R. A. FESSENDEN.

DYNAMO ELECTRIC MACHINERY.

APPLICATION FILED MAY 31, 1913.

1,167,366. Patented Jan. 4, 1916.

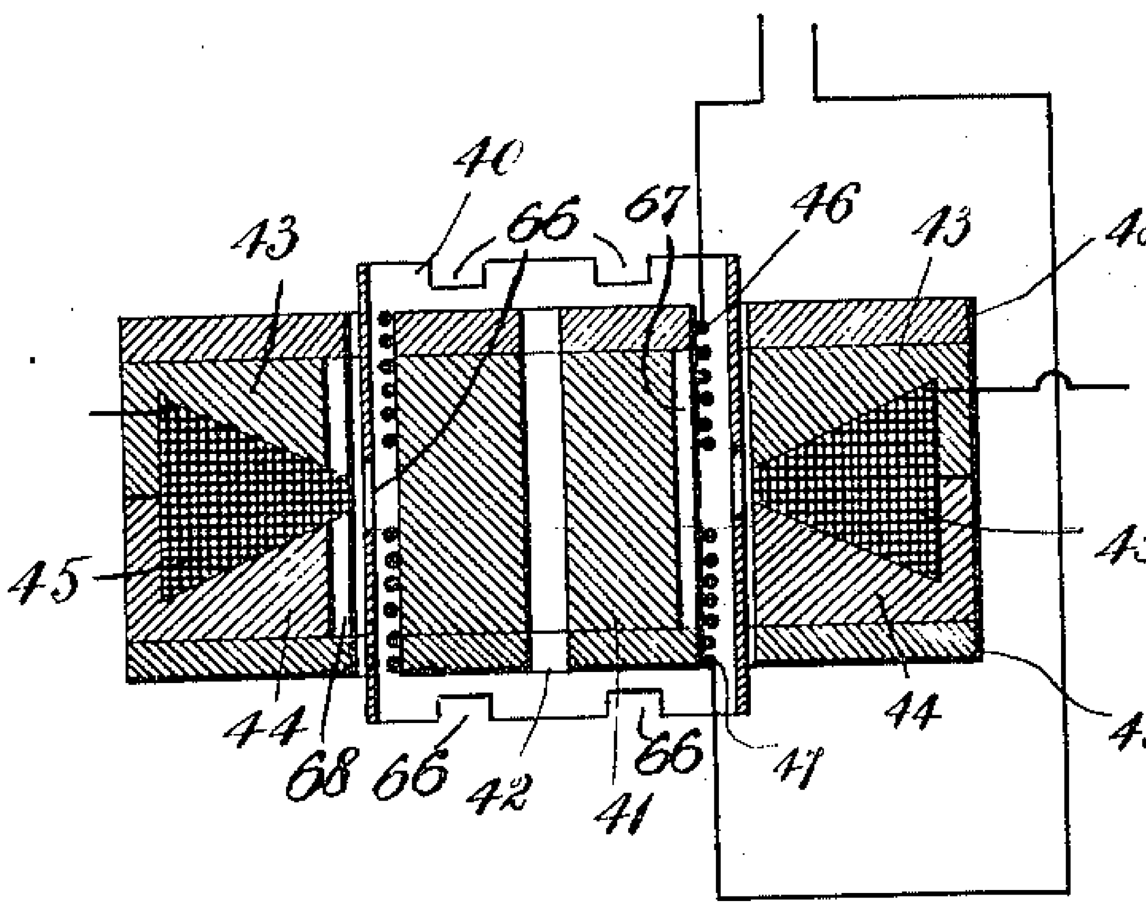

Fig. 1.

