S. EVERSHED AND W. D. KILROY.

SOUND EMITTER.

APPLICATION FILED SEPT. 12, 1916.

1,333,298.

Patented Mar. 9, 1920.

4 SHEETS—SHEET 1.

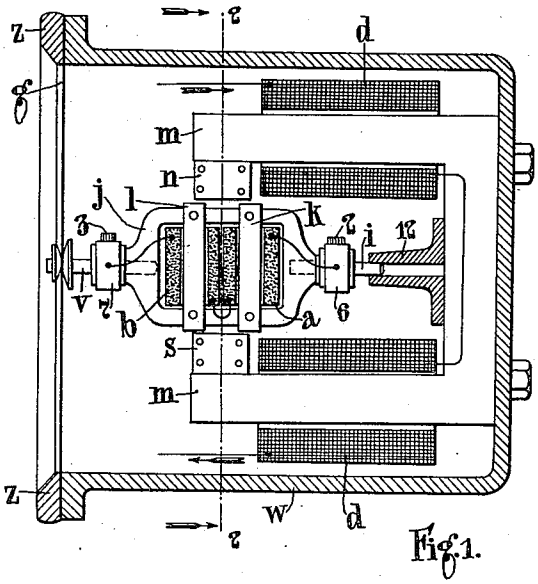


Fig. 1.

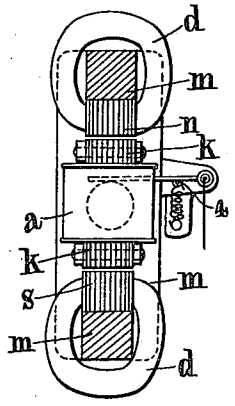


Fig. 2.

Inventors:

Sydney Evershed and

Willie D. Kilroy,

by Spear, Middleton, Donaldson & Spear

Attorneys.

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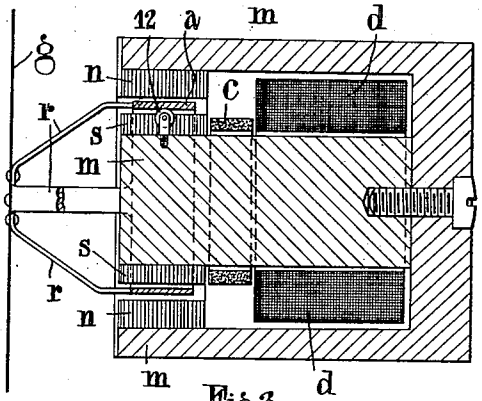


Fig. 3.

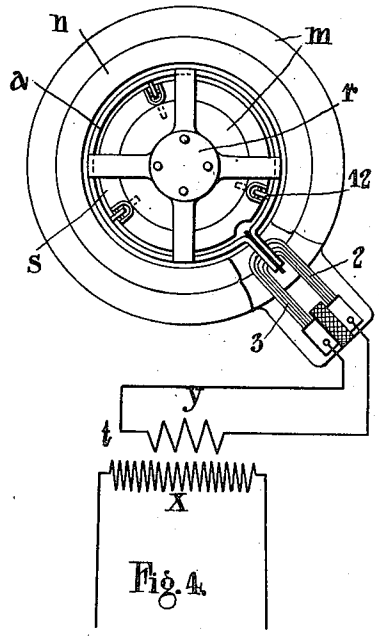


Fig. 4.

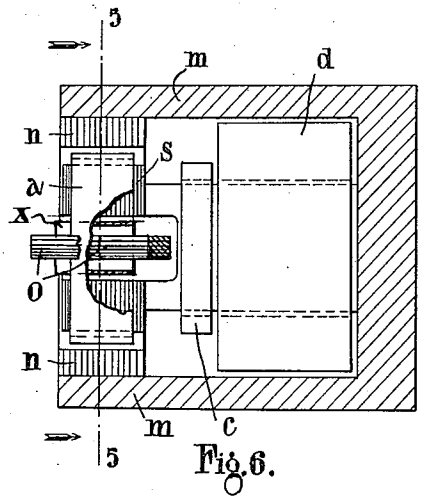


Fig. 6.

