

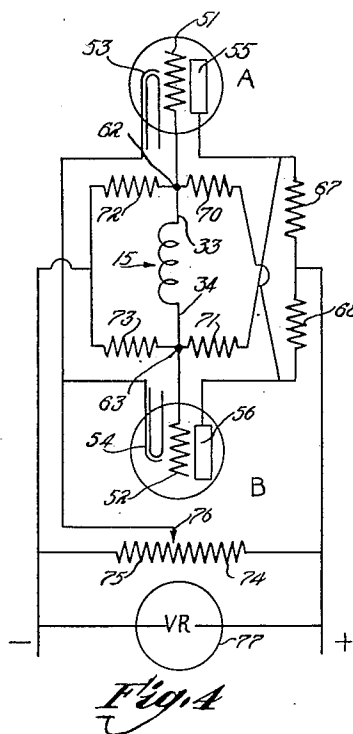
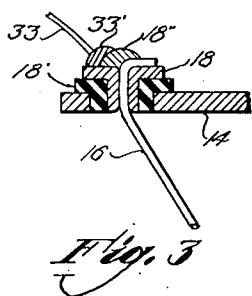
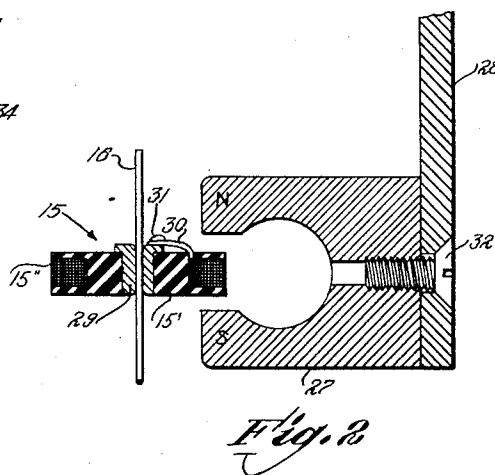
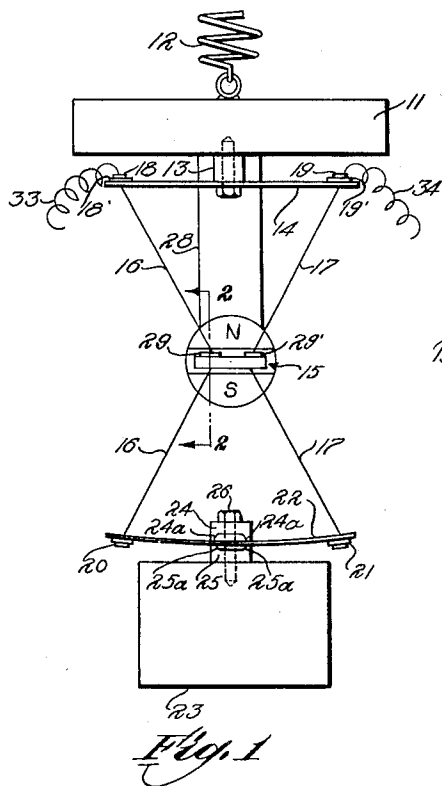
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VIBRATORY FREQUENCY STANDARD APPARATUS

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VIBRATORY FREQUENCY STANDARD APPARATUS

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11 Claims. (Cl. 250—36)

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My present invention relates to time measuring instruments including particularly vibratory frequency standard devices and apparatus. Examples of such devices and apparatus appear in my prior Patents 2,260,847 and 2,260,848 of October 28, 1941 issued to Warren Telechron Company, the instant invention being by way of improvement upon the substance of said patents.

Among the objects of the invention are to avoid objectionable torsional vibration effects in the vibratory element, to increase the voltage output from the vibratory unit with resultant decrease in external disturbance effects and reduction in amplification requirements, and to obviate separate driving means and plural circuits for the vibratory element. These and other advantages including novel provision for adequate temperature compensation will be evident from the following description in connection with the accompanying drawings, wherein:

Fig. 1 represents in front elevation one form of vibratory device embodying the invention;

Fig. 2 is an enlarged sectional view as if on the line 2—2 of Fig. 1;

Fig. 3 is a detail sectional view, also on a scale larger than Fig. 1, showing one of the anchorage arrangements as for example at the upper left in Fig. 1; and

Fig. 4 illustrates an electrical driving and control circuit comprised in the apparatus and especially adapted for use with the device of Figs. 1 to 3.

