

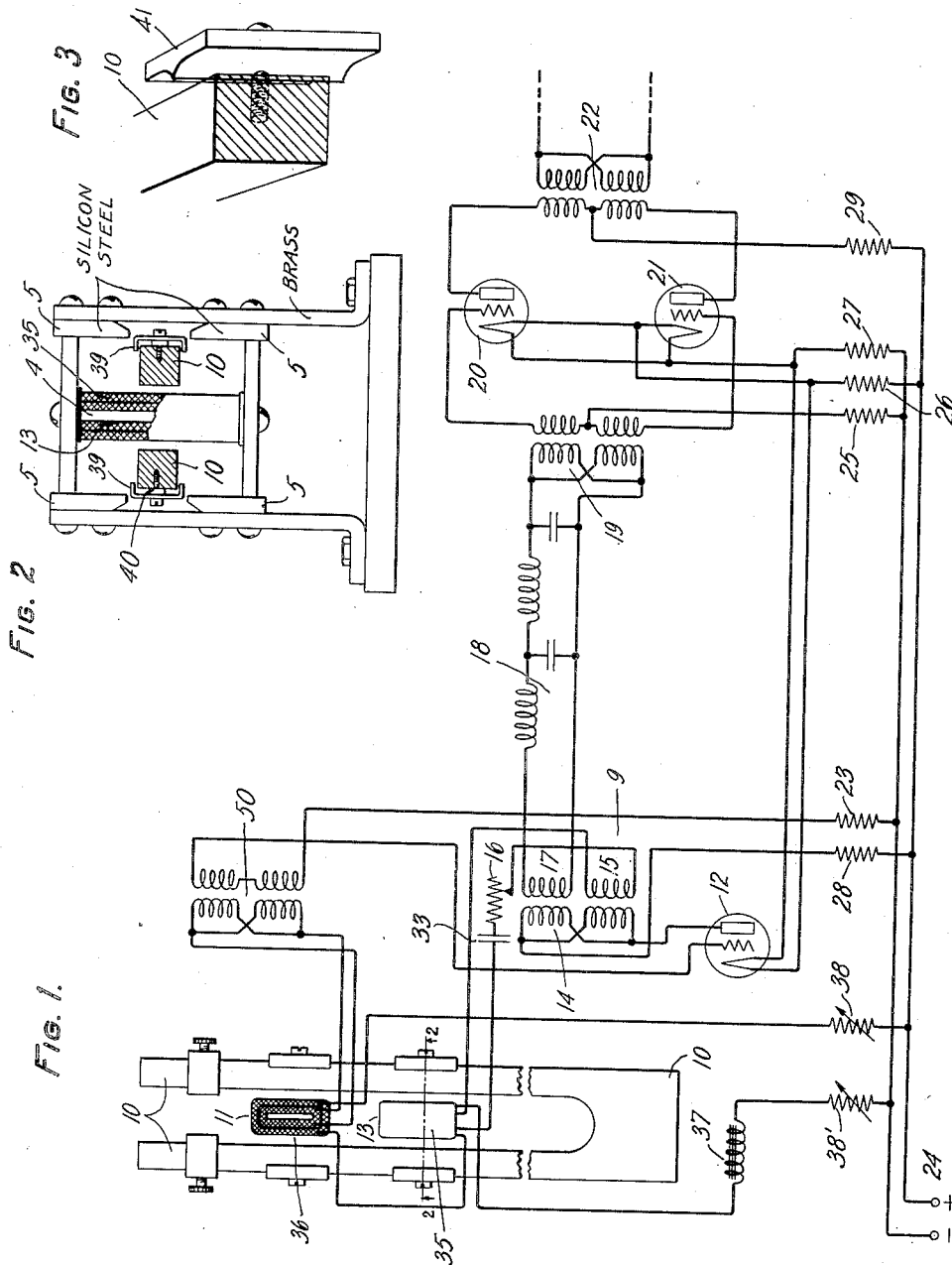
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FREQUENCY SETTING FORK

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FREQUENCY-SETTING FORK

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This invention relates to electrically operated frequency setting or oscillating devices of the tuning fork type such as are used to supply alternating current of very constant frequency.