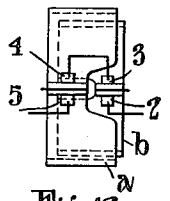


Fig. 12.

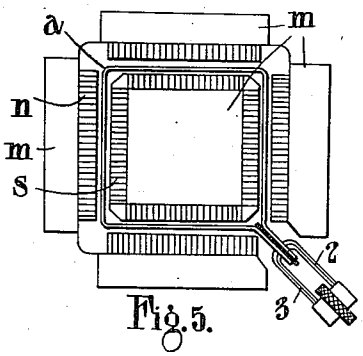


Fig. 5.

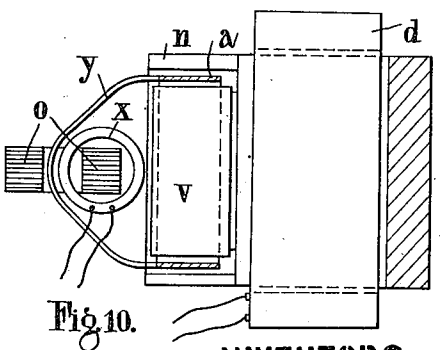


Fig. 10.

INVENTORS:

Sydney Evershed and

Willis D. Kilroy,

by Dean, Middleton, Duncan & Dean

ATTORNEYS.

S. EVERSHED AND W. D. KILROY.

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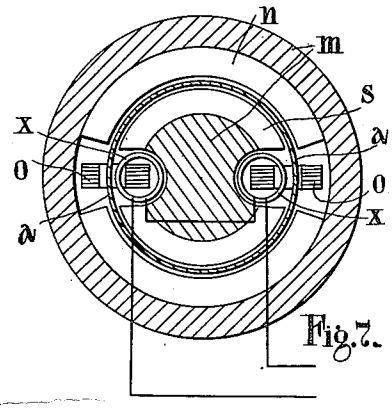


Fig. 7.

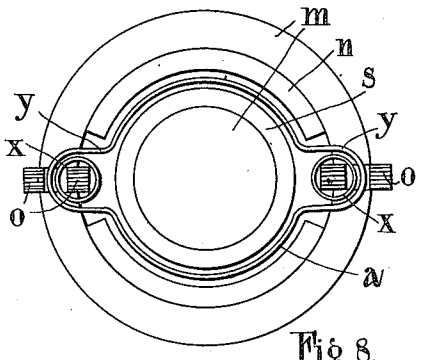


Fig. 8.

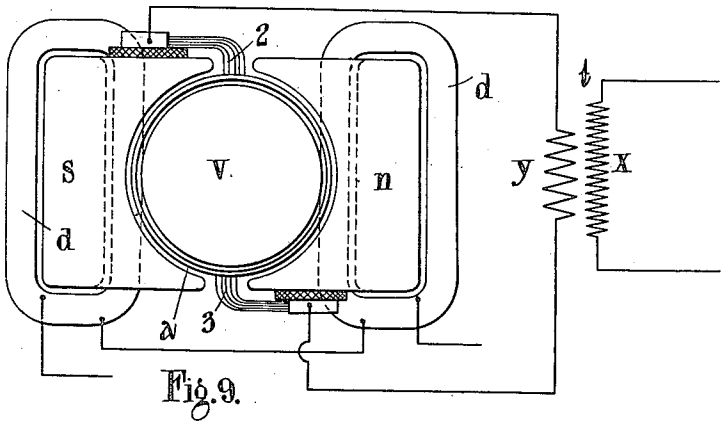


Fig. 9.