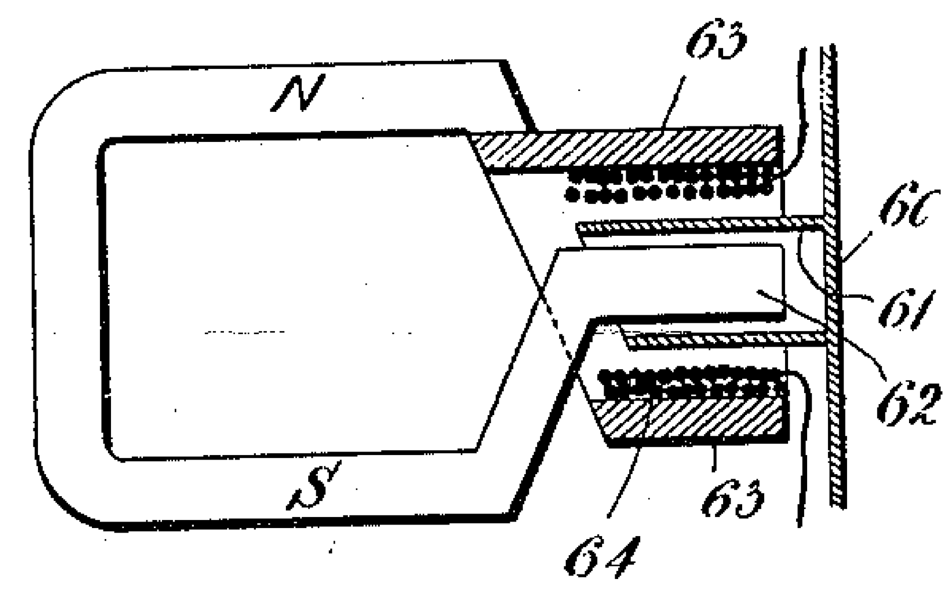

Fig. 2.

