June 22, 1926. 1,589,962

H. HECHT ET AL.

RADIATING MEMBER OF SOUND SIGNALING APPARATUS

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Fig. 1.

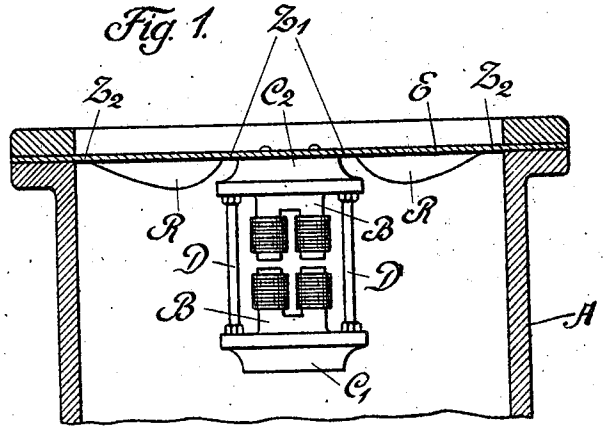
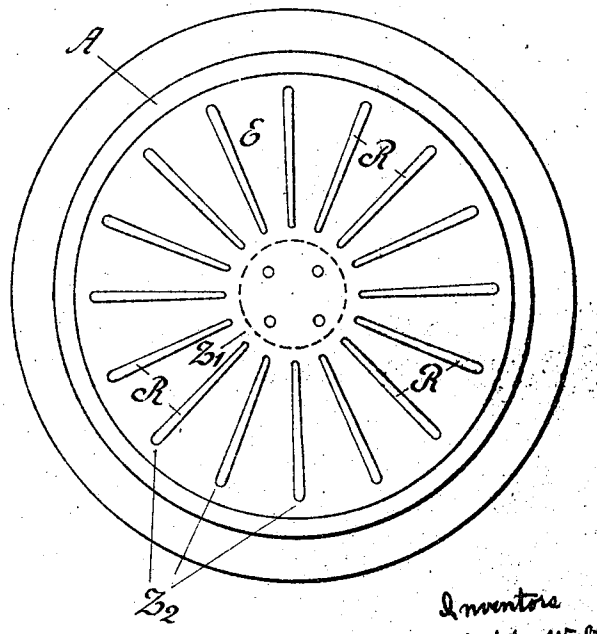


Fig. 2.



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Fig. 3.

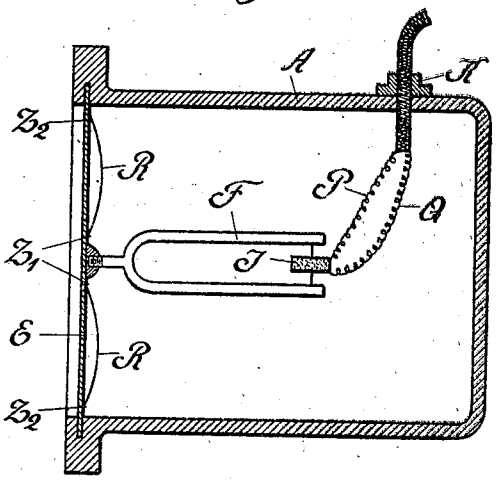
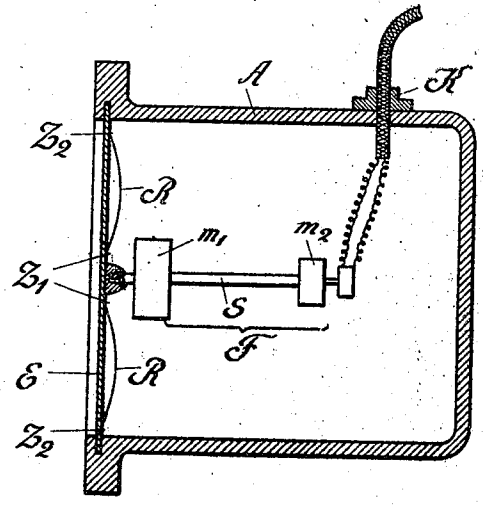


Fig. 4.



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Fig. 5.

