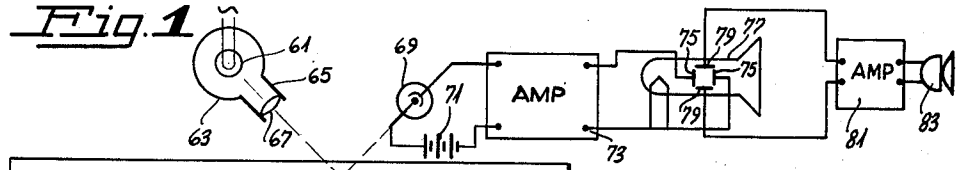
June 1, 1954 R. S. RYDER 2,679,782

TUNING INSTRUMENT

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Fig. 1



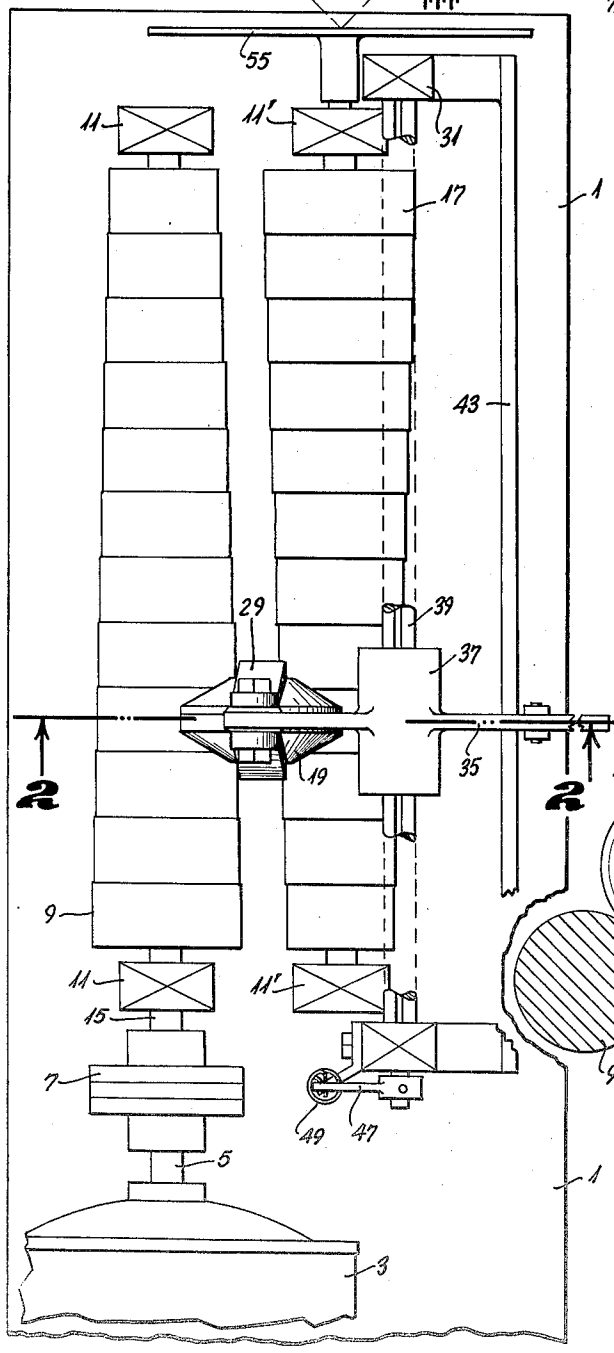




Fig. 3.

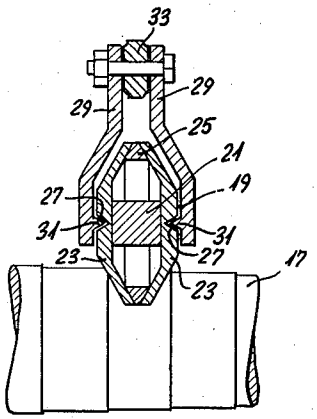
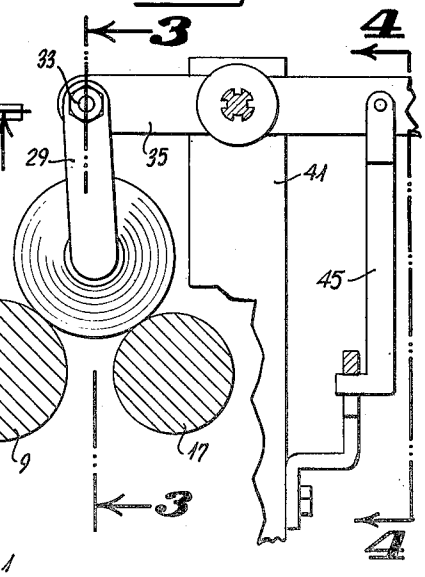



Fig. 2.