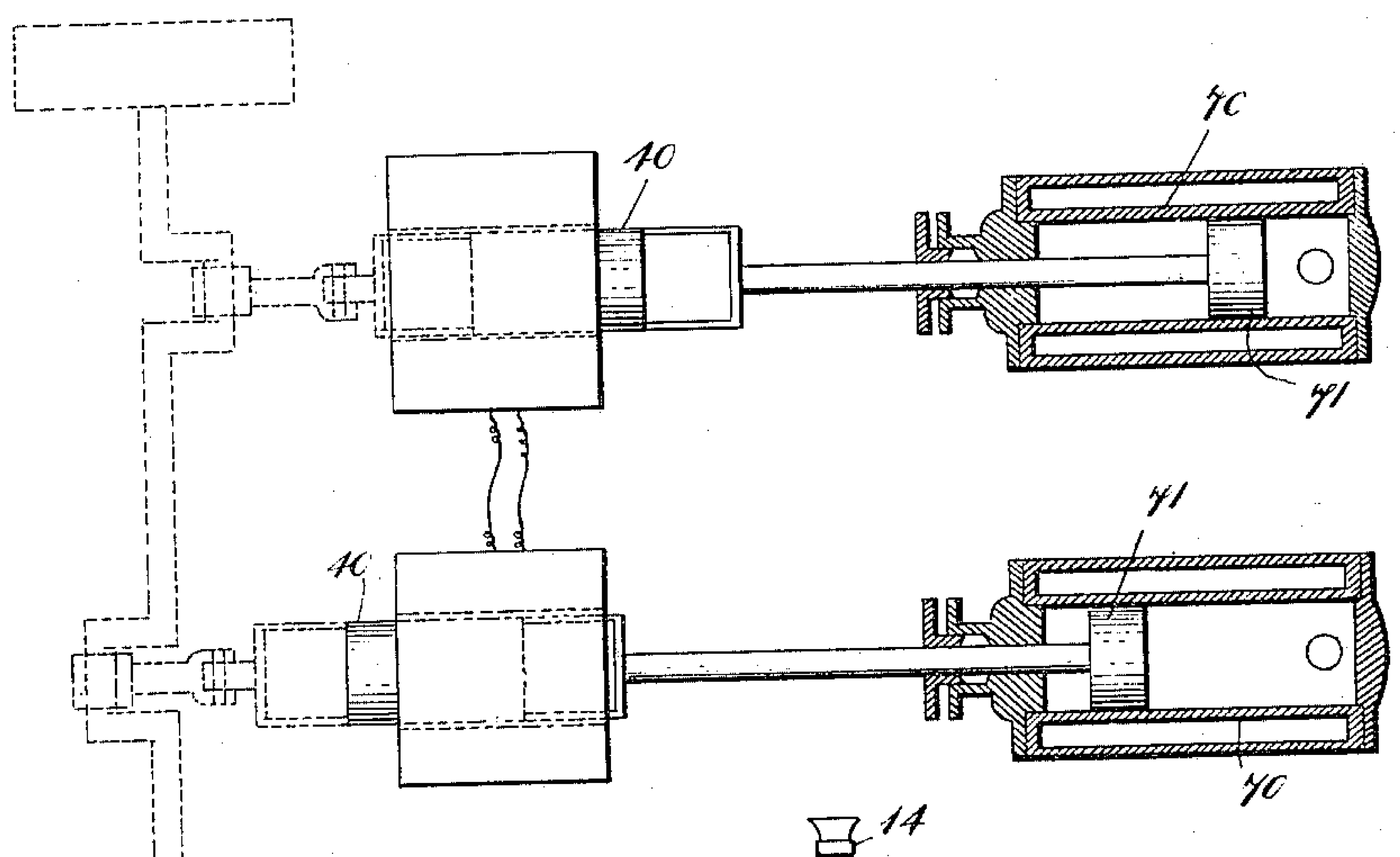

Fig. 3.

