

March 4, 1947.

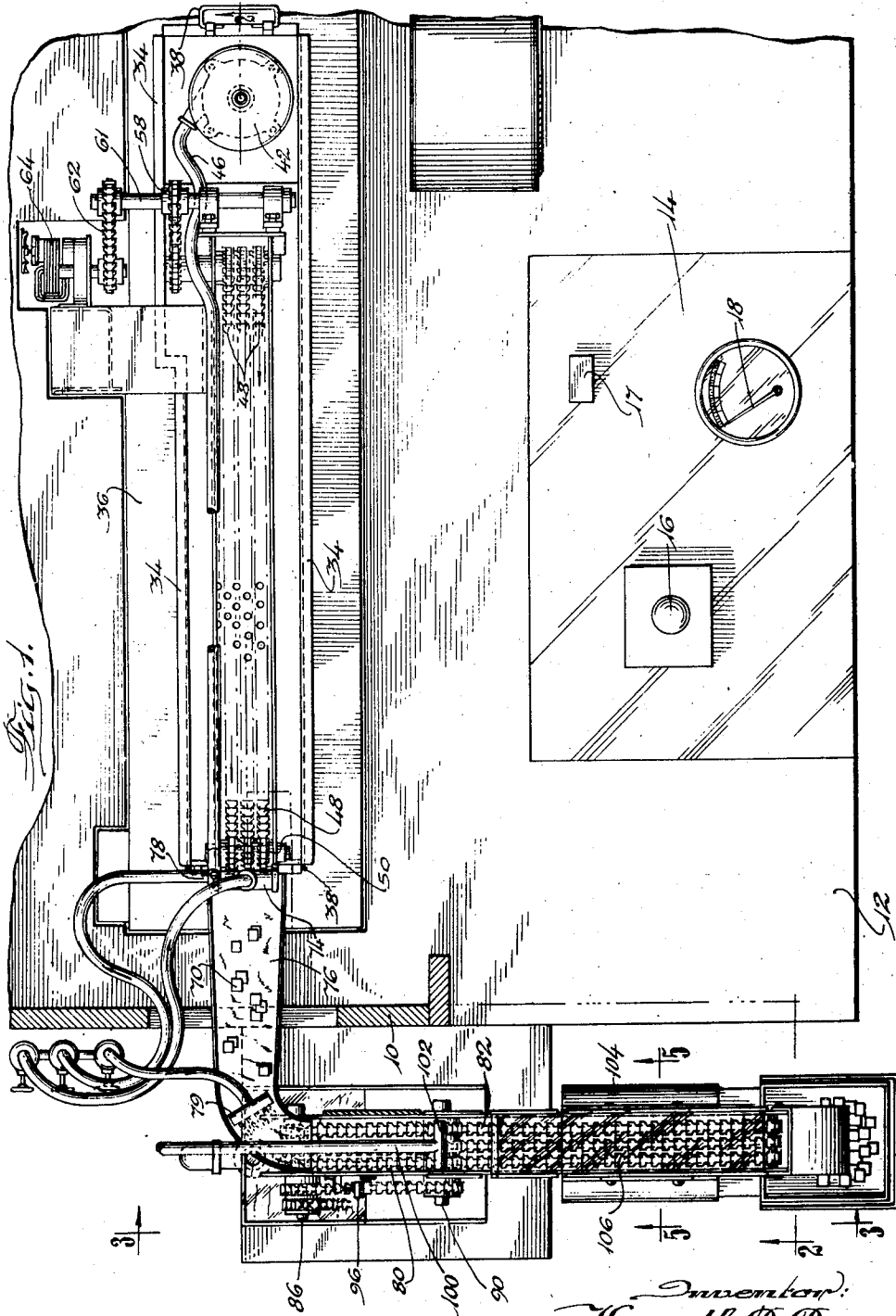
K. B. ROSS

2,416,716

APPARATUS FOR FINISHING PIEZOELECTRIC CRYSTALS

Filed March 6, 1944

4 Sheets-Sheet 1



Inventor:
Kenneth B. Ross
By *Williams, Braden & Hinkle*
attorneys.

March 4, 1947.