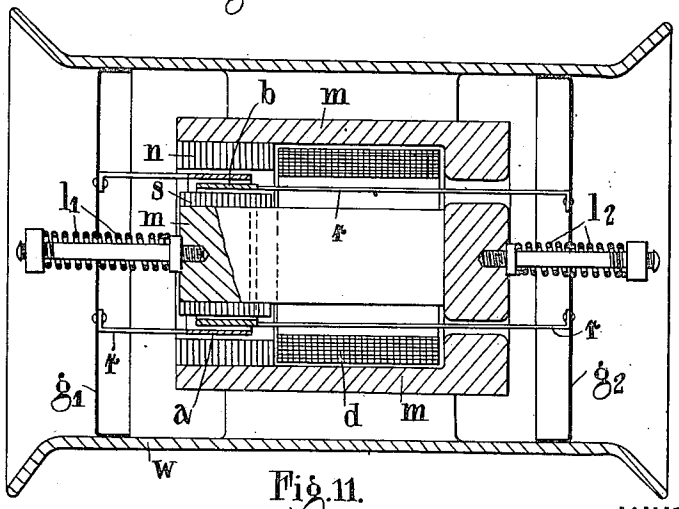


Fig. 11.

INVENTORS:
Sydney Evershed,
Willie D. Kilroy,
by Spear, Middleton, Donaldson & Spear
ATTORNEYS.

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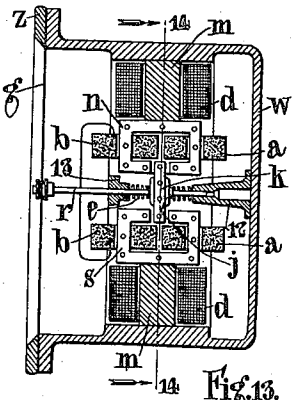


Fig. 13.

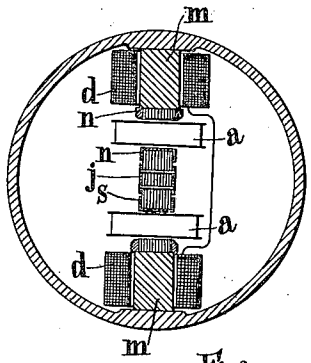


Fig. 14.

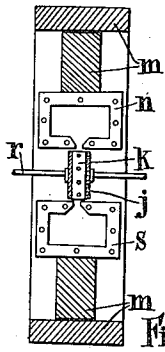


Fig. 15.

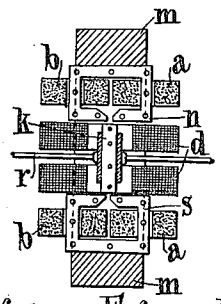


Fig. 16.

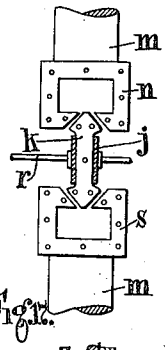


Fig. 17.

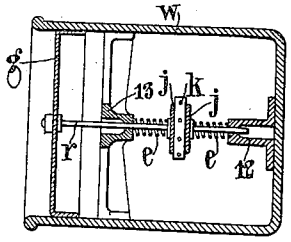


Fig. 18.

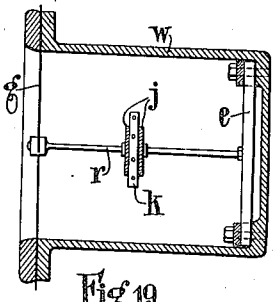


Fig. 19.

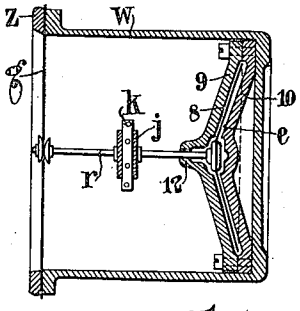


Fig. 21.

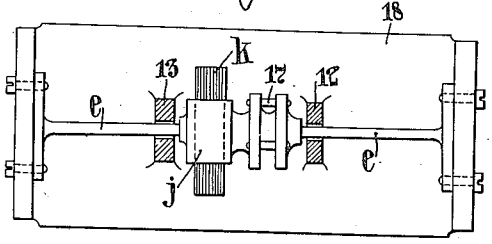


Fig. 20.

Inventors:
Sydney Evershed, &
Willis D. Kilroy,
by Spear, Middleton, Donaldson & Spear
Attorneys.

UNITED STATES PATENT OFFICE.