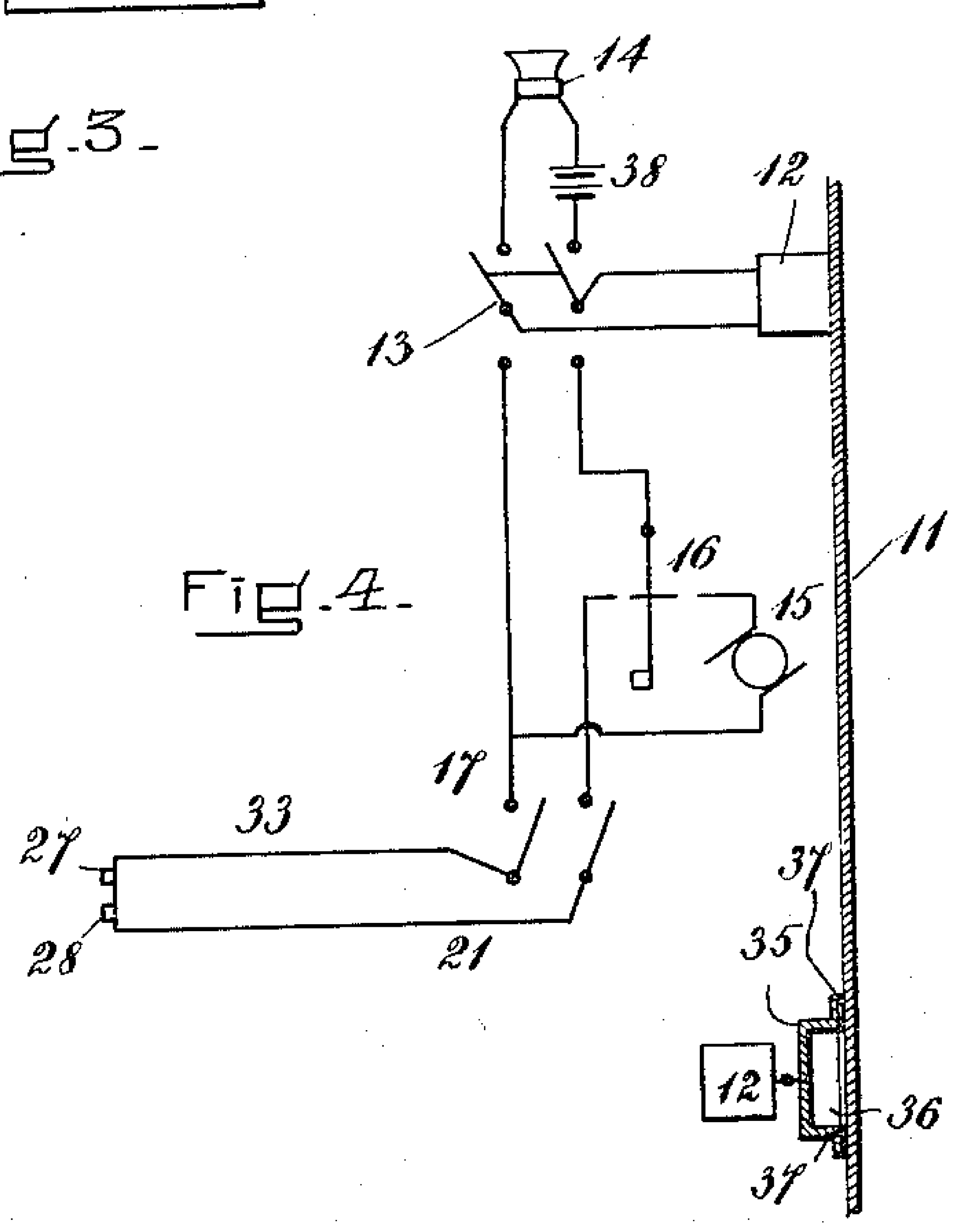

Fig. 4.

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UNITED STATES PATENT OFFICE.

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DYNAMO-ELECTRIC MACHINERY.

1,167,366. Specification of Letters Patent. Patented Jan. 4, 1916.

Original application filed January 29, 1913, Serial No. 744,793. Divided and this application filed May 31, 1913. Serial No. 770,857.

To all whom it may concern:

Be it known that I, Reginald A. Fessenden, of Brookline, in the county of Norfolk and State of Massachusetts, a citizen of the United States, have invented certain new and useful Improvements in Dynamo-Electric Machinery, of which the following is a specification.

The invention herein described relates to electrodynamic apparatus and methods and to the generation, the utilization, the transmission and the receipt of electric energy and more particularly to the production and detection of compressional waves, and still more particularly to submarine signaling.

It has for its object increased efficiency in these lines.

This application is a division of application Serial No. 744,793, filed by me in the United States Patent Office, January 29, 1913.

The invention will be understood more particularly by reference to the drawings in which it is shown in its preferred embodiment.

In the drawings Figure 1 is a diagrammatic cross section of apparatus embodying my invention; Fig. 2 being an elevation partly in section of a modification thereof. Fig. 3 illustrates the application of a gas engine to the apparatus for the purpose of operating a generator. Fig. 4 shows diagrammatically the application of the invention to the transmission and receipt of submarine signals.

A suitable form of apparatus for carrying out this invention is shown in Fig. 1. Here 40 is a copper tube say approximately eight inches in diameter and eight inches long (the length being preferably equal to or less than the diameter). 45—45 is the magnetizing coil of the magnetic circuit, 43—43 being the north pole and 44—44 being the south pole. The magnetic flux flows from 43—43 through the top air gap to the armature or core 41, thence through the bottom air gap 44—44 and back through the outside ring to 43—43. The tube 40 lies in the two air gaps and such part of it as is not over the windings 46, 47, is preferably slotted as at 66 or otherwise made of high resistance. The windings 46, 47 are preferably wound on the core 41 through they may be wound on the inside of the poles 43—43, 44—44. The core 41 and the poles are preferably slotted vertically and radially as at 67 and 68, respectively thereby increasing the efficiency of the apparatus by increasing the resistance to the flow of wasteful currents. The core 41 is preferably made of iron and the poles are preferably made of soft steel or wrought iron. The tube 40 is attached in any suitable manner to the object to be set in motion, or attached to the piston of an engine as shown in Fig. 3. As shown these two windings 46, 47 are two coils of a single winding though two windings may be used in which case there would be additional terminals. In operating, for example, the device shown in Fig. 1 an alternating current dynamo and telegraph key are connected to the terminals of the windings 46, 47, and a direct current dynamo with rheostat is connected to the terminals of the magnetizing coils 45. On passing an alternating current through 46, 47, the tube 40 acts as a short circuited secondary and has induced in it the same number of ampere turns as 46, 47, and consequently being in an air gap in which a magnetic flux exists it is driven up and down with great force. For example, if the alternating current has a frequency of 1,000 and the air gap contains as it may about 15,000 lines per square centimeter the force with which the tube is driven up and down will be over 4,000 pounds. The stroke may be of any desired length. If the sides of a ship or the piston rod of a locomotive be attached to the ends of the tube it will be set in motion.