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TUNING INSTRUMENT

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Fig. 4.

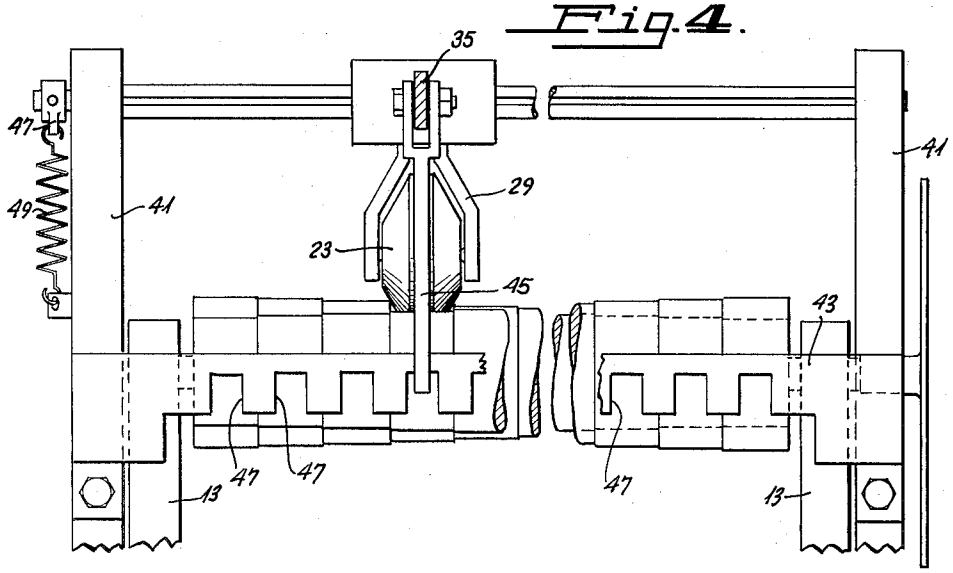



Fig. 6.

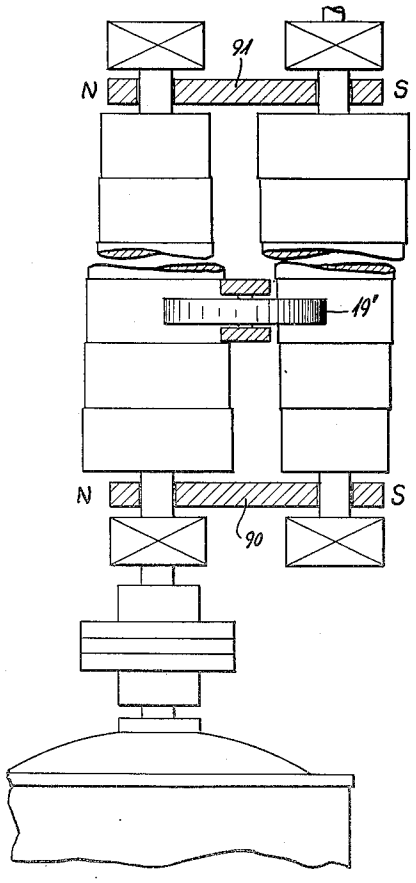
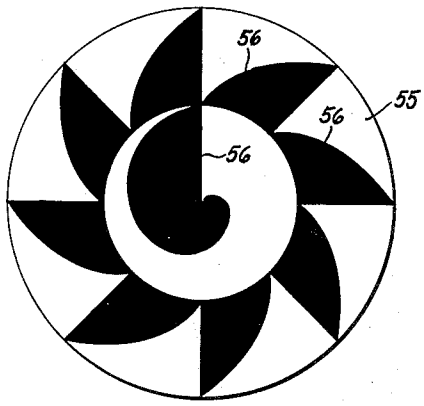



Fig. 5.