SYDNEY EVERSHED AND WILLIE DICKSON KILROY, OF CHISWICK, LONDON, ENGLAND.

SOUND-EMITTER.

1,333,298. Specification of Letters Patent. Patented Mar. 9, 1920.

Original application filed May 3, 1910, Serial No. 559,158. Divided and this application filed September 12, 1916. Serial No. 119,784.

To all whom it may concern:

Be it known that we, SYDNEY EVERSHED and WILLIE DICKSON KILROY, subjects of the King of Great Britain and Ireland, and residing at Acton Lane Works, Chiswick, in the county of London, England, have invented certain new and useful Improvements Relating to Sound-Emitters, of which the following is a specification.

This invention relates to the means by which electric energy is converted into the mechanical energy of sound waves in air, water or other medium of transmission, and in this specification the phrase "sound-waves" means any waves propagated like waves of sound and of any frequency whether within the limits of audibility or not. It relates more specifically to electric vibratory motors and their application for signaling to a distance.

The object of our invention is to produce continuous or interrupted trains of sound-waves of considerable intensity, which when propagated to a distance in either air or water may be heard or detected in any known manner, and may serve as signals or convey messages by Morse code signaling and the like, and to provide improved forms of vibratory motors for signaling and other purposes.

Our invention in brief consists in a vibratory electric motor having a fixed part hereinafter referred to as a "stator," and a movable part, hereinafter referred to as a "vibrator," mechanically coupled to a sound-producing body, hereinafter referred to as a "sounder."

Our invention also consists in a vibratory electric motor having substantially no wasteful mutual induction.

Our invention also consists in a vibratory motor having its alternating flux confined to a small part of the magnetic material of the motor or to a short magnetic circuit.

Our invention further consists in the various forms of, and improvements in, vibratory motors hereinafter indicated.

Referring now to the accompanying drawings—

Figure 1 is a longitudinal section of one construction of vibratory motor with alternating current windings on the vibrator cores;

Fig. 2 is a cross section on the line 2—2 of Fig. 1;

Fig. 3 is a longitudinal section, and

Fig. 4 a front elevation, of a form of vibratory motor with a ring conductor carrying an alternating current to act as vibrator.

Fig. 5 shows a modified form with square vibrator.

Fig. 6 is a section of a construction with a transformer included.

Fig. 7 is a cross section on line 5—5 of Fig. 6.

Fig. 8 is a modification of the form shown in Figs. 6 and 7.

Figs. 9 and 10 represent a modification of ring vibrator to prevent reaction upon the stator windings.

Fig. 11 is a longitudinal section of a duplex vibratory motor in which the two conductor rings are adapted to prevent reaction upon the stator windings.

Fig. 12 is a detail of the same.

Fig. 13 is a longitudinal section, and

Fig. 14 a cross section, on the line 14—14 thereon of a construction of vibratory motor of an inductor type.

Figs. 15 to 17 represent modifications of this type.

Figs. 18 to 20 illustrate details of vibrator constructions with sounders of no inherent elasticity.

Fig. 21 shows another modification in which the elasticity of air is used to increase the elastic force of the sounder.

In the form of the invention shown by way of example in Figs. 1 and 2, the magnetic circuit n, m, s, excited by direct current in the coils d, d, forms the stator, and the laminated iron cores k and l with the coils a and b—wound thereon or in slots or holes therein—form the vibrator of the motor. The cores k and l are fixed to a rigid frame j which is connected by means of a rigid rod v to a sounder g. The frame j, cores k and l, and coils a and b, are supported at one end by the sounder g, and at the other end by the rod i which is free to slide in the guide and support 12. The coils a and b are conductively connected with a source of single phase alternating current as by means of slip rings 6 and 7 and brushes 2 and 3; although flexible conductors adapted to permit the vibrator to vibrate, reciprocate or oscillate, freely over the required amplitude, may be employed if desired, the current traversing the two coils in opposite senses.

In Fig. 1 the coils are shown coupled in series, but the present invention is not confined to a series connection.