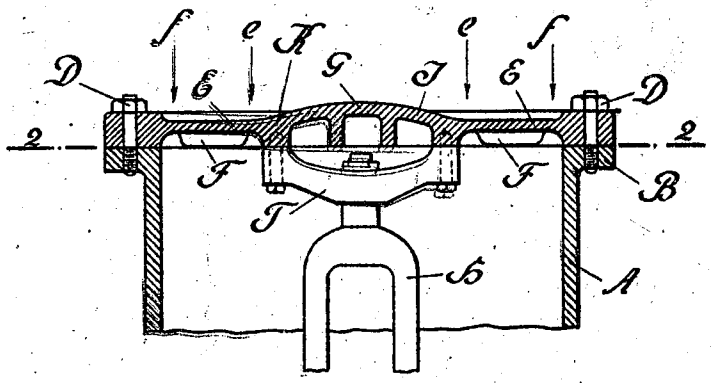
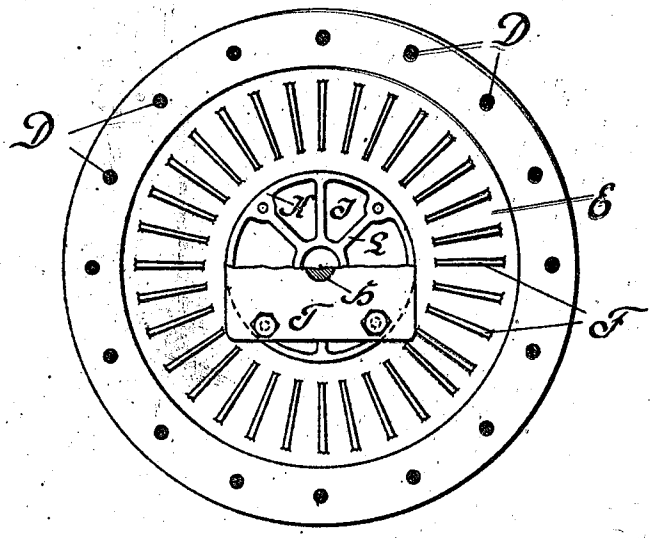


Fig. 6.



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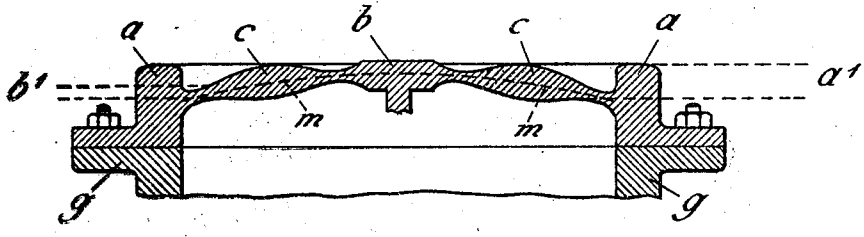
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Fig. 7



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UNITED STATES PATENT OFFICE.

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RADIATING MEMBER OF SOUND-SIGNALING APPARATUS.

Application filed January 6, 1921, Serial No. 435,565, and in Germany June 14, 1915.

This invention relates to improvements in submarine sound signaling apparatus for sending and receiving sound waves and in which a diaphragm or vibrating plate acts as a member for transferring sound energy from the liquid or water to the air or to the other members of the apparatus, or vice versâ.

If, in an apparatus of this kind, a plate that vibrates in response to sound waves is used whose natural note or rate of vibration is higher than the frequency at which it is to operate, i. e. higher than the frequency that is to be employed for signaling, it will have to be of a certain thickness because, apart from other factors that determine its dimensions, the natural tuning of such plate is determined by the ratio of its diameter to its thickness. At the relatively high frequencies or rates of vibration employed in submarine sound signaling the thickness of such a diaphragm will be very considerable. If its natural frequency is higher than the signaling frequency it is exceedingly difficult to so excite it when sending that it executes motions of sufficient amplitude, because this excitation has to be carried out by another vibratory member or structure that is coupled to the vibrating or radiating plate, and with the aid of which vibrations that correspond to the signaling frequency have to be produced in the entire apparatus, and it is a difficult matter to apply forces in an apparatus of this kind that are powerful enough to bend the thick diaphragm sufficiently. If the active parts of the "system" are excited without any advantage being taken of any natural frequency i. e. if the parts merely execute motions which external forces compel them to carry out regardless of any kind of tuning, the said difficulty will be increased.

