

Nov. 26, 1940.

C. H. RUMPEL

2,222,688

VIBRATORY FREQUENCY CONTROLLING DEVICE

Filed April 19, 1939

2 Sheets-Sheet 1

FIG. 1

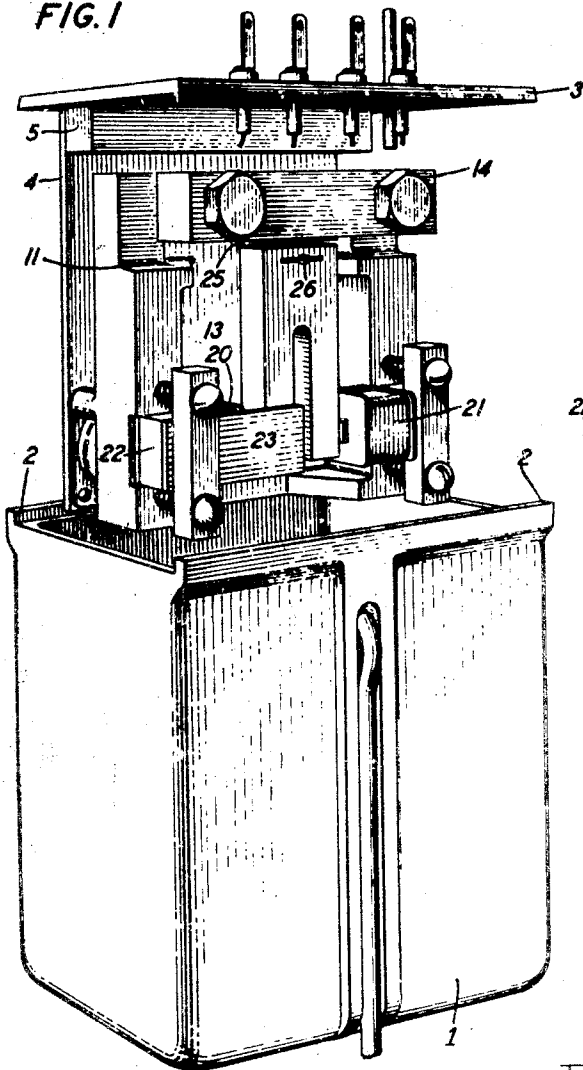


FIG. 2

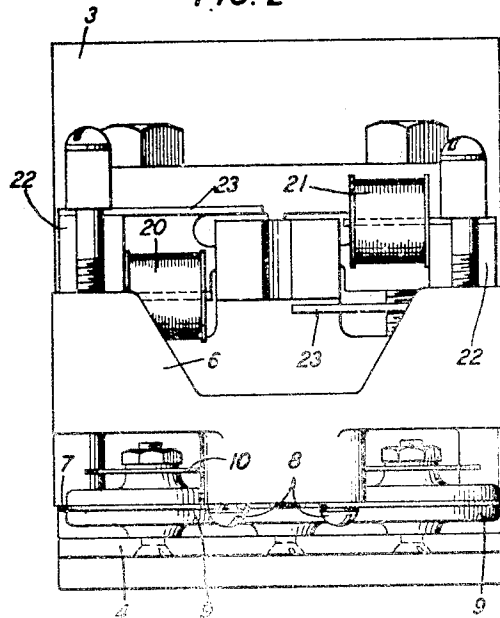
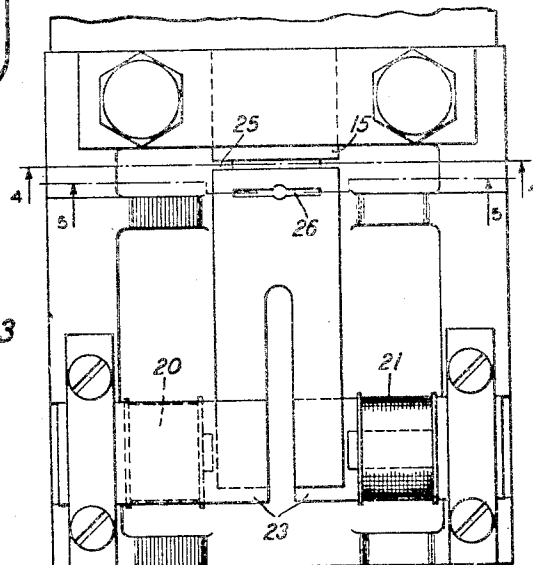


