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APPARATUS FOR THE AUTOMATIC GRINDING OF CRYSTALS

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2 Sheets-Sheet 2

FIG. 3

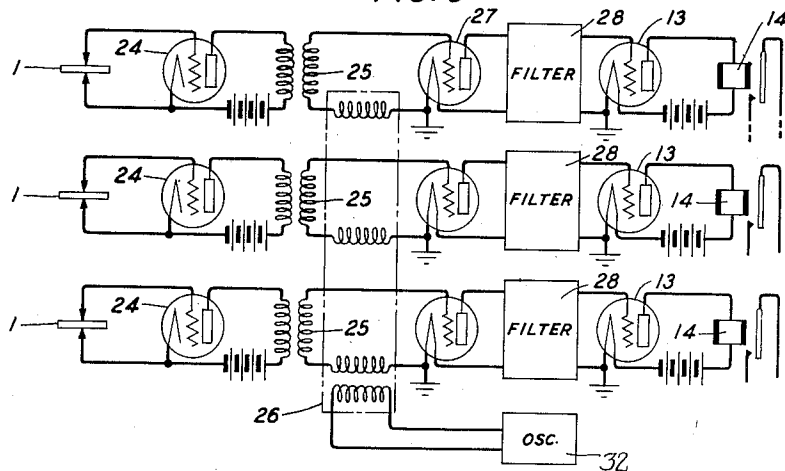


FIG. 2

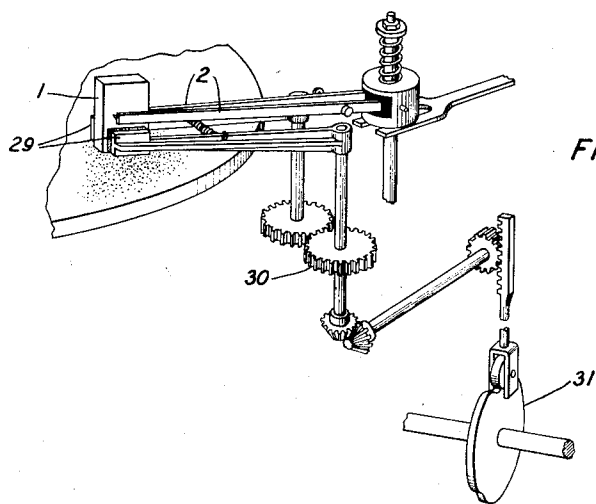
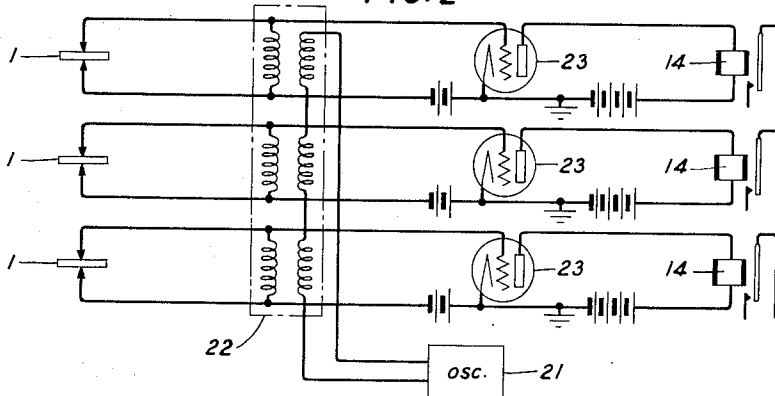


FIG. 4

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APPARATUS FOR THE AUTOMATIC
GRINDING OF CRYSTALS

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14 Claims. (Cl. 51—165)

This invention relates to automatic or semi-automatic grinding apparatus and particularly to means, responsive to the natural frequency of vibration of an elastic vibratory body such as a piezoelectric crystal body, for terminating the grinding of such body when a predetermined natural frequency thereof is achieved by the grinding operation. Incident to the grinding of such bodies to given frequencies and the attendant repeated measurement of natural frequency, as the critical frequencies are approached, there are certain auxiliary or preparatory operations such as cleaning, drying, conditioning for setting into vibration, etc. These operations are made a unitary part of the apparatus of applicant's invention.