The invention will best be understood from a consideration first of the mechanical, electromagnetic and electronic means of the illustrative embodiment in the accompanying drawings. Referring now to Figs. 1 to 3, the apparatus or vibratory unit in some instances have rigid support but preferably and as shown a mass 11 on which all other mechanical parts are mounted is resiliently suspended from a suitable support (not shown) as by a spring 12. A double cantilever, bridge or bar 14 is centrally secured to the supporting mass 11 as by bolting or otherwise, a spacer 13 being interposed between the bridge member and the mass. This upper bridge member 14 and a generally similar lower bridge member 22 operatively present a pair of tensioned vibrating elements 16 and 17 hereinafter referred to as wires, these being composed of electrically conductive strands, strips or like elongated members.

The upper ends of the wires 16, 17 are respectively attached at the opposite ends of the upper bridge piece 14, for example as seen in more de-

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tail in Fig. 3. The adjacent end of the wire 16 is secured in a metallic anchor 18 insulated from the bridge 14 as by a non-conductive grommet or the like 18', the wire 16 being fastened to the anchor 18 as by hard soldering as at 18''. One external lead wire 33 is connected in electrical communication with the wire 16 as by soft soldering to the anchor 18 as at 33'. The second vibratory wire 17 of the pair similarly has the upper end connected to the other end of the bridge 14 by a corresponding anchor 19 with insulating grommet 19', the other external lead 34 being attached to the anchor 19 similarly as in Fig. 3.

At the lower ends the vibratory wires 16, 17 are attached to the respective ends of the lower bridge 22 by means of fastenings 20, 21 which may be similar to those for the upper ends of the wires except that no lead connections are here needed.

At an intermediate portion of their lengths the two vibratory wires 16 and 17 support a coil designated generally at 15 which under this invention takes part in the plural functions of actuator and of controller in lieu of a plurality of separate elements therefor as in my prior patents noted. This coil 15 positioned upon the wires 16, 17 by extending the latter fixedly through corresponding metal bushings 29, 29' set in the spool or core 15' of the coil at diametrically spaced locations thereon. The coil 15 and bushing 29 for the wire 16 are seen on a larger scale in Fig. 2. The ends 30 of the coil winding 15' are respectively secured to the metal bushings 29, 29' and hence electrically to the wires 16, 17, one coil end 30 and the solder connection 31 to the bushing 29 being seen in Fig. 2.

The two wires 16, 17 are kept in tension by a weight 23, Fig. 1, suspended thereon through the medium of the lower cantilever 22. The attachment of the weight 23 as shown is by means of upper and lower blocks or jaws 24, 25 at opposite faces of the bridge piece 22 and having opposed gripping projections 24a, 25a. The blocks are clamped to the bridge 22 and secured to the weight 23 as by a through bolt 26. Accordingly an accurate distance is maintained between the points of clamping of the bridge 22 and the points of attachment 20, 21 of the wires 16, 17 thereto.

In association with the wire-supported coil 15 there is provided, noting particularly Fig. 2, a strong permanent magnet 27 having opposite poles N and S. This magnet is mounted on the mass 11 as by a pendant bracket 28 to which

the magnet is secured as by a screw bolt 32. The permanent magnet 27 is thus so disposed that the poles thereof are presented one above and one below the adjacent or rear portion of the coil 15, a portion thereof which is offset perpendicularly from the plane of the twin wire and bridge system. That is, the arrangement is such that a portion of coil 15 which projects generally perpendicularly to the main plane of the system is placed directly in the field of the magnet 27. By this provision of a relatively fixed permanent magnet in operative association with a coil on and movable with the vibratory element a powerful magnetic field is made available.