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2,679,782

# UNITED STATES PATENT OFFICE

2,679,782

## TUNING INSTRUMENT

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Application July 5, 1950, Serial No. 172,037

20 Claims. (Cl. 84—454)

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This invention relates to devices for use in tuning musical instruments; specifically, to devices for tuning keyboard instruments such as pianos which must, to be generally useful, employ a tempered scale. In certain respects it is a development of and an improvement on the tuning instrument disclosed in my prior application, Serial No. 27,419, filed May 17, 1948.

As set forth in the prior application above referred to the evenly tempered scale, wherein each successive half tone is related to the next lower tone by the factor, the twelfth root of two, is in practically universal use today. Where this scale is used notes which, in the natural scale, bear frequency relationships which can be expressed in simple fractions such as two-thirds, three-fourths, etc., differ very slightly from these simple relationships. Notes which do bear such simple relationships have harmonics which coincide in frequency, and in tuning pianos by ear the tuner strikes the notes simultaneously and adjusts the tuning until no beat note as between these harmonics is distinguishable. He then attempts to adjust the frequency of the particular string or note being tuned slightly off of the natural key until he believes that it has been detuned by the amount required to give the even temperament. If he succeeds in doing this exactly the instrument sounds equally well when played in any key. If he does not succeed the usual result is that some keys sound well while others may be seriously discordant. Learning to tune an instrument properly requires long and arduous training. The result is an approximation and even the best tuners meet with varying degrees of success in their efforts.

The prior application mentioned also shows that one of the most accurate methods of comparing two frequencies is by means of Lissajous figures displayed upon the screen of an oscilloscope and discloses instrumentalities by which this can be done. To be useful in tuning musical instruments this requires means for generating frequencies corresponding to the evenly tempered scale for comparison with the notes of the instrument to be tuned. The twelfth root of two, however, is a transcendental number and no arrangement of toothed gears can be devised which will give exactly the requisite ratio between two successive half tones. Synchronous motor drives can be devised which will hold one frequency of rotation with great accuracy, but to derive from such one standard frequency the related frequencies of the evenly tempered scale has proved to be difficult. Gears cannot

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be used satisfactorily for the reasons given above, and belts or friction drives as used in the past have been subject to slippage and other sources of inaccuracy which have led to their abandonment. Furthermore, the means used to generate electrical currents of the varying frequencies required have usually imposed a greater or less load upon the means used to drive them, with the result that slippage, if it occurred at all, has been a varying factor which could not be compensated and has further contributed to the inaccuracy of such devices.

The broad purpose of this invention is to provide a means of generating standard frequencies which can be used for comparison with the frequencies to be developed by an instrument to be tuned, such frequencies bearing the required relationships to form a tempered musical scale. Contributory to this broad purpose, among the objects of this invention are to provide a drive of the friction type which is substantially immune to slippage; to provide a drive of the type mentioned which will maintain its original accuracy indefinitely; to provide a means for transferring motion from a constant speed shaft to a variable speed shaft which is substantially unaffected by certain minor inaccuracies in the transfer mechanism itself; to provide a generator of comparison frequencies wherein the load is substantially a constant irrespective of the speed of the driven shaft and wherein the actual generation of the comparison frequency imposes no load upon the drive mechanism; and to provide a generator of standard frequencies wherein the frequency to be generated may be given any desired waveform and the various frequencies required may be selected quickly, easily, and accurately.

Considered from one broad aspect my invention comprises a pair of ferromagnetic rollers, one of which is a driving roller and the other a driven roller, a ferromagnetic transfer roller which, in operation, is supported solely at its points of contact with the parallel rollers above mentioned, and a magnet for forming a complete ferromagnetic circuit or circuits including portions of all three rollers; in this combination the important and critical factor is that the transfer roller shall be free and not constrained by a shaft or pivot, experience having proved that if so constrained the slightest inaccuracies as to concentricity, such as may appear in even the most meticulous machine work, are reflected as much greater inaccuracies in speed or uniformity of rotation of the driven shaft. Con-

sidered from another point of view the invention comprises a shaft which can accurately be driven at uniform speed to actuate a drive roller, a driven roller mounted accurately parallel thereto, at least one of these rollers being stepped in diameter so that successive steps bear, to the portions of the other roller facing them, ratios corresponding to successive tones or half tones of a tempered scale and means actuated by the driven roller for generating an electrical wave of a frequency integrally related to the frequency of rotation of the driven roller. This generating means is preferably an optical cam comprising sectors having light absorbent surfaces alternating with sectors which either transmit or reflect light, a light source for directing a beam of light against such optical cam, and a photocell positioned to receive the unabsorbed light of said beam. The variations in current passed by the photocell may be fed to a suitable amplifier and the amplified wave applied as the comparison frequency to deflect the beam of a cathode ray tube. Means are also preferably provided for seizing the transfer roller and shifting it from one step to another of the stepped roller.

