May 6, 1930. A. M. CURTIS 1,757,704

CONTACT DRIVE VIBRATORY FORK

Filed Oct. 29, 1927

FIG. 1

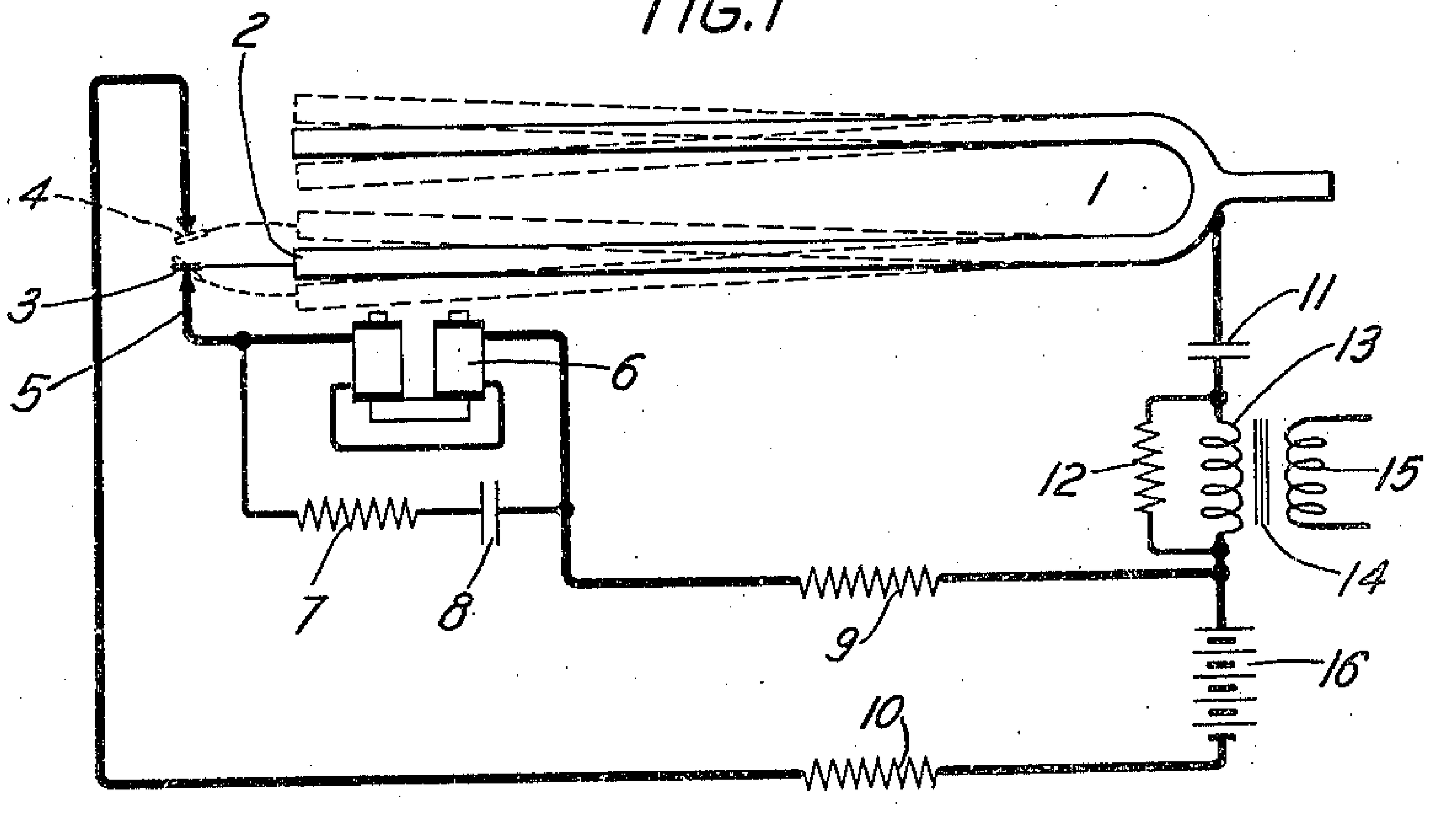


FIG. 2

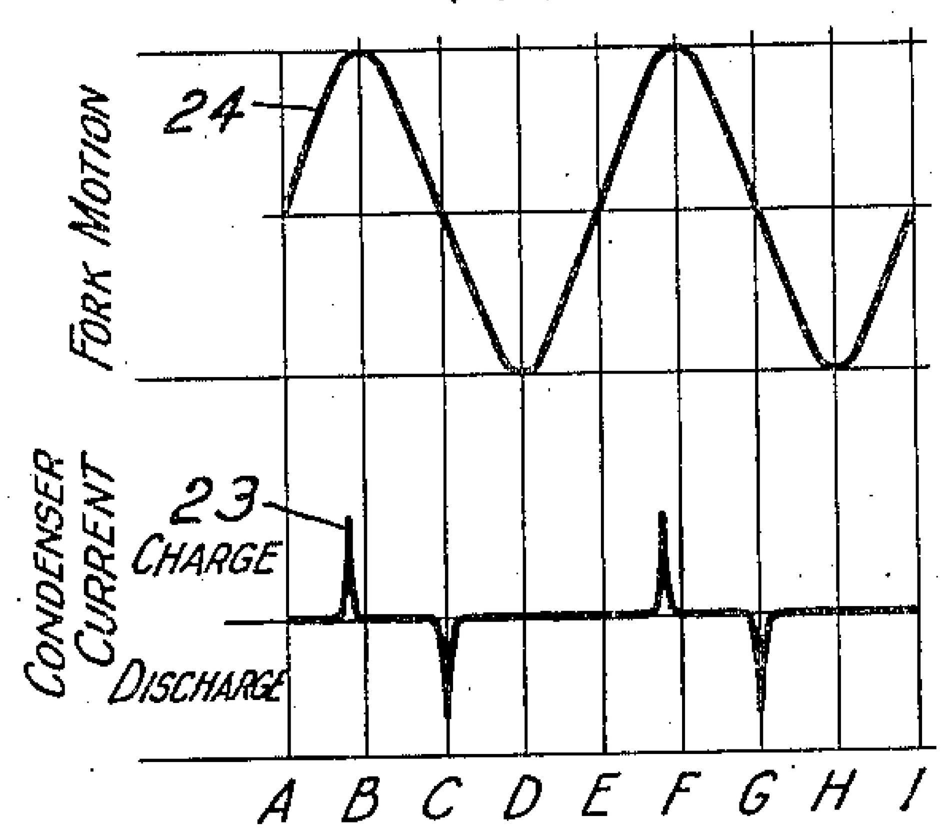


FIG. 3

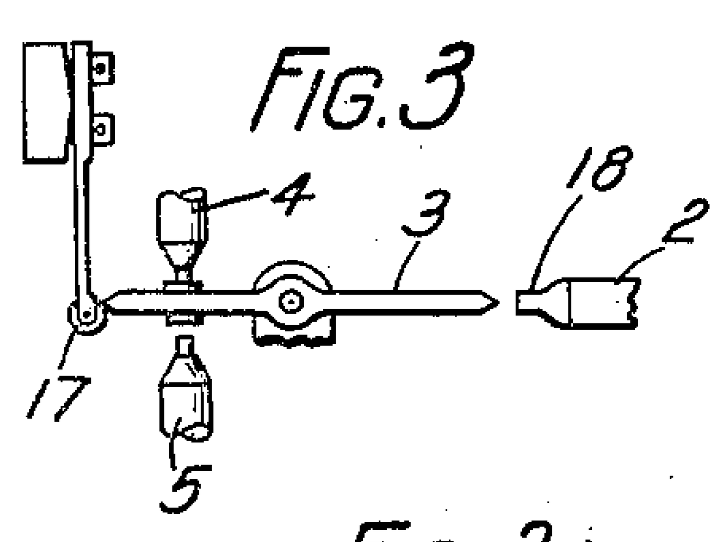


FIG. 4

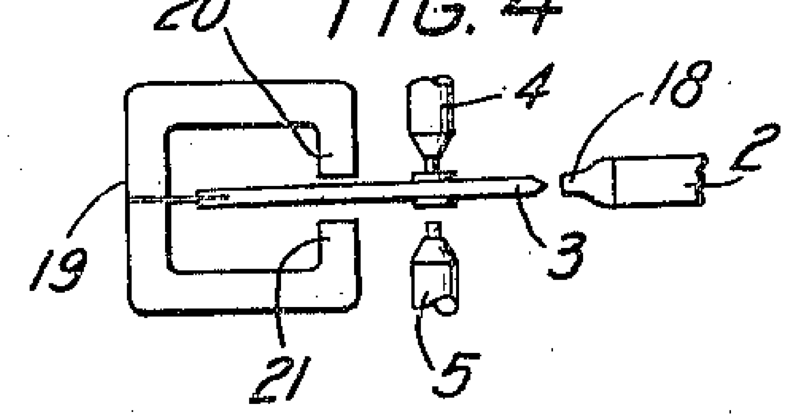


FIG. 3A

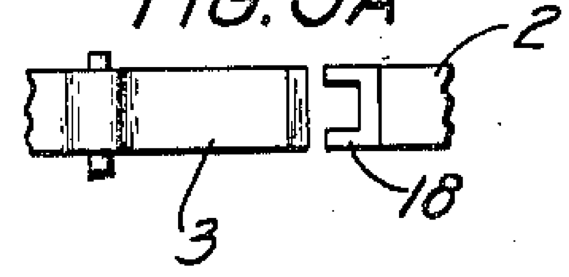
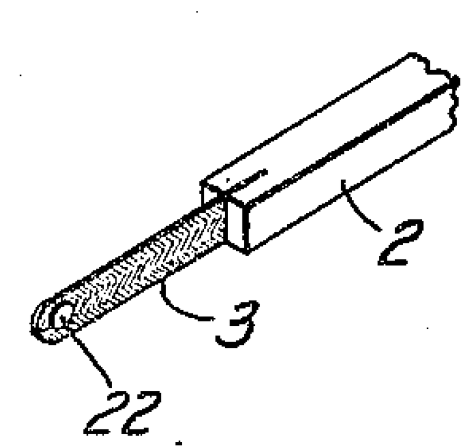


FIG. 5



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1,757,704

UNITED STATES PATENT OFFICE

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CONTACT-DRIVE VIBRATORY FORK

Application filed October 29, 1927. Serial No. 229,772.

This invention relates to electrically driven tuning forks and its object is a fork that combines the simplicity and cheapness of the conventional contact drive fork with a degree of accuracy and reliability in operation heretofore only associated with vacuum tube regenerative forks.

