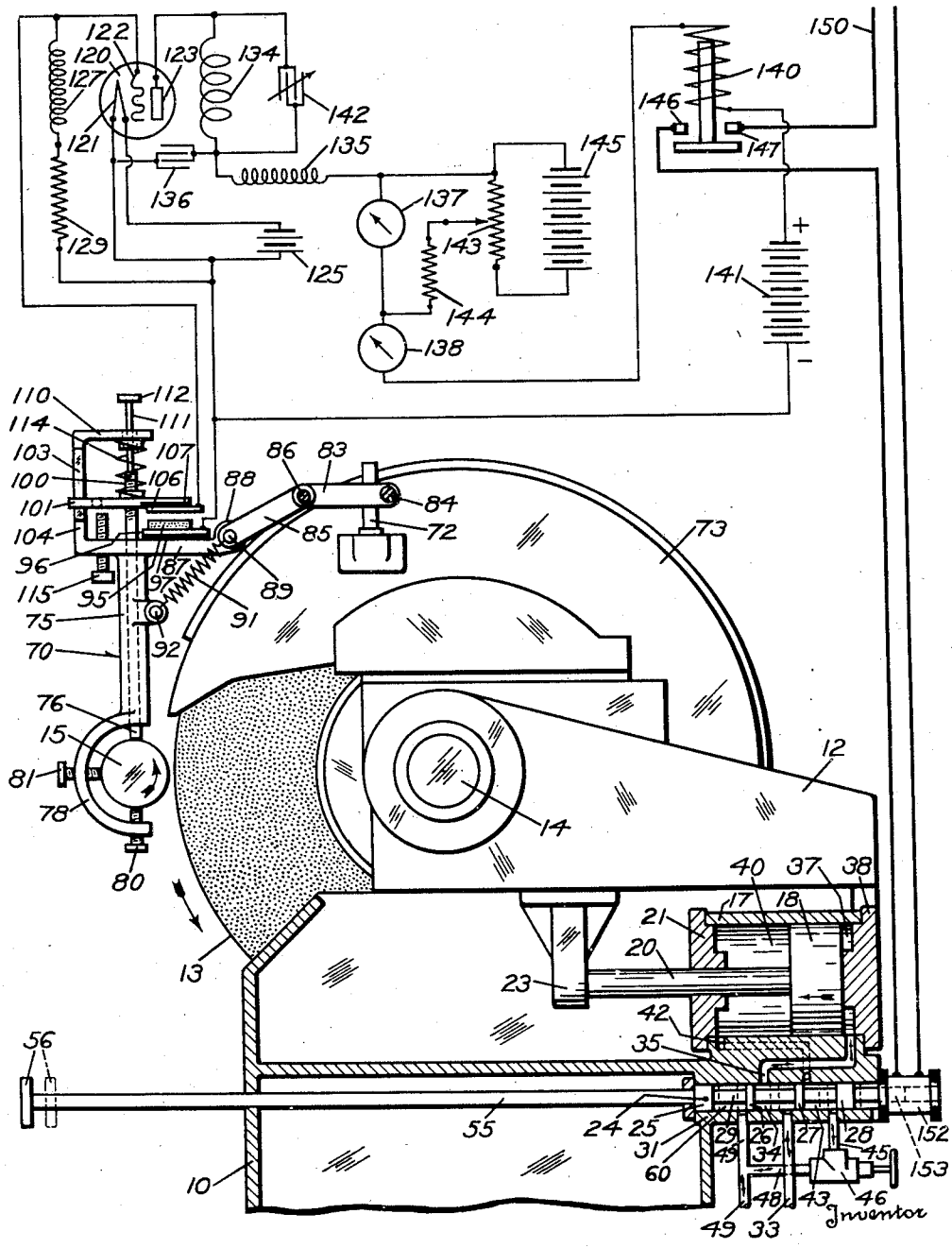
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ELECTRICAL SIZING DEVICE

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ELECTRICAL SIZING DEVICE

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This invention relates to work sizing devices and particularly to an electric control mechanism which may be arranged to measure the sizes of articles or to regulate the automatic operations of a machine tool, such as a grinding machine.