FIG. 3



INVENTOR
C. H. RUMPEL
BY E. V. Griggs
ATTORNEY

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FIG. 4

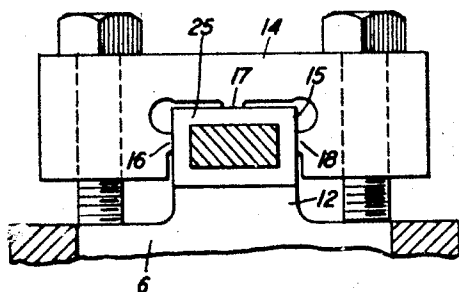


FIG. 5

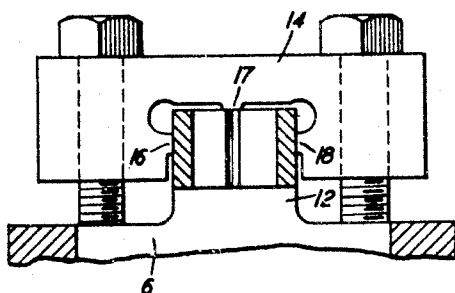
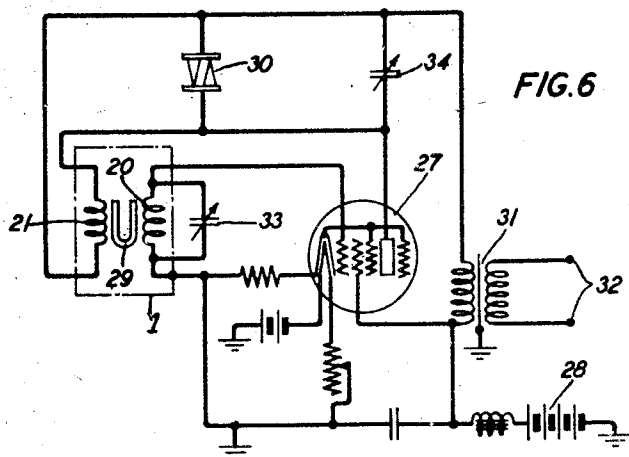


FIG. 6



INVENTOR
C. H. RUMPEL
BY *E. V. Briggs*
ATTORNEY

UNITED STATES PATENT OFFICE

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VIBRATORY FREQUENCY CONTROLLING
DEVICE

Carl H. Rumpel, Jackson Heights, N. Y., assignor
to Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

Application April 19, 1939, Serial No. 268,659

8 Claims. (Cl. 171—209)

This invention relates to oscillation generators and more particularly to vibratory frequency controlling devices adapted to maintain constant the oscillation frequency of such generators.

5 The vibratory characteristics of a tuning fork or other mechanical vibratory member depend upon the conformation, mass and dimensions of the vibratory member and the reaction of its supports and environment. In the case of apparatus designed to produce oscillations within the audible frequency range and to transform the oscillations by a frequency transformation process up to very high frequency waves it is necessary to reduce to a minimum changes in the base frequency due to any cause as, for example, effects of the tuning fork support. This is particularly true where multiplex carrier systems having closely spaced frequency bands with fixed selective systems for separating the bands representing different communication channels, utilize such tuning fork oscillators since a relatively small frequency aberration in the base frequency of the tuning fork oscillator may, when multiplied in the frequency transforming circuit, become intolerable. An object of the invention is to render the period of an electrically excited tuning fork as free as possible from effects of its support.