The invention will be more fully understood by reference to the ensuing detailed description of the preferred form of the device, taken in connection with the accompanying drawings, wherein:

Fig. 1 is a plan view of the operating portions of a device in accordance with this invention, certain parts being cut away in the showing for the purpose of simplicity in the drawing and to show underlying structures more completely and certain other portions being shown in diagrammatic form;

Fig. 2 is a transverse section of a portion of the device of Fig. 1, the plane of projection being indicated by the line 2—2 in the first figure;

Fig. 3 is a fragmentary sectional view of the transfer roller and its means of support, the plane of section being indicated by the appropriately numbered lines in Fig. 2;

Fig. 4 is a front elevation of the device shown in Fig. 1, certain portions being again cut away in this figure;

Fig. 5 is a face view of the optical cam employed in the device; and

Fig. 6 is an illustration of a modified form of the device using a different type of magnetic circuit.

In the drawings the reference character 1 indicates a base or bed plate upon which a motor 3 is mounted. This motor is of any suitable constant speed type; preferably a synchronous motor driven by an accurately controlled frequency. Various types of constant speed motors are well known in the art and the particular type here used is not considered to be a part of this invention.

The shaft 5 of motor 3 drives, through a suitable coupling 7, a drive roller 9. The latter is journaled in bearings 11 carried on columns 13 rising from the base 1. In the present instance the driving roller 9 takes the form of a stepped cone of twelve steps corresponding to the twelve notes of the chromatic scale. I prefer to make the roller 9 and its extension shafts 15 from a single bar of ferromagnetic material, since this method of construction I have found to give the greatest rigidity and concentricity, but it can, if desired, be made of a succession of ferromagnetic discs force fitted upon the shaft 15. I also prefer that the motor 3 drive the shafts 15 and roller 9 directly rather than through gearing, since the latter may introduce spurious gear tooth frequencies into the output electrical wave generated by the device.

A driven roller 17 is mounted similarly to roller 9 in bearings 11' on columns 13'. Roller 17 is, in this case, identically similar to roller 9 but is turned end for end with respect thereto. The steps on the two rollers are so dimensioned that the ratios of the apposed faces of the succeeding steps differ by successive factors of the twelfth root of two. These ratios should be computed and the rollers finished to size with the greatest possible accuracy.

Transfer of motion between the driving roller 9 and the driven roller 17 is accomplished by a magnetic "puck" or transfer roller 19. A preferred construction of the transfer roller is indicated in cross-section in Fig. 3. It comprises a central core 21 which is a permanent magnet formed preferably of a high coercive force alloy such as "alnico." This core terminates in a pair of cupped or dished polepieces 23, positioned on the core with their dished sides facing each other. Preferably, although not necessarily, there is included between the polepieces a ring 25 of non-magnetic material such as brass or bronze. As will be seen in the drawing the edges of the polepieces are slightly separated by this ring. The polepieces may be of mild steel and it is desirable that the material chosen for the ring 25 be of approximately the same hardness and resistance to wear, the ring being, if anything, very slightly softer than the materials of the polepieces. The composite face on the periphery of the transfer roller, formed by the two polepieces and the ring, is ground accurately parallel with the axis of the roller.

The material used for rollers 9 and 17 may also be of mild steel, but it is preferable that they be given a thin case-hardening prior to final grinding. Under these circumstances the wear which takes place in the operation of the device is almost entirely confined to the periphery of the transfer roller and experience has shown that it takes place uniformly over the surface thereof. Such wear is very slight indeed, but over long periods it does result in the formation of very fine particles of iron dust which the ring 25 prevents from entering into the gap between the polepieces. Experience has also shown that such wear does not destroy the circularity of the transfer roller, which is an important feature.