Referring again to Fig. 1, the distance between the bushings 29, 29' of the coil 15 at which the vibratory wires 16 and 17 support the coil is deliberately made different to, herein considerably less than, the lengths of the individual bridges 14 and 22 between the respective points of wire connection 18, 19 and 20, 21 thereat. Accordingly the twin vibrating wires 16 and 17 are each given an angular and herein opposite re-entrant formation, together approximating the shape of a letter X. In this angular formation the wires 16, 17 are disposed in a single plane, presenting a stiff uni-planar structure resisting forces acting in the common plane thereof. Hence periodic vibration in any direction within the common plane of the wires is practically impossible. Yet this same angular or X-form structure is free to vibrate periodically in a direction perpendicular to the plane containing the wires 16, 17 while at the same time effects of torsional vibration which have sometimes proved troublesome in previous constructions are substantially eliminated.

For similar reasons the described vibratory structure of the invention, involving separate wires 16, 17 electrically insulated from each other, makes it feasible to mount a vibrating coil such as 15 on the wires themselves. By then associating with the coil a relatively stationary strong permanent magnet such as 27 a comparatively high electromotive force may be had directly in and from the moving coil. The resultant current is carried by the vibrating wires 16, 17 themselves and via the leads 33, 34 to a stationary circuit to be described.

In earlier devices and apparatus of this type a vibrating coil would be impracticable both because of the torsional vibratory effects referred to and because only a single conductor was available for current-carrying purposes and the introduction of a second conductor would objectionably interfere with the vibratory action. Hence prior efforts along this general line, as for example in my patents identified, were limited to mounting a magnet (permanent) on the vibratory element, such magnet necessarily being small and producing a relatively weak field. In consequence the output voltage in earlier instruments was comparatively low as contrasted with that obtainable under the present invention and accordingly was more subject to objectionable influence by external electrical disturbances either of a static nature or arising from alternating fields whether magnetic or electrical. In accordance with the invention as herein disclosed the available voltage generated by the vibratory twin wire element 16, 17 is several times greater than heretofore had. Consequently less amplification is required and the associated electric system may be simplified, making for materially bettered amplitude control.

Still considering particularly Fig. 1, the geo-

metrical form of the vibratory system, including the symmetrical angular or X-arrangement of the twin wires 16, 17 provided by the spreader bridges 14, 22 and the intermediate spanner or tie means offered by the body of the coil 15 (or separately therefrom if preferred) affords automatic temperature compensation. It will be apparent that the bridges 14 and 22 constitute elastic couplings between the corresponding ends of the vibratory wires, as do also the wires between the weighted and the fixedly supported bridges. The materials of these wires 16, 17 and of the bridges 14, 22 are selected to have different temperature coefficients. For example, the selection may be such that a tendency of the wires 16, 17 to elongate and become less elastic and hence of decreased rate of vibration with rise in temperature may be fully offset by a simultaneous increase in length of the bridges 14, 22. In the course of such thermal length changes the angles at the X-formation are altered in such way as to increase the tension in the wires with increasing temperature with resultant effect of increasing the rate of vibration. The reverse applies in case of temperature decrease. In any instance, by proper calculation of the angles at the X or other angular formation of the system any increase in vibratory rate from the relatively different expansion of the wires and the attachments therefor may be made to compensate closely for any change in the vibratory rate produced directly in the wires themselves by temperature change, the converse being true for vibrational rate variations under temperature change in the opposite sense.

The apparatus as a whole further comprises an electrical and electronic circuit so associated with the vibratory device or system such as that of Fig. 1 that vibration therein is maintained at a constant amplitude.

As diagrammatically represented in Fig. 4 such circuit means comprises triode elements A and B, which may be disposed in a common twin tube. The respective filaments or cathodes 53, 54 of the triodes A and B are interconnected and are biased by a slider 76 operable along a voltage divider 74, 75 connected with a direct-current voltage source regulatable by a tube or other voltage regulator 77. The plates 55 and 56 of the respective triodes A and B are supplied from the same or other D. C. source through plate resistors 67 and 68 and are connected directly to ground, one through a high resistance pair 71 and 73 and the other through a similar resistance means 70 and 72.

At intermediate points designated at 62 and 63 on the respective resistance elements 70, 72 and 71, 73, the grids 51 and 52 of the triodes A and B are individually connected. The conjoint driving and control coil 15 of the vibratory system is connected across the same points 62 and 63 as indicated by the lead wires 33 and 34 respectively. Thus the two grids are cross-connected each to the plate of the opposite triode so as to form a circuit which tends to oscillate. It will be noted that no condensers are present in this circuit, wherefore current and voltage impulses are substantially in phase.

