July 3, 1934. R. A. FESSENDEN 1,965,226

METHOD AND APPARATUS FOR SOUND TRANSMISSION

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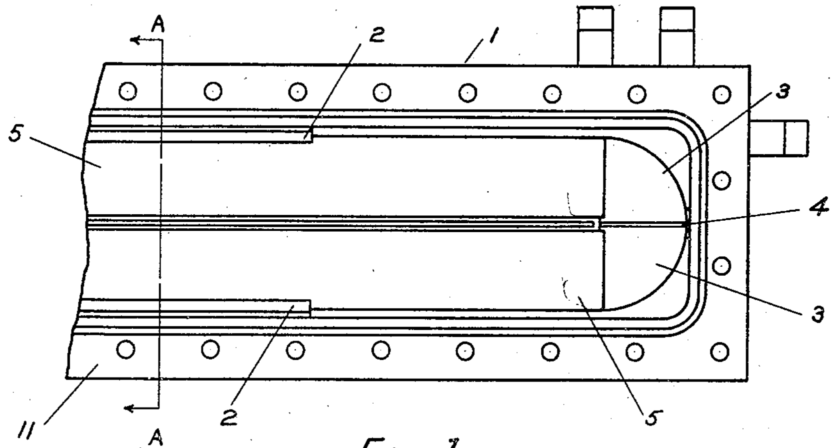

Fig 1

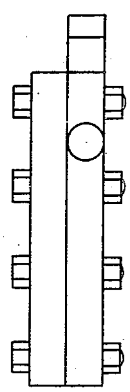

Fig 3

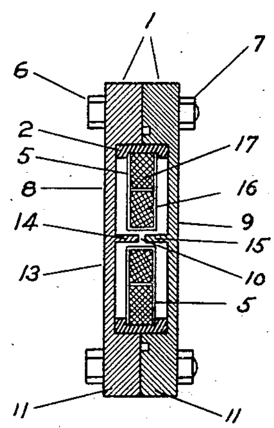

Fig 2

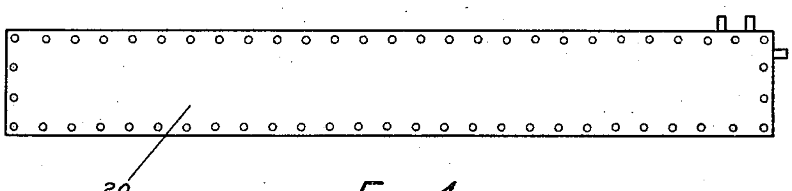

Fig 4

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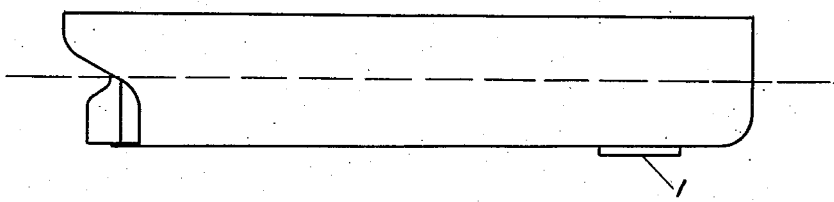

