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ACOUSTIC DEVICE

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Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

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The present invention relates to improvements in acoustic devices and has reference more particularly to sound receivers or reproducers adapted to transform sound vibrations into electrical variations or vice-versa, for instance, microphones or loud-speakers.

An object of the invention is to provide an acoustic device of the kind referred to having improved sound absorbing or sound radiating qualities.

Another object is to provide an acoustic device of improved efficiency.

A further object is to provide an acoustic device in which disturbance due to preponderance of response to a particular frequency is substantially eliminated.

Still another object of the invention is to remove the interference effect in acoustic devices which arises due to the difference in phase of the oscillations arising from the two sides of a diaphragm.

Other objects will be apparent from the description as it proceeds.

The invention is preferably, but not exclusively, applicable to electro-magnetic or electro-dynamic devices comprising a diaphragm functioning like a piston by undergoing displacement against a weak restoring force. When sound reproducers are in question, the means indicated in the following give the best results in combination with the devices of this type known by the name of Rice & Kellogg loud-speakers. Examples of the kind of loud-speaker referred to are described in Patents Nos. 1,707,617 and 1,748,858.

The invention will be more clearly understood from the following description in which reference will be made to the accompanying drawings.

In the drawings:

Fig. 1 shows diagrammatically a known form of loud speaker.

Fig. 2 is a curve showing the relation between frequency and wave length of acoustic oscillations.

Fig. 3 is a curve showing how uniform frequency response may be obtained with the use of two acoustic filters.

Fig. 4 is a curve showing the relation between frequency and wave length as in Fig. 2.

Fig. 5 shows how the interval between the frequency characteristics of two adjacent filters may be matched.

Fig. 6 is an elevation in section of one form of the invention in which acoustic filters are arranged axially parallel to the oscillator.

Fig. 7 is an elevation in section of an apparatus similar to that of Fig. 6.

Fig. 8 is a section on the line 3, 3 of Fig. 9 of an arrangement in which the oscillator is arranged with its axis horizontal.

Fig. 9 is a section on the line 4, 4 of Fig. 8, of the apparatus shown in that figure.

Fig. 10 is an elevation and Fig. 11 is a plan of an arrangement of tubes forming an acoustic filter.

Fig. 12 is a partial elevation and Fig. 13 is a plan of another arrangement of tubes forming an acoustic filter.

Fig. 14 is a sectional elevation of another embodiment of the invention, in which the acoustic filters are adjustable.

Fig. 15 is a sectional elevation of another form of the invention embodying further desirable features.

By employing a loud-speaker such for instance as the Rice & Kellogg loud-speaker referred to above under the usual conditions, that is, by causing it to act directly on the atmosphere, it is found, in the first place that the sound emitted is radiated in a given direction in the form of a more or less narrow beam; in certain rooms, such a concentrated beam is capable of causing over-pronounced reflection phenomena and consequently a bad distribution of the radiated acoustic energy. In the second place, it is difficult to provide a diaphragm sufficiently rigid to allow its partial vibrations to be completely suppressed; at elevated frequencies, there are observed on the diaphragm either stationary waves or progressive waves which are propagated towards its periphery. These partial waves, which may give rise to resonance phenomena, are radiated into space in a less regular manner than those corresponding to the "piston" oscillations and the result thereof is that the different frequencies are emitted with different intensities; the "saw-teeth" on the sensitivity curve of a loud-speaker are to a great extent due to these partial resonance conditions of the diaphragm.

It has already been proposed to obviate this disadvantage by the use of compression chambers such as are diagrammatically illustrated in Figure 1. The front face of the diaphragm produces variations of pressure in the non-resonant cavity 2; these variations in pressure correspond only to the piston-like movements of the diaphragm, given that the sum of the partial
displacements of the diaphragm is substantially equal to zero. Under these conditions, it is possible, at least theoretically, to obtain in the mouth of the chamber vibrations of the diaphragm. A similar arrangement may be provided on the other side of the diaphragm in order to increase the output of the device.