Fig. 2 shows another form embodying the same invention where the device is used for a telephone receiver. Here 60 is the telephone diaphragm made of any suitable material, 61 is the tube, NS is the magnet, 62 being the armature or core and 63—63 the pole circular in form, 64—64 being the winding. This winding is a single winding attached to the telephone line from which it is desired to receive telephonic messages. The tube while preferably made of copper may be of aluminum and is preferably attached to the diaphragm as shown. On currents from a microphone passing through 64—64 the tube 61 vibrates. In this construction only one air gap is used. In the construction shown in Fig. 1 wherein an electro-magnet is employed, also air gaps and coils 46 and 47 wound in opposite directions since the coils act differently as regards any fluctuations of the magnetized coil 45, silence except for the receiving signals is obtained. This is not necessary in the construction shown in Fig. 2 where a permanent magnet is used. Moreover, in Fig. 1 the tube 40 may be cut in two half way down and both ends may be made to move oppositely, the winding 46 and 47 being in the same direction. This gives no unbalanced inertia effects.

My invention also forms a very efficient generator of alternating currents. The tube 40 may be fixed directly to the piston rod of a gas engine as in Fig. 3 where 70 indicates the cylinders of the gas engines, the pistons 71 being set to operate in opposite directions to each other. Where a number of such units are used they may be connected in parallel, and the synchronizing effect is so strong that no crank shafts or fly wheels are necessary (though they may be used as shown in dotted lines in this figure) and the governing can be done by timing the ignition alone. This is of great importance with engines of the type invented by me where the power per cylinder is so great that the crank shaft if it transmitted the power would have approximately the same diameter as the cylinder.

My invention has many other uses which need not here be enumerated. If 46 be wound longitudinally instead of circumferentially and straps be placed across the tube 40 an oscillatory motion will be obtained about the axis of 41.

A convenient way of using a device of this character for submarine signaling is shown in Fig. 4, where 11 represents the skin of the ship. In place of this may be used a diaphragm inserted in a hole cut in the side of the ship, or a diaphragm attached to the side of the ship, preferably to the inside, the space between the diaphragm and the side of the ship being filled with water or other liquid, as oil, which may be under pressure. Or, instead of liquid, compressed gas, may be used, as air or carbonic acid. In Fig. 3, 35 is such a diaphragm, attached to the inside of the skin 11 of the ship, 36 being the liquid, and 37—37 a packing ring, preferably of rubber. The diaphragm may be so constructed that when struck it vibrates for sometime, like a tuning fork, or it may be dead beat.

The apparatus 12, mounted on the skin of the ship 11 is that shown in Fig. 1. When it is used and the switch 13 is thrown down, and the key 16 depressed (moved to the right) current from the alternating current dynamo or source of intermittent current 15 flows into 12 and causes the tube 40 of Fig. 1 to vibrate with great force, which may be, for example, in an apparatus of given size, over 4,000 pounds stress. This tube being attached to the skin of the ship directly or indirectly as in the case where it is mounted on the diaphragm 35, or attached to a rod or spring, produces compressional waves in the water outside of the ship's skin, analogous to sound waves in air which waves are transmitted and received at the receiving station. The frequency of the waves so transmitted may be any desired, ranging from 5 per second to several thousand per second. In practice the frequency is preferably determined by the frequency of the source 15. The key 16 may be used for telegraphing, as in the case of the ordinary telegraph. When the switch 13 is thrown up, the device 12 is put in circuit with the battery 38 and the controlling device 14, which may be a carbon telephone transmitter or where large currents are used a transmitter and relay. Telephonic transmission through the water is accomplished by talking into the transmitter 14. When the switch 13 is thrown down and the switch 17 up, and the key 16 is up (moved to the left) the device 12 is connected to the receiving circuit shown. In this position, when compressional waves strike against the side of the ship 11, coming from some other station, the waves cause the skin of the ship to move, carrying with it the tube 40 (Fig. 1), and the motion of 40 causes currents to be generated in the winding 46, 47 (Fig. 1) which currents actuate the receivers 27, 28. The current entering at the right hand side of the switch 17 and conductor 21 passes through the receivers 27 and 28 which are in series, and back through 33. In place of the switches the usual telephone circuit as used for land lines, may be used to allow simultaneous talking and listening.

At the present time dynamo electric machines, both generators and motors, are almost universally built with rotating members, especially alternating current electric machines, and machines to give any considerable amount of power; or, if with oscillator members, such as the telephone receiver, are of the inductor type.