Fig 5

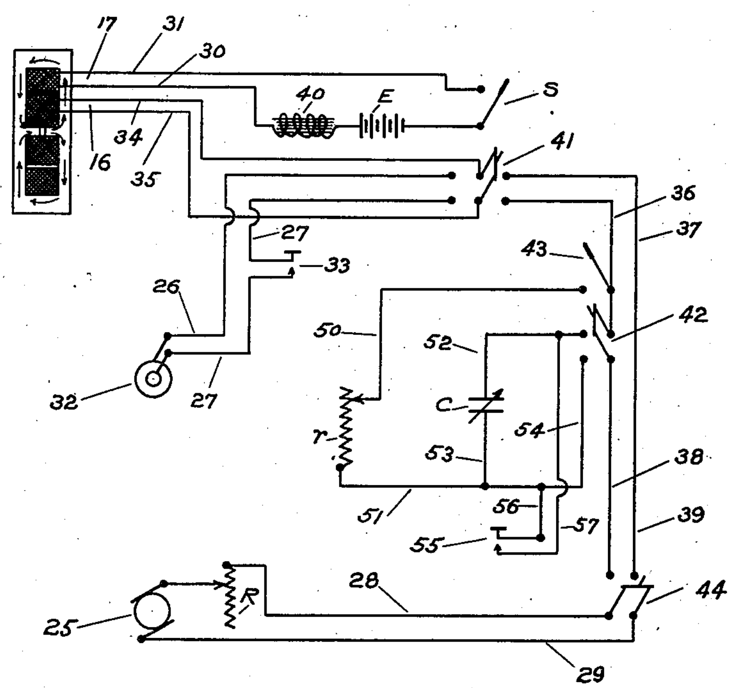

Fig 6

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METHOD AND APPARATUS FOR SOUND TRANSMISSION

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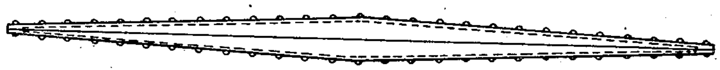

Fig 7

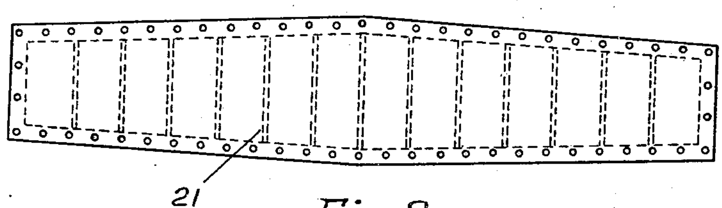

Fig 8

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UNITED STATES PATENT OFFICE

1,965,226

METHOD AND APPARATUS FOR SOUND TRANSMISSION

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Application August 8, 1927, Serial No. 211,520

13 Claims. (Cl. 177—386)

My invention relates to an improvement in a sound transmitting device and more particularly to an electro-magnetic means of emitting subaqueous sounds.

A purpose of my invention is to obtain a submarine sound sender which may be controlled accurately by no other means than those usually employed in simple sound emitting devices.

More particularly the purpose of this invention is to have such control over the oscillating parts of the sound emitter that an almost instantaneous cessation of the sound may be effected. It is also the purpose of this invention to control the sound emission at the beginning of the signal so that the vibrations will attain a maximum value as quickly as possible.

This invention has also a further distinguishing feature in that by a proper design it may be used as a loud speaking telephone receiver. For this purpose it is exceedingly useful, since the diaphragm may be so designed that it is equally resonant to all frequencies, thus overcoming one of the greatest causes of distortion of voice and vocal sounds.

Another purpose of this invention is to construct a sound sender which shall consist of a minimum number of parts and which shall have no complicated mechanical mechanism.

A further purpose of this invention is to construct a sound sender which shall be adaptable to be mounted along the keel, or other outward parts of a ship, and thus avoid the difficulty and expense of the other well known installations known as the skin and tank type.

It is now well known in the art of submarine signaling that, in order to adapt a sound sender for use in depth sounding by echo method for a great range of sea depths, from shallow to deep depths, the sound sender must be capable of emitting short notes when it is desired to measure short depths. This arises from the fact that sound travels about five times as fast in sea water as in air. In sea water of four fathoms, or twenty-four feet, the sound emitted at the surface will return reflected from the bottom of the water in about one hundredth of a second. Thus the signal sent, if one hundredth of a second long, or over, would overlap the signal received and no distinct impression of the received signal could possibly be received.

By means of my invention, it is possible to emit a distinct signal of even less than one hundredth of a second. In recent experiments, it has been found that a note of as short a duration as about two thousandths of a second could be made. It is evident, therefore, that the present sender, or oscillator, as it may be called is well adapted for use in depth sounding.

An embodiment of my invention is illustrated in the accompanying drawings in which:

Figure 1 represents the end part of the oscillator with the top case removed.

Figure 2 represents a section of the line AA of Figure 1.

Figure 3 represents an end view of the oscillator.

Figure 4 shows the complete oscillator assembled.

Figure 5 shows a position of the oscillator on the keel of a ship.

Figure 6 shows a circuit diagram which may be employed.

Figure 7 shows a modified form of the oscillator in a position equivalent to looking down upon the oscillator in Figure 4.

Figure 8 shows a similar view as in Figure 4 of another modified form of the oscillator.