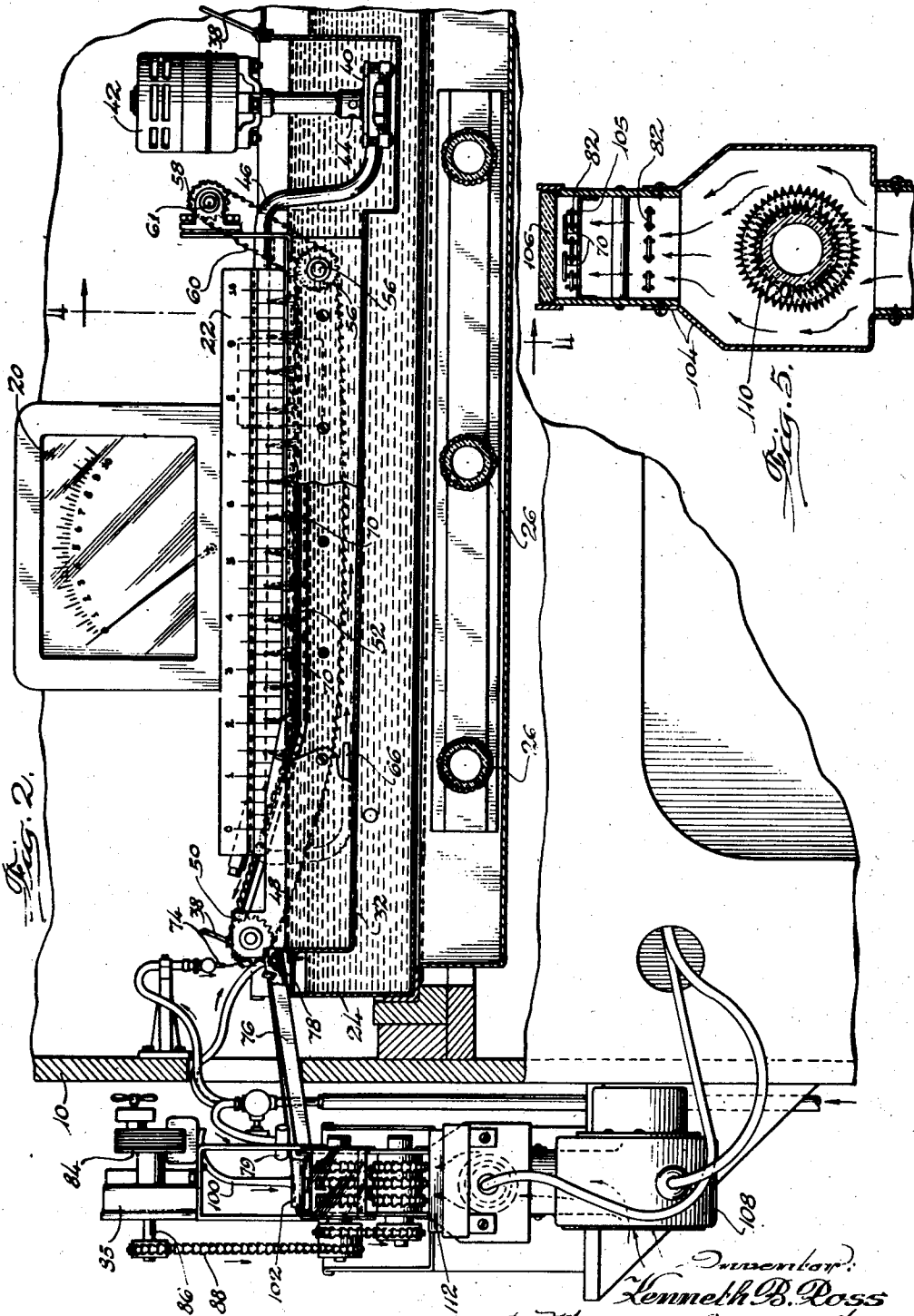
K. B. ROSS

2,416,716

APPARATUS FOR FINISHING PIEZOELECTRIC CRYSTALS

Filed March 6, 1944

4 Sheets-Sheet 2



Inventor:
Kenneth B. Ross
By Williams, Bradbury & Hinkle
attorneys.

March 4, 1947.