As explained in various prior patents, such as the patents to Cady Nos. Re. 17,357 and 1,450,246, it is commonly known that crystals of quartz, tourmaline, and various other materials, when compressed in certain directions, give positive and negative electrical reactions in various regions of their surfaces, and this phenomenon is referred to as piezo electricity.

These piezo electric crystals, when ground in the form of plates and subjected to alternating electrical fields of high frequencies, tend to vibrate longitudinally, and the frequency of crystal vibrations depends principally upon the thickness of the crystal. Hence, a piezo electric crystal may be ground to vibrate at a predetermined frequency.

A rectangular plate of any elastic solid may be struck a sudden blow upon one end and thereby set into longitudinal vibration. These mechanically impressed vibrations are considered free or natural and their frequency depends principally upon the modulus of elasticity of the material, its density and its dimensions. However, if the vibrations on a piezo electric plate are impressed by the field of a high frequency electric current, they are said to be forced and their amplitude of vibrations is extremely minute except when the frequency of the impressed oscillating circuit approximates the natural frequency of vibrations of the piezo electric plate.

A piezo electric crystal, such as quartz or tourmaline, should preferably be in the shape of a flat, rectangular plate having two opposed substantially parallel surfaces, although this is not absolutely necessary. A quartz crystal has been found to be extremely critical in tuning and will react upon a high frequency circuit at only one given frequency or harmonics thereof. It is essential that the piezo electric crystal shall be mounted and connected within an oscillating electrical circuit in such a manner as to electrically react upon the circuit at a particular frequency.

If the frequency of the electrically impressed oscillations on a piezo electric crystal plate is gradually increased from a lesser number of vibrations per second than its natural frequency to a slightly greater number of vibrations per second than its natural frequency, the amplitude of crystal vibrations which at first is very small, will suddenly rise to a large value as the resonant frequency is reached and as this critical point is passed, it will suddenly fall again to a very small value. Even though these electrically induced crystal vibrations are of themselves so minute as to be hardly detectable, they are sufficient to exert a very strong reaction upon the electrical oscillating circuit. The current flow in and to an electric oscillating circuit having a piezo electric crystal therein is found to suddenly change a maximum extent in strength of flow at a critical point which is at exact crystal resonant frequency.

It has been the usual practice when employing a piezo electric crystal plate, to mount it so that two opposed substantially parallel flat faces of the piezo crystal are in light frictional contact between two opposed flat metal electrically conductive plates acting as terminals therefor, and connected in an electrical high frequency oscillating circuit. However, it has been found that if one of these terminal plates remains in contact with a piezo crystal and the other terminal plate is moved through a very minute distance towards and from the surface of the crystal but not in actual contact therewith, the strength of current flow within and to an electrical oscillating high frequency circuit connecting said terminal plates and in exact tuned frequency circuit connecting said terminal plates and in exact tuned frequency therewith, is greatly affected.

My invention contemplates the provision of a work sizing device in which an electric circuit including a piezo electric crystal and cooperating electrically conductive plate is so arranged as to actuate suitable mechanism in accordance with variations in current flow in the controlling circuit which sizes the work and in which the work sizing mechanism may serve to directly indicate the exact size of the work and/or to automatically control the extent of a machining operation as a piece of work is being reduced in size. Broadly considered, the work sizing device serves to indicate the work size whether or not there is any visible indicator or signal which informs the operator as to the work size.

It is a further object of this invention to employ an electrical work sizing device including a piezo electric crystal arranged to respond to minute reductions in work size during a grinding operation thereon and stop said operation when a desired portion of the work has been reduced to a predetermined size, whereby one may automatically reproduce duplicate work pieces of any given size with extreme accuracy.

With these and other objects in view, as will be more fully apparent in the following disclosure, this invention resides in the combination of parts herein disclosed and covered by the appended claims.

The accompanying drawing diagrammatically illustrates one form of this invention as applied to control the size of cylindrical work finished in a grinding machine.