The cores *k* and *l* are magnetized by the stator, and the effect of the alternating current in the coils *a* and *b* is alternately to increase and decrease the magnetization of each core; an increase in one core coinciding with a decrease in the other. Hence the forces exerted by the stator on the cores *k* and *l* are no longer balanced, and the movable system is subjected to reciprocating resultant forces which set it in vibration at the same frequency as that of the alternating current.

The forces due to the magnetic field of the stator acting directly upon the coils *a* and *b* act in the same direction as the resultant forces upon the cores *k* and *l*.

Since the alternating current traverses the two coils *a* and *b* in opposite senses, there will be no mutual induction between the alternating current windings and the direct current windings *d*, *d*, when the movable system is symmetrically disposed as regards the poles *n* and *s*. This should therefore be the position of zero displacement for the vibratory system, and when this condition is fulfilled no compensating windings are required to prevent wasteful reaction between the direct current and alternating current windings.

When a vibratory motor is applied to sound signaling it is generally desirable to obtain the maximum force from a given mass of vibrator, even at some sacrifice of the efficiency of conversion. With the arrangement shown in Fig. 1 the force upon the vibrator will be a maximum when the demagnetizing effect of the alternating current is just sufficient to reduce the magnetic potential differences between the poles of one of the cores, and poles, *n* and *s* of the stator, to zero; while at the same instant the magnetization of the other core is at its greatest practicable value. This condition determines the proportions between the ampere-turns on the stator and those on the vibrator, as well as the relative proportions of the magnetic circuit of the stator, and the cores *k* and *l*. The relative dimensions of the coils are determined by the conditions of use; for example, where the vibratory motor is to be used for Morse code signaling the direct current coils *d*, *d*, are proportioned so that they may be left in circuit continuously, but since the alternating current circuit will be broken up into dots and dashes with intervals of zero. the coils *a* and *b* may be run at a comparatively high current density.

When the vibrator is working at its maximum force, the limits of the magnetic cycle will be zero density and maximum density, and hence the loss from hysteresis and eddy currents may be estimated to be rather less than one half the losses for a complete cycle.

The magnetic induction in the poles *n* and *s* shifts from one side to the other as the magnetization of the cores *k* and *l* rises and falls, and it is therefore preferred to construct them of laminated iron, as indicated in Figs. 1 and 2.

According to the modification shown in Figs. 3 and 4, the movable cores are not present, and the action depends entirely upon the direct force of the stator field upon the conductors carrying the alternating current. The stator is shown as a cylindrical magnet with concentric poles and the vibrator as a conducting ring *a*, of copper, aluminium or other suitable metal, placed within and concentric with the annular air gap of the stator, and free to vibrate along its own axis upon suitable guiding rollers 12, or equivalent devices. A solid conducting ring is preferred to a coil in order to avoid the difficulty of constructing rigid coils of insulated wire to act as vibrators at the high frequencies which are usually essential for sound signaling. The ring is made thin radially, both in order to avoid the skin effect with a high frequency current, and in order to enable the stator to be constructed with a narrow air gap. In a vibratory motor of large size the conductor ring may be laminated as a further precaution against the skin effect, and if each lamina is adapted to impart its kinetic energy to the rods *r*, *r*, independently of the others, the several laminæ may be connected in series as a coil of several turns.

With the arrangement shown in Fig. 3 the mutual induction between the vibrator ring and the direct current windings cannot be zero in any part of the working range of vibration. A compensating coil *c* is therefore placed upon the center core of the stator, and connected to the source of alternating current so that its magnetizing force may at every instant be sufficient to confine the magnetizing effect of the vibrator ring *a* to the stator poles *n* and *s*. In order to preserve the simplicity of the design, the stator poles are not laminated in the right direction to eliminate hysteresis and eddy current losses, but are formed out of rings of thin sheet iron as indicated in Fig. 3, and in this way the cross induction due to the alternating current in the ring *a* is greatly reduced.

In Fig. 5 a square vibrator ring and stator are shown, an arrangement which permits the stator poles to be properly laminated, but involves additional complication.