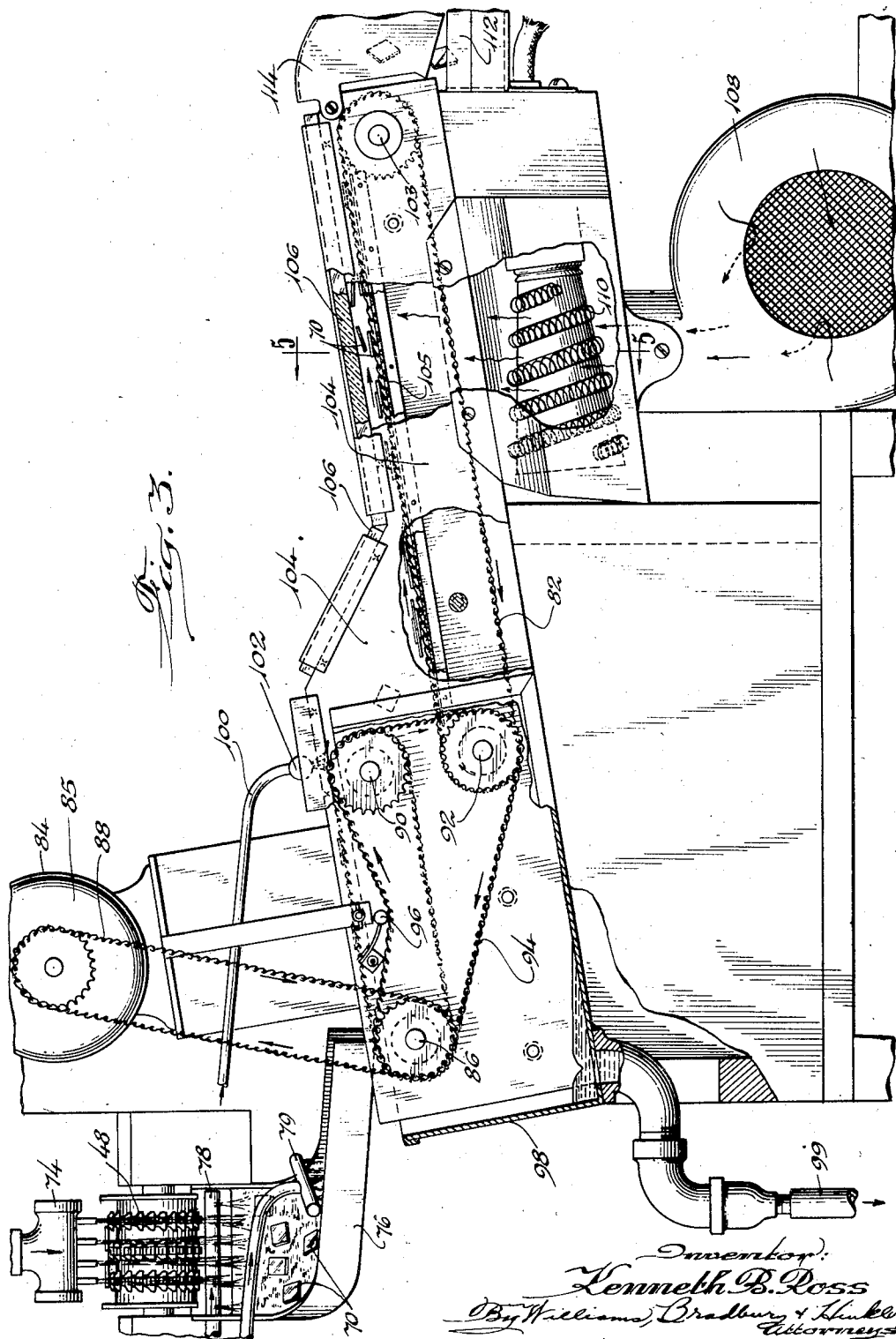
K. B. ROSS

2,416,716

APPARATUS FOR FINISHING PIEZOELECTRIC CRYSTALS

Filed March 6, 1944

4 Sheets-Sheet 3



March 4, 1947.

K. B. ROSS

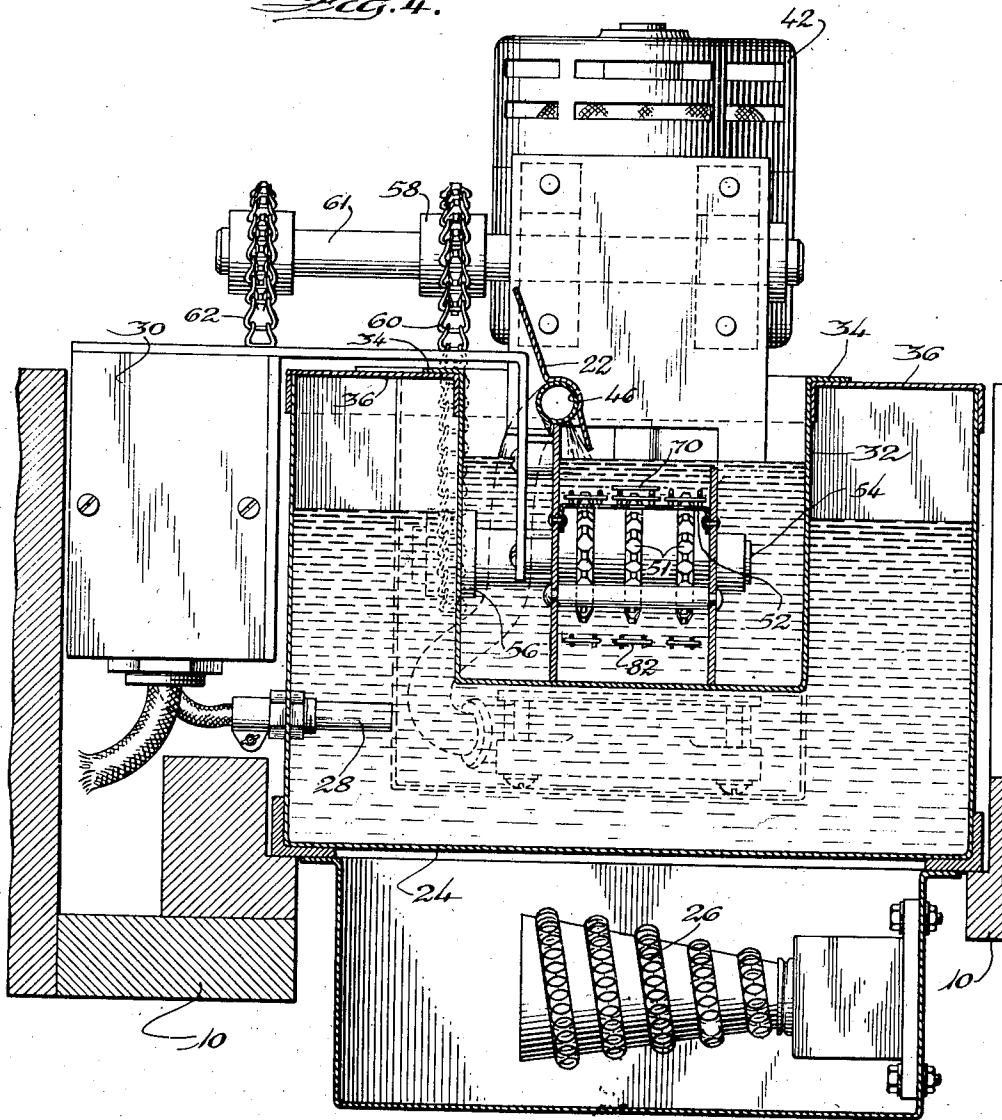
2,416,716

APPARATUS FOR FINISHING PIEZOELECTRIC CRYSTALS

Filed March 6, 1944

4 Sheets-Sheet 4

Fig. 4.



Inventor:
Kenneth B. Ross
By Williams, Bradley & Huber
Attorneys.

UNITED STATES PATENT OFFICE

2,416,716

APPARATUS FOR FINISHING PIEZO-ELECTRIC CRYSTALS

Kenneth B. Ross, Chicago, Ill.

