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W. HAHNEMANN

SOUND SIGNALING DEVICE FOR DENSE SOUND PROPAGATING MEDIUMS

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Fig. 1.

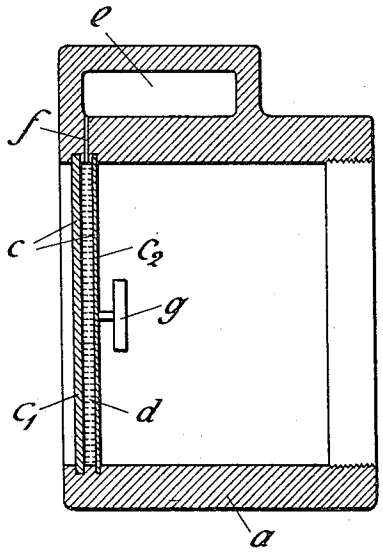
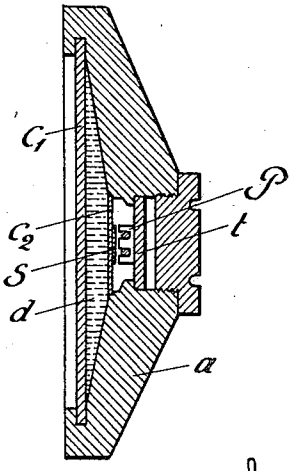


Fig. 2.



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SOUND SIGNALING DEVICE FOR DENSE SOUND-PROPAGATING MEDIUMS.

Application filed February 4, 1921. Serial No. 442,586.

To all whom it may concern:

Be it known that I, WALTER HAHNEMANN, citizen of the German Republic, residing at Kitzeberg, near Kiel, county of Schleswig-Holstein, State of Prussia, have invented certain new and useful Improvements in Sound Signaling Devices for Dense Sound-Propagating Mediums (for which I have filed applications in Germany March 3, 1917, Patent No. 348,746, and April 27, 1917, Patent No. 350,414; in Norway June 28, 1920, Patent No. 33,311; in Sweden June 29, 1920, Patent No. 53,124; in France July 7, 1920; in Italy July 9, 1920, Patent No. 541/68; in England July 10, 1920, Patents Nos. 148,427 and 148,982; in Denmark August 4, 1920, Patent No. 29,669; and in Holland August 23, 1920), of which the following is a specification.

In designing sound signaling apparatus intended for the reception or emission of sound waves from, or into, mediums of considerable density such as water, the question of protecting the vibratory elements or structures of the apparatus against the pressure of the external medium is one of considerable importance. Generally speaking the desired end has hitherto been more or less successfully reached in two different ways, the one consisting in giving the external medium access to both sides of the vibratory structure (diaphragm), and the other in interposing a chamber, filled with liquid and equipped with a pressure reducing device, between the said structure and the external medium, this chamber being separated from the external medium by a special wall or diaphragm.

The present invention relates to an arrangement of the latter kind adapted to protect the vibratory elements or structures of the apparatus against the pressure of the external medium. The procedure in constructing arrangements of this kind has hitherto been such that the vibratory body or structure that was relieved of the external pressure, as for example the diaphragm behind the interposed anti-pressure chamber, was made the seat of the tuning of the apparatus, whilst the dimensions of the interposed chamber and its external wall were selected more or less arbitrarily. The external wall used was generally such that its natural rate of vibration was different from the tuning of the actual vibratory structure of the apparatus, and this rate of vibration generally had to be very high on account of the necessary thickness of the protecting wall. The space between the outer wall and the vibratory structure was also generally made disproportionately large. This gave rise to various troubles, particularly to an unsatisfactory acoustic coupling between the external wall and the vibratory structure, and to obscure tuning conditions, etc.

In distinction therefrom, in the arrangement according to the invention, the vibratory structure proper of the apparatus, i. e. the inner diaphragm, together with the external protecting wall (outer diaphragm) and the space or chamber between the outer and inner diaphragms are collectively made the seat of the tuning of the apparatus; i. e. the outer protecting wall is separated from the vibratory structure by a coupling chamber that is so small and filled with a substance that is so incompressible that the wall and the structure are positively coupled and vibrate in unison, or in phase with each other. The substance chosen for filling the coupling chamber may consist as usual of a liquid. Liquids are specially suitable for achieving the desired object on account of their incompressibility. In order that the outer wall and the vibratory structure may vibrate in phase with each other it is necessary that the elastic force of the coupling connecting the two diaphragms, i. e. in the present instance, the elastic force of the medium in the coupling chamber, shall be great in comparison with the elastic forces of the diaphragms themselves. This will be the case if the gap between the two coupled bodies or diaphragms is made so small that the volume of the enclosed medium is small in comparison with the volume of the quasi-stationary oscillating field of the sound propagating medium in the vicinity of the apparatus. By the quasi-stationary field is meant the semi-spherical zone adjacent to the apparatus and having a radius of half a wave length of the particular sound in question, measured from the apparatus diaphragm abutting on the medium.