Oscillatory electric sounders with movable windings have been built, for example, by Lodge (*London Electrician*, January 6, 1899), and by Evershed (British Patent 16,895, 1909), and others. These types have as a rule consisted of a circular coil, or armature winding, located in the annular air gap of a permanent or electro-magnet, the armature winding or circular coil being mechanically attached to the diaphragm to be set in vibration. It is of course well known that the mutual induction between the armature and field winding should be as small as possible, and Lodge accomplishes this by either making the armature winding a circular plane perpendicular to the lines of force of the magnetic circuit, (*Elect.* Jan. 6, 1899, Fig. 5) or by a series of parallel opposed windings (Fig. 4, same article); and Evershed by means of a series of parallel opposed windings, and by laminations in a plane parallel with the armature windings. In the present invention, however, a radically different type of construction is used, in which a transformer consisting of a primary winding and a closed secondary winding are both placed in the air gap of a magnetic circuit, and one, preferably the closed secondary winding, free to move relatively to the other, and attached to the driving element or the element to be driven. By this improved method the following advantages among others are obtained: A. The moving element or secondary may consist solely of a cylinder of copper, thus presenting minimum resistance to the current and doing away with all outside connections and brushes or flexible leads, and minimum inertia resistance to the mechanical motion. B. Needing no insulation on account of not being split, the current density may be much above the values possible where the armature is divided and insulated. If the armature were insulated high current densities would heat it so as to destroy the insulation. C. Since the self-induction of the primary, as well as its mutual induction with the field, are annulled, there is no necessity of laminated fields, and there is no appreciable loss due to hysteresis or eddy currents, and the power factor is approximately unity, because the primary winding consists of two parts 46, 47, wound in opposite directions and lies adjacent to the short-circuited secondary consisting of the copper tube 40. D. The moving copper tube may if desired bear on the field pole faces, being lubricated; or, if this is not desired, can be kept true to shape, thus reducing the air gap and magnetizing current. E. The solid tube is much more mechanically rigid than any winding or split conductor, and transmits the vibrations better and without change of phase. F. The phase of the current in the secondary is always necessarily opposed to that in the primary winding, which cannot be the case in a compensating winding or two series windings, free to move, on account of the back voltage of motion, and other reasons. G. The current is evenly distributed in the moving element.

The importance of A, B and D, *i. e.*, small mass of moving part, large current density, and small air gap may be seen from the following: Assume the moving part to have a mass of 16 pounds, and to be operated by a current of 1,000 cycle frequency. Then if the amplitude of vibration is to be 1/100 inches, the force on the tube must be, roughly: $2 \times \text{mass} \times \text{amplitude} \times \text{frequency}^2$, or nearly two tons. Now this is the force necessary merely to move the tube itself, and takes no account of the force to do the work desired, for example, the establishment of a compression wave in water, a substance requiring very great force to compress it. From this example it will be understood why the invention here described is the first to actually accomplish what has often been previously attempted, *i. e.*, the practical electrical production of compressional sound waves in water.

The importance of E will be seen from the following considerations: When used as a motor to generate sound in water or as a generator to act as a microphone on receipt of such waves, the mechanical stress will be transmitted or received at a velocity dependent upon the velocity of sound along the axial length of the tube. If the frequency is 1,000 the quarter waves length in a solid copper tube will be of the order of one foot, if the tube be solid, and hence the whole tube, if not more than one foot long, will act as a whole. But if the moving element consist of a winding, then the quarter wave length will be, as a rule, of the dimensions of one inch, and the elastic wave from one part of the winding will reach the diaphragm at such a moment and phase as to neutralize that from the portion two inches away on either side. Consequently the resultant effect will be almost *nil*, both as sound producer and as microphone, *i. e.*, magnetophone. In addition the great forces mentioned above, rapidly alternating, are very destructive to insulating materials, especially when heated.

The importance of C and F and G are well known to all electricians. The necessity of even distribution of current is very great, as otherwise the back voltages due to the motion are not proportional to the currents, and cause great losses.