This arrangement, however, offers two disadvantages: the openings 4 and 5 necessarily exhibit selective properties from the point of view of the emission of sound, so that a uniform emission of all the audible range is not obtained. On the other hand, the two emissions having the orifices 4 and 5 are displaced by 180° so that they tend to counterbalance immediately they leave. This could be called an acoustic "short-circuit."

In accordance with one constructional form of the present invention, the orifices 4 and 5 are replaced by two or more acoustic filters so chosen that each of them allows a definite part of the audible range to pass. By thus selecting the emissions, any interference between the radiated acoustic waves is avoided because different parts of the audible range which preferably do not overlap are in question.

In the simplest case diagrammatically illustrated in Figure 3, two partial ranges are sufficient. In this figure, the abscissae represent the acoustic frequencies and the ordinates represent the corresponding wave lengths; the total audible range which is desired to be emitted corresponds to the length AC. By giving the member Q = BC of higher frequencies, two different emissions are obtained, between which no acoustic short-circuit is possible. Instead of employing only two filters, a plurality of them may be provided, each of them being constructed as a "band-pass" filter, and they may be suitably distributed over the two compression chambers 2 and 3. Each of these filters obviously represents a complex acoustic filter, the value of which may be determined by giving it a suitable form and dimension.

It is preferable, according to another aspect of the present invention, to choose these impedances such that the energy radiated by each face of the diaphragm is equal to that of the other face. In the simplest case of two-component ranges, it is preferable that the range Q should be shorter than Q, given that the energy of the low notes is, in the majority of auditions, greater than that of the high notes. Whatever may be the case under consideration, it is always possible to choose the dividing frequency B so as more or less to balance the acoustic energy emitted by the two faces of the vibrating diaphragm. The object of such balancing is to utilize the radiation of each face to the maximum and thus increase the acoustic output of the whole.

By a careful choice of the acoustic filters, the result diagrammatically represented in Figure 3 can be obtained. In this figure the ordinate represents the intensity of sound emitted as a function of the frequency. When an alternating current of constant energy and variable frequency is supplied to the loud-speaker, the filter replacing the opening 4 allows an acoustic wave to pass, the intensity of which varies in accordance with the curve Np. At frequencies in the neighbourhood of B, this curve falls rapidly and beyond this frequency, the filter corresponding to the other chamber passes the sound, the intensity of which varies in accordance with the curve Ng. In this manner a "sensitivity curve" is obtained which may be given, for instance, the horizontal form for a constant electrical energy or for a constant voltage at the terminals of the loud-speaker, or any other form desired.

It is obvious that the desired form can be more easily given to the resultant sensitivity curve by increasing the number of filters, that is, by subdividing the whole range of frequencies into a large number of relatively narrow elementary ranges and by adjusting each filter separately. In the limiting case, each of these filters passes a very restricted band and it may be formed by a relatively sharply tuned resonator of suitable form.

In carrying into effect this aspect of the present invention, two tuned tabular resonators may be employed, which are arranged essentially in accordance with the following points which may be taken separately or in combination:

1. The resonator tubes are placed in proximity to each other.
2. The tubes are placed in proximity to one another.
3. The oscillator which is preferably placed with its axis either vertical or horizontal, acts simultaneously by its two parts or walls on air layers contained in two baffle boxes similar to the boxes 2 and 3 of Fig. 1.
4. The two baffle boxes preferably control two parts, separated by the mean, of the sound range.
5. With a diffuser having a horizontal axis, it is preferable to arrange an independent group of horizontal tubes opposite the diaphragm for the higher notes, whilst the other notes are correspondingly distributed among various other groups of vertical tubes.
6. For the deep note tubes, orifices allow of reducing the size.
7. In order to avoid the intensities being reduced according to the dimensions of the resonator tubes, the small tubes for high notes are duplicated, either in parallel rows or in groups etc.