It will be seen that the construction of the transfer roller gives it a nearly complete magnetic circuit which is finally completed in two paths passing through the ferromagnetic material of the driving and driven rollers. The transfer roller therefore clings to both the other rollers with a very considerable force which is concentrated at the line contact therewith. A relatively strong torque can therefore be transferred from the driving roller to the driven roller without any measurable slippage. Experiments have shown that after many hours of operation at a one-to-one ratio the two shafts still maintain the same phase relationship that they bore at the start of the experiment.

This latter result, however, I have found is dependent upon the transfer roller or puck being unconstrained by any shaft or pivot being supported, in operation, solely by its points of contact with the other two rollers. The device therefore can be operated to develop the various fre-

quencies required of it by placing the transfer roller by hand on the desired steps and shifting it manually from step or step when such shift is required.

Such an arrangement is somewhat inconvenient, however, and therefore means are provided to lift and shift the transfer roller by semi-mechanical means. As will be seen in Fig. 3, each of the polepieces **23** is provided with an axial conical pit **27**. A pair of dependent arms **29** are provided with conical projections **31** and these arms are supported by a pin or bolt **33** from a lever **35**. The projections **31** enter loosely into the pits **27**, so they do not constrain the rotation of the transfer roller but do serve as a claw by which it can be raised out of contact with the drive and driven rollers.

The lever **35** is fulcrumed on a sleeve **37** sliding upon a splined shaft **39**, the latter being journaled in bearing **40** carried by columns **41** which rise from the base **1**. An index bar **43** spans the two columns **41** and is provided with (in this case) twelve notches, each notch being opposite to one of the steps of the driving and driven cones. A latch **45** depends from the arm **35**, the length of the latch being such that when it engages the notches **47** the projections **31** will not rest in the bottom of the depressions **29**. The lever **35** may be made of considerable length to facilitate raising the transfer roller from its contact with the other two rollers and because of its weight and its mechanical advantage it would therefore tend to raise the arms **29** and so cause friction between the projections **31** and the top of the depressions **27**. Accordingly there is provided, on an extension of the splined shaft **39**, a short lever **47** connecting by spring **49** with a bracket **51** on the column **41**. This spring serves to hold the latch **45** engaged with the notches in the index bar **43**.

There will, of course, be some lateral friction between the projections **31** and the depressions in the transfer roller with which they engage. Since the arms **29** are independently swung, however and the angle at which they hang is small, such friction cannot constrain the motion of the roller and experience has shown that it has no deleterious effects upon the accuracy of the device.

Various forms of comparison frequency generators may be mounted upon the shaft of roller **17**. In the preferred form of the device this comprises a disc **55** mounted on the driven roller shaft, the face of this disc forming an optical cam. One form of such cam is illustrated in Fig. 5. In this form of the device the face of the disc **55** is polished to a mirror finish upon which are imposed light absorbent areas **56**. One method of forming these areas is by photomechanical etching. The cam illustrated in Fig. 5 is a double one. In this case two concentric cams are shown, the light absorbent portion of the inner or smaller one being an Archimedean spiral of a single turn, while the outer cam consists of portions of eight such spirals. A light source **61** is provided with a housing **63** having a lens tube **65** wherein is mounted a suitable lens **67**. The housing is placed and the lens adjusted so as to focus light from the lamp in the plane of the optical cam; if the lamp used has a single straight filament it may be the image of the filament that is so focused but if other types of lamp are used a diaphragm or optical slit should be provided, the image whereof may be focused upon the cam. The adjustment of the part should be such that the linear image formed by either the filament or the slit falls radially upon either the inner or the outer cam, the dimensions of the image being such as to encompass substantially the entire radius carrying the light absorbent portion of either of the cam surfaces.

A photoelectric cell **69** is positioned to receive the light specularly reflected from the non-absorbent portions of the cam surface. Optical systems of the type described are well known in the art and have, in effect, been described in my prior application heretofore mentioned. It is obvious that with the setup as described the light reaching the photocell from the optical system will vary periodically, either once or eight times per revolution of the cam, depending upon which portion is receiving the light, and that within each period the light will vary linearly with time so as to generate a sawtooth waveform.

