at a desired frequency.

Thus far I have successfully applied my invention in the production of resonators cut from quartz crystals.

In the practice which I have made of my invention, I cut slabs of more or less uniform thickness from natural quartz crystals having piezo-electric properties. These slabs are so cut as to have dimensions slightly in excess of those necessary to the vibration of the crystals at the desired oscillation frequency. I have found it expedient to lap these cut slabs to bring their faces into parallelism and to approximate more nearly the dimensions required of the finished resonators.

The oscillation frequency of each cut and roughly lapped slab is then measured, preferably by the use of a frequency meter, whose indications correspond with the differences in frequency between the cut and roughly lapped slab and the oscillation frequency of a carefully prepared standard. The indications of the frequency meter correspond with the differences in the frequency of each cut and roughly lapped crystal and the standard resonator.

I then move each of the oversize slabs through a chemical etching bath. It would no doubt be desirable to move each slab through this bath for a distance corresponding exactly with the amount of material required to be removed from the slab in order to give it dimensions which would produce a resonator of the desired oscillation frequency—and corresponding with the oscillation frequency of the resonator employed as a standard in connection with the frequency meter hereinabove referred to. However, I have found it more expedient to subject each crystal to a succession of measuring and etching operations. The first etching operation brings the dimensions of the crystal to a point such that its oscillation frequency closely approaches, but does not quite attain, that required of a resonator having the desired oscillation frequency. I then re-measure the oscillation frequencies of the crystals, and then again subject them to a second etching operation. The second etching operation is less effective than the first; it removes less of the material and is, therefore, a more delicate operation. This delicacy may be attained by moving the crystals more rapidly through an etching bath of given potency. I prefer, however, to move the crystals at substantially the same rate, but through a more dilute and, therefore, less potent etching bath.

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The measuring and etching operations may be repeated as many times as may be desired, each time with a more delicate etching operation than in the preceding etching operation, until each crystal is brought to dimensions which will give it as nearly as may be desired the oscillation frequency of the given standard.

In practice I have found that four successive measuring and etching operations, with successively more dilute etching baths, will produce resonators having oscillation frequencies within the tolerances permitted by buyers' specifications currently in vogue.

The method of my invention is one which can be carried on successfully by relatively unskilled workers and in such a way as greatly to enhance the quantity of satisfactorily finished resonators which can be produced in a given time by a given operator or crew of operators. The details of my invention and of an apparatus which may conveniently be employed in carrying it out are set forth in the following specification. The apparatus is illustrated in the accompanying drawings, in which:

Fig. 1 is a perspective view indicating in a general way the arrangement of the apparatus;

Fig. 2 is a perspective view of one of the resonator crystals to be produced;

Fig. 3 is a plan view of apparatus which may conveniently be employed for carrying the crystals through the etching bath for appropriate distances;

Fig. 4 is a side view, largely in cross section, on the plane of line 4—4 of Fig. 3 of this apparatus; and

Fig. 5 is a cross sectional view of this apparatus taken on a plane represented by the arrows 5—5 of Fig. 3.

Corresponding parts have the same reference numerals in the various figures.

Referring first to the apparatus as more generally depicted in the perspective view of Fig. 1: 10 represents a table on and in which the apparatus may conveniently be arranged. 11 indicates a frequency meter. It is connected in a circuit containing a resonator 12' having the desired oscillation frequency. A cut and roughly

lapped slab of quartz crystal, such as that indicated at 12 in Fig. 2, is inserted into the jig 13. This jig in essence comprises electrodes such as those with which the crystal will later be associated in use, together with means for clamping the crystal temporarily between these electrodes. The two crystals are thus coupled in similar oscillator circuits, the outputs of which are coupled to produce a beat frequency. This beat or difference frequency is supplied to the frequency meter 11, so that its indicator hand will assume a position corresponding with the difference between the oscillation frequency of the standard crystal and that of the slab from which a more or less exact duplicate is to be formed.

The scale of the frequency meter could be arranged to read in cycles per second, but I have found it expedient to number this scale more or less arbitrarily, as, for example, from 0 to 10. Upon this arbitrary scale a reading of "0" indicates that the oscillation frequency of the crystal slab corresponds exactly with that of the standard resonator 12'. An indication of "1" represents a slab which requires but a very slight amount of etching in order to bring its dimensions down to a point where its oscillation frequency will correspond with that of the standard resonator. A reading of "2" indicates that twice as much material must be removed from the quartz slab in order that its oscillation frequency shall correspond with that of the standard resonator. The other indications, 3, 4 * * * 9, 10, indicate that the crystal slabs whose oscillation frequencies are undergoing measurement, require correspondingly increased reduction in dimensions in order to bring their vibration rates into accord with the vibration rate of the standard resonator 12'. The apparatus and circuits for making this comparison between an unfinished slab and a standard resonator are known and understood to the art and need not be more elaborately explained herein.