This form of a motor has the great advantage over all other current motors in that owing to the fact that the primary and secondary are concentric and closely adjacent to each other, there is practically no hysteresis or self inductance or eddy currents. Thus, for example, at a frequency of 1,000 per second and an ohmic resistance of four ohms from the windings a voltage of 87 volts will make 20 amperes pass through the circuit showing a very high power factor and this when the tube 40 is held still. When the tube is allowed to move the power factor is very close to unity. The losses are very small and the construction is very cheap per horse power as no laminated iron need be used and the winding is very simple while the amount of wire used is very small. The starting torque is very high. Two-phase current may be used, for example, one phase on 46 and the other on 47. A rectifier may be used on starting under load, the motion of the tube reversing the rectifier. The force is very high per unit of current and hence it is well adapted for submarine signaling. The force is of altogether different dimensions to what has been obtained heretofore and if applied for one second would give a 12-inch shell three times the velocity it has when fired from a 12-inch gun. It starts up very rapidly on account of the small time constant, *i. e.*, of about 1/10,000th of a second and is hence adapted for submarine telephony as well as telegraphy.

By the use of my invention the obstacle which has prevented the use of oscillating dynamos, *i. e.*, the dragging of the lines of force with the motion of the coil, is done away with. To such an extent is this true that the device here shown is more sensitive, for equal motions, than any carbon microphone. It will detect motions less than one per cent. of those which a carbon microphone will detect. The absence of dragging of lines and of inductance and hysteresis makes it very suitable for tuning, to which hysteresis is almost absolutely fatal. Such microphones may be coupled in series, or parallel, which carbon microphones cannot be, on account of difference of phase.

What I claim as my invention is:

1. An oscillating dynamo, means for generating a magnetic field, a primary coil situated in said magnetic field, and a closed secondary also situated in said magnetic field, and in inductive relation to said primary coil and so placed as to annul the self-induction of said primary coil.

2. An oscillating dynamo, means for generating a magnetic field, a primary coil situated in said magnetic field, and a closed secondary also situated in said magnetic field, and in inductive relation to said primary coil and so placed as to annul the self-induction of said coil, one of the two, said primary coil and said secondary, being movable.

3. An oscillating dynamo, means for generating a magnetic field, a primary coil situated in said magnetic field, and a closed secondary also situated in said magnetic field, and in inductive relation to said primary coil and so placed as to annul the self-induction of said coil, said secondary being movable and said primary coil being fixed.

4. An oscillating dynamo comprising means for generating a magnetic field, a primary coil situated in said magnetic field and a closed secondary also situated in said magnetic field concentric and closely adjacent to and in inductive relation to said primary coil, one of the two, said primary coil and said secondary, being movable.

5. An oscillating dynamo comprising means for generating a magnetic field, a primary coil situated in said magnetic field and a closed secondary also situated in said magnetic field concentric and closely adjacent to and in inductive relation to said primary coil, said secondary being movable and said primary being fixed.

6. An oscillating dynamo having means for generating a magnetic field comprising core members having an air gap between them, a coil situated in said magnetic field and a closed secondary also situated in said magnetic field and in inductive relation to said coil, the faces of said core members adjacent the said air gap being slotted.

7. An oscillating dynamo having means for generating a magnetic field comprising core members having an air gap therebetween, a coil situated in said magnetic field and a closed secondary also situated in said magnetic field and in inductive relation to said coil, so placed as to annul the self-induction of said coil, the faces of said core members adjacent said air gap being slotted.

8. An oscillating dynamo having means for generating a magnetic field comprising core members having an air gap therebetween, a coil situated in said magnetic field and a closed secondary also situated in said magnetic field and in inductive relation to said coil, one of the two, said coil and said secondary, being movable and the faces of said core members adjacent to said air gap being slotted.

9. An oscillating dynamo having means for generating a magnetic field comprising core members having an air gap between them, a coil situated in said magnetic field and a closed secondary also situated in said magnetic field and in inductive relation to said coil and so placed as to annul the self-induction of said coil, one of the two, said coil and said secondary, being movable and the faces of said core members adjacent to said air gap being slotted.

10. An oscillating dynamo having means for generating a magnetic field comprising core members having an air gap therebetween, a coil situated in said magnetic field and a closed secondary also situated in said magnetic field and in inductive relation to said coil, said secondary being movable and said coil being fixed, the faces of said core members adjacent said air gap being slotted.