The increasing use of piezoelectric crystals, which have to be accurately ground to predetermined frequencies, has inspired efforts directed to the use of means whereby a piezo-electric crystal, or a plurality of crystals, may be inducted into the final stage of their grinding operation whereby they are accurately adjusted as to frequency, with the assurance that when the desired frequency is achieved by the removal of a critical mass of material, and strictly in response to the natural frequency of the crystal at that point, the grinding operation will stop. By such a means, as exemplified by this invention, there is a benefit accruing from the elimination of the personal error which would tend to exist where this final crystal grinding, or frequency adjustment, is done manually or at least under the control of an operator with periods of grinding interspersed with manual frequency tests. There is an economical advantage in that a single attendant may supervise an indefinite number of machines since personal attendance is not necessary at the climax of the grinding operation of any one crystal, when the predetermined frequency is achieved. For example, an attendant may start the grinding of a dozen crystals on one or several machines with the assurance that the grinding will be automatically stopped when the crystal which is being ground thereby has been ground to the desired predetermined frequency.

An object of the invention is to terminate the grinding of an elastic vibratory element automatically, responsively to a predetermined natural frequency of the body which is being ground.

Another object of the invention is to grind a piezoelectric crystal or the like to a given predetermined frequency and to automatically terminate the grinding when said frequency has been reached, by means responsive to the natural fre-

quency of vibration of the crystal, rather than responsively to an attained mass, dimension, or other approximate indicia of a given natural frequency condition.

The invention has a special application in the grinding of piezoelectric crystals which have been cut with their principal faces perpendicular to a pair of natural faces of the primitive crystal, this being commonly known as the "perpendicular cut". This is partly by reason of the fact that such a crystal element is adjusted as to frequency by grinding on one or more of the edges of the crystal element rather than on one or more of its principal faces. The mass of material removed for a given frequency adjustment is usually rather small and is quite definitely related to the change in frequency which is produced. The shorter the crystal is made the higher its natural frequency or conversely the narrower it is made the lower its natural frequency.

Crystal elements of the type described in the above paragraph are commonly used as electric filter elements. For practical reasons such crystal elements are usually required to be electroplated to provide electrodes having the desired characteristics relative to the crystal itself. By necessity this metallic coating tends to cover the whole crystal and therefore must be removed from the edges by a grinding operation or the like. Furthermore, the addition of the mass corresponding to the metallic coating tends to change the natural frequency of the crystal or combination principally comprising the crystal, so that it is difficult to predict in advance the exact value of the natural frequency. It is evident that, for these reasons, the filter crystal usually requires adjustment of its dimensions and the automatic grinding means of this invention is well adapted for such use.

Besides the automatic means for terminating the grinding of a crystal element on the attainment of a predetermined natural frequency, the means of the invention is adapted to perform certain auxiliary functions which are attributory to this main purpose. For example, since in some instances the crystal would not vibrate at its natural frequency while being ground, the organization of the invention is adapted to periodically remove the crystal element from contact with the grinding surface and/or other parts except the holder for which it is designed. Also, in like sequence, the crystal element is chemically cleaned and dried preparatory to testing its natural frequency of vibration.

The invention will be more readily understood by reference to the following detailed description when taken in connection with the accompanying drawings in which:

Fig. 1 is a schematic diagram of a preferred form of circuit and apparatus of the invention.

Figs. 2 and 3 illustrate derivation and test circuits which are alternative to those shown in the comprehensive structure of Fig. 1, and

Fig. 4 illustrates a modified form of an element included in the comprehensive structure of Fig. 1.