Application March 6, 1944, Serial No. 525,276

22 Claims. (Cl. 171—327)

1

My invention relates generally to the production of piezoelectric crystals for use as resonators in radio transmitters, and other similar apparatus. More particularly, my invention relates to improved apparatus for finishing the crystals to the size and form necessary to secure their oscillation at predetermined frequencies.

It is a primary object of my invention to provide an improved apparatus for performing finishing operations upon piezoelectric crystals necessary to cause them to have a predetermined natural frequency of oscillation, in which the skill required of the operators is reduced to a minimum, which is capable of finishing the crystals at a rapid rate, and which thus greatly reduces the cost of the finishing operation while at the same time improving the quality of the crystals produced.

A further object is to provide an improved crystal finishing apparatus having improved means for separating the crystal slabs from one another after they have been treated and washed.

A further object is to provide an improved apparatus for finishing piezoelectric crystals by the etching process, in which the operator, after determining the amount of etching required of a particular crystal, may place it in the apparatus in a position such that the required amount of etching will be accomplished automatically.

A further object is to provide an improved apparatus for finishing crystals by the etching process, in which the rate and duration of the etching of the crystals is automatically controlled.

A further object is to provide an improved apparatus for use in a crystal finishing process, in which the skill and attention required on the part of the operator is reduced to a minimum, and in which the crystals may be finished rapidly, and their cost of production reduced.

Other objects will appear from the following description, reference being had to the accompanying drawings, in which:

Fig. 1 is a fragmentary plan sectional view of a major portion of the apparatus;

Fig. 2 is a vertical sectional view taken on the line 2—2 of Fig. 1;

Fig. 3 is a fragmentary side elevational view with portions of the casing broken away, and taken generally on the line 3—3 of Fig. 1;

Fig. 4 is a fragmentary transverse sectional view taken on the line 4—4 of Fig. 2; and

Fig. 5 is a fragmentary sectional view taken on the line 5—5 of Fig. 3.

General description

It is believed that the detailed description of the invention will be more readily understood if preceded by the following general description of the apparatus and the functions performed thereby.

2

In general, the apparatus comprises a conveyor moving through an etching solution continuously at a constant speed. The crystals to be etched are placed upon this conveyor at preselected positions so that they will be conveyed through the etching solution for a predetermined length of time and thus will be etched to a predetermined extent.

To determine the position at which the crystals are to be placed upon this continuously moving conveyor, the operator inserts a crystal to be etched into a suitable clamping fixture, which couples the crystal in a resonant electrical circuit, as, for example, of an oscillator, the output of which beats with the output of a standard frequency oscillator. The beat frequency from the outputs of the two oscillators is supplied to a frequency meter which thus furnishes an indication of the additional etching required. For convenience, the frequency meter is calibrated to correspond with graduations along the conveyor, so that, for example, if the operator notes the meter reading to be "8," she will place the crystal at position "8" on the conveyor, and as a result such particular crystal will be subjected to the etching process for eight units of time, while if the meter reading were "4," the crystal would be placed on the conveyor at the "4" position and thus etched for a period of only four units of time.

At the end of the conveyor chain, the crystals are elevated from the etching solution and are removed from the conveyor by means of a water spray, and are washed to remove any adhering etching solution and stop the etching process. Thereafter the crystal slabs are dried by means of a hot air blast.

One of the difficulties encountered in the past was that the crystal slabs tended to collect in bunches, and it was a difficult task for the operator to separate them, since the crystals are very thin, light, small flakes, and because of their extremely smooth surfaces, tend to adhere strongly to one another as a result of the surface tension of the wash water films between them. In order to separate such adhering crystals from one another, they are subjected to a blast of hot air which heats them to a temperature of slightly over 212° F., thus causing the intervening films of water between adhering crystals to vaporize rapidly. Such vaporization takes place so suddenly that miniature explosions occur as the adhesion between adhering crystals is overcome by the steam pressure generated between adhering crystals, and as a result, the crystals fly apart in the manner of popping corn.

Due to this method of separating the crystals, they may be collected in a receptacle and will not adhere to one another therein, and may

thereafter be readily handled individually by means of tweezers.

In general, the crystal slabs are initially cut and lapped slightly oversize, and are successively processed through an apparatus as described generally above, etching them at progressively slower rates during the successive stages of the process so that by the last etching step they are brought exactly to the size required for oscillation at a predetermined frequency, within very small tolerance limits.

The extent to which the etching takes place in the several steps of the process is determined by various factors, such as the composition and concentration of the etching solution, the temperature thereof, and the speed at which the crystals are moved through the solution. Any one or more of these factors may be varied in the successive stages of the finishing operations, the variation being preferably in logarithmically graduated steps, so that in the last stage the etching is accomplished at a very slow rate, and the required resonant frequency may thus be obtained with a high degree of precision. I have found it practical to accomplish the etching in four successive steps or stages.

At each stage of the etching process, the crystal slabs are checked for activity, so that those lacking the required degree of activity at any stage may be discarded without the necessity of further processing.

Piezoelectric crystals finished in this manner and by means of this apparatus, do not appear to require aging to cause them to attain a stable resonant frequency. Instead, it is found that, with minor exceptions, crystals finished in this manner have a high degree of activity and maintain the same resonant frequency and activity throughout their useful life. It is believed that this is due to the fact that a crystal finished in this manner does not have any microscopic chips and cracks and loosely adhering projections, as are found in crystals finished by the customary lapping process.

Detailed description of the apparatus

The apparatus is illustrated as mounted in a work bench structure 10 having a top 12 in which is mounted a panel 14, located in front of the operator's working station. On the panel 14 is mounted a suitable clamping fixture 16 for the reception of a piezoelectric crystal, which is thus coupled in a suitable oscillating circuit for obtaining an indication of its natural frequency of oscillation, and of its activity. Its natural frequency is compared with that of a standard crystal held in a suitable mounting 17.