The milliammeter whose dial is indicated at 14, is included in a circuit which is closed when the unfinished slab of quartz is clamped in the jig 13, and such that the activity of the crystal in the jig will be reflected by the position assumed by the hand of the milliammeter 14. The initial test circuit, including this milliammeter, enables the operator at once to discard any crystals whose activity does not come up to the required standard of excellence.

I have found it convenient to locate the etching bath and its concomitant apparatus on or in the same table as that upon which the foregoing measuring instruments are located. The etching bath is a chemical solution, such for example as hydrofluoric acid, as described in Marrison Patent 1,869,160, issued July 26, 1932, although I have found it expedient, in lieu thereof, to use a bath of ammonium fluoride. The bath is preferably placed in a container which is equipped with a circulating pump for maintaining the bath in a condition of more or less uniform effectiveness. The container for this chemical bath is preferably mounted in a water bath or jacket, whereby a given temperature of the bath may be maintained by thermostatically controlled electric heating elements. There may desirably be a thermometer 14' by means of which the operator can be sure that the requisite temperature is being maintained.

I have found it expedient to provide a conveyor belt for conveying the crystals through the etching bath and to have them thus conveyed at a uniform speed, and also to provide the bath and conveyor mechanism with a scale to guide the operator in depositing the unfinished crystals upon the conveyor belt at points such that they will be etched in the appropriate amounts or degrees.

I have found that the details of this apparatus may conveniently be arranged as follows: The etching bath 15 of hydrofluoric acid or ammonium fluoride is placed in a tank-like container 16. Within this tank is mounted a conveyor belt 17. This is in the form of three metal sprocket chains mounted side by side in simulation of a single chain. Each of the chains is trained around sprocket wheels, such as those indicated at 18a, 18b and 18c, at the driving end and over corresponding sprocket wheels, such as indicated at 19a, 19b and 19c at the other end.

The sprocket wheels 18a, 18b and 18c are fixedly mounted on a shaft 20. This shaft carries another sprocket wheel 21. It is driven by a sprocket chain 22 which is trained around another sprocket wheel 23. This latter sprocket wheel is mounted on a shaft 24, which, by means of still another sprocket wheel 25 and still another sprocket chain 26, are driven from an electric motor 27 (Fig. 3). The electric motor is preferably of the synchronous type and is supplied with electric current at uniform frequency in the manner now commonly in vogue by utility companies, and in such a way that the electric motor and the associated mechanism will run at a reliably uniform speed.

As will subsequently appear, the crystal slabs which require to be etched, are placed upon the upper part of the conveyor chain. The direction of motor rotation, etc., are such that this upper flight of the conveyor belt will move in the direction indicated by the arrows in Figs. 3 and 4.

A scale 29, graduated from 1 to 10, as best shown in Fig. 4, is located immediately above the level of the etching solution and extends substantially the full length of the chain conveyor 17. A perforated guide 30 is suitably secured beneath the upper stretches of the chains comprising conveyor 17 and at the discharge ends of these conveyor chains the guide has an upwardly sloping portion 31, as best shown in Fig. 4. In order to assure that the chains will rest upon the guide 30, 31 and not be stretched taut so as to be raised therefrom, a brake is provided on the idler pulleys 19a, 19b, and 19c, this brake being in the form of a sponge rubber block 32 which imposes a frictional drag on the conveyor chains so that the slack in the chains will be present in the upper stretches thereof.

In order that the etching action of the etching bath may be uniform, I have found it desirable to mount the tank 16 in a water bath or tank, the level of the water being indicated at 34 and the bottom of the water tank at 36. Beneath the bottom of this water bath or tank, and preferably within an enclosing box, are mounted three electric heating elements 38. Electric current is supplied to these heating elements under the control of a thermostat 40, which, through suitable relays contained in a box 42, controls the energization of the heating elements 38. The operation is such as to maintain a uniform temperature within the water bath and therefore within the etching bath 15

A further means for maintaining uniform the etching action of the etching bath 15, comprises means for circulating the etching solution. This means comprises a rotary pump 42 driven by a

motor 44, the pump having an inlet 46 adjacent the bottom of the tank 16 and discharging through a pipe 48 which extends longitudinally above, and slightly to the side of, the multiple chain conveyor 17, as best shown in Fig. 5. At intervals along its length, the pipe 48 has nozzle perforations so that a portion of the discharge from the pump is sprayed substantially uniformly along the length of the chain conveyor. The left-hand (Fig. 4) end of the pipe has a Y formation, one end 50 of the Y being provided with a stopper 52 which may be removed for cleaning the pipe 48 by means of a brush. The other portion 54 of the Y extends downwardly to the bottom of the tank 16 and has a return bend portion 56 of reduced diameter forming a nozzle to direct the etching liquid along the bottom of the tank 16 to stir up any sediment which might otherwise collect along the bottom and to provide sufficient circulation to maintain the etching fluid substantially homogeneous throughout the tank.

The tank 16, together with the conveyor driving motor and mechanism, as well as the pump and its motor, are preferably constructed as a unit so that they may be removed from the table 10. For this purpose the tank 16 is provided with a pair of handles 58 at its ends.