In Fig. 1, a crystal 1, which it is desired to adjust to a predetermined natural frequency, is held between two supports 2 at the mechanical center, or the nodal point of its vibration. A grinding wheel 3 is driven by a source of power, such as the motor 4 and has on its surface abrasive material with which the crystal is ground. Through an appropriate gear train 5 a number of cams are also rotated so as to provide, in sequence, for various operations on the crystal until the grinding has proceeded to a point where the natural frequency of the crystal has reached a predetermined value. The first of these cams to operate is marked 6 and is arranged to raise the crystal up from the grinding surface by means of a mechanical link. Immediately after this operation cam 7, through an appropriate mechanical linkage, moves the crystal horizontally away from the grinding surface until it is under a stream of cleansing fluid 8, which is provided by a pump 9. Next in sequence cam 7 moves the crystal out of the stream of cleansing fluid to an intermediate position above a stream of dry air which issues from a nozzle 10. In this way the cleansing fluid, which might be alcohol, or other suitable material, is rapidly dried, thus insuring that the crystal is free from dirt or other material which might influence its period of vibration.

After a suitable interval cam 7 moves the crystal out of the air stream and another cam 11 closes an electrical circuit in such a way that the two plated surfaces of the crystal are connected through the supports 2 which are of insulating material to the grid of a vacuum tube 12 arranged in circuit relation such that the circuit as a whole will oscillate at the predetermined frequency to which it is desired to grind the crystal if, and only if, the natural frequency of the crystal has reached the proper value. If the natural frequency of the crystal is not at the proper value the electrical circuit does not function and cam 7 returns the crystal to a position above the grinding surface. Cam 6 then lowers it onto the surface to resume the grinding operation.

This sequence of events will be followed through periodically until the natural frequency of the crystal, as held between the supports, reaches the desired value. When that point is reached the oscillator circuit, comprising the crystal 1 and vacuum tube 12 and associated circuits, will oscillate so as to produce a relatively large oscillating voltage on the grid of rectifier tube 13. This will give rise to a sufficient plate current in the rectifier tube to cause the operation of relay 14 and so terminate the grinding operation.

Two simple methods of stopping the grinding are indicated depending upon the position of the switch 15. If switch 15 is thrown downward as shown, the operation of relay 14 is used to shut off the power supply through a motor control 16 and stop the entire automatic process. In case switch 15 is thrown upward relay 14 operates a more powerful relay 17 which disengages a me-

chanical stop 18 and thus allows a spring 19 to raise the crystal from the grinding surface. The latter arrangement is of advantage in case a plurality of crystals are to be adjusted simultaneously on the same grinding wheel, the means shown being individual to a certain one of said crystals. In either case the operation of relay 14 is arranged to give a suitable alarm as indicated at 20. These crystals may all be ground simultaneously on the same wheel and may be provided with individual automatic means for their adjustment to any desired frequency as described above.

If it is desired that all the crystals be ground to the same frequency some economy may result from the use of an arrangement as is indicated on Fig. 2 in which a plurality of crystals, each marked 1, are energized by a high frequency current from a common source 21 through the loosely coupled multiple winding transformer 22. In this case use is made of the fact that the impedance of a crystal rises sharply to a very high value at its resonant point. As long as the resonant frequency of the crystal departs materially from the desired value its impedance will be relatively low and the resulting voltage on the grid of the associated rectifier tube 23 will be so low that the rectified current will not operate the corresponding relay 14, which is used to stop the grinding. When any crystal has reached its proper frequency, however, its impedance will rise abruptly, thus energizing the associated rectifier 23 and relay 14 and so terminating the grinding operation on that particular crystal. Such an arrangement insures that all crystals are ground to the same frequency and at the same time minimizes the amount of apparatus required.