The activity of the crystal is indicated by a meter 18, while the extent to which the natural frequency of oscillation of the particular crystal inserted in the fixture 16 differs from that of the standard crystal is indicated by a meter 20 (Fig. 2). The meter 20 has a scale reading from 0 to 10, which is calibrated to correspond to positions 0 to 10 indicated upon a panel 22.

Suitably supported by the bench structure 10 is a water bath tank 24, beneath which are mounted a plurality of electrical heaters 26. The heaters 26 are adapted to be energized in response to the operation of a thermostat 28 (Fig. 4) projecting through the side wall of the water bath tank 24, the thermostat operating through suitable relays contained in a junction box 30, to control the energization of the heaters 26. The thermostat is of the type which is capable of

maintaining the temperature of the water within the tank 24 accurately within a small temperature range.

The etching solution tank 32, which is partly immersed in the water bath, is provided with marginal flanges 34 at its upper edge, these flanges resting upon the top 36 of the water bath tank 24. The etching solution tank 32 may be removed from the water bath tank 24, handles 38 being provided for this purpose. The right-hand end (Fig. 2) of the tank 32 is of increased dimensions, for the reception of a rotary pump 40 driven by an electric motor 42, the pump having inlet ports 44 and discharging through a manifold pipe 46. This pipe 46 extends lengthwise of the etching solution tank 32, and is perforated at intervals to provide nozzle apertures through which the discharge of the pump is sprayed along substantially the whole length of the etching solution tank 32. The tank 32 is substantially filled with a suitable etching composition or solution, such as a solution of hydrofluoric acid, ammonium fluoride, or other suitable chemical capable of etching the quartz or other material of which the crystals are composed.

A plurality of endless chains 48 are mounted closely adjacent one another on suitable sprockets 50 and 51, and together form a conveyor having its major portion of its upper reach in horizontal plane beneath the level of the etching bath, while the left-hand (Fig. 2) end portion thereof slopes upwardly out of the etching bath. To cause the conveyor chains 48 to move horizontally and up the incline, they are supported by a suitable perforated guide 52. The sprockets 51 are mounted upon a shaft 54 at the end of which a sprocket 56 is secured, the sprocket 56 being driven from a sprocket 58 through a chain 60. The sprocket 58 is secured to a suitably journaled jack shaft 61 connected by a sprocket and chain 62 with a synchronous or other constant speed motor 64. The conveyor chains 48 are thus driven at a constant speed in a direction indicated by the arrows. There is sufficient slack in the chains 48 that the upper reach of these chains is pushed along the guide 52 rather than being under tension, as is customarily the case with conveyor chains. Because of this slack in the chains 48, they rest upon the guide 52 throughout their upper reaches.

The etching solution discharges from the pipe 46 in sprays directly over the conveyor chains 48, and the end of the pipe 46 is bent back upon itself as shown at 66 in Fig. 2, to form a nozzle extending along the bottom of the tank 32 so as to prevent the accumulation of sediment along the bottom of the tank, and to increase the circulation of the solution in the tank, thereby to assure that it is of uniform consistency and temperature. It will be noted that as the conveyor chains are pushed up the inclined portion of the guide 52 toward the sprockets 50, they emerge from the etching solution.

As more fully disclosed in my copending application Serial No. 511,725, filed November 25, 1943, crystal slabs to be etched are first placed by the operator in the clamping fixture 16, and provided the meter 18 indicates that the crystal has sufficient activity, the operator notes the reading on the meter 20, which indicates, by the arbitrary scale 0 to 10, the deviation of the natural resonant frequency of the crystal in the fixture 16 below the required frequency. The operator thereupon removes the crystal slab, such as the slabs 70 shown in the drawings, from the fixture 16 by means of suitable tweezers (to prevent con-

tamination of the crystals by oil on the operator's fingers) and places the crystal on the conveyor chains 48 at a position numbered on the panel 12, to correspond with the meter reading. The calibration of the meter 20 and the graduations on the panel 22 are so correlated with the etching rate of the particular etching solution being used, and the speed at which the conveyor chains 48 move, that when the crystal is placed on these conveyor chains at the numbered position indicated by the meter 20, the crystal slab will remain on the conveyor chains 48 a sufficient length of time to etch away a predetermined portion of the crystal substance so as to increase its natural resonant frequency to that desired.

It will be noted that during the travel of the crystal slabs upwardly along the inclined portions of the conveyor chains 48, they will not be immersed in the etching solution, but the etching thereof will nevertheless continue due to the adherence thereto of a film of the etching solution. As the crystal slabs on the conveyor chains 48 pass over the sprockets 50, they are removed therefrom by a spray of warm water admitted from nozzles 74. This water is preferably at a temperature in the order of 170° to 175° F. The nozzles 74 project the warm water downwardly past the conveyor chain so as not to touch the latter, but sufficiently close thereto that any crystal slab tending to adhere to the chains will be drawn therefrom by the water spray and will fall into the upper end of a chute 76. In this way dilution of the etching solution by the water admitted from the nozzles 74 is prevented but the crystal slabs are nevertheless reliably removed from the conveyor chains. The warm water discharged from the nozzles 74 flows down the chute 76 and carries with it the crystal slabs 70. Additional nozzles 78 and 79 also supplied with warm water, discharge respectively into the upper and lower ends of the chute 76 and assure the flow of the crystal slabs down the chute and their discharge from the end of the chute upon an intermediate chain conveyor 80. While resting upon the chain conveyor 80, water adhering to the crystals is partially drained therefrom, and the crystals fall from the forward end of the chain conveyor 80 upon a third chain conveyor 82.