As one specific embodiment of this invention, I have illustrated a grinding machine having its wheel feed mechanism controlled by an electric work sizing device which has a caliper or gauge including a feeler member engageable with the work and responsive to minute variations in work size. This device employs a piezo electric crystal and a plate which are relatively movable and react within and control the current flow in a sensitive thermionic vacuum tube high frequency oscillating circuit in critical tune with the natural frequency of the piezo crystal. The sudden change in current flow within the oscillating circuit is arranged to operate work size indicating mechanism such as a meter calibrated to accurately indicate work size and/or to operate other electrical mechanisms regulating the extent of a grinding operation upon a work piece so as to reduce said work to a predetermined size within extremely narrow limits of accuracy. The expression "size indicating mechanism" is employed in the claims to cover any suitable mechanism which may be operated by or controlled in response to variations in the high frequency oscillating electric circuit, whether it be a gauge which directly measures the work size, or whether it be a control mechanism which serves to control a machine which operates upon the work, such as is required for reducing its size or for performing any operation needed in connection with taking a measurement of the work size.

As illustrated, the work sizing device is applied to control a grinding machine wherein a machine base 10 is arranged to slidably support a wheel slide 12 for transverse movement thereon so as to feed the wheel into the work. A grinding wheel 13 is mounted for rotation with a shaft 14 journaled within the wheel slide and arranged for movement therewith towards and from a work piece 15 suitably supported for rotation relative to the base. If desired, the work piece 15 may be arranged for longitudinal axial movement in any well-known manner such as by a work table mounted to slide longitudinally of the base and having a headstock and tailstock thereon arranged to axially support and rotate the work. Since the work support does not constitute a part of my invention and since it may comprise any familiar construction, it has not been illustrated.

Any suitable power operated mechanism may be employed to cause a feeding movement of the grinding wheel 13 and wheel slide 12 relative to the work piece 15. In the present instance, for convenience of illustration, this mechanism comprises a fluid pressure actuated device such as a cylinder 17 integral with the base 10 and having a piston 18 slidably mounted therein for axial movement. A piston rod 20 is slidably mounted within a cylinder head 21 and affixed at one end to piston 18 and at the other end to a depending member 23 secured to the wheel slide 12 whereby any axial movement of piston 18 within cylinder 17 may cause a relative feeding movement of the grinding wheel 13 towards or from the work piece 15 as desired.

A reversing valve 24 is provided to control the direction and extent of movement of piston 18 and wheel slide 12 whereby the grinding wheel may be fed towards and from the work as desired. This valve is preferably of the balanced piston type and is provided with pistons 25, 26, 27 and 28 secured on a valve stem 29, said pistons and valve stem being simultaneously slidable within the valve cylinder 31 and arranged to direct the flow of fluid to and from opposite ends of cylinder 17. Fluid under pressure from any suitable source such as a pump (not shown) is admitted to the reverse valve through a pipe 33 into valve chamber 34 between pistons 26 and 27. As illustrated, fluid may flow under pressure from chamber 34 through a passage 35 into a chamber 37 at the right-hand end of cylinder 17 between piston 18 and cylinder head 38 tending to move piston 18 towards the left as indicated and cause a relative infeed of the grinding wheel towards and into the work. Fluid within chamber 40 at the left-hand end of cylinder 17 between piston 18 and cylinder head 21, will exhaust at this time through a passage 42 into a chamber 43 between valve pistons 27 and 28. Exhaust fluid may flow from chamber 43 through a pipe 45 into an adjustable throttle valve 46 and thence through pipes 48 and 49 into the fluid supply system as indicated by arrows. It will be appreciated that the machine operator may regulate valve 46 to control the flow of exhaust fluid therethrough and thereby precisely regulate the rate of wheel feed towards and into the work.

The left-hand end of valve stem 29 is connected to a rod 55 terminating in a handle 56 conveniently located on the front of the base whereby the operator may shift the piston positions within the reverse valve to those indicated in dotted lines and cause fluid flow under pressure from the pipe 33 and chamber 34 to enter passage 42 and flow into chamber 40 at the left-hand end of cylinder 17 causing a rearward movement of piston 18 and a consequent withdrawal of the grinding wheel from the work until piston 18 encounters cylinder head 38. During this rearward movement of piston 18, fluid will exhaust from chamber 37 through passage 35 into chamber 60 between pistons 25 and 26. The fluid is free to flow from chamber 60 through pipe 49 back into the supply system. Since the flow of exhaust fluid on the rearward movement of piston 18 is not restricted, it will be appreciated that the grinding wheel will be rapidly withdrawn from the work to its initial starting position as illustrated.