In devices of the contemplated kind the known provision is preferably made for taking up the external statical pressure, this consisting in placing the coupling chamber in communication with a second chamber filled with highly compressible mediums into

which the incompressible medium from between the two coupled diaphragms or structures may pass when the exterior diaphragm is bulged in. To prevent the rigidity of the coupling from being relaxed by this arrangement, the communicating passage between the two chambers must be so narrow that it exerts a throttling effect on the enclosed medium when it is vibrated by sound waves, and only allows this medium to pass out of the coupling chamber when it is oscillated or moved very slowly.

The relative sizes of the two diaphragms which, by the close coupling of their intervening chamber, are practically united into a single vibratory structure, have, so far, not been discussed. But this ratio is important because, assuming that the tuning of the entire structure and the other conditions remain the same, an increase of the diameter of the outer diaphragm will be accompanied by a considerable increase of the resistance of the diaphragm to flexure, as the following considerations will show.

To keep the tuning of the entire vibratory structure constant it is necessary, when altering either of its diaphragms, to maintain a constant ratio of the thickness of the diaphragm to the square of its radius. In the formula for determining the natural rate of vibration or the number of vibrations that a plate executes per second, the measure in which the frequency depends on the thickness s and the radius r of the plate is, if other factors, which may be neglected here, are left out of account, given by the magnitude $\frac{s}{r^2}$, so that, if the values which do not interest us here are called c_1 the formula may be written thus:

$$n = c_1 \cdot \frac{s}{r^2} \quad \text{----------} \quad (1)$$

The bulge or flexure of a circular plate which is fixed all round its periphery is expressed by the formula:

$$f = \psi \cdot \frac{r^4}{s^3} \cdot \frac{p}{E}$$

In this formula ψ is a constant, p the evenly distributed pressure in kgs. on a square centimetre of the plate, E the modulus of elasticity in kgs. referred to the same unit. Since the pressure p per unit of surface and the modulus of elasticity E are constant in the cases of the two diaphragms of different radiuses and thickness that we are here comparing, these values and the constant ψ may be termed c_2 so that the flexure will then be expressed by the formula:

$$f = c_2 \cdot \frac{r^4}{s^3} \quad \text{----------} \quad (2)$$

In the equation (1) which gives the frequency of the vibrations of the plate, the radius r is a quadratic quantity, whereas in the equation (2) that gives the flexure f the radius r of the diaphragm is raised to the fourth power and the thickness s to the third power. From this it follows that, assuming the tuning of a plate and the pressure to which it is subjected to be kept constant, the flexure of the plate will be smaller the larger it is made. Approximately the stress on the material of the outer plate decreases, under the same pressure and other equal conditions, at the ratio of the third power of its radius.

The conditions to be observed with regard to the size given to the layer of liquid between the two diaphragms when the diameters of these diaphragms are altered remain as stated above. But a new point that arises is the following:

If the tuning of the outer diaphragm is kept the same, but its diameter is made larger than that of the inner diaphragm, the motion that it executes at its centre when oscillating will be smaller than that executed by the centre of the inner diaphragm as the following consideration will show. At a given amplitude of the external compressional sound waves the volume v displaced through the bending of the outer diaphragm is given by the function f (F. d), in which F is the surface and d the flexure at, say, the centre of the diaphragm.

As the very small volume of liquid between the two diaphragms may be assumed to be practically incompressible the small diaphragm must be bent so much that it displaces the same volume. Here also a function of the former f (f. D.) will apply in which, since $f <$ F, D must be larger than d. Hence in addition to the axial motion of the liquid in the direction of the amplitudes of the diaphragms another motion perpendicular to the direction of these amplitudes, i. e. a radial motion of the liquid must also occur. Another feature of the invention consists in causing the radial speed of the liquid between the diaphragms to be as nearly as possible equal to its axial speed, i. e. the distance between the two plates is made approximately equal to half the radius of the smaller plate. It will be found that the most efficient action of a receiving apparatus will be obtained if the thickness of the layer of liquid between the two plates is made such that the requirement just mentioned is fulfilled. If the width of the liquid chamber is made larger, the quantity of the liquid between the two plates—which represents a mass that, in the calculation of the diaphragms, must be added to these—will be too large and will effect too great a reduction of the damping of radiation of the vibratory structure formed by the vibrating diaphragms and the liquid, and the apparatus will, if used as a receiver, reproduce all

the occurring disturbances in the character of its own natural frequency. If the liquid chamber is made narrower another deleterious effect will arise by the useless damping of the apparatus increasing to an inconvenient extent in consequence of the enhanced friction between the liquid and the walls of the interposed chamber.

Hence one feature of the invention consists in making the outer diaphragm larger than the inner one, whilst keeping the tuning of the entire structure unchanged. Further the invention consists in so selecting the size of the liquid chamber between the two diaphragms, that when these diaphragms vibrate, the axial motion of the liquid at the interior of the diaphragms is approximately equal in magnitude to its radial motion.