As best shown in Figs. 2 and 3, a motor 84, operating through a suitable speed reducing gearing contained in a housing 85, drives a shaft 86 through sprockets and a chain 88, the shaft 86 having secured thereto sprockets for the conveyor chain 80. In addition, the shaft 86 drives shafts 90 and 92 through a drive chain 94, which engages suitable sprockets secured to these shafts. The slack in the chain 94 is taken up by means of a resiliently mounted bar 96 which presses against the chain 94. Water draining from the crystals carried by the conveyor 80, and the water discharged from the chute 76, is collected in a tank 98 which is connected to a suitable drain pipe 99. The crystals are blown from the forward end of a chain conveyor 80 by compressed air supplied through a pipe 100 terminating in a nozzle structure 102, and fall upon the upper reach of the conveyor chain 82. The chains constituting the conveyor 82 pass around suitable sprockets secured to the shaft 92 and around suitable similar sprockets secured to a shaft 103, and the upper reaches thereof rest upon a perforated guide plate 105.

The chain conveyor 82 is enclosed in a suitable housing 104, the top of which is closed by trans-

parent removable plates 106 of glass or other suitable material.

Beneath the chain conveyor 82 there is located a motor driven blower 108, which blows air past an electrical heater 110 and thence through the casing. The air is heated to a temperature in the order of 280° F. for a purpose explained hereinafter. The crystals resting upon the chain conveyor 82 are thus dried and separated from one another and fall from the end of the chain conveyor 82 into a suitable receptacle 112, which is protected by a hinged hood 114.

As the crystals pass through the chute 76, and as they are conveyed by the chain conveyor 80, they are wet and due to their extremely smooth surface, they frequently adhere to one another tenaciously. The forces resulting from surface tension of the intervening film of water are so strong, relative to the masses of the crystals, that two partially overlapping crystals will be drawn together in alignment with one another solely by these forces. This adherence of the crystal slabs to one another was a troublesome condition in the past, since it required that the operator individually, by means of tweezers or the like, separate the adhering crystals. However, as these bunches of adhering crystal slabs are carried through the stream of heated air by the chain conveyor 82, they are at first externally dried, due to the flow of heated air past them, and after their external surfaces are quite dry, they are heated sufficiently to cause the films of water between adjacent crystals to change to steam. This conversion of the intermediate films of water into steam takes place substantially in the form of miniature steam explosions. As a result, the adhering crystals are exploded apart, and thereupon becoming dried, fall back upon the chain conveyor 82 in separated relation so that as the crystals drop into the receptacle 112, they are completely dry and do not adhere to one another, and may thus be readily individually picked up by tweezers in the next step of the finishing process. The transparent cover plates 106 prevent the crystal slabs from "jumping" off the conveyor 82.

All of the chains used as conveyors have links of a type which provide small areas of contact with the crystal slabs resting upon them, and the etching, washing, and drying operations are thereby facilitated.

Operation

The operation of the various parts of the apparatus has been generally described in the previous detailed description, and it is therefore necessary at this point to set forth but briefly the manner in which the process as a whole is performed with the use of this apparatus.

Assuming that the finishing process is to be carried out in four successive steps, there will be provided four sets of the apparatus disclosed herein for each production line. (In plants having small production, a single apparatus of the type shown herein may be employed, and the potency of the etching solution reduced progressively for the successive steps of the etching process.)

The crystal slabs are cut from the quartz crystal in the usual manner, and are roughly lapped to a size known to exceed somewhat the finished dimensions required for the frequency at which they are to oscillate. These roughly lapped crystal slabs are then inserted in the

holding fixture of the apparatus used for the first etching step, and having their degree of activity checked, the operator notes by the indication of meter 20 the position at which he should drop the crystal on the conveyor chain 48. The position at which the crystal is dropped determines the length of time that the crystal will be acted upon by the etching solution. The chain conveyor 48 moves relatively slowly so that the operator will be able to place quite a number of crystals on the chain 48 for simultaneous etching.

Since the amount of etching to be done on each crystal is a random factor, it will frequently happen that a number of crystals are placed on the same portion of the conveyor chain and thus they may drop from the end of the chain in groups or bunches, or they may collect in groups as they slide down the chute 76. It is therefore desirable, after the crystals are washed, to dry them by heating them above 212° F. and cause their separation from one another in the manner previously described by the utilization of the expansive force of the steam generated between adhering slabs.

The apparatus used for the first etching step has an etching solution of such potency relative to the scale and calibration of the meter 20 that the crystals leaving this apparatus approach roughly the dimensions required to give them a natural resonance frequency closer to the required standard frequency. However, their natural frequency will still be measurably less than that of the standard frequency.

In the apparatus used for second, third, and fourth steps, the etching solution is made progressively less potent, by substantially logarithmic steps, so that the successive etching operations on the crystals will be of a progressively more precise nature and the crystals will be progressively reduced in dimensions by the etching steps so that their oscillation frequencies will progressively approach more closely to the standard frequency. In the last etching step, the etching solution is very dilute (or other factors effecting the potency of the etching are changed) so that only the minutest changes in dimensions of the crystals are effected in this final step. The crystal slabs, after having this final etching step performed upon them, will be of the same frequency as the standard frequency, within any required commercial tolerances.