To facilitate an accurate grinding operation wherein work pieces may be successively and automatically finished to precisely the same size, I have provided an extremely sensitive electrically responsive work sizing device which indicates minute variations in work size and serves to operate the reverse valve and rapidly remove the grinding wheel from the work when the work has been reduced to a predetermined size, irrespective of grinding wheel wear or extent of the wheel feed into the work. To accomplish this, I have provided a calipering device 70, arranged to engage the work and measure it during a grinding operation. The calipering device may be positioned upon the work in any desired fashion, but is here shown as supported by means of a bracket 72 suitably secured to the grinding wheel guard 73. The caliper may consist of any convenient mechanism wherein a feeler member responds to minute variations in work size and

serves to move a piezo electric crystal and plate relative to each other to control the operation of other electrical mechanisms. In the present instance, the caliper comprises a casing 75 carrying a slidable feeler rod 76, movable in response to variations in work size. The lower end of the casing terminates in an anvil 78 provided with an adjustable contacting screw 80 diametrically opposed to and aligned with the end of feeler rod 76, and with another adjustable contact screw 81 arranged to laterally bear upon the work and maintain the end of the feeler rod and screw 80 in desired locations and preferably diametrically of the work when the grinding operation is completed. In order to reduce the wear of said contacting screws and the end of the feeler rod engaging the work to a minimum, they are preferably provided with hard contact points, such as diamonds, set in the ends thereof. By adjusting screws 80 and 81, it will be appreciated that the calipering device may be regulated to measure cylindrical work pieces of various sizes which may be automatically duplicated in successive grinding operations.

In order to facilitate precise measurement with my calipering device, it may be supported in any convenient manner so that the weight of the casing 75 and the parts assembled therewith are not supported by feeler rod 76. To accomplish this, I provide a link 83 which may be clamped in any convenient position on bracket 72 by means of a screw 84. A link 85 is pivotally and frictionally supported on link 83 by means of a bolt 86 in such manner that said link may be moved about its pivot by the operator but will remain in the position to which it is set. The upper end of casing 75 is provided with an L shaped projecting frame 87 terminating in an enlarged portion 88 loosely pivoted to link 85 by a pin 89. A spring 91 engages pin 89 and an ear 92 on casing 75 under sufficient tension to maintain screws 80 and 81 in frictional contact with the work, thereby supporting the caliper and providing a free sliding action of the feeler rod 76 therein.

To provide an extremely sensitive work sizing device, the feeler rod 76 is arranged to cause a relative movement between a piezo electric crystal plate and an adjacent metal plate which members are connected in an electrical oscillating circuit in such manner that they control the current flow therein and thereto. Various piezo electric crystals may be employed in various ways to control such a circuit, but I preferably utilize a rectangular piezo electric crystal plate of quartz or similar material ground relatively thin to oscillate at a known high frequency. As illustrated, I have provided a piezo electric crystal plate 95 secured to a terminal member 96 which is firmly supported on the frame 87 but insulated therefrom in any convenient manner as by a non-conducting member 97. The upper portion of feeler rod 76 is provided with a fine threaded portion 100 arranged to adjustably support a member 101 which is movable therewith and prevented from rotary movement by a slide-way 103 in an upstanding portion 104 of frame 87. An upper terminal plate 106 is supported on the underside of member 101 directly above and parallel to the flat upper face of the piezo electric crystal 95. Plate 106 may be separated from member 101 by a non-conductor member 107.