An object of the invention is to improve the constancy of frequency or speed of such devices.

Another object is to improve the degree of and to simplify the means of compensation for changes in voltage of the current supply sources of such tuning forks.

A feature of the invention is a tuning fork made of a material the elasticity of which is independent of temperature variations.

A further object is to improve the wave form of the alternating current supplied by such a fork.

Other objects and features of the invention will become apparent from the description of its mode of operation.

Vacuum tube regenerative tuning forks customarily comprise a tuning fork of steel, a pick-up coil and a drive coil, and a vacuum tube amplifier connected between them. Each coil is threaded by a magnetic flux from a permanent magnet, the magnetic circuit of which is completed through the steel tuning fork. Vibration of the fork changes the flux threading the pick-up coil, which generates a feeble alternating current; this current is amplified by the vacuum tube amplifier and applied to the drive coil where it reacts on the fork to maintain the latter in vibration.

Forks of the above type, as heretofore constructed, are subject to the difficulties: (1) that there is magnetic coupling, through the steel fork tines, between the pick-up coil and the drive coil, which complicates the original adjustment of the fork; (2) that the force exerted on the fork tines by the drive coil does not bear a simple relation to the amplitude of vibration of the fork, which prevents the fork from being self-starting, prevents it from maintaining itself in vibration if the amplitude falls below a certain critical value, and distorts the output wave; (3) that a slight change in the potential applied to the plate of the vacuum tube amplifier tends to

change the speed of the fork, this necessitating the use of a third or compensating electromagnet mounted opposite the tine ends for the purpose of permitting a variation of the damping and effective elasticity of the tines to be produced by a change of voltage in such a manner that frequency changes are prevented; (4) that this compensating electromagnet draws considerable power from the fork, increasing its damping and reducing the effective power output; (5) and that the fork, being made of tool steel the elasticity of which changes appreciably for small changes in temperature, must be maintained at a very constant temperature, if it is to run at constant speed.

The manner in which the present invention overcomes these difficulties will be understood from the following description taken in connection with the accompanying drawings, in which:

Fig. 1 represents schematically a vacuum tube circuit controlled by a tuning fork in accordance with the principles of the invention;

Fig. 2 shows a transverse section along line 2-2 of Fig. 1 for the purpose of showing certain details of fork design; and

Fig. 3 shows a perspective view partly in cross section of another detail of fork design.

In Fig. 1 the fork-controlled oscillator circuit comprises tuning fork 10, pick-up coil 11 which feeds into the input circuit of vacuum tube 12, through transformer 50, provided for increasing the grid voltage to the required value, and driving coil 13. Primary winding 14 of transformer 9 in the output circuit of tube 12 impresses a portion of its energy upon winding 15 which is coupled back through adjustable resistance 16 and condenser 33 to driving coil 13. Another portion 17 of the secondary winding of transformer 9 feeds through filter 18 into transformer 19 connected as shown to the amplifying tubes 20 and 21. Transformer 22 is connected in the output circuits of said amplifier. Direct current source 24 is provided for the supply of all necessary power to the fork circuit. The filament heating current flows through resistance 26 from the positive

side of source 24, and completes its circuit through the tube filaments and resistance 27 to the negative side of source 24. The drop of potential across resistance 27 is effective as a negative biasing voltage on the grids of the tubes. The plate currents are supplied through resistance 28 in the case of the tube 12, and through resistance 29 for tubes 20 and 21. Resistances 23 and 25 are inserted in the grid circuits of tubes 12, 20 and 21 merely for the purpose of preventing a destructively large current being drawn from the source 24 in case of accidental crosses in the wiring or other failures of the apparatus. The connections of transformer 50, driving coil 13, and pick-up coil 11 to the vacuum tube 12 are such as to constitute a regenerative circuit when considered with relation to their effect on the fork.