11. An oscillating dynamo having means for generating a magnetic field comprising core members having an air gap therebetween, a coil situated in said magnetic field and a closed secondary also situated in said magnetic field and in inductive relation to said coil and so placed as to annul self-induction of said coil, said secondary being movable and said coil being fixed, the faces of said core members adjacent to said air gap being slotted.

12. An oscillating dynamo, means for generating a magnetic field, a coil situated

in said magnetic field, and a closed secondary also situated in said magnetic field, and in inductive relation to said coil, and the parts of the moving member lying outside of the magnetic field being of relatively high electric resistance.

13. An oscillating dynamo, means for generating a magnetic field, a coil situated in said magnetic field, and a closed secondary also situated in said magnetic field, and in inductive relation to said coil and so placed as to annul the self-induction of said coil, and the parts of the moving member lying outside of the magnetic field being of relatively high electric resistance.

14. An oscillating dynamo, means for generating a magnetic field, a coil situated in said magnetic field, and a closed secondary also situated in said magnetic field, and in inductive relation to said coil, one of the two, said coil and said secondary, being movable, and the parts of the moving member lying outside of the magnetic field being of relatively high electric resistance.

15. An oscillating dynamo, means for generating a magnetic field, a coil situated in said magnetic field, and a closed secondary also situated in said magnetic field, and in inductive relation to said coil and so placed as to annul the self-induction of said coil, one of the two, said coil and said secondary, being movable, and the parts of the moving member lying outside of the magnetic field being of relatively high electric resistance.

16. An oscillating dynamo, means for generating a magnetic field, a coil situated in said magnetic field, and a closed secondary also situated in said magnetic field, and in inductive relation to said coil, said secondary being movable and said coil being fixed, and the parts of the moving member lying outside of the magnetic field being of relatively high electric resistance.

17. An oscillating dynamo, means for generating a magnetic field, a coil situated in said magnetic field, and a closed secondary also situated in said magnetic field, and in inductive relation to said coil and so placed as to annul the self-induction of said coil, said secondary being movable and said coil being fixed, and the parts of the moving member lying outside of the magnetic field being of relatively high electric resistance.

18. An oscillating dynamo, means for generating a magnetic field, a coil situated in said magnetic field, and a closed secondary also situated in said magnetic field, and in inductive relation to said coil, the magnetic circuit having two air gaps, and the coil wound in two parts, in opposite directions.

19. An oscillating dynamo, means for generating a magnetic field, a coil situated in said magnetic field, and a closed secondary also situated in said magnetic field, and in inductive relation to said coil and so placed as to annul the self-induction of said coil, the magnetic circuit having two air gaps, and the coil wound in two parts, in opposite directions.

20. An oscillating dynamo, means for generating a magnetic field, a coil situated in said magnetic field, and a closed secondary also situated in said magnetic field, and in inductive relation to said coil, one of the two, said coil and said secondary, being movable, the magnetic circuit having two air gaps, and the coil wound in two parts, in opposite directions.

21. An oscillating dynamo, means for generating a magnetic field, a coil situated in said magnetic field, and a closed secondary also situated in said magnetic field, and in inductive relation to said coil and so placed as to annul the self-induction of said coil, one of the two, said coil and said second secondary, being movable, the magnetic circuit having two air gaps, and the coil wound in two parts, in opposite directions.

22. An oscillating dynamo, means for generating a magnetic field, a coil situated in said magnetic field, and a closed secondary also situated in said magnetic field, and in inductive relation to said coil, said secondary being movable and said coil being fixed, the magnetic circuit having two air gaps, and the coil wound in two parts, in opposite directions.

23. An oscillating dynamo, means for generating a magnetic field, a coil situated in said magnetic field, and a closed secondary also situated in said magnetic field, and in inductive relation to said coil and so placed as to annul the self-induction of said coil, said secondary being movable and said coil being fixed, the magnetic circuit having two air gaps, and the coil wound in two parts, in opposite directions.

24. The method of generating alternating currents in a main conductor which consists in oscillating a closed conductor in a magnetic field whereby an alternating current is generated therein, causing said alternating current to induce an alternating electromotive force in the main conductor and causing the currents resulting from the electro-motive force in the main conductor to substantially neutralize the inductance in the oscillating conductor at full load.

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