Figs. 10 and 11 show in elevation and plan respectively the correction of the intensity of the sounds by the provision of a plurality of tubes of small dimensions arranged in parallel rows.

Figs. 12 and 13 show a similar arrangement, with the tubes arranged in groups.

In the apparatus shown in Figs. 6 and 7, the diaphragm is arranged with its axis vertical, and when it is actuated by the reception of a music-modulated current, it acts on the air layers contained in two baffle boxes 11 and 12 respectively by its front face (interior wall) and its rearmost part (exterior wall).

Mounted on the box 11 is a series of tubes 13 open at their two ends and each tuned to a note of the musical scale extending from the medium to the highest note. On the box 12 is fixed a series of tubes 14 open at their two
ends or closed at one end and each tuned to a note of the musical scale ranging from the medium to the lowest note.

The position of these tubes with respect to the diaphragm of the oscillator is calculated so that their position with respect to the diaphragm yields maximum excitation. Hence the shortest tubes, for the highest notes, are nearer the diaphragm than the longer tubes, for the lower notes.

On account of the position of each of these tubes, i.e., that position which corresponds to the point of optimum excitation, each of these tubes enters into resonance when the note for which it is tuned is emitted by the diaphragm of the oscillator. This fundamental note, generally emitted without harmonics, is reconstructed by the tube with all the missing harmonics.

Orifices 15 are provided at the base of these tubes, corresponding to the lower notes, having their ends closed whereby their natural frequency is lowered by an octave and their size thus diminished.

In the modification shown in Figs. 8 and 9, the oscillator 10 is arranged with its axis horizontal and acts, as before, on two baffle chambers 11 and 12. A series of tubes 16 corresponding to the highest notes of the scale are horizontally placed in proximity to and in front of the diaphragm of the oscillator; a plug 17 may be employed to close the opening in front of the oscillator should the group 16 not be employed. The tubes 18, tuned to the medium to high notes are placed vertically and the chamber 11, while the tubes 19, tuned to the medium of the scale are mounted on the chamber 12. Finally, the tubes 20 and 21, tuned to the lowest notes, are attached to the rearward extremities of the chambers 11 and 12. All these tubes are placed at suitable distances, as explained above in connection with the first form of apparatus.

It is known that the audibility of the excitation diminishes in proportion to the size of the tube. In order to overcome this disadvantage, the tubes corresponding to the highest notes are provided in numbers proportional to the pitch of the note to which they are required to respond; this latter feature of the invention is applied preferably to notes ranging from the highest to the medium to high.

In the group formation shown in Figs. 10 and 11, the tubes are placed in parallel rows and in that of Figs. 12 and 13 they are arranged in groups.

In all cases, the oscillator may be placed either at the centre of the baffle chamber or displaced to any point of the baffle chamber which may correspond to the best utilization of the excitation. In accordance with the invention, the resonators must be arranged so that the relationship between their useful excitation surface and that of the vibrating diaphragm has a preferable rather high value, higher than 7:1, for example. Thus, with a vibrating diaphragm of 32 cm. diameter having a surface of about 800 sq. cm. it is possible to excite under the best conditions a combination of resonators tuned semitone by semitone over 7 octaves between the frequencies of 25 and 3,444, the total cross-sectional area of these resonators being about 8,000 sq. cm. It is obvious that the present invention is not limited either to the application of resonators or to their sub-division into two groups only, and that the arrangements represented in Figs. 8 to 13 have only been given by way of example.

It covers in a more general manner the subdivision of the total acoustic range into any number of sections P, Q, R, S, T, etc. (see Fig. 4) preferably but not necessarily chosen so as to correspond to quantities of energy of the same order of magnitude, each of these sections being emitted through a band-pass acoustic filter. These filters are arranged on both sides of the diaphragm and grouped as desired. It is possible, for instance, to arrange the filters P, Q, R for the low frequencies on one side, and the filters S, T, etc. corresponding to the high notes on the other side of the filters P, R, T may be arranged on one side and the filters Q, S on the other.