When diaphragms are employed that are tuned to the signaling frequency the said difficulty, although it is reduced, still exists; and another obstacle to be contended with is that it is exceedingly difficult in any case to accurately tune large diaphragms and to maintain their tuning in a practical installation, the more so because, as will be shown hereinafter, it is as a rule not possible to damp such diaphragms sufficiently, or in other words the crest of the resonance curve of the diaphragm cannot be made broad enough.

If diaphragms or plates are used whose natural frequency is considerably below the signaling frequency and if the attempt is made to excite them at the signaling frequency the plate will, as a rule, execute a form of vibration that corresponds to the signaling frequency i. e. the form of vibration of an harmonic. When oscillating in this way the behaviour of the plate is often such that different parts of its surface move in opposite directions. This is a great drawback because it is most desirable that as much as possible of the whole surface of the diaphragm shall operate to radiate energy into the water i. e., as much as possible of the entire area shall operate simultaneously in producing an increased pressure or a reduced pressure in the volume of water against which it abuts. If different parts of the surface oscillate in opposite directions the water will be enabled to move to and fro between these parts, i. e. it would be able to escape from one part to another of the diaphragm without the desired changes of pressure being produced in it. Hence a phenomenon arises similar to that known in the science of electricity as a wattless current, i. e. a part of the energy imparted to the radiating member or radiator is dissipated in causing useless motion of the water.

But even if this does not happen in such a marked degree i. e., even if certain parts of the diaphragm that are comparatively remote from the actual point where it is excited merely remain motionless, the drawback will still exist that instead of the entire area of the diaphragm only that part of it which is near to the point of excitation is taken advantage of for receiving or sending out energy.

But above all things there is one objection in particular, which is equally serious for senders and receivers, that forbids the use of thick i. e., highly tuned, plates. Experience has shown that with such plates it is not possible to obtain a damping effect, i. e., a breadth of the crest of the resonance curve of the plate, that is large enough for a satisfactory useful damping and to render it possible to keep the signaling frequency (i. e. the rate of vibration used for signal-

ing) within the limits between which a sufficiently high efficiency is obtained. To obtain the desired result stiffening members are used, or the diaphragm is made thicker, at the parts where undesirable nodal lines are likely to be formed in it. The essential difference between a plate of this kind and an ordinary plate of uniform thickness consists in the mass and elastic force of the former being unevenly distributed over its surface, and the idea that this distribution must be carried out in accordance with the form of the vibrations that the diaphragm is desired to execute is the fundamental idea underlying the present invention.

In the case of the fundamental form of vibration the simplest plan consists in providing stiffening ribs on the diaphragm that extend in the direction from its periphery towards its centre. Radial blades stood on edge, or perpendicular to the surface of the diaphragm, may be used for this purpose. They are preferably bevelled down towards the periphery and towards the middle of the diaphragm, and they are made of such length that they do not extend as far as the periphery and as far as the center of the diaphragm, so that zones at the periphery and middle of the diaphragm are left unribbed. This is done in order to make the diaphragm flexible at these parts, these flexible parts being necessary to render a bulging of the diaphragm at all possible. With this arrangement the vibrating or exciting force is applied or taken from the centre of the diaphragm where a stiffened plate-like zone is preferably left or produced. This zone may be smaller or larger in extent. If it is made very large a body will result all of whose points will move parallel to each other and execute the same travel, i. e. a body that oscillates like a piston. Around this body there will then be an annular ribbed zone.

The rendering substantially rigid or stiffening of a certain zone or zones of the diaphragm may be accomplished by means of ribs or by increasing the thickness of the diaphragm at the said zone or zones.

The invention is shown in the drawing as applied to various constructional forms of sound signaling apparatus.

Fig. 1 represents a longitudinal section of a part of a sending and receiving apparatus whose diaphragm is provided with radial ribs in such manner as to cause it to execute vibrations of the desired form.

Fig. 2 shows a front view of the diaphragm of Fig. 1.

Fig. 3 illustrates a constructional form of a similar type of apparatus in which the diaphragm is connected with another form of vibratory structure,

Fig. 4 shows the apparatus of Fig. 3 provided with a special kind of vibratory structure that consists of two separate masses connected to each other by an elastic rod.