The casing of the oscillator, as shown in section in Figure 2, consists of two symmetrical parts 1, 1 which in the assembled position have the faces of flanges 11, 11 opposite and touching each other. The two halves of the casing are bolted in position by bolts 6 and bolt nuts 7 which run the length of the oscillator as shown in Figure 4. If necessary, there may be shims, packing, or other means to keep the joint between the faces 11, 11 watertight. The casing 1 consists of the outer flange portion 11 extending all the way around the edge of the rectangular face 20. Within the flange portion of the casing is the thin membrane portion 13, which has a rectangular shape whose ratio of length to width is made large dependent upon the pitch of the note and the necessary power of the oscillator. At the middle of the membrane 13 extending almost along the whole length thereof is a tooth or pole portion 14 which is opposite the tooth portion 15 of the face 9. The air gap between the teeth is very small, of the order of that between the rotor and stator of a motor. The width of the teeth strips are also as narrow as possible so that the whole mass at the center of the membrane is very small and so that thereby the inertia of the whole membrane is very small. The natural pitch of the membrane, also, will be practically unaffected by the presence of the teeth strips.

The energizing mechanism of the membrane consists of two coils, one alternating current coil 16, and one direct current coil 17, although in Figure 6 the coil 16 may at times be used for direct current also. Ordinarily, the direct current coil polarizes the teeth strips 14 and 15 thus initially placing a magnetic pull upon the membranes. When the alternating current circuit is closed, this pull is either increased or diminished depending upon the direction of the alternating current at that moment. Since the current in the alternating current coils reverses every half cycle, the pull upon the membranes will be reversed every half cycle, resulting in the oscillation of the diaphragm at the same frequency as that of the alternating current.

The coils 16 and 17 are placed in the recess formed by the flange 11, the membrane 8, and the tooth 14, and extend the complete length of the inner portion of the case about the tooth 14. As a support for the coils, U shaped brass members 5 are fitted about the inner edge of the coil 16 covering the upper and lower surface of the coil 17 as well. At the end portion of the coils, two quadrant U shaped members 3, 3 also of brass are separated by a fibre insulating U shaped piece 4 so that the brass members will not have a complete electrical circuit and thus oppose the action of the coils. To prevent the coils from shaking while the oscillator is being operated, fibre strips 2 lapping over the brass members 5 are wedged between the inner side of the flange 11 and the members 5 respectively.

The oscillator is designed to have light vibrating parts, which are shown in the preferred form as rectangular membranes but which may be incorporated in some other shapes, illustrations of which are shown in Figures 7 and 8. It is designed also to be compact and adaptable for various work, consisting of only two mechanical parts which may be machined or even cast of metal to the correct dimension.

In the ordinary construction of the oscillator, the length of the casing may be about four feet, the width about six inches, and third dimension, the thickness of the oscillator, about one and one-half inches. The wall portion of the casing, to conform with the above dimensions, is about one and one-fourth inches, and the thickness of the membrane is approximately one eighth of an inch depending upon the pitch desired. Within the space between the two membranes and the side walls the energizing coils are wound about the narrow pole strips which extend the length of the membranes but for an end space needed for the ends of the coils. This space is just sufficient for the coils so that there is practically no free space within the oscillator. The narrow pole strips, which may be flared into a large pole surface, have been made about one-fourth of an inch wide and have an air space of the order of eight thousandths of an inch between the two pole surfaces. The coils are wedged against the side walls of the oscillator so that they may be free from the motion of the vibratable parts which consist of the membranes and the pole strips, which are negligible in mass compared with the vibratable parts of all other oscillators, or compared with the total water mass which is set in motion.

The magnetic circuit, as shown by arrows in Figure 6, of the flux due to the energizing coils may be traced as across the air gap through the pole strip to the membrane where it divides into two parts, half flowing to one side wall, and half to the other, across the narrower dimension of the face of the oscillator, through the side walls, returning to the pole strips through the membrane of the other face. The magnetic circuit is an almost closed magnetic circuit with little stray flux due to the very small air gap.

As seen in Figure 2 and Figure 6 the magnetic action which is to pull the pole strips together exerts pulls on the middle of the membranes, thus causing the membranes to vibrate as though there were two tuning forks joined at their prongs, end to end, with an electromagnetic operated mechanism between the prongs at the point of junction. In this way it may be seen that the natural frequency of the membrane depends upon its half width and thickness, being inversely proportional to the square of the half width and directly proportional to its thickness. Since it is possible to keep the width very small, the thickness will be small for the same pitch as compared with a circular diaphragm of the same pitch and area.