In case a very high degree of accuracy is desired in the adjustment of the crystal a somewhat different electrical arrangement may be advantageous, as indicated in Fig. 3, in which a plurality of crystals, each marked 1, are associated with vacuum tubes 24 and the circuits are so arranged that the vacuum tubes will oscillate and produce appreciable voltages across transformers marked 25 if the natural frequencies of the crystals have reached approximately the desired values. The output transformers of the several oscillating circuits are each placed in series with a winding of a multiple winding transformer 26 which is fed from a common source of oscillations 32. By means of this heterodyne arrangement these two relatively high frequency oscillating voltages are beat together in a modulator tube 27 and their difference frequency after passing through a filter 28 and a rectifier tube 13 is used to operate a relay 14. This relay, as in previous disclosures, is used to control the grinding operation and terminate it when the natural frequency of the crystal has reached the desired value. It is apparent that such a heterodyne method is capable of far greater accuracy in terminating the grinding operation as it depends upon the difference of two relatively high frequencies.

Certain precautions are needed to insure that the desired accuracy of grinding is obtained. One important matter is the manner in which the crystal is supported mechanically as this may affect its natural frequency of vibration. In the above disclosures it is contemplated that the supports for the crystal in this mechanism and the electrical connections it will be so similar to those which will be used in the final practical application of the crystal that the same overall natural frequency will result. In some cases, however,

where the desired natural frequency is rather low, crystals are so large that difficulty may be encountered in holding them with sufficient rigidity for grinding purposes in the clamps referred to above. In such cases it is provided that an auxiliary set of clamps be made available which will hold the crystal rigidly while it is on the grinding wheel, but will be removed from the surface of the crystal during the automatic test of its natural frequency, thus assuring that the crystal is held only at its nodal point in the proper clamping device when the test of its frequency is applied. Such auxiliary arms are indicated on Fig. 4 in which crystal being adjusted is marked 1, the normal supports are marked 2 and the auxiliary clamps 29. A suitable mechanism 30 for removing the auxiliary clamps is operated from a cam 31 which is connected to the grinding mechanism in such a manner that the auxiliary clamps release the crystal during the operation of cleaning, drying and testing as previously disclosed.

It will be seen that the rapidity of grinding and the frequency of testing are readily adjustable by simple changes in the gear train 5 of the mechanism disclosed above. For example, if a very high degree of accuracy is desired the testing operation may be repeated at frequent intervals with a very small amount of grinding between successive tests; or if speed is more desirable than accuracy the grinding period might be relatively long with only occasional tests. It may often prove desirable to make the initial grinding at a rapid rate to an approximate frequency and follow this with a slow grinding to the more exact value.

The embodiment of this invention as described above is but one of many arrangements which will be apparent to one versed in the art. For example it might well happen that in the case of crystals of a certain type or of relative dimensions it would be possible to cause the crystals to oscillate while being ground. The apparatus of Fig. 1 could be very much simplified to suit such a condition, all that would be necessary being the use of a cam like cam 11 of Fig. 1 and its immediately associated circuits and structures to condition the crystal for oscillation and test. In fact even this cam and associated circuit and structures could be avoided to permit the crystal to oscillate continuously through the whole grinding operation.

What is claimed is:

1. In combination, means for grinding a crystal surface by relative motion between said surface and an abrasive surface, together with means periodically indicating the condition of the crystal relatively to a predetermined desired condition depending on the amount of material removed from the crystal and to automatically, responsively to the attainment of said desired condition, terminate the grinding operation.

2. In combination, means for grinding an elastic vibratile element to a given frequency which is a function of its dimension in the direction of grinding, means for periodically testing the frequency, and means for automatically, responsively to the attainment of the given frequency, terminating the grinding operation.

3. An automatic grinding apparatus for a plurality of elastic vibratile elements each of which elements has an elastic vibrational frequency which is a function of a particular dimension, comprising a common abrasive means for said elements and means for producing a relative motion between said abrasive means and said elements to adapt said elements to be ground simultaneously

along their frequency significant dimensions, and automatic means, responsive to the attainment of a predetermined vibrational frequency individual to each element for stopping the grinding of each said element when ground to said frequency without affecting the grinding of the remaining elements.

4. An apparatus for grinding a plurality of elastic vibratile elements so as to have the same natural frequency of vibration, comprising, in combination, abrasive means and means providing a relative motion between said abrasive means and said vibratile elements to enable a simultaneous grinding of said elements, and means for periodically indicating the frequency condition of each said element relatively to a desired common frequency and for automatically, responsively to the attainment of the desired frequency, terminating the grinding operations of the respective elements as said frequency is attained.