The geometrical arrangement of the different filters or groups of filters is very important and is decisive for the best distribution of the sounds to be reproduced. The emissions of the various frequency ranges may be directed in a manner adapted to the acoustics of the room in which the device is operated in order to obtain the best results. Thus the various filters may be directed in different directions as in Fig. 8. The production of a confined beam of emitted sound is thus avoided by the present invention.

The acoustic filters to be employed may be of any nature. For instance, they may take the form of more or less confined masses of air, the inertia and elasticity of which is utilized in order to obtain, as in electrical filters, the desired selection of frequencies. Such filters have been the subject of several investigations and the various forms of construction thereof are known.

Certain of the filters may be replaced by exponential horns functioning as high-pass filters. Such an arrangement is shown in Fig. 15 where the smallest tubes corresponding to the highest frequencies are replaced by the exponential horn 22 fixed centrally in the wall 6. It is also possible to modify the characteristics of the filters by introducing vibrating diaphragms of known type, the mechanical characteristics of which are variable such as the diaphragm 23 shown in Fig. 15. The characteristics of the sounds emitted may also be varied by the arrangement of the wall 6 in which the tubes 7 and the exponential horn 22 are mounted and which is slidable so that the volume of the chamber 2 may be varied.

Finally, the particular case given above may be employed: According to this particular arrangement, each of the two filters is formed from a group of narrow band resonators arranged at suitable distances from the oscillator. Such distances must correspond theoretically to a quarter of a wave length or to an odd multiple thereof.

If these resonators take the form of cylindrical tubes, the length of each of them corresponds to an ordinate of the hyperbolic curve illustrated in Figs. 2 and 4. As concerns the choice of the interval between two adjacent resonators, this may be determined as in the case of tuned electrical resonators (see Fig. 5). Referring to Fig. 5, if M is the resonance curve of a tube tuned to a frequency $f_1$ and N the corresponding curve of the adjacent resonator tuned to the frequency $f_2$, the resultant curve is represented, as is known to be the case, by the envelope of the curve L for this interval. The value of $f_2$ may be assumed as being about 8,000 sq. cm. It is obvious that the present invention is not limited either to the application of resonators or to their sub-division into two groups only, and that the arrangements represented in Figs. 8 to 13 have only been given by way of example.
to adjust the diameters of the elementary resonators and to modify their number for each frequency for the purpose of obtaining the resultant curve of the desired form.

In order not to increase excessively the number of elementary resonators, a certain undulation of the curve L may be allowed by taking for a (see Fig. 5) the value of 2 decibels for importance.

In the case of filters of different construction which permit of passing wider bands, the desired modifications in the quality of the reproduced sound may also be effected by incorporating in each of the compression chambers or in the filter members themselves damping members which may comprise, for instance, baffles or vibration-absorbing materials. These damping members may be adjustable by varying their dimensions, their mechanical tensions or their position. Finally it is possible in certain cases to provide more or less tight mechanical or pneumatic couplings between the different oscillating parts of the filters for the purpose of modifying the form of the sensitivity curve in the desired sense.

As concerns the form and dimensions of the two chambers 2 and 3 on which there act the two faces of the vibrating diaphragm, the inventor has ascertained that there corresponds to each filter or combination of filters arranged on one side of the diaphragm as well as to each type of loud-speaker (see Fig. 1) an optimum volume of these cavities. In order to facilitate the adjustment of this volume, movable walls may be provided so as to effect this adjustment in the course of operation of the apparatus; the sound is thus given the desired intensity and timbre. The walls of the cavities 2 and 3 may be displaced parallel to themselves or else rotate about suitable pivots in order to give these cavities not only the best volume but the best form: in effect it is necessary to take into account especially the phenomena of reflection of the sound which must be redirected in directions corresponding to the disposition of the different filters and resonators. Fig. 14 represents by way of example a con-}

1. Acoustic device for the reception or emission of sounds comprising an oscillating diaphragm, a housing defining a space surrounding said diaphragm, said space being divided by said diaphragm into two compartments and means comprising a combination of acoustic filters of differing frequency characteristics affording communication between the interiors of said compartments and the atmosphere.