In accordance with the invention the coupling between the vibrating tine portion of a tuning fork and its stem is reduced by slots and openings which intercept substantially all vibration paths between the tines and stem. The effect on the stem of its support is further largely reduced by a clamping device which engages the stem at several distinct points and serves to hold the fork firmly without presenting substantial areas of contact between the stem and the clamping device at which energy dissipation may occur.

In the drawings, Fig. 1 shows in perspective a tuning fork assembly removed from its casing; Fig. 2 is an end view of the tuning fork assembly viewed from the tine end of the fork;

Fig. 3 is a front view of the assembly;

Fig. 4 is a section of a detail of the fork and its mounting taken along the plane 4—4 of Fig. 3;

Fig. 5 is a similar section along plane 5—5 of Fig. 3; and

Fig. 6 is a schematic diagram of a tuning fork oscillator embodying the invention.

50 Referring to Fig. 1, the casing 1, preferably made of brass and solder dipped to eliminate any possibility of porosity in the casting, is provided with top marginal flanges 2 to receive the cover 3 to which is soldered the supporting back plate 4 and the brace bar 5 which fits into the angle between

the cover 3 and plate 4. The tuning fork and its driving and pick-up coils are mounted on a rugged and massive base casting 6 of bronze or other substantially non-magnetic metal. The base member 6 is fastened to a plate 7 by screws 8 and the plate is supported by three resilient "Lord mountings" 9 on the plate 4. The large mass of the casting 6 serves in conjunction with the resilient support to constitute a mechanical filter in order to substantially prevent vibration energy from entering or leaving the tuning fork mounting. When the tuning fork assembly is withdrawn from the casing 1 as shown in Fig. 1 it may be placed with the back plate 4 down as in Fig. 2 and the entire fork and electromagnetic structure then bears on the three resilient mountings 9 which form the only mechanical link between the fork structure and its ultimate support. The mechanical arrangement is therefore such that the tuning fork is normally floating and comparatively free to move but the maximum amount of motion is restricted by the supporting back plate 4 and a disc 10. The purpose of thus restricting the motion is principally to reduce the possibility of damage during shipment. The mounting while permitting motion of the fork is also rugged enough to insure against permanent displacement of the fork faces with respect to the pole-pieces.

At its upper end the bronze casting is cut away as indicated at 11 and is provided with a raised seat 12 (see Fig. 4) projecting upwardly from its centrally recessed portion 13. A clamping bar 14 bolted firmly to the casting 6 serves to hold the stem 15 of a tuning fork against the seat 12. To reduce dissipation of energy at the boundary surface between the clamping bar and the fork and to decrease the mechanical coupling the bar 14 is so formed, as indicated in Figs. 4 and 5, that it embraces three sides of the stem over relatively restricted areas at the surfaces of the bosses 16, 17 and 18 which are located at approximately the centers of their respective sides. The dimensioning of these machined parts is so exact that the bar 14 must virtually be sprung over the stem 15 and, accordingly, serves to grip it with a vise-like grip on each of the three sides.

The tuning fork as will be apparent from Figs. 1 and 3 is of approximately rectangular external contour. The driving and pick-up coils 20 and 21 are placed adjacent the outer surfaces of the tines with their magnetic cores lying in the direction of motion of the tines which form variable reluctance magnetic gaps with the cores. The

rear portions of the cores terminate in the larger permanent magnets 22 to which are tightly clamped plates 23 of magnetic material which overlie their respective tines with a very small constant magnetic gap spacing to complete the magnetic path. In order to minimize any mutual coupling between the magnetic paths of the two coils, one coil and its core is set with its center line near the plane of the upper surface of the tines and the other coil and core with its center near the plane of the lower surface as may be seen in Fig. 2.