In the complete design of the oscillator the radiating surface has purposely been made large as compared with the vibrating mass of the oscillator, so that there will be as little energy as possible stored in the vibrating mass. It is easily seen that in this oscillator the vibrating mass is, practically, only the mass of the membranes which are exceedingly light.

In Figure 6 is shown the electrical circuit which may be employed in the operation of the oscillator. The outer or D. C. coil may be energized through the leads 30 and 31 by means of a direct current source E, a switch S, being provided to close the circuit. A choke coil 40 is also provided in the circuit to smooth the pulsations due to the alternating current induced from the other circuits. The A. C. coil may either be energized by the alternating current source 32 by closing a key 33 or some circuit closing means through the leads 34 and 35 after the switch 41 has been thrown to the left, bringing the alternating current generator potential across the key 33 through the leads 26 and 27, or by means of a direct current source 25. The direct current source 25 has a resistance R in circuit so that the potential across the coil 16 may be varied. When the direct current source 25 is used, the switch 41 is thrown to the right and the switches 42, 43, and 44 are also closed. The switch 43 connects through the lead 50 to a variable resistance R, which in turn connects to one side of a condenser lead 53 through the lead 51. The switch 42 throws the variable condenser C in circuit through the leads 52 and 53 connecting to the opposite terminals of the condenser C. A key 55 is shunted across the condenser C by the leads 56 and 57. The switch 44 impresses the potential of the generator 25 by means of the leads 28 and 29 upon the circuit. It is not necessary for all operations to have the switch 43 closed as the function of the resistance R is to discharge the condenser C when it is not desired to have the condenser discharge back through the coil 16.

If the switches 41, 42, and 44 are closed the circuit may be operated as follows. The current impressed through the generator 25 flows through the lead 28, through the switch 44, the lead 38, the switch 42, the leads 54, 56, key 55, when closed the lead 57, the switch 42, the lead 36, the switch 41, the lead 35, the coil 16 returning through the lead 34, switch 41, leads 37, 39, switch 44, lead 29, source 25. When the switch 41 is closed to the left, the circuit is closed through the source 32 in the following manner: source 32, lead 27, key 33 when closed, lead 27, switch 41, lead 35, coil 16, returning through lead 34, switch 41, lead 26, source 32.

When the switch 41 is closed through the key 33 the oscillator emits sounds of continuous waves dependent upon the frequency of the alternating current source 32. The key 33 which may be any automatic closing means or even a manual closing means may, in the case of it being an automatic closing means, operate the oscillator at definitely determined intervals for a desired length of time.

The prime purpose of the circuit associated with the throwing of the switch 41 to the right is to clamp or block the membrane from further movement when a very abrupt cessation of sound is desired. Under ordinary conditions, the vibrations of the membrane will be rapidly damped by the circuit including the source 40 but if it is desired to limit the motion to exceedingly small intervals of time this latter means may be employed.

The key 55 may either operate to open the circuit already closed, or close the open circuit. When the circuit is closed through the source 25 the current flows in such a manner through the coil 16 that the pull exerted between the teeth strips is increased. The pull may be so great as to cause the faces to touch, although this is not necessary. When the circuit is broken through the opening of the key 55, the energy in the coil which is not consumed in the break of the circuit is used to charge the condenser C which may be discharged through the resistance R if the switch 43 is closed.

The key 55 may be made to operate automatically such that it remains open only a very short interval of time with the result that only one or a few vibrations of the membrane is made before the full current of the source 25 is on again and prevents any further movement of the membrane. Thus in this method of operation, the initial position of the membrane is one of tension wherein the teeth strips are drawn together then the key is opened and the tension is released, allowing the membrane to vibrate freely when it is again blocked or held on the closing of the key which allows the current to come on.

The oscillator may be operated another way also. The circuit may normally be open. In this case the key is pressed either manually or automatically whereby the current flows drawing the membranes inward and holding them in this position until the current is released. The sound may be emitted either way, by a make or break of the key and further the time interval between the make and break may be regulated automatically so that just the right length of a sound may be produced.

This manner of operation is especially adaptable to the oscillator. It is well known that the energy stored in a moving system is dependent upon its mass. In the case of an oscillator this mass includes both the moving mass of the apparatus and that of the water mass which the membrane must set in motion to radiate energy. This total mass in the present type of oscillators is about three-fourths due to the apparatus, and one-fourth due to the water. In my apparatus, however, the mass of the apparatus is very light and practically no energy which is stored is due to the apparatus, all of it being due to the water mass which thus decreases the total amount of energy stored in the system for the same resulting amount of radiation.