2. Acoustic device for the reception or emission of sounds comprising a diaphragm, means for imparting oscillations to said diaphragm, a housing defining a space surrounding said diaphragm, said space being divided by said diaphragm into two compartments, and means comprising an acoustic filter adapted to pass a band of high acoustic frequencies affording communication between any one of said compartments, and the atmosphere and means comprising an acoustic filter adapted to pass a band of low acoustic frequencies affording communication between the other of said compartments, and the atmosphere.

3. Acoustic device for the reception or emission of sounds comprising a diaphragm, means for imparting oscillations to said diaphragm, a housing defining a space surrounding said diaphragm, said space being divided by said diaphragm into two compartments, means comprising an acoustic filter adapted to pass a band of high acoustic frequencies affording communication between one of said compartments, and the atmosphere, and means comprising an acoustic filter adapted to pass a band of low acoustic frequencies affording communication between the other of said compartments and the atmosphere.

4. Acoustic device for the reception or emission of sounds comprising a diaphragm, means for imparting oscillations to said diaphragm, a housing defining a space surrounding said diaphragm, said space being divided by said diaphragm into two compartments, and means comprising a plurality of acoustic filters affording communication between each of said compartments and the atmosphere, said filters being provided in groups, each group being adapted to form an acoustic path of substantially the same resistance between a compartment and the surrounding atmosphere.

5. Acoustic device for the reception or emission of sounds comprising a diaphragm, means for imparting oscillations to said diaphragm, a housing defining a space surrounding said dia-
phragm, said space being divided by said diaphragm into two compartments, and a plurality of tubes affording communication between each of said compartments and the atmosphere, each of said tubes being tuned to a particular acoustic frequency.

6. Acoustic device for the reception or emission of sounds comprising a diaphragm, means for imparting oscillations to said diaphragm, a housing defining a space surrounding said diaphragm, said space being divided by said diaphragm into two compartments, and a plurality of tubes affording communication between each of said compartments and the atmosphere, the tubes in connection with one of said compartments being tuned to frequencies in a band of low acoustic frequencies, the tubes in connection with the other of said compartments being tuned to frequencies in a band of high acoustic frequencies.

7. Acoustic device for the reception or emission of sounds comprising a diaphragm, means for imparting oscillations to said diaphragm, a housing defining a space surrounding said diaphragm, said space being divided by said diaphragm into two compartments, a plurality of tubes affording communication between the interiors of each of said compartments and the atmosphere, each tube being tuned to a particular acoustic frequency, a plurality of said tubes being tuned to the same frequency whereby the total intensity of resonance to said frequency is augmented.

8. Acoustic device for the reception or emission of sounds comprising a diaphragm, means for imparting oscillations to said diaphragm, a housing defining a space surrounding said diaphragm, said space being divided by said diaphragm into two compartments, means comprising an acoustic filter affording communication between one of said compartments and the atmosphere, adapted to pass a restricted band of acoustic frequencies and an acoustic filter affording communication between the other of said compartments and the atmosphere and adapted to pass a restricted band of acoustic frequencies different from the first said filters being directed in different directions in space.

9. Acoustic device for the reception or emission of sounds comprising a diaphragm positioned with its axis horizontal, means for imparting oscillations to said diaphragm, a housing defining a space surrounding said diaphragm, said space being divided into two compartments by the said diaphragm, a plurality of tubes directed with their axes horizontal, affording communication between one of said compartments and the atmosphere, said tubes being adapted each to pass a high acoustic frequency and a plurality of tubes each adapted to pass a low acoustic frequency and directed with their axes vertical affording communication between the other of said compartments and the atmosphere.

