July 3, 1951 A. N. STANTON 2,558,991

TUNING FORK DRIVER

Filed Dec. 5, 1949

FIG. 1

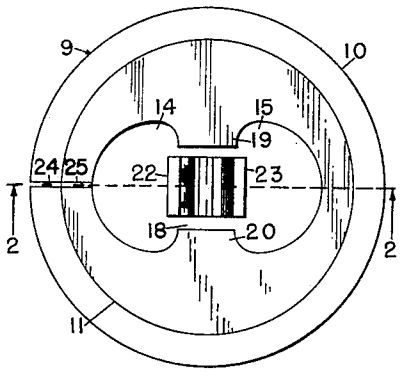
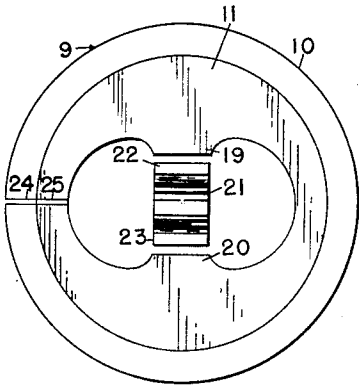


FIG. 3



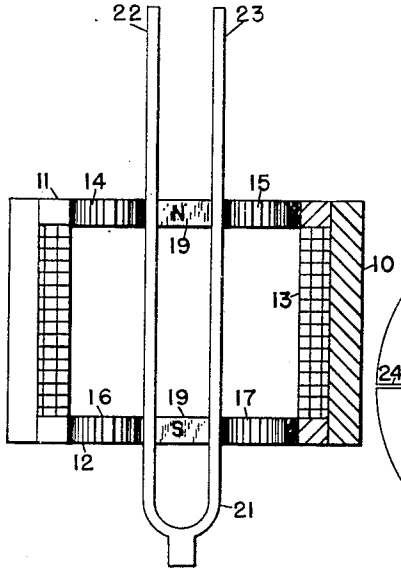


FIG. 2

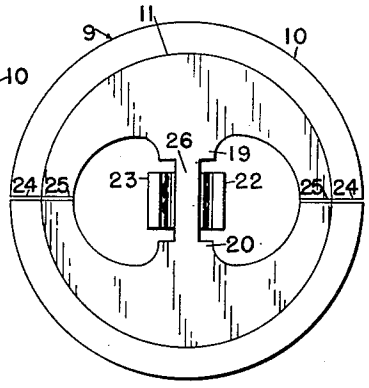


FIG. 4

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TUNING FORK DRIVER

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This invention relates to tuning forks and more particularly to driving means for tuning forks.

In many applications the energy available to drive a tuning fork is very small at the time of initiation of operation, which is the time during which the energy need of the driving means is greatest. It is therefore necessary that the energy available be utilized with apt efficiency. Furthermore, the driving means must be compact, and light in weight in order that its use be practicable in applications where weight and size are limiting factors.

Accordingly, it is an object of my invention to provide a new and improved driving means for tuning forks.

It is another object of my invention to provide a new and improved electromagnetic driving means for tuning forks.

It is another object of my invention to provide a new and improved electromagnetic driving means for a tuning fork which applies the driving force over a considerable area of the tuning fork.

It is another object of my invention to provide a new and improved electromagnetic driving means for a tuning fork which allows minimum clearance between the tines of the tuning fork and the pole pieces of the driving means.

It is another object of my invention to provide a new and improved electromagnetic driving means for a tuning fork which applies symmetrical driving forces to the tines of the tuning fork with the use of only one driving coil.

It is still another object of my invention to provide a new and improved electromagnetic driving means for mechanical vibrators which will cause the frequency of vibration of the vibrator to be equal to the frequency of the exciting alternating current in the driving means.