The caliper frame is further provided with a horizontal projection 110 having a hole therein arranged to receive a reduced portion 111 of feeler rod 76 terminating in a knob 112, whereby the threaded portion 100 may be turned to adjust the position of plate 106 relative to the top face of the piezo crystal plate 95. To prevent lost motion in the threaded part and turning of the feeler rod due to vibration, a spring 114 has been provided which tends to force the feeler rod into firm frictional contact with the work, as well as plate 106 toward the crystal 95. To prevent damage to the piezo crystal, an adjusting screw 115 is threaded through the frame and arranged to limit the downward movement of plate 106 before it actually engages the piezo plate 95. It will be appreciated that the illustration has been exaggerated to diagrammatically show the operation of the various parts of my caliper device. In actual practice, the plate 106 may be as close to the piezo crystal as one thousandth of an inch, and a movement of said plate through one ten thousandth of an inch or less may be sufficient to control the current flow in the oscillating circuit and effect other electrical control mechanisms to measure and/or size the work.

Various types of oscillating electrical circuits may be controlled by the piezo crystal and plate 106, but I preferably utilize a thermionic vacuum tube of the type used in radio communication and I utilize the variable flow of electric current in a plate circuit of said tube to operate a milliammeter which is calibrated in fractions of a thousandth of an inch to indicate variation in work size. I also employ a very sensitive relay in the plate circuit to make and break contacts in a power circuit operating a solenoid which is arranged to shift the reverse valve 24 and cause a sudden withdrawal of the grinding wheel 13 from engagement with the work and stop the grinding operation when the work has been reduced to a predetermined size.

One circuit which has been found successful is diagrammatically shown in the drawing. It comprises a thermionic vacuum valve 120 of the familiar three element type having a filament 121, a grid 122, and a plate 123. The filament or cathode 121 is heated by a battery 125. An input circuit is provided between the grid 122 and filament 121 which includes an inductance 127 and resistance 129. The piezo electric plate is connected to the filament 121 and the movable plate 106 is connected to the grid 122, thereby subjecting the piezo crystal to the field of an oscillating high frequency electrical circuit. An output circuit is provided and connected across plate 123 and filament 121 of the vacuum tube including inductance 134, choke 135, condenser 136, meters 137 and 138, electromagnet winding of relay 140 and a source of potential, such as a battery 141. A variable condenser 142 is shunted across the inductance 134 and serves to tune the output tube circuit to any desired frequency.

When condenser 142 tunes the output circuit to the natural frequency of the piezo electric crystal plate 95, the valve 120 will oscillate and the piezo crystal will vibrate at a maximum extent. At this point, the two valve circuits are said to be in exact resonance. However, in the circuit illustrated, it has been found that at the exact point of resonance, there is a minimum current flow in the plate circuit; whereas at a point wherein the plate circuit is tuned just below resonance, the current flow in the plate circuit is at a maximum and movement of plate 106 toward or from the piezo crystal plate 95 through a minute distance, greatly increases or decreases

the current flow in the plate circuit. It is this phenomenon which has been taken advantage of.

If it is intended to measure the work directly, either with or without controlling a grinding operation, the meters 137 and 138 may be graduated to accurately indicate the work size. For example, meter 138 may be graduated in thousandths of an inch and meter 137 may be calibrated so that a whole scale reading registers only one thousandth of an inch in the measurement. It will be appreciated that meter 137 is much more sensitive than meter 138. To aid in regulating this meter and preventing a heavy flow of current therethrough, a balancing battery 145, a balancing variable resistance 143 and resistance 144 has been provided. By regulating the balancing resistance 143, the indicator needle of meter 137 may be positioned at the zero point of its scale. This adjustment need be made only when setting up the apparatus or when changing from one work size to another. It will thus be apparent that whenever the calipering device engages a work piece, the meters 137 and 138 will accurately and precisely indicate the exact size of the work.

Since an infinitesimal movement of the plate 106 towards the piezo electric crystal causes a relatively large increase in current flow through the output circuit which includes the sensitive relay 140, said relay may be regulated so that it will connect two switch points 146 and 147 in a power circuit 150 whenever the meters 137 and 138 indicate a desired strength of current flow corresponding with a predetermined work size. When the switch points 146 and 147 are closed, the current will be free to flow therethrough from any suitable source and energize a solenoid 152 having an armature 153 slidably mounted therein. Said armature may be connected to the valve stem in any suitable manner, or as shown it may comprise an extension of the valve stem. When the solenoid is energized, the armature 153 will be suddenly drawn therein, causing a reversal of the reverse valve 24 by moving the pistons therein to the dotted positions shown and resulting in a consequent and instantaneous withdrawal of the grinding wheel from the work when the work gauge has indicated a predetermined desired size of work.