This is due to the fact that the diaphragm has practically no weight attached to it, which is not true in other oscillators, nor any heavy central pole face, nor coils to move with it. The only moving parts are the two membranes and their narrow teeth strips in the center. It is thus possible to have the membrane clamped rapidly in its natural operation or to forcibly stop its oscillations by the attraction of the two teeth strips or pole faces.

Another feature which causes the rapid damping is due to the fact that normally there are two surfaces exposed to the water in the operation. This is evident from Figure 5 which shows the oscillator mounted on the keel of a ship. This is only one way of mounting, but other methods and positions both within and without the boat will readily occur to one skilled in the art whereby both surfaces may be brought in contact with the water.

In the operation of the oscillator, when the proper currents are sent through the coils 16 and 17, the pull in the air gap between the teeth or pole strips mutually react upon the two membranes such that both membranes move with the same phase relation. Both membranes are thus moving inwardly, or both are moving outwardly thereby effecting a double radiating area whose radiations are in phase. If the membranes did not oscillate in phase there would be a tendency for the flow of water due to the pressure to oscillate back and forth from one membrane to the other, thus putting an additional water mass in motion. In my oscillator this is prevented by causing the oscillations of the membranes to be exactly in phase thus eliminating all oscillatory flows from one membrane to the other. It is to be noted further that the damping of the oscillator is thus increased since the effective radiating surface is increased.

The radiating surface may also be increased by lengthening the oscillator. Under such conditions since the radiating surface is increased, the radiating capacity is also increased, thus allowing the construction of an oscillator of higher power. As regards the ability to make the membrane oscillate in phase this is easily accomplished since the pull in the air gap is uniform throughout at any instant, and the same pull will be exerted uniformly over the whole membrane. There will, however, be a directional effect when the oscillator becomes long as compared with the wave length which will tend to lessen the sound intensity in the direction of the length of the oscillator as at certain points on this line the sounds coming from the various points on the radiating surface of the oscillator will be out of phase due to the varying length of the water path from those points on the radiating surface. Theoretically, this effect should become noticeable when the length of the oscillator becomes longer than one half the wave length of the sound emitted. This feature of the oscillator may be usefully applied when it is desired to locate a receiving unit nearby the oscillator without much interference from the sound of the oscillator. For the practical use of the oscillator in sending and for depth sounding, this directional effect has also been found useful while it also allows a greater radiating surface and thus an oscillator of greater power. In one oscillator of this type which I have constructed the length was made a little over four feet while the width was about six inches for a note of about 1000 cycles per second. A ratio of this order of 8 to 1 for length to width has been found advantageous in all kinds of work. Where it is desirable that the oscillator should be equally resonant over a range of frequencies, as in voice or vocal transmission, this form of a diaphragm has proved very valuable.

In Figure 7 a means of obtaining such a device which can easily be made equally resonant to all frequencies is shown. It has been mentioned above that the pitch of the diaphragm in the case of the rectangular diaphragm shown in Figure 4 is dependent upon the square of the half width of the diaphragm and the thickness, being inversely proportional to the square of the half width and directly proportioned to its thickness. Thus there develops two different ways of adjusting a diaphragm to resonance for a range of frequencies by graduating the dimensions of the diaphragm so that parts will respond to one frequency and other parts to another frequency. By a proper design, in this manner, it is possible to construct a device which will respond with equal energy output for equal energy input over a range of frequencies. Figure 7 shows the thickness of the diaphragm tapered. This tapering is usually only a very slight amount, thousandths of an inch, so that the same type and size of nuts and bolts may be used as shown in Figure 2 at 6 and 7 for the whole length of the oscillator. Besides being tapered the under surface of the oscillator diaphragm may be grooved as shown in Figure 8 to allow more freedom to the parts of the oscillator diaphragm to respond to their own particular frequency.

Figure 8 shows the tapering of the width of the oscillator commencing at the center line and tapering towards the ends, although it is equally possible to have the diaphragm taper from one end to the other. Since the pitch of the diaphragm is inversely proportional to the square of the half width, the end portions of the diaphragm are resonant to higher frequencies than the central portions, whereas in Figure 7 where the tapering is in the thickness of the diaphargm from the center to the end, the opposite is true; namely, that the central portions respond to higher frequencies than the end portions of the diaphragm. This is easily seen to be true from the fact that the pitch of the diaphragm is directly proportional to its thickness. The diaphragm is grooved on the inner side as shown at 21, the dimensions of the grooves and the space between the grooves depending upon the particular design desired.