Briefly stated, my new and improved driving means for tuning forks comprises a tubular main portion of magnetic material provided at each end with a pole piece of magnetic material. Each pole piece is provided with a pair of spaced substantially circular apertures, the apertures of one pole piece being aligned with the apertures of the other pole piece. The substantially circular apertures of each pole piece are connected by a rectangular aperture. Each pole piece has a pair of inwardly projecting tongues whose innermost edges face one another and form two parallel sides of the rectangular aperture and whose side edges constitute portions of the sides of the substantially circular apertures. A driving coil having a main axis coincident with the main axis of the tubular portion is disposed within the

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main tubular portion and between the pole pieces. The tuning fork to be driven is disposed within the substantially circular apertures, each tine lying within two aligned apertures of the pole pieces and having its inner side substantially in line with the side edges of the tongues which form part of the sides of the aligned circular apertures. The driving coil may be energized by either a pulsating direct current or an alternating current to cause the tines of the tuning fork to move alternately into positions adjacent each other between the inwardly projecting tongues of the pole pieces and into positions remote from each other and beyond the inwardly projecting tongues of the pole pieces.

For a better understanding of my invention, reference may be had to the following description taken in connection with the accompanying drawing in which:

Figure 1 is a top plan view of a preferred embodiment of my invention;

Figure 2 is a sectional view taken along line 2—2 of Figure 1;

Figure 3 is a top plan view of a modified form of the device shown in Figures 1 and 2;

Figure 4 is a top plan view of another modified form of the device shown in Figures 1 and 2.

Referring now to the accompanying drawing, Figures 1 and 2 illustrate a preferred embodiment of tuning fork driving means 9 which comprises a tubular member 10. Tubular member 10 may be made of a magnetic substance having a low reluctance, such as soft iron, or it may be a permanent magnet which is magnetized parallel to its main axis. Positioned at each end of tubular member 10 perpendicular to the main axis of tubular member 10 are disk shaped pole pieces 11 and 12. Pole pieces 11 and 12 are preferably made to have a diameter equal to the inside diameter of tubular member 10 and are positioned within tubular member 10 having their outside surfaces flush with the ends of tubular member 10. It will be obvious that pole pieces 11 and 12 may be made to have a diameter equal to the outside diameter of tubular member. In this case, the pole pieces 11 and 12 would be positioned at each end of tubular member 10 and would have their outside periphery coinciding with the outer periphery of tubular member 10. The construction illustrated in the drawing is preferred however, since the pole pieces 11 and 12 can be easily secured to tubular member 10 by providing a tight fit between the inner cylindrical surface of tubular member 10 and the outer annular surfaces of disks 11 and 12.

Disposed between pole pieces 11 and 12 and within tubular member 10 is a helically wound coil 13 having a main axis which coincides with the main axis of tubular member 10. Coil 13 has an outside diameter equal to the inside diameter of tubular member 10 to preclude relative movement between coil 13 and tubular member 10.

Each of the pole pieces 11 and 12 is provided with a pair of substantially circular apertures 14 and 15, and 16 and 17, respectively. Connecting apertures 14 and 15 of pole piece 11 is a substantially rectangular passage which is formed by the inwardly projecting tongue portions 19 and 20. Pole piece 12 is an exact duplicate of pole piece 11. Further description and illustration of pole piece 12 is therefore unnecessary.

The fork 21 to be driven by driving means 9 has tines 22 and 23 which are disposed in apertures 14 and 16, and 15 and 17, respectively. The inner sides of tines 22 and 23 are aligned on each side of tongue members 19 and 20 so that a slight inward movement of tines 22 and 23 toward each other will bring them directly between the tongue members 19 and 20 of pole pieces 11 and 12. The tines 22 and 23 are driven toward each other by the magnetic field set up by coil 13 when coil 13 is energized. If we assume now that tubular member 10 is of soft iron and that coil 13 is so energized that pole piece 11 is a north pole and pole piece 12 is a south pole of the driving means 9, the flux flowing through tongue members 19 and 20 will seek the flux path of lowest reluctance to the tongue members 19 and 20 (not shown) of pole piece 12. Since tuning fork 21 is made of magnetic material, the flux will travel from tongue member 19 of pole piece 11 through tines 22 and 23 to tongue member 19 of pole piece 12. Similarly, flux flowing from tongue member 20 of pole piece 11 will travel through tines 22 and 23 to its corresponding tongue member 20 (not shown) of pole piece 12. The magnetic field set up by coil 13 between the tongue members 19 and 20 of pole piece 11 and tongue members 19 and 20 (not shown) of pole piece 12 will exert a force on tines 22 and 23 which will draw tines 22 and 23 toward each other. When the current in coil 13 ceases to flow, the force drawing tines 22 and 23 together is removed and tines 22 and 23 move away from each other and their momentum will carry them past their original positions to a position remote from each other. If another pulse of current is applied to coil 13 as tines 22 and 23 as they return from the positions remote to each other in their original positions, tines 22 and 23 will again be drawn to positions near each other. By properly timing the pulses of unidirectional current transmitted to coil 13, tuning fork 21 can be set and maintained in vibration at a frequency equal to the frequency of pulsation of the unidirectional current in coil 13. Pole pieces 11 and 12 will always be north and south magnetic poles, respectively, as long as the direction of flow of current in coil 13 is not changed.