In the operation of my machine, the work piece 15 is inserted in grinding position and rotated in any suitable manner. Handle 56 is moved by the operator to its full line position as shown, causing a flow of fluid pressure from any suitable source through the reverse valve into cylinder chamber 37 and resulting in an infeed of the grinding wheel as indicated. Adjustment of valve 46 in the exhaust system regulates said rate of infeed of the grinding wheel. The caliper 70 may be placed on the work at any time prior to the reduction of the work to the desired size. As the work reduces in diameter, the feeler rod 76 will move downward due to the action of gravity aided by spring 114 until the increase in current flow in the plate circuit energizes relay 140 sufficiently to connect switch points 146 and 147, energizing solenoid 152 and instantly shifting valve 24 to a reverse position causing a rapid withdrawal of the grinding wheel to its initial position. Relay 140 is so adjusted that it will close the power circuit 150 when meters 137 and 138 indicate the desired work size. At this point, plate 106 will not have reached its greatest possible downward travel as limited by screw 115. Upon completion of the grinding operation, it is only necessary for the machine operator to replace the finished work piece with a fresh work blank and shift handle 56 to its full line position to again start the machine through its automatic cycle to produce another work piece of identical size.

It will be appreciated that my work sizing device may be employed as a work or inspection gauge which accurately and precisely indicates the variation in thickness or diameter of any work piece as compared to a desired or standard size. For example, my invention could be employed in accurately measuring precision finished automotive parts such as piston pins wherein it is desirable to maintain accuracy within one ten thousandths of an inch. In such a device, the construction above described may be suitably modified to only include the calipering device and the input and output circuits. The power circuit 150, relay 140 and solenoid 152 would be eliminated. The suitably calibrated meters 137 and 138 would directly indicate work size.

It will further be appreciated that my sizing device may be applied to accurately control the stock removal operation of any machine tool and it is not intended that the invention be limited to the specific example illustrated.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. In combination with a work sizing device, a piezo electric crystal and plate which are movable relative to each other in response to minute variations in work size, a high frequency oscillating electrical circuit including the crystal and plate, said parts being so connected within the circuit that any relative movement between the crystal and plate serves to vary the current flow without affecting the frequency of oscillations, and size indicating mechanism responsive to changes in said current flow.

2. In combination with a work sizing device, a piezo electric crystal and plate which are movable relative to each other in response to minute variations in work size, a high frequency oscillating electrical circuit including said crystal and plate so arranged that any relative movement between the crystal and plate serves to vary the current flow within the circuit without changing its frequency of oscillation, size indicating mechanism for the work sizing device which is responsive to variations of current flow within the circuit, and means operating upon the work which is controlled by said mechanism.

3. A work sizing device comprising a piezo electric crystal and a plate which are movable relative to each other, means engageable with the work for causing said relative movement, a high frequency oscillating electrical system having an input circuit including the crystal and plate which are so arranged that any relative movement therebetween serves to vary the current flow within and to the input circuit and an output circuit responsive to current changes in the input circuit and tuned to the approximate resonance of the natural frequency of the crystal and an electrical device responsive to the current flow in the output circuit which measures the work.

4. A work sizing device comprising a piezo electric crystal and a plate movable relative to each other, means engageable with an article to be gauged for causing such relative movement as determined by the size of the article, an electrical high frequency oscillating system including

the piezo crystal and plate, which system is so arranged that any relative movement of the crystal and plate serves to vary the current flow in the system, and mechanism responsive to the variations in current within the oscillating system which measures the size of said article.

5. A work sizing device comprising a piezo electric crystal and a plate movable relative to each other, a work gauge for causing said relative movement, an oscillating system employing a thermionic vacuum valve having an input circuit including the crystal and plate which are so arranged that any relative movement therebetween acts to vary the current flow of the input circuit, and an output circuit responsive to changes in the flow of current within the input circuit and tuned to the approximate resonance of the natural frequency of the crystal, means for reducing the size of the work and an electrical device operated by the output circuit which controls the work reducing means and limits the final size of the work.