In accordance with the present invention the drive magnet and pick-up magnet shown at 13 and 11, Fig. 1, respectively, of tuning fork 10 are so designed that there is no appreciable magnetic coupling through the fork tines between these two circuits. This is accomplished by causing the flux to traverse the fork tines only in the direction perpendicular to their length, thus including in the magnetic circuit a relatively small portion of the tuning fork material, if this is magnetically permeable. The drive magnet 13 is not permanently magnetized but carries a magnetizing winding 35 energized by the voltage supplying the amplifying tube and wound upon the magnet core shown at 4 in Fig. 2. The magnetic circuit of this coil divides and passes vertically through the fork tines, if these are of magnetic material such as ordinary steel, or through small plates or shoes of magnetic material 39, if the fork is made of a non-magnetic material. In the case where the tines are made of a magnetic material, the polarities of the poles of the drive and pick-up coils are chosen so as to avoid cross circulation of flux along the tines between the cores. In order that the small plates or shoes may complete the magnetic circuit of the drive and pick-up magnets without appreciably interfering with the free motion of the fork tines, they are not in direct contact with the tines for any appreciable portion of their length. In one embodiment of this feature of the invention the plates 39 are separated from the tines 10 by interposing small washers 40, as shown in Fig. 2. These washers restrict the binding effect to a small portion of the length of the plates. Alternatively the plates may be given the form of a knife-edge 41 and sustained against the tines 10 as shown in detail in Fig. 3. Silicon steel has been found to be a suitable material for plates 39 or plates with knife-edges 41.

In accordance with another feature of this

invention the fork tines are made of a material the elasticity of which changes very little with temperature variations, thus reducing the necessary accuracy of temperature regulation. One material which has been found to be suitable for this purpose is a steel comprising about 36% nickel, 12% cobalt and the balance iron.

Furthermore, the poles of the drive magnets, made of silicon steel, are shaped as shown at 5 in Fig. 2, and they are located in such a manner with respect to the fork tines that the force exerted by the drive magnet poles does not decrease very rapidly as the amplitude of vibration decreases, nor increase very rapidly as the amplitude of vibration increases, but instead remains approximately constant for amplitudes of vibration up to a certain value, after which the tension of the poles is reversed and the fork tends to stabilize itself at an amplitude set by the dimensions and relative positions of the poles. The poles of the pick-up magnet, also made of silicon steel, are similarly shaped and located and give a voltage which increases with the amplitude of vibration up to a certain value, after which it becomes relatively constant. It has been found as a result of this design that in particular cases the tuning fork can be made self-starting or may be started from rest by a slight disturbance in the amplifier circuit, and that the tendency for the amplitude to increase until the tines strike the pole pieces, which was troublesome in previous designs, is obviated.

In accordance with the present invention a high degree of perfection in speed regulation is attained and voltage compensation obtained by taking advantage of the characteristics of the drive and pick-up magnets. These magnets are not permanently magnetized but carry magnetizing windings, schematically shown at 35 and 36, which are energized by the voltage which supplies the fork amplifier. A choke coil 37 and adjustable resistances 38 and 38' are inserted in this circuit to prevent power being drawn from the amplifier by the magnetizing windings. The force exerted by the poles of the driving magnet on the tines of the fork is a function of the square of the sum of the permanent flux produced by the direct current effective in winding 35 and of the alternating flux due to the current fed back from the output circuit of amplifier 12 into coil 13. The effective permeability of the core of the driving coil, however, is influenced by the steady flux due to the magnetizing winding; as a result the force exerted by the poles increases as the magnetizing current is increased up to a certain value, after which it decreases. A similar effect takes place in the pick-up coil in which the voltage generated by the motion of the tines is first increased

by an increase in the magnetizing flux and later decreased. The combination of these two effects causes the amplitude at which the fork vibrates to increase as the voltage on the magnetizing windings 35 and 36 of the drive and pick-up coils is increased up to a certain value and then to decrease. In order to utilize this effect in compensating for variations of the amplifier voltage supply, the cores of either or both the drive and pick-up coils are magnetized by current drawn from the source which supplies the amplifier; a proper selection of the normal value of this current causes the changes in the magnetization, caused by variations in this voltage, to produce changes in efficiency of the fork magnetic circuits which just compensate the changes in efficiency of the amplifier resulting from the same voltage variations. A proper adjustment of the air gaps between the pole faces and the tines of the fork permits this value of magnetizing current to be made quite near to the value which gives the most efficient operation of the fork. In this manner the fork is compensated for changes of line voltage and made to maintain a substantially constant frequency of vibration without the use of the additional compensating coil referred to above.