The photocell **69** is connected in series with a D. C. source **71** and the output current, as varied by the amount of light reflected from the cam, is fed to an amplifier **73**. The amplified output, in turn, is fed to one pair of deflecting plates **75** of a conventional cathode ray oscilloscope **77**. The other pair of plates **79** is connected to the output of an amplifier **81** the input whereof is supplied by a microphone **83** which picks up the tone from the instrument to be tuned.

In the preferred mode of operation it is desired that the lowest speed at which the cam should be driven be 55 revolutions per second, corresponding to the 55 cycle second A on the piano keyboard when tuned to international pitch. With the transfer roller in contact with the uppermost step of the cone rollers as depicted in Fig. 1 there is a step-down ratio of approximately 7 to 5 in the relative speeds of revolution of the two shafts, which requires that driving roller **9** rotate at about 63 revolutions per second or just under 3800 R. P. M. This corresponds to a supply frequency of the motor **3**, if this be a 2-pole synchronous motor as is preferred, of about 63 cycles per second. The figures are given in this approximate form since although 55 cycles per second is the value of the A when the instrument is tuned to international pitch there are many instances where it is desired to vary the tuning more or less from this pitch and consequently it is preferable that the motor **3** be supplied by an oscillator the frequency whereof is slightly variable—say over a range of approximately 6% of its lowest value—in order to accomplish such variation. This arrangement has been described in my prior application and therefore is not repeated here.

With the speed of the driving shaft adjusted to the desired value in the neighborhood of 55 revolutions per second and the optical system focused upon the inner cam, a sawtooth wave of this frequency will be developed by the photocell and the beam of the cathode ray tube will sweep the luminescent target of the tube at this rate, providing a linear time base. From this time base the A's of the lower part of the piano register, comprising the first five octaves may be tuned, by applying a pickup from the microphone, as amplified, to the other set of deflecting plates of the tube and adjusting the tuning of the strings until stationary Lissajous figures are formed. The five lower A's of the instrument can thus be tuned by observing Lissajous figures of ½, 1, 2, 4 and 8 cycles respectively as referred to the comparison frequency, progressing up-

wardly along the scale. I have found that more than eight loops cannot usually be used satisfactorily since the next step would require 16 cycles to be observed and in this case there is danger of tuning to a stationary display of 15 or 17 cycles, which would result in a very serious mistuning. Accordingly, in tuning to the sixth and higher A's of the scale, it is preferable to refocus the optical system upon the outer cam. This will pick up where the frequencies checked against the inner cam leave off, and provides a check on the 8-cycle tuning of the fifth A from the bottom of the scale, which, at the new comparison frequency, gives a single cycle figure. The process can be repeated using multiple loops on up the scale.

The other notes to the chromatic scale, from A sharp to G sharp, can be tuned by moving the transfer roller to successive steps on the driving and driven rollers. It is possible, of course, to go up or down the scale in any sequence.

Fig. 6 shows a modified form of the device wherein the same principles are used but the magnetic circuit which holds the rollers in contact is of a different type. In this form of the equipment the motor, the driving and driven rollers, and the support for the transfer roller may be identical in form with those previously described. The magnetomotive force for holding the transfer roller in contact with the others is, however, provided by a pair of bar magnets **90** and **91**. These magnets, like the magnet in the form of the device first described, are preferably of the permanent type and are formed of high-coercive-force alloy. They span the space between the shafts of the driving and driven rollers, and are so mounted that like poles are adjacent the shaft of the same roller as is indicated in the figure, the north pole of each magnet being in this case shown as surrounding the shaft of the driving roller while the south pole surrounds that of the driven one. This could, of course, be reversed.

With this arrangement the transfer roller **19'** can be a simple disc of mild steel or other ferromagnetic material of fairly high permeability. It establishes a consequent pole on both rollers at its points of contact, completing the magnetic circuits of both magnets. These magnetic circuits are longer than in the previous case, there are air gaps to be considered, and the magnetic leakage is greater but the magnets themselves are longer and capable of establishing higher magnetomotive forces so that the actual flux at the lines of contact can be maintained at about the same value as in the form first described. As in the previous case the mounting should be such that it exercises no restraint upon the transfer roller, the latter being supported solely at its points of contact with the rollers **9** and **17**.

It is clear that in this form the permanent magnets **90** and **91** can be replaced by electromagnets, this being practically impossible in the form first described because of the difficulty in introducing current without at the same time constraining the rotation of the transfer roller.