The invention is illustrated in the drawing in which Fig. 1 shows an apparatus comprising two diaphragms of equal diameters and a pressure relief chamber for reducing the static pressure on the inner diaphragm.

Fig. 2 represents an apparatus in which the outer diaphragm is made larger and thicker than the inner diaphragm and in which no pressure relief chamber is provided.

In Fig. 1 a vibratory structure c in accordance with the invention is shown that is composed of two diaphragms c_1 and c_2 and a narrow chamber d filled with liquid. The compound diaphragm c closes one end of the casing a that contains a microphone fixed to the inner diaphragm c_2. A pressure relief chamber e is connected with the liquid chamber d by a passage f. This passage is so narrow that liquid from the coupling chamber d will only pass through it when the plate c_1 is bulged in slowly as by static pressure. But when the plate c_1 moves in and out very rapidly as in executing sound vibrations the narrow passage f exerts a throttling effect and does not allow the liquid to pass out of its chamber into the air chamber. Hence the inner diaphragm is only relieved of the statical pressure of the external medium but not of the rises of pressure due to the compressional sound waves. In an arrangement of this kind the thickness of the individual parts c_1 and c_2 of the diaphragm c is of no consequence because they may be conceived as being so rigidly coupled with each other as to form an integral plate. Hence in accordance with the invention the front plate c_1 may be made thicker than the rear plate c_2 so that at a given statical pressure the flexure of the front plate may be reduced to the utmost limit and in some cases the air chamber or pressure relief chamber may be dispensed with. The size of the chamber d will, if it is made very narrow (only a few millimetres deep for example) be independent of the frequency of the sound vibrations within very wide limits. In calculating the tuning of the compound diaphragm the mass of the liquid must be considered.

Fig. 2 is a vertical section of a modified form of device according to the invention. In the box or capsule a, which is closed at the front by the two diaphragms c_1 and c_2 and the intervening liquid d, an electromagnet p is arranged whose armature s is fixed to the inner diaphragm c_2. As the body of the magnet is immovably fixed on the cross-bar t it is very important that c_2 may not be bent in, because this would result in the very small gap between the armature and the poles of the magnet being altered in an impermissible degree. This arrangement is equally important in cases where pressure microphones with two fixed electrodes are used as detectors in receiving apparatus.

It will be obvious that instead of using two diaphragms only, several plates may be placed one behind the other and arranged so as to form a single monoresonant vibratory structure, i. e. a structure which is tuned as a whole to a single note. The circular form of diaphragm may be substituted by plates of other shapes.

Finally it may be mentioned that the plates need not necessarily be arranged in parallel planes.

The term "sound radiating structure," used in the claims, designates the vibratory structure which is in contact with the propagating medium either in submarine senders or receivers.

I claim:

1. A composite sound radiating structure for submarine acoustic apparatus, comprising two diaphragms and a layer of liquid therebetween, the composite structure being tuned as a whole to a definite frequency.

2. A composite sound radiating structure for submarine acoustic apparatus, comprising two diaphragms and a layer of liquid therebetween, one of said diaphragms abutting on the sound propagating medium and being thicker than the other, and the composite structure being tuned as a whole to a definite frequency.

3. A composite sound radiating structure for submarine acoustic apparatus, comprising two diaphragms and a layer of liquid therebetween, one of said diaphragms abutting on the sound propagating medium and being of greater area than the other, and the composite structure being tuned as a whole to a definite frequency.

4. A composite sound radiating structure for submarine acoustic apparatus, comprising two diaphragms and a layer of liquid therebetween, one of said diaphragms abutting on the sound propagating medium and being thicker and of greater area than the

other, and the composite structure being tuned as a whole to a definite frequency.

5. A composite sound radiating structure for submarine acoustic apparatus, comprising two diaphragms, and a layer of liquid therebetween having a volume not greater than that of the quasi-stationary field of the sound propagating medium adjacent the structure, the composite structure being tuned as a whole to a definite frequency.

6. A composite sound radiating structure for submarine acoustic apparatus, comprising two diaphragms and a liquid-filled space therebetween, one of said diaphragms abutting on the sound propagating medium and being of greater area than the other, the depth of the liquid-filled space being such that when the diaphragms vibrate the axial speed of the liquid is approximately equal to its radial speed, and the composite structure being tuned as a whole to a definite frequency.

7. A composite sound radiating structure for submarine acoustic apparatus, comprising two diaphragms and a liquid-filled space therebetween, one of said diaphragms abutting on the sound propagating medium and being of greater area than the other, the distance between the two diaphragms being at least approximately equal to half the radius of the small diaphragm, and the composite structure being tuned as a whole to a definite frequency.

In testimony whereof I affix my signature in presence of two witnesses.

WALTER HAHNEMANN.

Witnesses:
WILHELM RUDOLPH,
GUSTAV WOLFF.