6. A work sizing device comprising work reducing mechanism, a control mechanism arranged to stop the work reducing operation, a piezo crystal and plate movable relative to each other in response to minute variations in work size, an oscillative high frequency electrical circuit including the crystal and plate so arranged that any relative movement of the crystal and plate serves to vary the current flow in the circuit, and an electrical device responsive to variations in the current flow within the circuit which is connected to cause said control mechanism to operate and stop the work reduction when it has reached a predetermined size.

7. A work sizing device having a cutting tool movable toward and from a work piece to produce a stock removing operation, said device including a piezo electric crystal and a plate movable relative to each other in response to a change in work size, an oscillating system having an input circuit including said crystal and plate, and an output circuit responsive to changes in the current flow in the input circuit and tuned to substantially the same frequency as that of the natural crystal, and electrical means operated by the output circuit which indicates the work size during reduction of the work.

8. A machine for reducing the size of a work piece comprising controllable work reducing mechanism, a control mechanism arranged to stop the work reducing operation, a control mechanism therefor including a piezo electric crystal and plate which are movable relative to each other in response to a minute variation in work size, an oscillating system having an input circuit including the crystal and plate which are so arranged that any relative movement therebetween serves to vary the current flow within and to the input circuit and an output circuit responsive only to current changes within the input circuit and tuned in approximate resonance of the natural frequency of the piezo crystal and an electrical mechanism responsive to variation in current flow within the output circuit which serves to cause the control mechanism to operate and stop the work reduction when it has reached a predetermined size.

9. A machine tool comprising a cutting tool movable toward and from a work piece to produce a stock removing operation, a piezo electric crystal and a plate movable relative to each other, a work engaging member arranged to cause said movement, an oscillating system having an input circuit, including said crystal and plate, and an output circuit responsive to variations of current flow in the input circuit and tuned in approximate resonance with the natural frequency of the crystal, and means responsive to a variation of current flow in the output circuit to stop the stock removing operation when the work has reached a predetermined size.

10. A machine tool comprising a cutting tool movable toward and from a work piece to produce a stock removing operation, a piezo electric crystal and a plate movable relative to each other in response to a change in work size, a feeler member engageable with the work and arranged to cause said movement, an oscillating system having an input circuit and an output circuit responsive to said input circuit, said input circuit including the piezo crystal and plate which is so arranged that any relative crystal and plate movement serves to vary the current flow within the circuit, said output circuit being tuned substantially in resonance with the natural frequency of the piezo crystal, a device in the output circuit responsive to changes in current flow therein to indicate the work size during a cutting operation thereon, and separate means responsive to the current flow in the output circuit to stop the stock removing operation when the work has reached a predetermined size.

11. A grinding machine comprising a rotatable grinding wheel movable toward and from a work piece, mechanism to feed the wheel into the work, a control device therefor, a piezo electric crystal and a plate movable relative to each other, means to cause said movement in response to a change in work size, an oscillating system having an input circuit including said piezo crystal and plate which are so arranged that any relative movement of the crystal and plate serves to vary the current flow in said circuits, and an output circuit tuned substantially in resonance with the natural frequency of the crystal and responsive to current fluctuations in the input circuit, and electrical means actuated by the output circuit arranged to operate the control device and stop the grinding feed when the work has reached a predetermined size.

12. A grinding machine comprising a rotatable grinding wheel movable toward and from a work piece, mechanism to feed the wheel into the work, a control device therefor, a piezo electric crystal and plate movable relative to each other, a work gauge for causing said movement in response to a change in work size, an oscillating system having an input circuit and an output circuit responsive to said input circuit, said input circuit including the piezo crystal and plate which are so arranged that any relative crystal and plate movement acts to vary the current flow within the circuit, said output circuit being responsive to current changes in the input circuit and tuned substantially in resonance with the natural frequency of the crystal, means actuated by the output circuit which indicates the work size and separate mechanism responsive to the output circuit arranged to terminate the grinding operation and remove the grinding wheel from the work when it has been reduced to a predetermined size.

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