If alternating current is supplied to coil 13, and tubular member 10 and pole pieces 11 and 12 are of soft iron, then the tuning fork 21 will vibrate a frequency which is twice the frequency of the alternating current. Tines 22 and 23 will be drawn toward each other twice during each cycle of the alternating current since each half cycle of the alternating current will set up a separate or opposite magnetic flux between pole pieces 11 and 12. For example, during the positive half cycle of current pole piece 11 may be a north pole and pole piece 12 will then be a south pole. During this half cycle tines 22 and 23 will be first toward each other and will then move back to positions remote from each other. During the negative half cycle of current, pole piece 11 will become a south pole and pole piece 12 will become a north pole. During this negative half cycle, tines 22 and 23 will again be drawn toward each other and will move back to positions remote from each other. In this manner two equal and opposite fluxes will be set up in driving means 9 during each cycle of the alternating current flowing in coil 13 and consequently tines 22 and 23 will also be drawn toward each other twice during each cycle of the alternating current. In this manner, the frequency of vibration of tuning fork 21 caused by driving means 9 will be twice the frequency of the alternating current flowing in coil 13.

In many applications, it is desirable that the tuning fork vibrate at a frequency equal to the frequency of the alternating current applied to coil 13. In order to make the frequency of vibration of tuning fork 21 equal to the frequency of the alternating current flowing in coil 13, the tubular member 10 is permanently magnetized parallel to its main axis. In this case, tubular member 10 is made of a suitable magnetic alloy having a high magnetic retentivity. Pole pieces 11 and 12 are made of soft iron in all cases. If we assume now that tubular member 10 is a permanent magnet, tines 22 and 23 will be constantly drawn toward each other but the strength of the permanent magnet, which tubular member 10 constitutes, and the position of tines 22 and 23 with respect to tongue members 19 and 20 of pole pieces 11 and 12 are so chosen that tines 22 and 23 may be drawn still closer together when a current is supplied to coil 13 which strengthens the magnetic flux between pole pieces 11 and 12. For example assuming that the magnetization of tubular member 10 is such that pole piece 11 is a north pole and pole piece 12 is a south pole, and that a positive half cycle of alternating current in coil 13 will also tend to make pole piece 11 a north pole and pole piece 12 a south pole, a positive half cycle of alternating current flowing in coil 13 will cause tines 22 and 23 to be drawn still closer to each other. The succeeding negative half cycle of alternating current in coil 13 will tend to cause pole piece 11 to become a south pole and pole piece 12 to become a north pole. The strength of the tubular member 10 permanent magnet, and the number of turns in, and the current transmitted by, coil 13 are such however, that the negative half cycle of current can never reverse the polarity of pole pieces 11 and 12. The negative half cycle of current will merely lessen the amount of flux between pole pieces 11 and 12, decrease the force drawing tines 22 and 23 toward each other, and therefore allow tines 22 and 23 to move further away from each other. The next cycle of alternating current will again draw tines 22 and 23 toward each other and again allow them to move into positions relatively remote from each way. In this way each cycle of alternating current in coil 13 will cause one cycle of vibration of tuning fork 21 and the frequency of vibration of fork 21 will be made equal to the frequency of the alternating current in coil 13. The full cycle of the alternating current is therefore utilized to drive tuning fork 21 at a frequency

of vibration equal to the frequency of the alternating current.