Fig. 5 is a partial section and

Fig. 6 a bottom view of an apparatus in which the middle portion of the diaphragm is stiffened by ring-shaped stiffening members and interconnecting radial stiffening members.

Fig. 7 shows a form of plate or diaphragm in which the stiffening effect is obtained by thickening the diaphragm instead of by individual ribs.

In Fig. 1, A is a casing, preferably cylindrical in shape, containing a sender equipment, and arranged to be submerged. The electromagnetic exciter is formed of an electromagnet B that is divided into two parts by an air gap. The two parts of the electromagnet B are rigidly fixed to two masses C^1 and C^2 which in turn are connected to each other by elastic rods D, D whose aggregate cross-section is made such that the system composed of the parts C^1, C^2, D, D, B represents a vibratory structure or exciter that is tuned to the frequency to be employed in signaling.

The one end of the casing A is closed by the diaphragm E to the middle of which the mass C^2 and hence the whole exciting device is fixed.

In accordance with the invention the free annular surface of the diaphragm between the edge of the casing A and the mass C^2 is provided with stiffening ribs R, R whose length is such that a free flexible zone Z^1 remains near the periphery of the mass C^2 and another free flexible zone Z^2 is left near the edge of the casing A. Thus at these zones the diaphragm offers comparatively little resistance to forces that tend to bulge the diaphragm in and out. But the ribs R, R are of such size that the alternating forces required to bend them would have to be of a much higher frequency than those by which the diaphragm is excited. Hence the ribs suppress the tendency of the diaphragm to form a nodal line at or near the middle of the annular portion of its surface that is located between its periphery and the mass C^2. In other words the ribs force the diaphragm to execute vibrations of the form of its fundamental vibrations in spite of its being excited by an alternating force whose frequency is much higher than its fundamental note.

An apparatus of this kind is equally applicable for the sending and receiving of sound waves. For sending purposes the alternating current winding of the magnet is connected to a source of alternating current and for receiving it is connected to a telephone receiver or some other form of an alternating current detector.

The parts in Figs. 3 and 4 which correspond to these of Figs. 1 and 2 have similar

signs of reference. But in Fig. 3 a tuning fork F with a microphone J is attached to the diaphragm. P and Q are electric conductors passed through a stuffing box K and connected to the microphone.

In the arrangement shown in Fig. 4 the vibratory structure F employed consists of two separate masses m^1 and m^2 connected to each other by an elastic rod S. Instead of a single rod a plurality of the same may be used.

Receiving devices of the above-described kind offer the advantage that on account of the form of the vibrations executed by the diaphragm being well defined, it is possible to make their tuning and damping uniform although their constructions may differ. The entire surface of the diaphragm vibrates in unison, and as its mass is small while its area is comparatively large, it can be damped in a much higher degree than an ordinary diaphragm.

A particular advantage gained by combining a vibratory structure of the kind shown in Fig. 4—which structure itself is not a part of this invention—with a diaphragm constructed in accordance with the invention is that it permits of the most important factors pertaining to the vibrations of the apparatus, as for example the radiation and damping, to be calculated and fixed beforehand.

The desired stiffening may be accomplished, although not so completely, by simply thickening the diaphragm at the places where its stiffness is to be increased. A diaphragm constructed in this manner will, when excited by vibratory forces, also produce greater acoustic effects than an ordinary diaphragm of uniform thickness. The difference between the two forms of stiffening means (ribs and thickening) lies only in their efficiencies.

In order to obtain a form of vibration that is as regular as possible, a circular shape of diaphragm generally is preferred. But if for any reason a diaphragm of a different shape, say a square diaphragm, is to be employed, the above-mentioned means for suppressing harmonics may be immediately applied if it is used, in the proper sense. The sound-figure that is most apt to be formed by the diaphragm when excited by the selected exciting means must then be sought, and the ribs are then applied so as to form bridges across the nodal lines. In the case of a square diaphragm these ribs will have to extend radially as in a circular diaphragm. Of course, in this case too, the stiffening may be accomplished by thickening the diaphragm.