5. The combination recited in claim 4, utilizing an individual indicating and terminating means for each element together with a common source of local oscillations for all of said indicating and terminating means, each said indicating and terminating means comprising means whereby it becomes effective to terminate the grinding operation when a natural frequency of vibration of the corresponding element coincides with the frequency of the wave from said local source.

6. An apparatus for the automatic grinding of an element which has a natural period of elastic vibration bearing a simple relation to a given dimension of the element, which comprises means for grinding the element in the frequency-significant direction by relative motion between the grinding surface of the element and an abrasive material together with means periodically indicating the frequency condition of the element relative to a desired terminal frequency thereof and for automatically, responsively to the attainment of said terminal frequency, terminating the grinding operation.

7. In combination, means for grinding a piezoelectric crystal surface by relative motion between said surface and an abrasive material, circuit means indicating the attainment of a given natural frequency of the crystal by such grinding, means periodically coupling said crystal to said indicating means and sequentially restoring the crystal to its initial grinding relation and addition means associated with said indicating means for automatically, responsively to the attainment of the given desired frequency, terminating the grinding operation.

8. In combination, means for grinding a piezoelectric crystal surface by relative motion between said surface and an abrasive means, an indicating means having a critical frequency characteristic and responsive to the coupling therewith of a piezoelectric crystal having a coincident frequency to produce a current of like frequency, mechanical means for periodically electrically coupling it to said indicating means and then uncoupling it therefrom, and means responsive to the current produced by the indicating means on the attainment of the desired coincident crystal frequency to terminate the grinding operation.

9. The combination recited in claim 8 in which the indicating means is an incomplete crystal controlled oscillator circuit and adapted by the coupling of the crystal thereto to become complete and to oscillate at the crystal frequency but which will not oscillate unless the crystal fre-

quency has a value set by the electrical characteristics of the circuit without the crystal.

10. The combination recited in claim 8 in which the indicating means comprises, a local source of oscillations whose frequency corresponds to the desired terminal frequency of the crystal, a repeating device, and circuit means so associating the crystal, local source and the repeating device when the crystal is coupled to the indicating means that a condition of frequency coincidence results in a change of impedance of the path for the local source of current with a resultant change of current therefrom capable of being indicated by said repeater device.

11. A combination like that recited in claim 8 comprising additional mechanical means operating synchronously with the periodically coupling and uncoupling of the crystal and indicating means and coordinately therewith with said coupling for lifting the crystal from the grinding surface during the indicating operation and restoring the crystal to said grinding surface at the termination of the indicating operation.

12. A combination like that recited in claim 8 including a mechanical means operated by the means providing the relative motion for achieving the periodical coupling to and uncoupled from the indicating means and additional mechanical means likewise operated by the means providing the relative motion, for removing the crystal from the grinding surface just prior to each coupling and for restoring it thereto just after each cou-

pling and for, between the removing and coupling steps, moving the crystal to stations at which it is chemically cleaned and dried preparatory to the frequency indication.

13. The combination recited in claim 8 comprising means for mechanically supporting the crystal corresponding to the mode of crystal support which is planned to be later used, so that the frequency to which the crystal is automatically ground is that frequency at which it naturally vibrates in its ultimate use.

14. The combination recited in claim 8 including a crystal supporting means applicable while the crystal is actually being ground which is adequate to support the crystal under such conditions, and mechanical means additional to those recited in claim 8, but operating with a like periodicity and coordinately with the operation of the means there recited, for removing the crystal from the abrasive means at the beginning of the sequence of operations repeated at said periodicity and substituting for the original crystal support a support which simulates the support planned to be used with the crystal in its normal use as a completed frequency controlling element, and means for sequentially, and with a like periodicity, after each periodical indicating step, restoring the original crystal supporting means and replacing the crystal on the abrasive means.

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