Since the tines 22 and 23, as shown in Figure 1, move transversely with respect to tongue members 19 and 20, a very small air gap between tongue members 19 and 20 and tines 22 and 23 may be employed. The probability of tines 22 and 23 hitting or contacting any portion of driving means 9 is minimized since a very large clearance for normal and abnormal vibration is provided by apertures 14, 15, 16 and 17. Vibration of tines 22 and 23 in directions perpendicular to the normal directions of vibration will be very small even under external physical impacts to fork 21 since the rigidity of tines 22 and 23 is comparatively great in the direction perpendicular to the normal direction of vibration of fork 21.

The forces exerted on tines 22 and 23 by the flux flowing between pole pieces 11 and 12 are symmetrical once fork 21 is properly positioned in driving means 9 since only one coil 13 is employed. Where two coils are employed, one to drive each tine 22 and 23, considerable time and care must be employed to so position each coil with respect to its tine that the forces exerted on the tines of the fork are equal. In addition, the coils must be identical and must be supplied with equal energizing currents. The driving means 9 constructed in accordance with the teachings of my invention are simply and inexpensively constructed since only one coil is needed to produce symmetrical driving forces on each tine 22 and 23 of tuning fork 21. Moreover, the force exerted on each tine 22 and 23 is applied over a considerable portion of each tine which decreases the amplitude of harmonic vibration of tines 22 and 23. The force exerted on each tine 22 and 23 is applied over the portion of the fork extending from pole piece 11 to pole piece 12 since the flux flowing from pole piece 11 to pole piece 12 through these portions of tines 11 and 12 will exert forces throughout these portions.

If desired, the tuning fork 21 may be positioned as shown in Figure 3 in which case the movement of tines 22 and 23 will be toward and away from tongue members 19 and 20 instead of transversely between tongue members 19 and 20. The air gaps between tines 22 and 23 and tongue members 19 and 20 will necessarily be greater but the forces applied to tines 22 and 23 will still be symmetrical. The advantages of symmetrical drive by an easily and inexpensively constructed driving means 9 will still remain.

The driving means 9 is preferably positioned intermediate the length of tuning fork 21 so that the magnetic field set up by coil 13 will not set up forces tending to move fork 21 longitudinally parallel to the main axes of tubular member 10 and coil 13. The pulsating unidirectional current or the alternating current in coil 13 will tend to generate eddy currents in tubular member 10 and pole pieces 11 and 12. To avoid excessive heating of these members of driving means 9, tubular member 10 and pole pieces 11 and 12 are split as at 24 and 25, respectively, to provide air gaps which will prevent the flow of eddy currents about these members. Since the cross sectional areas of tines 22 and 23 are comparatively small, the eddy currents generated in tines 22 and 23 will also be very small and lamination of tines 22 and 23 will usually be unnecessary, the small amount of heat generated in tines 22 and 23 by the eddy currents being easily dissipated into the air in their vibration.

Figure 4 illustrates a modified form of the device illustrated in Figures 1 and 2. In the embodiment illustrated in Figure 4 a central portion 26 joining tongue members 19 and 20 is provided on each pole piece 11 and 12. When coil 13 is energized, the flux flowing between central portions 26 exerts forces on tines 22 and 23 in planes parallel to the plane of vibration of vibrator 21. Central portions 26 are provided to increase the magnetic forces tending to cause tines 22 and 23 to vibrate.

It will be apparent to those skilled in that art that various changes and modifications may be made in the illustrated and described embodiments of my invention without departing from the spirit and scope of my invention and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A vibrator comprising a tubular member; a pair of circular pole pieces having diameters equal to the inside diameter of said tubular member, each of said pole pieces being disposed within said tubular member and adjacent one end thereof, each of said pole pieces having an outer surface lying in the same plane normal to the central axis of said tubular member as an adjacent end of said tubular member, said tubular member and said pole pieces being of magnetic material; a tubular coil disposed within said tubular member and between said pole pieces having a central axis coincident with central axis of said tubular member, said pole pieces each being provided with a pair of apertures symmetrically disposed about said central axis and a substantially rectangular aperture communicating with said apertures, the apertures of one of said pole pieces coinciding with the apertures of the other of said pole pieces; and a tuning fork having tines extending parallel to said central axis and through said apertures adjacent said substantially rectangular apertures and being adapted to have said tines drawn together and into said substantially rectangular aperture.