Electrically driven tuning forks are used as sources of waves of constant frequency and have particular application as frequency controllers in synchronous communication systems. In the past, two general types of excitation have been used to vibrate such forks. In the oldest and most generally used type the fork tines are periodically attracted by an electromagnet excited from a source of direct current received through a fixed contact and a contact on the fork prong, in the same manner as a simple buzzer is actuated. That type of fork has the serious disadvantages that the driving force is applied to the fork tine as a long impulse when the tine is near the end of its swing and that the length of the impulse depends on the amplitude of vibration. Thus if from any cause, such as a variation in the voltage of the power supply, the amplitude of vibration increases, the longer contact closure tends to still further increase the amplitude. Since the frequency of vibration of a tuning fork is a function of the amplitude, slight variations in the supply voltage produce excessive variations in the frequency. That type of drive furthermore, requires a relatively heavy exciting current, which must be broken by the fork contacts. This sometimes causes sticking and burning of the contacts which not only necessitates frequent attention but also tends to make the fork erratic in operation. It has been realized before that a driving impulse applied to the fork prong as it passes through its normal position of rest, would be much more effective and would require a smaller effective operating current. Some systems have been developed which utilize this principle but they have required rather complicated mechanisms which more or less defeated the attainment of a reliable, accurate fork.