30 What is claimed is:

1. In an electrically driven tuning fork comprising a vacuum tube amplifier having a source of cathode-anode potential, means for maintaining said fork in vibration, polarizing means in combination with said vibrating means and energized from said source of cathode-anode potential independently of the amplifier cathode-anode current.

2. A vibrating body having an inherent natural period, electric pick-up and electric drive means coupled thereto, an amplifier having a current supply source and of efficiency variable with the voltage of its current supply source coupling said pick-up and drive means, said pick-up and drive means being at least in part energized by an electrical energizing element of characteristic such that the efficiency of said means changes with changes in said voltage but in an opposite direction to the change in efficiency of said amplifier, said energizing element being connected to said source and being independent of the output current of said amplifier.

3. An electrically driven tuning fork having pick-up and drive coils, a vacuum tube amplifier therefor having a source of operating potential, characterized in this, that each pick-up and drive coil has associated therewith a coil for polarizing its core, energized from said source of potential independently of the amplifier output current.

4. A vacuum tube regenerative tuning fork having pick-up and drive coils, characterized in this, that the coils are so positioned with respect to the vibrating members of the fork

that their magnetic fluxes pass through the fork only in a direction transverse to its length.

5. A vacuum tube regenerative tuning fork having pick-up and drive electromagnets so positioned with respect to the vibrating members of the fork and having pole faces of such width that an increase in the effective driving force of the drive coil cannot produce a proportionate increase in the amplitude of vibration, above a predetermined maximum amplitude.

6. A constant frequency tuning-fork-driven vacuum tube oscillator characterized in this, that the vibrating members of the fork are made of a material comprising about 36% nickel, 12% cobalt and the rest iron.

7. A method of obtaining compensation for line voltage changes in a regeneratively driven tuning fork, which consists in utilizing the change in magnetic permeability of the core of at least one of the drive and pick-up coils, caused by a variation in the polarizing flux derived from the line voltage, to affect the efficiency of said coil or coils in the sense and to the degree necessary to offset the change in efficiency which the same change in line voltage causes in the amplifier.

8. In a constant frequency vacuum tube regenerative tuning fork having pick-up and drive coils, means for avoiding magnetic coupling through the tines of said fork comprising independent paths of low reluctance for the magnetic lines of force emanating from said coils.

9. In an electrically driven tuning fork having tines made of material having high magnetic reluctance, the method of reducing the reluctance of the magnetic circuit which comprises causing only a minor portion of the lines of magnetic flux to traverse said tines and causing a larger portion of said flux to traverse magnetic material supported by said tines but not in direct contact therewith for a material length thereof.

10. A tuning fork having pick-up and drive coils with magnetic cores having pole faces narrow with respect to the direction of movement of the fork tines and magnetic pole faces mounted on said tines adapted to oscillate across the narrow dimension of said pole faces.

11. The method of rendering self-starting a vacuum tube regenerative tuning fork having pick-up and drive coils, which method comprises giving the poles of the pick-up and drive coils such a location with respect to the fork tines that the force exerted by the poles of said coils does not decrease very rapidly as the amplitude of vibration decreases, nor increase very rapidly as the amplitude of vibration increases.

12. A frequency control system comprising in combination a mechanical vibratory member having electric pick-up and electric drive

coils coupled thereto by a space discharge
amplifier having a source of space current,
means for producing a magnetizing force
variable with the voltage fluctuations of
5 said source, said means being independent of
the space current and being connected to said
source for energizing the core of at least one
of the pick-up and drive coils in such a man-
ner as to cause the interaction between the
10 coil and the vibratory member to increase as
the voltage of said source increases to a cer-
tain value and then to decrease.

13. A system as defined in claim 12 fur-
ther characterized in this, that said interac-
15 tion is a function of the effective permeabil-
ity of the core of said coil.

In witness whereof, I hereunto subscribe
my name this 1st day of October, 1928.

AUSTEN M. CURTIS.

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