The successive etching steps of the process are so simple that the operations may be performed by relatively unskilled help, with little training. The operator's time required for finishing a crystal using this apparatus is but a fraction of the time required to finish a crystal by the usual hand lapping method, and the finished crystal has superior stability, in frequency and activity, as compared with a crystal finished by the prior lapping method.

From the foregoing, it will be apparent that the potency of the etching solution is an important factor in the operation of the apparatus, and is therefore carefully controlled. One such control resides in the fact that the etching solution is maintained at a constant temperature. Another factor contributing to the uniform potency of the etching solution is that it is maintained in circulation by the pump and thus is kept homogeneous. The fact that the crystals on the conveyor chain 48 move through the solution and that the solution adjacent the crystal

is maintained in motion by the jets of the solution spraying from the pipe 46, also contribute to the uniformity of the etching effect of the solution upon the crystal slabs.

The apparatus is so constructed that the etching of the crystals is stopped at a predetermined time after their insertion in the etching solution, and the crystals are immediately thereafter thoroughly washed to prevent additional uncontrolled etching. Except for the measuring operation and the operation of placing the crystal slabs upon the conveyor chains 48, the crystal finishing operations are entirely automatic.

While I have shown and described a particular embodiment of my invention, it will be apparent that numerous variations and modifications thereof may be made without departing from the underlying principles of the invention. I therefore desire, by the following claims, to include within the scope of my invention, all such variations and modifications by which substantially the results of my invention may be obtained through the use of substantially the same or equivalent means.

I claim:

1. In an apparatus for finishing piezoelectric crystals, the combination of a conveyor, means to drive said conveyor at a constant speed, means for applying an etching solution to crystals carried by said conveyor, means for determining the extent of etching of a crystal slab required to increase its frequency of oscillation to a predetermined value, means adjacent said conveyor for indicating the extent that a crystal placed on said conveyor at various positions therealong will be subjected to the action of said etching solution, means for removing said crystal slabs from said conveyor when they have been conveyed to a predetermined position, and means for washing said crystal slabs promptly after their removal from said conveyor.

2. In a piezoelectric crystal finishing apparatus, the combination of a standard frequency source, means for indicating the difference between said standard frequency and the natural oscillation frequency of a crystal slab to be finished, means providing an etching solution bath, a conveyor moving at constant speed through said bath, means adjacent said conveyor for indicating positions corresponding to those provided by said difference frequency indicating means whereby a crystal placed at a position corresponding to the indication of said indicating means will be subjected to said etching bath for a time interval related to the difference between the said standard frequency and the natural frequency of the crystal slab, means for removing the crystal slab from the influence of said etching bath at the termination of said time interval, and means for washing the crystal slab promptly upon its removal from said conveyor, thereby to stop the etching effect of the solution adhering to the crystal slab.

3. In a crystal finishing apparatus, means for separating crystal slabs adhering to one another due to the surface tension of intervening films of wash water comprising, a conveyor having air passageways extending therethrough, means for providing a blast of heated air to adhering slabs on said conveyor, the temperature of said blast of air being sufficient to cause rapid conversion into steam of the film of water intermediate adhering crystals whereby said crystals will be separated from one another by the action of the steam formed between the adhering crystals.

4. The method of separating small piezoelectric crystal slabs from one another and to overcome their adhesion due to the surface tension of wash water between adhering crystals, which comprises moving them through an atmosphere of air heated substantially above 212° F. so as to cause the crystals to be heated above the boiling point of water and rapidly to conduct heat to the water film between them, thereby to cause the water film to be converted into steam at a sufficiently rapid rate to cause explosive generation of steam pressure sufficient to force the crystal slabs apart in opposition to the forces tending to cause the slabs to stick together.

5. Apparatus for use in finishing piezoelectric quartz crystals, comprising an elongated tank containing a solution capable of etching unfinished crystal slabs placed therein, a conveyor extending longitudinally of the tank and having the major portion thereof immersed in the etching solution, means for driving said conveyor at a constant speed, means for indicating a plurality of positions at which crystals are to be placed upon said conveyor, means operating in response to natural resonant frequency of a crystal to be finished, said means including an indicator calibrated to show the position along said conveyor at which the crystal slab is to be inserted in order to have it etched for a length of time sufficient to cause its natural frequency to approach closely a predetermined frequency, means at one end of said conveyor for automatically removing crystal slabs therefrom, means for washing said crystal slabs, and means for drying and separating the crystal slabs comprising means providing a stream of air heated above 212° F. directed against the crystal slabs.

6. In an apparatus for finishing piezoelectric quartz crystals so as to cause them to have a predetermined natural frequency of oscillation, a plurality of etching units; each unit comprising: an etching bath, a conveyor for exposing crystal slabs to said etching bath for lengths of time determined by the position at which the crystal is placed upon said conveyor, means providing an indication of the positions at which the crystal slabs are to be placed on said conveyor in order to increase their frequency of oscillation to approach more closely to said predetermined standard frequency, means at one end of said conveyor for removing said crystal slabs therefrom, and means for drying said crystals and separating adhering crystals from one another; said etching units having etching baths of less potency in a geometrical progression, whereby said crystal slabs upon being etched successively by said units will have their natural frequencies increased by successively smaller increments until the natural frequencies of the crystals are within a permitted range of tolerance of said predetermined standard frequency.