The connection points 62 and 63 mentioned are so located that the D. C. voltage to the grids is about equal, and by regulation of the slider 76 the D. C. voltage to the cathodes is made approximately the same.

From the foregoing in connection with the drawings it will be evident that the slightest volt-

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age set up in coil 15 by each minute vibration of the twin-wire vibrator element 16, 17 will be considerably amplified at plates 55 and 56, and that positive feed-back current will appear in the resistances 71 and 70 tending to increase the amplitude of vibration of the wire element 16, 17. This build-up process continues until the generated voltages at the grids approach the points of cut-off of the respective triodes, whereupon constant amplitude of vibration will be maintained. This amplitude can readily be controlled by the position of the slider 76. If desired further amplification of voltage may be had, as by feeding that here available to the grids of other tubes by suitable coupling with the plates 55 and 56.

Thus in further contrast to the prior apparatus as typified by the herein identified patents the improved vibratory time standard of the present invention avoids the use of plural circuits at the vibrating device or system and dispenses with the necessity for plural separate driving and control elements thereat. As herein disclosed the signals created by the vibrating twin-wire element are directly amplified in a push-pull circuit arranged to provide feed-back directly and in exactly the same phase to the generating coil 15. Therefore in effect the one coil serves the plural functions of motor or driving agent and of controller, setting up and maintaining its own vibration at a constant value.

The two wires 16, 17 which with the movable coil 15 constitute the vibrating element themselves furnish all needed connections to the external electrical system. As herein disclosed there is no auxiliary or secondary drive circuit coupled either magnetically or mechanically to a primary or pick-up circuit. Further, in the single conjoint electric driving and control circuit of the invention any phase variations between the output of the vibrating coil and the operation-maintaining feed-back are made exceedingly small by reason of maximum elimination of capacity and inductance effects and through the use of relatively high-resistance connections. The balanced push-pull circuit such as disclosed tends to cancel out the effects of outside electrical or magnetic disturbances upon the system, it being noted that in accordance with the invention there is provided straight resistance amplification of the signal from the vibrating coil with a small amount of in-phase feed-back for maintaining the vibration.

My invention is not limited to the particular embodiment thereof illustrated and described herein, and I set forth its scope in my following claims.

I claim:

1. For frequency standard apparatus, a vibratory system comprising a pair of laterally spaced equal length wires, supporting and tensioning bridges to which the opposite ends of the wires are insulatively connected, means centrally securing one bridge to a support, a tensioning weight attached to the other bridge, means angularly deflecting the wires symmetrically in a common plane so that the wires, bridges and said means define a uniplanar system relatively stiff and resistant to vibration in the plane thereof but adapted to vibrate periodically transversely to that plane, a coil medially carried by the wires for unidirectional vibration therewith, and a relatively stationary permanent magnet positioned to have its field traversed by the vibrating coil.

2. For frequency standard apparatus, a vibra-

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tory system comprising two separate elongated electrically conductive vibrating elements, spreader bridges at the opposite ends of the elements for holding them in spaced and mutually insulated relation, means nonconductively spanning the elements at an intermediate point along them and according them a symmetrical uni-planar form including angularly related portions for each element, fixed supporting means for one bridge, an equipoised tensioning weight attached to the lower bridge, the tensioned elements and bridges disposed in a common plane and being resistant to vibration in that plane but free to vibrate periodically in a direction transverse thereto, a coil intermediately mounted on and electrically connected across the elements so as to take part in the vibration thereof, a fixed strong permanent magnet disposed with its field across a projecting portion of the coil whereby a substantial voltage is set up in the coil attendant on the vibration, and an external electrical connection for each of said tensioned elements.

3. A time measuring instrument comprising generator means including a fixed magnet and a coil movable across the field thereof; means for vibrating said coil at a constant rate including a pair of wires tensioned between opposed cantilever elements and convergently embraced intermediate their ends by said coil whereby the uniplanar wires have a general X-formation, the coefficients of expansion of the cantilevers and wires being such that for a given temperature change the change in elasticity of the wires is compensated by a tension change; and a balanced push pull oscillator connected through said wires to said coil and controlled by said generator and maintaining a constant amplitude of vibration for said coil.