The tapering shown for uniform design of equal output energy for equal input energy over the frequency range for which the device is designed would demand a tapering curve somewhat in the shape of a parabola, but in most cases it has proved very nearly as good to have a uniform or straight line taper.

Various other modifications in the method of operation and the apparatus may be used in my invention as will readily appear to one skilled in the art and thus I do not limit myself to the exact details described but claim:

1. A sound emitting device comprising a magnetic casing of two symmetrical parts, each of said parts having a thick outer rim at which the halves of the casing join one another, a thin elongated membrane portion within the thick rim, an elongated pole strip portion at the middle of the membrane portion, said elongated strip portions having surfaces opposing one another to form an air gap, electromagnetic exciting means comprising exciting coils resting within said casing in the enclosed space formed by the outer rims, the membranes, the pole strips and the air gap.

2. A sound emitting device comprising a magnetic casing of two symmetrical parts, each part of the said casing having a thin elongated membrane portion exposed to a sound transmitting medium on opposite sides of the casing, said membrane portions having formed at the middle of their inner side elongated pole strips whose surfaces cppose one another to form an air gap, electromagnetic exciting means and means for positioning said electromagnetic exciting means mechanically free from said membranes.

3. A sound emitting device comprising a magnetic casing of two symmetrical parts, each of said parts having a thick outer rim forming a rigid outer wall for the casing, a thin vibratable elongated membrane portion exposed to a sound transmitting medium forming two opposite faces of the casing, and light elongated pole strip portions on the inner side of said membrane portions, electromagnetic exciting means, and means for positioning said electromagnetic exciting means mechanically free from said membranes whereby the total vibratable metallic mass is insignificant compared with the total vibratable water mass.

4. A sound emitting device comprising a magnetic rectangular casing whose ratio of length to width is large about a ratio of 8 to 1 composed of two symmetrical parts each of said parts having a thick outer rim forming a rigid outer wall for the casing, a thin vibratable elongated membrane portion exposed to a sound transmitting medium forming two opposite faces of the casing, and light elongated pole strip portions on the inner side of said membrane portions, and electromagnetic exciting means resting within said casing for vibrating said vibratable membranes.

5. In a sound emitting device, a diaphragm having length and width dimensions, said diaphragm having substantially straight sides and being tapered in width along its whole length, said diaphragm having grooves cut on its inner surface whereby parts of the said diaphragm are resonant to different frequencies.

6. A sound emitting device including an elongated substantially rectangular diaphragm tapered in width and grooves cut substantially perpendicular to its length.

7. A sound emitting device including an elongated substantially rectangular diaphragm tapered in width and grooves cut on the inner side thereof and substantially perpendicular to its length.

8. A sound emitting device including an elongated substantially rectangular diaphragm tapered in at least one dimension and grooves cut substantially perpendicular to its length for sectioning said diaphragm to provide for resonant portions of different frequencies.

9. A submarine sound signaling device comprising a watertight casing composed of two vibratory plates recessed to form heavy outer rims to provide space for the sound generating mechanism and means contained within said space operating directly upon the two plates for generating the sound vibrations.

10. An oscillator of the type described, comprising a casing, a diaphragm on one side of said casing, elongated and approximately eight times its width in length and means within said casing for oscillating said diaphragm.

11. An oscillator of the type described, comprising a casing, a diaphragm on one side of said casing, elongated and approximately eight times its width in length, and means within said casing for oscillating said diaphragm, said length being approximately a wave length of the sound to be emitted and said means operating said diaphragm in phase, whereby a directional effect of the emitted sound is produced.

12. A sound emitting device comprising a diaphragm having length and width dimensions, said diaphragm being of uniform thickness and being tapered in its width and electrical means acting on the diaphragm to produce mechanical forces along the whole length of the diaphragm normal thereto.

13. A sound emitting device comprising a diaphragm having length and width dimensions, said diaphragm being of uniform thickness and being tapered in its width and having grooves therein across the width thereof, and electrical means acting on the diaphragm to produce mechanical forces along the whole length of the diaphragm normal thereto.

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