In the device shown in Fig. 5 the diaphragm is provided with a comparatively large rigid middle portion. Diaphragms having a middle portion that is stiffened or strong enough to cause all its parts to move along parallel lines, and that is held by a marginal spring member, are known, but an important fact in connection therewith was overlooked and this is that this marginal spring portion or member, if it is simply made in the form of a thin portion of the plate, is bulged inwards by the pressure directed against the middle portion, while the middle portion is moving outwards and vice versa. To prevent this, in accordance with the invention, the marginal spring portion is stiffened with radial ribs, the arrangement of these ribs being such as to leave two only very narrow circular zones—an inner and an outer zone adjacent to the annular spring portion—unstiffened, each of the unstiffened zones acting as a movable joint that extends along a circle. It is possible in this way to compel all parts of the ring-shaped marginal spring portion to vibrate in phase with each other. In accordance with the invention the stiff middle portion of the plate is made of such size or shape that its fundamental note is higher than the highest rate of vibration used for signaling. If this rate of vibration is high the middle portion would have to be exceedingly thick and heavy. Hence it is advantageous to stiffen this middle portion also by ribs stood on edge. In this way a vibrating plate is formed which consists chiefly of a portion whose various parts all oscillate along parallel lines like the parts of a piston and upon whose remaining ring portion no harmful evasive motions occur at the frequency at which the diaphragm is operated. By proceeding along these lines it is possible to produce vibrating plates that oscillate in a certain well defined manner and which in spite of this, have a much larger diameter than such plates may have if their entire surface from the periphery to the centre is made so as to permit of its different portions moving in opposite directions.

By placing the points at which the exciting force is applied apart from each other as far as possible the uniformity of the form of the vibrations of the plate may be ensured in a still greater degree.

Fig. 5 shows a longitudinal section of a sender of the kind foreshadowed in the last two paragraphs, and Fig. 6 is a section on the line 2—2 of Fig. 5.

Fixed at its margin to the flange B of a casing A (only partly shown) in the ordinary way by means of screw bolts D is a vibrating metal plate J. The annular portion E between e and f near the periphery is stiffened by radial ribs F, F which are made of such size that the natural note of the annular area is much higher than the signaling frequency. The middle portion G situated between the points e, e is also ribbed in order to obtain the greatest possible stiffness with a minimum of weight. But whereas the

arrangement of the stiffening ribs F, F in the annular portion adjacent to the periphery is such that small unribbed zones are left one at *f* near the margin and one at *e* adjacent to the middle portion G, which act as movable joints when the plate vibrates, the middle portion is surrounded by a high peripheral rib K and is stiffened by radial ribs L in such a manner that it is, as a whole, as stiff as possible.

In the constructional form shown the exciting device by which the plate is caused to vibrate consists of a tuning fork H whose prongs may be oscillated by an electromagnet (not shown). The stem of the fork is not directly attached to the middle of the central rigid portion of the plate but is connected to points near the periphery of this portion by the medium of a very stiff transverse beam or coupling plate T. By this means the exciting force is applied at points near to the circumference of the stiff middle portion G of the vibrating plate, so that these forces are distributed as uniformly as possible over the surface of the middle portion.

This arrangement may be used to equal advantage both in sound producers and receivers.

In Fig. 7, *a* is a thick rim by which the vibrating plate is attached to a casing *g* or the like, *b* is a thick middle portion and *c*, *c* a thick annular portion extending along a circle whose radius is about half that of the entire diaphragm. Between the thick annular portion *c* and the parts *a* and *b* there are two thinner flexible parts or zones as shown. The middle line *m* of the plate may be arched inwards, or outwards as shown, or it may be straight.

We claim:—

1. A vibratory diaphragm for acoustic apparatus, provided with rigid and flexible zones arranged in radial symmetry, there being only two flexible zones, these flexible zones being ring-shaped, one forming the outer boundary of the diaphragm and the other being concentrically arranged within the first-named, a central rigid zone being enclosed by the inner flexible zone, and another rigid zone being enclosed between the two flexible zones.

2. A device according to claim 1, in which the rigidity of the two rigid zones is secured by means of stiffening ribs.

3. A device according to claim 1, combined with a tuned vibratory structure attached to the central rigid zone.

4. A device according to claim 1, in which the two flexible zones are extremely narrow.

5. A device according to claim 1, in which the central rigid zone executes the largest amplitudes of vibration.

6. A device according to claim 1, in which the two rigid zones vibrate in phase with each other.

In testimony whereof we affix our signatures.

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WILHELM RUDOLPH.
ALARD DU BOIS-REYMOND.