As has previously been indicated, the device in either form will transfer motion between the two rollers substantially without slippage. This is the case even if the rollers are polished to substantially a mirror surface, although fine grinding is to be preferred as conducive to greater accuracy than most polishing processes. It works out that if the sum of the diameters of any step of the two rollers is 2 inches, a tolerance of one ten-thousandth of an inch in their dimensions will result in a maximum error in temperament of one and one half beats of the highest note of the scale of a standard 88 piano. At this portion of the sound spectrum the ear cannot detect an error of this magnitude. In the median portion of the scale, or where the ear is most sensitive, the maximum error is a small fraction of a beat, also too small to be recognized.

This assumes that all of the errors due to inaccuracies within the tolerances are cumulative and represents the maximum departures from even temperament and not the error in true pitch of any single note. Actually, the errors are of the compensating type and those actually found by the most careful measurements have been less than a quarter of the maximum to be expected.

It will be obvious that by making the diameters of the driving and driven rollers larger the percentage error can be decreased. It will also be clear that it is not necessary that both rollers be of stepped construction; either can be made a straight cylinder and the other one stepped, as long as the proper ratios of diameter are maintained. Furthermore, while it is convenient to use a double cam of the type illustrated with one and eight light absorbent sectors respectively, it is also possible to use cams with more sectors and to shape these sectors in any manner desired to give the comparison waveforms; one possible form of cam being a three-range device having one, four and sixteen sectors. Various other modifications will naturally suggest themselves to those skilled in the art.

I claim:

1. A transmission device comprising a ferromagnetic driving roller, a ferromagnetic driven roller out of contact with said driving roller said rollers having cylindrical surfaces and substantially parallel axes, a ferromagnetic transfer roller having a cylindrical surface in contact with said driving and driven rollers, said transfer roller being supported only at its contacts with said driving and driven rollers and free of other contacts, and a magnet positioned to establish at least one substantially complete ferromagnetic circuit through at least a portion of said transfer roller and driving roller and at least a portion of said transfer roller and driven roller with said circuit being completed through portions of said driving and driven rollers solely through the medium of said transfer roller, whereby said transfer roller is held in frictional engagement with said other rollers substantially by magnetic attraction.

2. A transmission device in accordance with claim 1 wherein said transfer roller comprises a pair of spaced circular pole pieces the peripheries whereof constitute the surfaces contacting said other rollers and said magnet comprises a permanent magnet of high coercive force axially interposed between said pole pieces.

3. A transmission device in accordance with claim 2 including a spacer of non-magnetic material and of substantially the same diameter as said pole pieces interposed therebetween.

4. A transmission device in accordance with claim 1 wherein said driving and driven rollers are each provided with ferromagnetic shafts, and said magnet comprises a bar of ferromagnetic material spanning said shafts.

5. A transmission device in accordance with claim 4 including a pair of magnets spanning op-

posite ends of said shafts, like poles of each of said magnets being adjacent the same shaft.

6. A tuning device for musical instruments comprising a driving motor of synchronous type, a driving shaft actuated by said motor, a driven shaft journaled substantially parallel to said driving shaft, a pair of rollers of ferromagnetic material mounted respectively on said shafts, at least one of said rollers being in the form of a stepped cone successive steps whereof bear different ratios of diameter to the portion of the other roller opposite thereto, a transfer roller of ferromagnetic material having a cylindrical surface engageable optionally with both of said rollers at any step of said cone roller, said transfer roller when so engaged being supported only at its contacts with said other rollers and free of other contacts, a magnet positioned to establish a substantially complete ferromagnetic circuit through said transfer roller and portions of each of said other rollers, and means for comparing the rotational frequency of said driven shaft with a frequency generated by an instrument to be tuned.

7. A tuning device in accordance with claim 6 wherein said frequency comparing means comprises means actuated by said driven shaft for generating an electrical wave of a frequency integrally related to the rotational frequency of said driven shaft, a microphone for picking up a frequency generated by the instrument to be tuned, an oscilloscope, and means for applying said electrical wave and the output of said microphone to said oscilloscope to deflect the index of the latter in two dimensions.

8. A tuning device in accordance with claim 6 including a power supply for said motor comprising a stable oscillator adjustable over a range of frequencies of at least 6% of its minimum frequency.