In order to minimize magnetic couplings substantially all parts of the apparatus except the fork itself and the magnetic path elements are constructed of substantially non-magnetic material such as brass or bronze. The fork is carefully machined from a cast billet of a special molybdenum nickel steel alloy described and claimed in the application of J. E. Harris, Serial No. 227,064 filed August 27, 1938, which, while magnetic, is self-compensating in its vibrational frequency characteristics for relatively large changes in temperature. Care is taken to insure that all portions with slag inclusions or which are spongy are discarded so that the fork may be homogeneous throughout. In manufacturing the fork, the billet is originally cast to have a thickness of more than twice that of the fork. It is then hot rolled at 1200° C. to about half its original thickness and the pipe end is cut off. The billet is then heated three hours in a furnace at 950° C. and allowed to cool in the furnace over-night before machining. To avoid springing of the tines they are formed by cutting an open-ended slot in the blank and thereafter the fork is machined all over leaving enough material on the ends of the tines to permit removal after test. After the test and removal of the quantity of material to secure the desired frequency the finished fork may be heat treated in a vacuum at 950° C. for three hours and allowed to cool slowly to room temperature without removal from the furnace.

The effect of energy leaving the tuning fork and entering the fork mounting is that the fork decrement is reduced and its frequency becomes easily affected by small variations which occur in parts other than the fork itself. As has already been stated the mounting including the very massive brass casting carrying the mechanical load of the tuning fork, including the driving and pick-up coil units, and including the highly resilient mounting supports 9, is designed to function as a mechanical filter of the suppression type to prevent transfer of vibrational energy between the assembly and any external mass. In order to reduce the effects on the tuning fork frequency of any parts within the assembly resort is had to an expedient for reducing the coupling between the remainder of the fork and the portion of the stem of the fork which is engaged by the clamping bar and seat. This consists in a combination of slots one peripheral and the other laterally through the center of the stem in such manner as to intercept substantially all vibrational paths from the clamped stem to the tines. The peripheral slot 25 and the through or central lateral slot 26 serve to introduce a mechanical compliance or yielding which serves to shunt the reactions of the fork tines from the clamped portion of the stem and therefore to render these reactions more nearly independent of the variations in the characteristics of the masses which are intimately associated

with the stem. These slots also help to prevent the fork clamp from producing strains in the fork. The effect of mechanical strains in the tuning fork is to bend it out of its proper shape and thus change its frequency and decrement by an amount dependent upon the tightness of the tuning fork clamp. Another species of mechanical filtering action takes place at the surfaces 16, 17 and 18 which, while firmly holding the tuning fork in its place, tend to prevent transfer of a large vibrational effect to the clamping bar 14 and base member 8.

The cover 3 may be soldered to the casing 1 to hermetically seal the device. The electrical leads to the apparatus may pass through insulating seals such as are disclosed and claimed in United States Patent 2,125,315, issued August 2, 1938 to V. L. Ronci. An exhaust tube permits atmosphere to be removed and if desired nitrogen or other inert gas may be introduced. Hermetically sealing and evacuating the device eliminates the effects of atmospheric pressure changes, oxidation, humidity and the mechanical damping of the fork vibrations caused by any air or gas, which would otherwise surround the fork. Introduction of nitrogen may be desirable to insure against leakage of atmosphere into the casing but it is attended with the disadvantage that any gaseous filling, as compared with a vacuum, increases the mechanical damping of the fork and also facilitates transmission of temperature changes.

The circuit of Fig. 6 includes a pentode electron discharge device 27 of well-known type having a source 28 of space current. The source 28 should preferably be of as constant voltage as is feasible and in some cases it may be desirable to provide a regulator. Similarly the cathode heating current and the grid bias should be derived from substantially constant voltage sources. The tuning fork designated by 29 is shown in the feedback path with its associated pick-up coil 20 and driving coil 21. In order to prevent overload of the vacuum tube with its undesirable effects upon frequency of the oscillator a shunt thyrite varistor limiter 30 of the general type disclosed and claimed in United States Patent 2,049,177, issued July 28, 1936 to C. H. Rumpel is employed. As an alternative, the element 30 may consist of a thermo-sensitive resistance such as, for example, that described in the patent to F. W. Lyle, No. 1,094,733 April 28, 1914. An output transformer 31 serves to associate the oscillator with the load circuit 32 to which oscillations of very constant frequency are supplied by the oscillator.