The alternating current is led to and from the ring by means of the brushes 2 and 3 (Fig. 4), and since the use of a ring or coil of only a single turn involves the use of a large current, it is preferred to supply the

current from the low tension winding y of a transformer t, the primary winding x being arranged to suit the pressure of the source of supply. The compensating coil c, Fig. 3, may conveniently be connected in series with the primary coil x.

When the frequency for which the vibratory motor is designed is very high—for example, several hundred periods per second—the transformer t can be made of very small dimensions, and in such cases the secondary coil y and brushes 2 and 3 are not required; and, by linking the magnetic circuit of the transformer with the conductor ring, the required low tension current is generated in the ring itself. An arrangement of this kind is shown in Figs. 6 and 7, in which a recess is provided in each side of the stator pole s, of the necessary size for the magnetic circuit, o, and primary coil, x, of a transformer. Two transformers are shown as being a symmetrical arrangement, but one will suffice if the sectional area of the magnetic circuit o be doubled.

In Fig. 8 a modification is shown in which any reduction in the sectional area of the stator pole and center core is avoided. In this modification the vibrator ring is formed with two loops y, y, with each of which a magnetic circuit o is linked.

In Figs. 9 and 10, a modification is shown in which the stator is formed as a field magnet with two air gaps in series like the magnetic system commonly employed in moving coil ammeters and the like. The magnetic circuit of the stator is arranged with two poles n and s surrounding a central detached core v, leaving two narrow annular air gaps between them, each embracing an arc of about 160 degrees. The conductor ring or moving coil a is free to vibrate along its own axis, and alternating current is supplied to it either by means of the brushes 2 and 3, Fig. 9, placed at opposite ends of a diameter in the spaces between the pole tips, or by means of an interlinked magnetic circuit o, shown in Fig. 10. At any instant the current flows in opposite senses in the two halves of the ring, and hence the forces on the two halves are in the same direction, and impel the ring along its own axis, and the mutual induction between the stator windings and the ring is zero at zero displacement.

In Fig. 11 a further modification of our conductor ring vibrator is illustrated in which the mutual induction between the ring a and the stator windings d, is neutralized by means of a second ring b concentric with and inside a. The alternating current is made to traverse the two rings in opposite senses by means of the brushes 2, 3, 4 and 5, and connecting wires shown in Fig. 12. The ring b at each instant is impelled by a force equal and opposite to that exerted by the stator field upon the ring a, and we may utilize its force to impart vibration to a second sounder, the whole arrangement forming a duplex vibratory motor for working two sounders simultaneously. On the other hand, if the ring b be fixed in its position inside the vibrator a, then it merely acts as a compensating coil of a more efficient type than that shown in Figs. 3 and 6.

It is generally more economical to excite the stator with direct current, and pass alternating current through the conductor ring; although it is to be understood that we may modify our motor in many ways corresponding with the modifications commonly employed in rotary alternating current motors, for example the stator may carry alternating current windings, and the vibrator may be excited by direct current. In this case the whole of the magnetic circuit is preferably laminated. Also we may construct our motor on the same principle as an inductor alternator, that is to say both the stator windings and the vibrator windings may be fixed and the vibrator core alone may be free to move.

A modification of motor is shown in Figs. 13 and 14, which is referred to as of an "inductor" type, in which both the direct current and alternating current windings are fixed on the stator, and the vibrator forms a detached part of the magnetic circuit of the stator. The laminated pole pieces n and s are each divided into two arms, and the magnetic flux created by the coil d divides into two streams, one half traversing one arm, and the other half the other arm of each pole, and unites again on passing across the air-gaps into the vibrator core k. The alternating current windings a a and b b are fixed upon the four polar arms, and connected in such order that the current flows in one sense in the coils a a, and the opposite sense in the coils b b, thus alternately increasing and decreasing the flux in the right hand arms, and simultaneously decreasing and increasing the flux in the left hand arms. Hence the vibrator k experiences reciprocating forces which set it vibrating at the same frequency as the alternating current.