9. A tuning device in accordance with claim 6 wherein successive steps on said cone roller bear ratios of diameter to the portion of the other roller opposite thereto which differ by a factor equal to the difference in frequency of half tones of a musical scale.

10. A tuning device in accordance with claim 6 wherein successive steps on said cone roller bear ratios of diameter to the portion of the other roller opposite thereto which differ by a factor equal to the twelfth root of two to provide an evenly tempered scale.

11. A tuning device in accordance with claim 6 wherein said frequency comparing means include an optical cam mounted on said driven shaft, said cam including light absorbent areas and non-light absorbent areas, a light source, a photoelectric cell and an optical system for directing a beam of light from said source onto said cell, said optical cam being interposed in said beam to absorb a variable proportion thereof depending on its angular position, an amplifier fed by the output of said cell, and means for comparing electrical waves delivered by said amplifier with waves generated by the instrument to be tuned.

12. A tuning device in accordance with claim 11 wherein said optical cam comprises an integral number of light absorbent portions, each such portion being in the form of an arithmetic spiral.

13. A tuning device in accordance with claim 6 wherein said frequency comparing means comprises a circular element mounted on said driven shaft, said element including at least one area differing in light-reactive value from other areas of said element, means for illuminating said element, microphonic means for translating sounds produced by the instrument to be tuned onto electric waves, and means dependent upon said waves and the differing light-reactive values of different areas of said element for comparing the frequency of rotation of said element with the frequency of said electric waves.

14. A tuning device in accordance with claim 6 wherein said transfer roller comprises a pair of spaced circular pole pieces the peripheries whereof form the bearing surface of said transfer roller and are so dimensioned that both will contact one step of said cone roller simultaneously, and said magnet comprises a permanently magnetized bar of high coercive-force material interposed axially between said pole pieces.

15. A tuning device in accordance with claim 6 wherein said magnet comprises a bar of ferromagnetic material spanning said shafts, and said transfer roller is formed of material of low coercive force.

16. A tuning device in accordance with claim 6 including an additional magnet, said magnets comprising bars of ferromagnetic material spanning said shafts and having like poles adjacent the same shafts, whereby a consequent pole is formed on both rollers intermediate said magnets, the position of said poles being determined by the position of said transfer roller.

17. A tuning device in accordance with claim 6 wherein the rollers on said driving and driven shafts comprise a pair of complementary stepped cones, whereby the separation between said rollers is substantially constant throughout the length thereof.

18. Means for producing a plurality of electrical waves the relative frequencies of which correspond to a musical scale comprising a driving motor of the constant-speed type, a driving shaft connected for rotation by said motor, a driving roller of ferromagnetic material mounted on and fixed to said shaft, said roller comprising at least twelve sections to correspond to an octave of the chromatic scale, an equal number of driven roller sections of ferromagnetic material mounted for rotation on axes parallel to and opposite said driving roller sections, the ratio of diameters of corresponding driving and driven sections differing from the next higher or lower ratio by a factor equal to the difference in frequency of successive half tones of a musical scale, means for imparting rotational motion from any of said driving sections to the corresponding driven section comprising a transfer roller of ferromagnetic material engaging both driving and driven sections and supported only at its contacts therewith and a magnet positioned to establish a substantially complete ferromagnetic circuit through at least a portion of said transfer roller and driven sections and through at least a portion of said transfer roller and said driving sections, and means associated with all of said driven sections for generating electrical waves the frequency whereof is integrally related to the rotational frequencies of said driven sections.

19. A device in accordance with claim 18 wherein said wave generating means comprises a circular element having areas of light reactive value varying from point to point around the circumference thereof, a light source, a photoelectric cell and an optical system for directing a beam of light from said source to said cell, said circular element being interposed in the path of

said beam, to modulate the latter in accordance with the angular position of said element.

20. A tuning device comprising a ferromagnetic driving roller, a ferromagnetic driven roller out of contact with said driving roller, a ferromagnetic transfer roller positioned to establish linear contact with each of said driving and driven rollers, and a magnet located to establish magnetic flux in at least a portion of each of the driving roller, the driven roller and the transfer roller in such manner that magnetic flux flow in the transfer roller is necessary to complete a magnetic circuit.

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