4. The structure of claim 3, wherein the wires become less elastic with increase in temperature and wherein the cantilever elements have a coefficient of expansion predeterminedly in excess of that of the wires and such that for a given temperature rise the change in the angles of the X and corresponding increase in the tension of the wires compensates for the decrease in elasticity of the wires.

5. For frequency standard apparatus, a vibratory system according to claim 1 wherein the coefficient of elasticity of the wires and the coefficients of expansion of the wires and bridges are predeterminedly such that for a given temperature change the change in the length and elasticity of the wires is compensated by a change in tension of the wires, and the rate of vibration of the coil is maintained substantially constant.

6. Frequency standard apparatus comprising a vibratory system including a pair of laterally spaced wires, supporting and tensioning bridges at the opposite ends of the wires, a support for one bridge, the other bridge having a tensioning weight applied thereto, and means angularly deflecting the wires symmetrically in a common plane intermediate the ends thereof whereby the wires and bridges define a relatively stiff, uniplanar system which is substantially non-vibratory in the plane thereof; and a coil element and a permanent magnet in voltage creating relation under relative movement thereof, one element mounted on the wires for vibration therewith and the other element having adjacent relatively stationary support.

7. Frequency standard apparatus comprising a support, a vibratory system suspended thereon

including a pair of laterally spaced vertical wires, upper and lower supporting and tensioning bridges at the opposite ends of the wires, the lower bridge having a tensioning weight thereon, and means convergently tying the wires intermediate the ends thereof whereby the wires, tie means and bridges define a relatively stiff uniplanar system of general X-form limiting vibration to the direction normal to the plane thereof, a permanent magnet element and a coil having a portion thereof in the field of the magnet, one of said elements mounted on and so as to vibrate with the wires and the other element having relatively fixed carriage on said support.

8. In frequency standard apparatus, a vibratory system comprising a support means, a first elastic bridge connected thereto, a second elastic bridge spaced therefrom, a pair of wires connecting said bridges, a gravity weight associated with said second bridge for maintaining said wires under uniform tension, and means engaging and deflecting intermediate portions of said wires uniplanarly into a symmetrical angular geometric form whereby the system is given a fixed reference plane for vibration transverse thereto, the bridges and wires being of materials so selected with respect to thermal length and elasticity characteristics that the effect of thermal length changes on the vibration rate of the wires is compensated by a change in the wire tension.

9. In frequency standard apparatus, a vibratory system comprising a support means, a first elastic bridge connected thereto, a second elastic bridge spaced therefrom, a pair of wires connecting said bridges, a gravity weight associated with said second bridge for maintaining said wires under uniform tension, and means uniplanarly deflecting the wires into a symmetrical geometrical form whereby the system has vibratory capacity only transversely to a fixed reference plane, the coefficient of expansion of the bridges being predeterminedly different from that of the wires, such that for a given temperature change the resultant changes in lengths and in wire tension have a compensating effect on the vibration rate of the wires to maintain it substantially uniform.

10. A time measuring instrument comprising

generator means including a fixed magnet and a coil movable across the field thereof, means for vibrating said coil at a constant rate including opposed cantilever elements, a tensioning weight supported by one cantilever element, and a pair of wires tensioned between said cantilever elements and convergently embraced intermediate their ends by said coil whereby the uniplanar wires have a general X-formation, the coefficient of expansion of the cantilevers and wires being such that for a given temperature change the change in the length and elasticity of the wires is compensated by a change in the force component of said weight expressed along said wires resultant from a change in the angles of said X-formation, and a balanced push-pull oscillator connected through said wires to said coil for the purpose of maintaining a constant amplitude of vibration of said coil.

11. The structure of claim 10, wherein the wires become longer with increase in temperature and wherein the cantilever elements have a coefficient of expansion predeterminedly in excess of that of the wires such that for a given temperature rise the change in the angles of the X-formation and corresponding increase in the tension of the wires compensates for the increase in length of the wires.

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