In carrying out the method of my invention in quantity production of piezo-electric quartz crystals, the operator inserts the partially finished crystal in the jig 13 and first notes from the reading of the milliammeter 14 whether the crystal has the required degree of activity. If it does not have such activity, it is discarded, but if it has sufficient activity it will cause its associated oscillator to oscillate at the inherent resonant frequency of the crystal. By heterodyning the output of this oscillator with the output of the oscillator associated with the standard 12', a beat frequency, representing the difference between the frequencies of the two oscillators, will be produced and the magnitude of this beat frequency will be indicated by the frequency meter 11.

Assuming, for example, that this meter reads "5.5" in a particular case, the operator will then remove the crystal 12 from the jig 13 and place it on one of the chains of the conveyor 17 in alignment with the graduation "5.5" on the scale 29. The crystal will thereafter be carried by the conveyor 17 at a constant speed until it reaches the "0" position, when it is removed by the operator. It will be noted that due to the inclined portion 31, the crystal will be substantially removed from the etching solution as it reaches the "1" graduation on the scale 29. There will, however, usually be sufficient etching solution adhering to the crystal so that the etching action continues to some extent until the crystal reaches the unloading position at "0."

After this etching operation has been completed, it is repeated a number of times, successively using an apparatus containing an etching solution of less potency, or by moving the crystals at higher speed, or both.

Generally speaking, the potency of the etching solution comprising, for example, hydrofluoric acid or ammonium fluoride, is determined not only by the concentration, but also by the temperature. Thus, there are a number of factors which may be varied to reduce the amount of etching: (1) the composition or concentration of the etching solution may be changed; (2) the temperature at which the etching solution is maintained may be reduced; (3) the speed of the chain conveyor belt may be increased. I have found that it is most convenient to reduce successively the concentration of the active agent in the etching solution, and also to reduce its temperature in order to obtain the reduced potency or the reduced etching rate for successive stages of the complete process, since the speed of movement of the chain coveyor may thus be maintained at a constant optimum value corresponding with the average abilities of the operators to make the beat frequency determinations and to place the crystals upon the chain conveyor and to remove them therefrom.

In the quantity production of crystals, I have found it convenient to provide four sets of the etching apparatus such as described herein, so that it will not be necessary for the operator to change the settings of the thermostat or to change the scale of the beat frequency meter 11. It will be understood that the beat frequency meters used on the successive stages will have similar appearing scales, but will require geometrically progressing lower beat frequencies to obtain full scale deflection of their indicators.

If, however, the production rate is not sufficient to warrant the acquisition of four sets of the complete apparatus, some saving may be effected by using a common table, water bath, and heating apparatus for four sets of the etching bath and conveyor mechanisms, and this is one of the reasons why the latter parts are made removable from the water bath as a unit. Under the latter circumstances, the frequency meter 11 will be provided with scale changing means and the scale will be adjusted by the operator to accord with the particular etching bath being used.

After completion of the lapping operations by which the crystal is partially finished, it is found that the surface of the crystal contains microscopic imperfections in the form of partially severed extremely minute fragments. The activity of the crystal has been found to be disadvantageously affected by such adhering fragments. Further, it has been discovered that these fragments are substantially completely removed by etching for a reasonable length of time with a reasonably powerful etching solution. It is partly for this reason that I have found it desirable to rely upon the etching process for a substantial reduction in the thickness of the crystal. The word "substantial" is intended to mean "large" in the microscopic sense; that is, the etching should be carried on a sufficient length of time to remove the microscopic fragments which are partially severed from the crystal.

From the foregoing, it will appear that the improved method of finishing crystals to cause them to have a predetermined resonant frequency makes it possible for operators of negligible skill quickly and accurately to produce crystals finished to the required standards, since the steps of the process are of utmost simplicity and do not require the exercise of any substantial skill or judgment based on experience. An operator may therefore be trained to perform the method in a very short time, and will be able to produce more crystals, with less spoilage, and within a smaller tolerance, than could be produced by a highly skilled operator using the conventional hand-lapping method for reducing the crystals to the required size.

While I have disclosed the preferred manner of carrying out the method of my invention, it will be apparent to those skilled in the art that minor variations and modifications in the indi-

vidual steps thereof may be made without departing from the underlying principles of the invention. I therefore desire, by the following claim, to include within the scope of my invention such modified and varied methods by which substantially the results of my invention may be obtained through the use of substantially the same or equivalent steps.

I claim:

The method of finishing quartz piezo-electric crystals to cause them to conform closely to a standard in their resonant frequency characteristics, which comprises, determining empirical numbers representative of the frequency differences between the resonant frequencies of a plurality of unfinished crystals and that of a standard crystal, and passing such unfinished crystals through an etching bath of known etching properties at a constant speed through distances corresponding to the previously determined empirical numbers for each of the crystals, the extent of etching being sufficient to remove any portions at the surfaces of the crystal which have properties differing from those of the body of the crystal.

KENNETH B. ROSS.

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