The second type mentioned above is the vacuum tube regenerative fork in which the motion of the fork changes the flux in the core of an electromagnet placed in inductive relation thereto and generates a weak alternating current in the winding. This weak current is amplified in a vacuum tube amplifier and applied to the fork-driving-electromagnet. With such an arrangement all current breaking contacts are eliminated and vacuum tube regenerative forks are noted for their accuracy and reliability. However, they are more expensive and more complicated than ordinary contact drive forks.

This invention comprises a contact drive fork in which the driving impulse is applied to the fork tine when it is passing through its normal position of rest, and in which the contacts are not required to break a current during normal operation. The above effects are obtained by utilizing a condenser so connected in the driving circuit that it is charged once during each cycle, through a back contact of the fork and subsequently discharged through a front contact of the fork and the driving electromagnet as the fork tine passes through its mid-point.

The invention will now be explained in connection with the drawing, in which:

Fig. 1 shows a preferred embodiment of a circuit embodying the invention;

Fig. 2 contains curves illustrating the operation of the circuit of Fig. 1; and

Figs. 3, 3A, 4 and 5 show various types of contacts that may be used on the tuning fork of Fig. 1.

Referring to Fig. 1 a tuning fork 1 has a tine 2 carrying a contact 3 arranged to engage a fixed back contact 4 or a fixed front contact 5. A driving electromagnet 6 is mounted in inductive relation to prong 2 and has its winding connected between contact 5 and one pole of battery 16. A transformer 14 having a primary winding 13 and a secondary winding 15 is used to supply a load circuit with alternating current of the frequency of vibration of the fork. A large condenser 11 of several microfarads capacity is connected in series with the transformer primary winding 13 and is an important feature of the system. Resistance 7 and condenser 8 shunted across driving magnet 6 are to damp the inductive effect, on the rest of the circuit, of the driving magnet. Resistances 9 and 10 are to control the current flow when condenser 11 charges and discharges, and a low resistance 12, shunted across the primary of the output transformer 14 is to effectively remove from the circuit including condenser 11, the large inductance of the transformer primary winding. Resistances 7, 9, 10 and 12 and condenser 8 may be disregarded in following the operation of the system.

The operation of the system shown in Fig. 1 will now be explained in connection with the curves of Fig. 2. Curve 24 represents the vibration of the fork and curve 23 the current through the contact 3, both plotted against time. Assume that the fork is in vibration and that at time A (see Fig. 2) the prong 2 is moving away from driving magnet 6 and that moving contact 3 has just broken contact with fixed contact 5. The fork prong 2 continues its swing upward and at time B has reached its uppermost position, in which contact 3 makes on contact 4 and closes a circuit from the upper plate of condenser 11, through the tuning fork, contact 3, contact 4, battery 16, and the primary winding of transformer 14 to the lower plate of condenser 11, and charges condenser 11 to the potential of battery 16. Curve 23 represents the direction and time duration of current flowing in the condenser circuit, charging impulses being represented as positive values and discharges as negative. Tine 2 having completed its upward swing returns to its mid-point as represented at C in Fig. 2 and causes contact 3 to close on contact 5. This closes a circuit from condenser 11 through the tuning fork and contact 3, contact 5, driving magnet 6, resistance 9, and primary winding 13 of the output transformer 14 to the other plate of condenser 11. Condenser 11 therefore discharges through the circuit just described, as disclosed in the curve 23 of Fig. 2 and energizes driving magnet 6 which thus momentarily attracts the tine 2. The fork tine 2 continues its travel and at time D has reached its lowermost position and at time E has again returned to the midpoint and causes contacts 3 and 5 to open. Since the discharge of condenser 11 was of only momentary duration no current is flowing across contacts 3 and 5 at time E when they break, and no destructive sparking can take place.

Theoretically there is practically no current flowing through the contacts at the time they are broken and this condition would be attained in practice providing chattering could be entirely eliminated. Actually, it is very difficult to obtain a moving contact such as shown in 3 of Fig. 1 that will not rebound or bounce slightly from impact with the fixed contacts. Since this rebound may occur before the condenser 11 has completely charged or discharged it may result in some slight sparking at the contacts. To reduce chattering to the minimum special contacts have been devised and are illustrated in Figs. 3, 3A, 4 and 5.