10. Acoustic device for the reception or emission of sounds comprising a diaphragm, means for imparting oscillations to said diaphragm, a housing defining a space surrounding said diaphragm, said space being divided by said diaphragm into two compartments and a plurality of tubular resonators in communication with each of said compartments, said resonators being positioned at a distance from said diaphragm of the order of one quarter of the wavelength to which said resonator is tuned.

11. Acoustic device for the reception or emission of sounds comprising a diaphragm, means for imparting oscillations to said diaphragm, a housing defining a space surrounding said diaphragm, said space being divided by said diaphragm into two compartments and a plurality of acoustic filters affording communication between each of said compartments and the atmosphere at least one of said filters comprising an exponential horn.

12. Acoustic device for the reception or emission of sounds comprising a diaphragm, means for imparting oscillations to said diaphragm, a housing defining a space surrounding said diaphragm, said space being divided by said diaphragm into two compartments and a plurality of acoustic filters affording communication between each of said compartments and the atmosphere, each tuned to pass most strongly only one acoustic frequency, the frequencies of successive filters being so chosen that a substantially uniform sensitivity to a band of acoustic frequencies is obtained.

13. Acoustic device for the reception or emission of sounds comprising a diaphragm, means for imparting oscillations to said diaphragm, a housing defining a space surrounding said diaphragm, said space being divided by said diaphragm into two compartments, and a plurality of acoustic filters affording communication between each of said compartments and the atmosphere, and damping means for broadening the resonance curves of said filters to obtain substantially uniform transmission of all frequencies in a band of acoustic frequencies.

14. Acoustic device for the reception or emission of sounds comprising a diaphragm, means for imparting oscillations to said diaphragm, a housing defining a space surrounding said diaphragm, said space being divided by said diaphragm into two compartments, and a plurality of acoustic filters affording communication between each of said compartments and the atmosphere, and coupling means interconnecting said filters for reducing the damping and sharpening the resonance curves of said filters.

15. Acoustic device for the reception or emission of sounds comprising a diaphragm, means for imparting oscillations to said diaphragm, a housing defining a space surrounding said diaphragm, said space being divided by said diaphragm into two compartments, and a plurality of acoustic resonators affording communication between each of said compartments and the atmosphere, said resonators being arranged in parallel relation whereby a coupling is produced therebetween to reduce damping and to sharpen the resonance curves thereof.

16. Acoustic device for the reception or emission of sounds comprising a diaphragm, means for imparting oscillations to said diaphragm, a housing defining a space surrounding said diaphragm, said space being divided by said diaphragm into two compartments, and a plurality of acoustic filters affording communication between each of said compartments and the atmosphere, the resonators tuned to the low notes of a band of acoustic frequencies passed by said filters having closed ends and being provided with orifices at their juncture with the corresponding compartment.

17. Acoustic device for the reception or emission of sounds comprising a diaphragm, means for imparting oscillations to said diaphragm, a housing defining a space closed on one side by said diaphragm, a second housing having an...
adjustable wall defining a space on the side of said diaphragm exterior to said first housing and means comprising acoustic filters affording acoustic communication between the interiors of each of said housings and the atmosphere.

18. Acoustic device for the reception or emission of sounds comprising a diaphragm, means for imparting oscillations to said diaphragm, a housing defining a space surrounding said diaphragm, said space being divided by said diaphragm into two compartments, and a plurality of acoustic filters affording communication between each of said compartments and the atmosphere, the total cross-sectional area of said acoustic filters being at least seven times the surface area of said diaphragm.

19. Acoustic device for the reception or emission of sounds comprising a diaphragm means for imparting oscillations to said diaphragm, a housing defining a space surrounding said diaphragm, said space being divided by said diaphragm into two compartments, and a plurality of tubular resonators in communication with each of said compartments, said resonators being positioned at a distance from said diaphragm of the order of an odd multiple of one quarter of the wave length to which said resonator is tuned.

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