2. A vibrator comprising a tubular member; a pair of disk shaped pole pieces, one of said pole pieces being disposed at and closing off one end of said tubular member and the other of said pole pieces being disposed at and closing off the other end of said tubular member, each of said pole pieces being provided with an aperture; a pair of tongue members integral with each of said pole pieces and extending inwardly into said aperture and toward each other; a tubular coil disposed within said tubular member and between said pole pieces; and a tuning fork having tines extending through said apertures of said pole pieces and through said tubular member, said tines being positioned adjacent said tongue members and being adapted to be drawn toward each other and between said tongue members.

3. A vibrator comprising a tubular member; a pair of circular pole pieces, one of said pole pieces being disposed at and closing off one end of said tubular member, the other of said pole pieces being disposed at and closing off the other end of said tubular member, each of said pole pieces being provided with an elongated aperture, each of said pole pieces being provided with a pair of inwardly projecting tongue members; a tubular coil disposed within said tubular member and having a central axis coincident with the central axis of said tubular member; and a fork having a pair

of tines disposed within said coil and extending through said elongated apertures of said pole pieces, said tines being disposed adjacent said tongue members and adapted to be drawn toward each other between said tongue members.

4. A vibrator driving means comprising a tubular member symmetrically disposed about a central axis; a pair of pole pieces, one of said pole pieces being disposed at and closing off one end of said tubular member and the other of said pole pieces being disposed at and closing off the other end of said tubular member, each of said pole pieces being provided with an aperture and a pair of tongue members extending inwardly and toward each other constricting said aperture at its central portion; and a tubular coil disposed within said tubular member having a central axis coincident with said central axis of said tubular member, said tubular coil when energized tending to magnetize said tubular member parallel to said central axis, said tubular member and said pole pieces being of magnetic material, said tubular member being permanently magnetized parallel to said central axis.

5. A vibrator driving means comprising a tubular member symmetrically arranged about a central axis; a pair of pole pieces, one of said pole pieces being disposed at and closing off one end of said tubular member and the other of said pole pieces being disposed at and closing off the other end of said tubular member, each of said pole pieces being provided with a pair of apertures, each of said pole pieces being provided with a pair of inwardly extending tongue members partially separating said apertures, said apertures and tongue members being symmetrically arranged about said central axis, each of said pole pieces being provided with a central portion connecting said tongue members; and a tubular coil within said tubular member having a central axis coinciding with said central axis of said tubular member, said coil tending to magnetize said tubular member parallel to said central axis when said coil is energized.

6. A vibrator comprising a tubular member; a pair of pole pieces, one of said pole pieces being

disposed at and closing off one end of said tubular member, the other of said pole pieces being disposed at and closing off the other end of said tubular member, each of said pole pieces being provided with an elongated aperture, each of said pole pieces being provided with a pair of inwardly projecting tongue members; a tubular coil disposed within said tubular member and having a central axis coincident with the central axis of said tubular member; and a fork having a pair of tines disposed within said coil and extending through said elongated apertures of said pole pieces, said tines being disposed adjacent said tongue members and adapted to be drawn toward each other between said tongue members.

7. A vibrator comprising a pair of pole pieces spaced along a central axis and lying in planes normal to said axis; a tubular coil having a central axis coincident with said first mentioned central axis disposed between said pole pieces; means of magnetic material disposed exteriorly of said coil providing a magnetic connection between said pole pieces, each of said pole pieces being provided with an elongated aperture, each of said pole pieces being provided with a pair of inwardly projecting tongue members constricting said aperture, and a fork having a pair of tines disposed within said coil and extending through said apertures of said pole pieces, said tines being disposed adjacent said tongue members and adapted to be drawn toward each other between said tongue members.

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