Although the frequency of the oscillator is primarily determined by the vibrational characteristics of the tuning fork it is to a small extent dependent upon the associated electrical circuit since these reactances introduce phase shifts in the transition through the amplifier and feedback paths. The oscillating system adjusts itself to that frequency at which during operation of the device the phase shift through the vacuum tube, tuning fork and associated electrical circuit amounts to 360 degrees. In order to be able to vary the phase shift by slight amounts so as to set the frequency at the precise value required, any means of shifting the phase through the fork driving circuit may be used. This may be accomplished by means of variable capacitors 33 and 34 or a combination of fixed capacitors, if the requirements are not too exact, or a combination of both fixed and variable capacitors. 75

These capacitors are connected across the driving and pick-up coils as shown.

What is claimed is:

1. A tuning fork having a pair of tines and an integral stem, the stem having a slit extending partially thereacross to reduce the coupling between the vibrating tines and the remote end of the stem.
2. A mechanical vibrator comprising an elongated body having one end portion free to vibrate laterally at a periodicity determined essentially by its length, density and elasticity, an integral supporting portion at the end remote from the vibrating end portion, the supporting portion having a circumferential slot therearound and an interior lateral slit therein, the slot and the slit serving together to intercept substantially all vibrational paths of wave motion from the vibrating portion to the remote end of the supporting portion whereby the effect upon the frequency and decrement of vibrations of the vibrating portion caused by engagement of the supporting portion with other masses is materially reduced.
3. A tuning fork having a pair of tines and an integral stem, a massive metallic base member having a supporting surface, a clamp connected to the base member and holding the stem of the tuning fork firmly in contact with the supporting surface, the clamp comprising a unitary member having a plurality of widely separated integrally connected small area contacts with the stem whereby imposition of bending stresses affecting the vibrating characteristics of the fork is reduced.
4. A tuning fork having a pair of tines and an integral rectangular stem member, a massive base member having a flat supporting surface in contact with one side surface of the stem, a U-shaped clamping member encircling the stem and having projecting portions contacting therewith over relatively small areas, and means for holding the clamping member in fixed position with respect to the massive base member to clamp the stem firmly thereagainst.
5. A tuning fork comprising a pair of tines and an integral stem, a massive base member, means contacting with the stem at a plurality of small areas for clamping the stem firmly against the base member and a lateral incision extending partly across the stem at a point between the tines and the clamping means whereby the effect of the clamping means and the massive base member upon the vibratory characteristics of the fork is greatly reduced.
6. In an electrically driven tuning fork vibrator, in combination, a tuning fork having a pair of tines and a stem, an electromagnetic driving member adjacent one tine and an electromagnetic pick-up member adjacent the other, a massive support to which the tuning fork is clamped to prevent substantial linear shifts of the tines with respect to the driving and pick-up means, and an aperture extending laterally partially across the stem to reduce the effect of undesired coupling between the tines and the massive support.
7. A tuning fork comprising a stem portion and a pair of tines integral therewith at one end of the stem, lateral incisions in the fork intercepting substantially all paths of wave motion from the tines to the stem in order to reduce coupling between the tines and the stem, a massive base member, and means clamping the stem to the base member to prevent permanent displacement of the fork, the clamping means contacting with the stem on three sides over very restricted areas to reduce mechanical coupling between the stem and the massive base member whereby reaction of the massive base member upon the vibrating tines is largely precluded.
8. In combination, a tuning fork, a massive base member, means clamping the fork to the base member and resilient means for supporting the base member, the tuning fork comprising a stem portion to be clamped and vibrating tines integral therewith, and lateral openings between the tines and the stem portion to reduce transfer of vibrational energy between the tines and stem portion, the means for clamping the stem having projections of small surface area contacting with the stem on three sides to reduce transfer of vibrating energy between the stem and the base member, and the massive base member cooperating with the resilience of the supporting means to reduce transfer of vibrating energy through the supporting means.

CARL H. RUMPEL.