The conditions as regards maximum force are the same in the inductor type of motor as those referred to in connection with Fig. 1, with the addition that to obtain the greatest force with a given mass of vibrator it is necessary to magnetize the vibrator core k to the practical limit of saturation. Although the flux in the central part of the core k is constant in amount and direction, the direction of the flux at each end shifts from side to side under the alternating magnetic potential difference between the two arms of each pole n and s. Hence it is desirable to laminate the ends of the core k,

and practical considerations make it easier to construct it entirely of laminated iron as indicated in Figs. 13 and 14.

In the form shown in Fig. 13 the amplitude of vibration is limited by the length of the air gaps, and when a large amplitude is required, the type of magnetic circuit shown in Figs. 15 and 16 is preferred.

In the form shown in Fig. 16, the direct current windings surround the vibrator core *k*, a position more favorable for creating an intense magnetization in the core, and form a more compact but less accessible arrangement of parts than that shown in Fig. 13.

In the motors of Figs. 1, 15 and 16 the force exerted upon the vibrator is the component of the magnetic attraction acting in the direction of motion, whereas in Fig. 13 the whole magnetic force acts in the direction of motion. The choice between the two forms depends upon the amplitude it is desired to attain, and involves estimating the force in each case.

In Fig. 13 the force of attraction when the field in the gaps on one side is zero, and on the other side is H, is (as is well known) equal to

$$\frac{B^2A}{8\pi} \text{ or } \frac{H^2}{8\pi}$$

per square centimeter, for each gap. In the form shown in Figs. 1, 15 and 16, the component force in the direction of motion, under the same circumstances, is

$$\frac{H^2 \times W \times S}{8\pi}$$

for each gap, where W is the width of the air gap normal to the direction of motion, and S is the length of air gap from pole to core end measured in a direction parallel with the length of the core. These formulæ neglect the effect of fringes, but they are useful guides.

The present invention is not limited to the two forms which act by indirect or direct force. For example, a combination of the two as indicated in Fig. 17 may be employed.

The vibratory motor is preferably arranged in a suitable containing case *w*, as shown by way of example in Figs. 1 and 13, where one end of the case is closed by an elastic plate *g*, to act as the sounder, clamped by means of a ring *z*. In the induction type of motor the case *w* may be made of iron or steel, so that it may form part of the magnetic circuit of the stator, as shown in Figs. 13 and 14. Suitable means can be employed to render the case watertight, so that the sound generator may be used below the surface when it is desired to signal through water.

For signaling through the air, it is not essential to close the case *w*, and rigid piston-like disks *g g* may be used (as shown in Fig. 11) to act as sound generators; a modification which permits a large amplitude to be attained.

When the elasticity of the sound generating body is insufficient to give the mass of the vibratory system a natural frequency of vibration equal to the frequency of the alternating current, the additional force required to compel the vibrator to work at the same frequency as the current would be provided—for example—by an idle current flowing in the alternating current windings. The magnitude of the additional force to be provided (and hence the strength of the idle current) can be estimated when the natural frequency of the vibratory system is known by means of the formula: Additional force at its maximum value$=4\pi^2 am\ (F^2-n^2)$, where *a* is the amplitude of vibration; *m* is the mass (or equivalent mass) of the vibratory system; F is the frequency of the current; and *n* is the natural frequency of the vibratory system. The additional force is assumed to be a sine wave.

In order to reduce the idle current as much as possible the elastic force of the sound generator may be increased by means of springs. A construction of this kind is shown in Fig. 13, where the two springs *e e* abut at one end against the guides 12 and 13, and at the other end against the frame *j* of the vibrator.

For high frequencies an elastic bar of steel may be used as a spring, as shown at *e* in Fig. 19.

When the motor is of the type in which the vibrator oscillates about an axis additional elastic force may be provided by means of two axial rods of elastic material, preferably of circular cross section, each fixed at one end to the vibrator and at the other end to a rigid framework. For example, in Fig. 20 the oscillatory vibrator core *k* is mounted in the frame *j* which is rigidly fixed to two elastic rods *o o*. The elastic rods are rigidly fixed to a framework 18, which may conveniently form part of the frame or case of the motor, and their torsional elasticity provides the required additional elastic moment about the axis of oscillation.