7. In an apparatus for the finishing of piezoelectric crystals, the combination of a tank containing an etching liquid, a conveyor having a generally horizontal portion immersed in the etching liquid in said tank, means to drive said conveyor at a constant speed, indicating means adjacent said conveyor and extending therealong to locate positions at which crystal slabs are to be placed upon said conveyor, means for removing crystals from the end of said conveyor, said means including a water spray for washing from said crystals any etching composition adhering thereto, means for draining water from the washed crystals, and means for separating ad-

hering crystals by heating them to a temperature sufficient to cause vaporization of the water film between them, and a receptacle for collecting the separated crystals.

8. An apparatus for finishing piezoelectric crystals by an etching process, which comprises, a conveyor continuously moving at a constant speed through an etching solution, means for determining the extent by which the natural frequency of an unfinished crystal departs from the required natural frequency of the crystal, means indicating the position corresponding to said frequency departure on said conveyor at which said crystal shall be placed for movement thereby through the etching solution, and means for removing crystals from said moving means and washing the etching solution therefrom to arrest further etching.

9. The combination set forth in claim 8, in which means are provided to separate crystals adhering to one another due to the intermediate film of washing liquid, comprising heated air supplying means effective to heat the crystals above the boiling point of the washing liquid to cause vaporization of the liquid film intermediate adhering crystals.

10. The method of separating small piezoelectric crystal slabs which adhere to one another due to the surface tension of liquid films intermediate the adhering slabs, which comprises heating adhering crystal slabs to a temperature sufficient to cause vaporization of the intermediate liquid films at a rate sufficient to cause said vaporization to take place in an explosive manner, and thereby physically separate the adhering crystals.

11. The method of preventing the adherence of small piezoelectric crystal slabs during the course of their manufacture when such adherence is due to the presence of a liquid film between the adhering crystals, which comprises heating said crystals at a relatively rapid rate and to a sufficiently high temperature to cause explosive change of the intermediate films of liquid to the vapor phase, whereby adhering crystals will be forcibly separated from one another.

12. In a piezoelectric crystal etching apparatus, the combination of a tank containing an etching solution, a conveyor moving at a constant speed through the etching solution in said tank and having a portion extending above the level of the etching solution at one end of said tank, means supplying a stream of water across said portion of said conveyor to remove therefrom crystal slabs adhering thereto, additional means for washing etching solution from crystal slabs removed from said conveyor, and means for drying the washed crystal slabs.

13. The combination set forth in claim 12, in which said drying means comprises means for causing flow of a stream of air at a temperature above 212° F. past the crystal slabs.

14. The combination set forth in claim 12, in which there is provided a scale adjacent said conveyor, and in which means responsive to the natural oscillation frequency of a crystal to be etched is provided to indicate the position along said scale at which the crystal to be etched is to be placed on said conveyor to secure an amount of etching thereof which will cause the natural oscillation frequency of the crystal to approach the predetermined frequency to which the crystal is to be finished.

15. The combination set forth in claim 12, in

11

which there is provided means to maintain the etching solution in continuous circulation.

16. The combination set forth in claim 12, in which means are provided to pump the etching solution from the tank and distribute it along said conveyor.

17. The combination set forth in claim 12, in which means are provided to maintain the etching solution in said tank at a constant temperature.

18. The combination set forth in claim 12, in which said conveyor is conformed to provide a plurality of closely spaced upwardly extending parts having small areas of contact with a crystal slab resting upon them.

19. The combination set forth in claim 12, in which said conveyor is formed of a plurality of continuous chains, and in which a perforated guide is provided for the portions of said chains upon which the crystal slabs may be placed.

20. An apparatus for finishing piezoelectric crystals by an etching process comprising, a tank containing a crystal etching solution, means for determining the extent by which the natural frequency of an unfinished crystal departs from the required natural frequency of the crystal, means for moving the crystal through the etching solution in said tank a predetermined distance bearing a definite relationship to the extent by which the natural frequency of the unfinished crystal departs from the required natural frequency thereof, means for removing the crystal from the etching solution after it has been moved through the etching solution said predetermined distance, and means for rapidly heating the crystals after they have been washed to cause separation of mutually adhering crystals by rapid heating of the films of water between them.

21. An apparatus for finishing piezoelectric crystals by an etching process comprising, a tank containing a crystal etching solution, means for determining the extent by which the natural frequency of an unfinished crystal departs from the required natural frequency of the crystal, means for moving the crystal through the etching solution in said tank a predetermined distance bearing a definite relationship to the extent by which

12

the natural frequency of the unfinished crystal departs from the required natural frequency thereof, means for removing the crystal from the etching solution after it has been moved through the etching solution said predetermined distance, means for washing the crystal promptly after its removal from the etching solution to remove any of the etching solution therefrom and thereby arrest further etching of the crystal, and means for rapidly heating the crystals after they have been washed to cause separation of mutually adhering crystals by rapid heating of the films of water between them.

22. An apparatus for finishing piezoelectric crystals by an etching process comprising, a tank containing a crystal etching solution, means for determining the extent by which the natural frequency of an unfinished crystal departs from the required natural frequency of the crystal, means for moving the crystal through the etching solution in said tank for a time interval bearing a definite relationship to the extent by which the natural frequency of the unfinished crystal departs from the required natural frequency thereof, means for removing the crystal from the etching solution after it has been moved through the etching solution said predetermined distance, means for washing the crystal promptly after its removal from the etching solution to remove any of the etching solution therefrom and thereby arrest further etching of the crystal, and means for rapidly heating the crystals after they have been washed to cause separation of mutually adhering crystals by rapid heating of the films of water between them.

KENNETH B. ROSS.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,364,501	Wolfskill	Dec. 5, 1944
928,922	Albert et al.	July 27, 1909
2,378,052	Waldeman et al.	June 12, 1945