Of the three types of contacts shown, that in Fig. 5 is to be preferred. It consists of a flexible ribbon 3 woven of bronze wire which is rigidly attached to the fork prong 2 and carries a welded contact point 22 at its free end. The woven bronze ribbon 3 is flexible and elastic, but is effectively damped by the internal friction between the individual strands, of which it is composed, so that it has little or no tendency to vibrate at a natural frequency of its own.

In the arrangement of Fig. 3 the contact arm 3 is pivoted to swing freely between the fixed contacts 4 and 5. It is not attached to the fork tine, but is coupled thereto by magnetic attraction, a small permanent magnet 18 being mounted at the end of the fork, as shown to better advantage in Fig. 3A. Since contact arm 3, or at least the end thereof, is of magnetic material and is mounted close to magnet 18 it tends to follow the motion of the fork. The jockey roller 17 is held against a knife edge on the opposite end of contact arm 3 and tends to hold the latter against one or the other of the fixed contacts, but does not exert sufficient pressure to prevent it from vibrating. The pressure is sufficient, however, to reduce the tendency of the contact 3 to rebound after it closes on one of the fixed contacts 4 or 5.

The arrangement of Fig. 4 is similar to that of Figs. 3 and 3A, in that the contact arm 3 is coupled to the fork by magnetic attraction, but differs from it in the method of reducing chatter. In Fig. 4 the element 3 which is of magnetic material is mounted to vibrate between poles 20 and 21 of a permanent magnet 19. Since the attraction exerted on the element 3 by either pole of the permanent magnet 19 varies inversely as the distance between them, it will tend to hold contact arm 3 firmly against whichever fixed contact 4 or 5 it may be touching, and thus prevent chattering. The magnetic attraction between magnet 18 and element 3 is the controlling force. The magnet poles 20 and 21 serve merely to hold the element 3 in its extreme positions.

Tests have revealed that the average value of current required to operate a fork of the type disclosed is about one-tenth of that required for the ordinary type of contact drive fork. Thus, sparking and arcing at the contacts would be greatly reduced, even if current were flowing at the time of contact break, but since with an efficient anti-chatter contact there is practically never any current flowing at a time of contact break, sticking and burning of the contacts is largely eliminated. Furthermore, the driving impulse is dependent only on the capacity of the condenser 11 and the electromotive force of the battery 16, whereas, as pointed out before, in the ordinary fork the time during which current is applied depends upon the amplitude of vibration as well as the electromotive force of the battery. This results in a fork that vibrates at a relatively constant frequency and yet retains the simplicity and the low cost of the ordinary contact drive fork.

What is claimed is:

1. The method of driving a vibrating element which comprises storing electrical energy and subsequently releasing it to apply a driving impulse to said element as it is passing through its normal position of rest.

2. A vibratory element and electrically operated driving means therefor, the operation of which is controlled by contacts controlled by the motion of the vibratory element, and means for preventing a flow of current through said contacts at the time they are broken.

3. In combination with a vibratory element, electrical driving means therefor, a source of electrical energy, a condenser, electrical switching means adapted to connect said source to said condenser when the vibratory element is near the end of its swing in one direction, and to connect said condenser to said driving means when the vibratory element is passing through its normal position of rest.

4. In combination with a tuning fork, a driving electromagnet in inductive relation thereto, a source of current, a condenser, and contacts controlled by the motion of the fork whereby said source is connected to the condenser during one phase of the fork's motion and the condenser is subsequently connected to the driving electromagnet during another phase of the fork's motion.

5. In combination with a tuning fork, a driving electromagnet in inductive relation thereto, a source of direct current, a condenser, a fixed contact connected to one terminal of said source, a second fixed contact connected through said driving electromagnet to the other terminal of said source, a contact movable between the fixed contacts under the control of the fork and connected through the condenser to said other terminal of said source.

6. In combination, a vibratory element, means for vibrating said element comprising a contact attached to said element by a flexible supporting arm consisting of a woven wire ribbon.

In witness whereof, I hereunto subscribe my name this 27th day of October, A. D., 1927.

AUSTEN M. CURTIS.