When the sounder has no elasticity, the whole of the elastic force can be provided by means of springs of any suitable type, for example, as indicated at *e e* in Fig. 18. An arrangement of this kind is also shown in the duplex sounder of Fig. 11, where the pistons *g g* are free to slide to and fro upon the pins or studs which carry the springs *e e*.

In Fig. 21 a method of obtaining additional elasticity by an elastic fluid—for example air—is illustrated, by means of the

conical piston 8, which is inclosed in a shallow chamber formed by inclosing plates 9 and 10. The maximum elastic force which the fluid exerts upon the vibratory system, depends upon the ratio of the amplitude to the clearance between the face of the piston and the inclosing plate. The fluid may be prevented from traveling from one side of the piston to the other, by fixing a flexible ring to the periphery of the piston and clamping the outside of the rim between the plates 9 and 10.

It will be understood that various modifications may be made in the constructions according to the present invention, for example, any of the sound producing devices may be duplicated as required to effect signaling in more than one direction.

The vibrators described herein have been mechanically coupled to the sounder in a rigid manner; that is so that there may be as little loss of motion and energy as possible in communicating the energy of the vibrator to the sounder.

The elastic recoils when provided on non-elastic sounders should be adapted to give a constant proportionality of elastic force to displacement over a wide range of displacement, or stroke, of the vibrating system. In this way the idle currents flowing in the alternating current windings of the motor may be considerably reduced, and if the frequency at which the sounder is to be used be constant, the strength of the spring may be so adjusted with relation to the mass or inertia of the moving parts as to give the vibrating system the same natural frequency of vibration as that of the alternating current. By this adjustment the idle currents may be reduced to a negligible value, and the total alternating current flowing in the motor will be that employed in overcoming frictional and other losses in the motor, and in imparting energy to the sounder.

As an alternative to a sounder without inherent elasticity, any known form and disposition of elastic sound producing body may be employed in conjunction with a vibratory motor.

Whatever form of sounder and type of motor be employed, the vibrating system may be adapted to vibrate either freely or against a stop or stops.

Although vibratory motors and sounders according to the present invention are particularly adapted for generating sound waves at high frequencies suitable for Morse code signaling and the like, that is to say at frequencies far above the lower limit of audibility, they may be usefully applied for other frequencies either above or below that limit.

Having now described our invention, what we claim as new and desire to secure by Letters Patent is:—

1. An electromagnetic sound emitting apparatus comprising a stator field magnet energized by a steady electric current supplied by a dynamo generator, a vibrator having an armature disposed in the magnetic field of the field magnet and energized by changing electric current from a dynamo alternator, electro-magnetic means for annulling wasteful mutual induction, and a sound producing body rigidly connected to the vibrator.

2. An electromagnetic sound emitting apparatus comprising a stator field magnet energized by a steady electric current supplied by a dynamo generator, a conductor ring vibrator disposed in the magnetic field of the field magnet and energized by changing electric current from a dynamo alternator, electromagnetic means for annulling wasteful mutual induction, and a sound producing body rigidly connected to the vibrator.

3. An electromagnetic sound emitting apparatus comprising a stator field magnet energized by a steady electric current supplied by a dynamo generator, a conductor ring vibrator disposed in the magnetic field of the field magnet and energized by changing electric current from a dynamo alternator, a compensating coil on the core of the stator energized by alternating current to annul the mutual induction between the field magnet and the vibrator when in its position of zero displacement, and a sound producing body rigidly connected to the vibrator.

4. An electromagnetic sound emitting apparatus comprising a stator field magnet energized by a steady electric current supplied by a dynamo generator, a conductor ring vibrator disposed in the magnetic field of the field magnet and energized by changing electric current from a dynamo alternator, inductive means in the circuit between the alternator and the vibrator for transforming the electric current, a compensating coil on the core of the stator energized by alternating current to annul the mutual induction between the field magnet and the vibrator when in its position of zero displacement, and a sound producing body rigidly connected to the vibrator.

In testimony whereof we have affixed our signatures.

SYDNEY EVERSHED.
WILLIE DICKSON KILROY.