

Mar. 3, 1925.

1,528,418

W. HAHNEMANN ET AL
MEANS FOR TRANSLATING VIBRATIONS

Filed Nov. 4, 1921

Fig. 1.

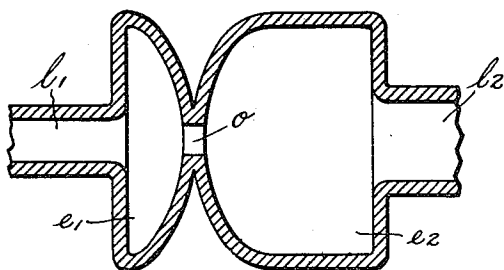


Fig. 2.

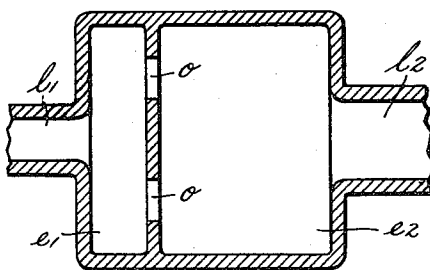


Fig. 3.

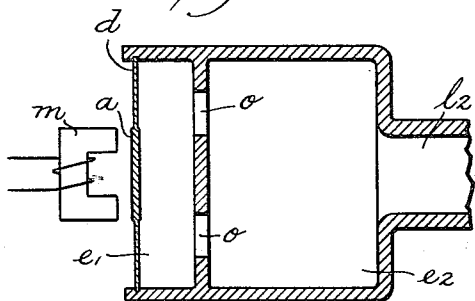


Fig. 4.

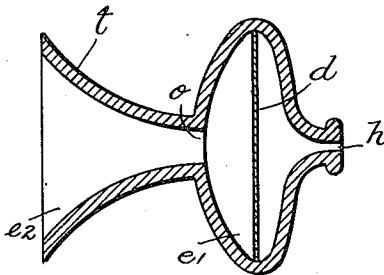
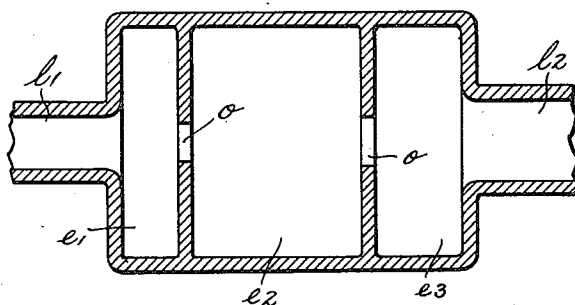


Fig. 5.



WITNESSES

Oliver H. Holmes

INVENTOR

Walter Hahnemann, Heinrich Hecht, & Bernhard Settegast

BY

Knight & Bury
ATTORNEYS

UNITED STATES PATENT OFFICE.

WALTER HAHNEMANN, OF KITZEBERG, NEAR KIEL, AND HEINRICH HECHT AND
BERNHARD SETTEGAST, OF KIEL, GERMANY, ASSIGNORS TO SIGNAL GESELL-
SCHAFT MIT BESCHRANKTER HAFTUNG, OF KIEL, GERMANY.

MEANS FOR TRANSLATING VIBRATIONS.

Application filed November 4, 1921. Serial No. 512,946.

To all whom it may concern:

Be it known that we, WALTER HAHNEMANN, HEINRICH HECHT, and BERNHARD SETTEGAST, citizens of the German Republic, and residing at Kitzberg, near Kiel, and at Kiel, county of Schleswig-Holstein, State of Prussia, Germany, have invented certain new and useful Improvements in Means for Translating Vibrations (for which we have filed applications for patent in Germany on September 25th, 1920; October 2nd, 1920; October 28th, 1920; March 7th, 1921; and September 24th, 1921; and in Argentina on July 12th, 1921), of which the following is a specification.

One of the most important problems that has to be faced particularly frequently by engineers dealing with mechanical vibrations is to transfer vibrations with the smallest possible loss of energy from one vibratory body or unit to another vibratory body or unit. When the ratio of force to motion of one of the vibratory bodies or units is different from the ratio of force to motion of the other vibratory body or unit, the problem of transmission or transfer of sound from one to the other effectively and efficiently becomes more difficult. One form of transferring or transmitting means is disclosed in a copending application, Serial No. 435,563, filed January 6, 1921. The present application is directed to another form, which is adapted for use in some cases where the former is not well suited.

The transferring or transmitting means according to the present invention is a space oscillation system, which comprises a dual chamber, the individual compartments of which are in communication with each other by a passage or passages, the dual chamber being designed so that it has only one fundamental oscillation, in other words so that the system is a one wave system. By analogy to the copending application, Ser. No. 435,563, in the present case the elastic forces reside in the fluid in the individual chambers or compartments while the mass of the system is represented by the fluid vibrating through the communicating passage or passages.

As has already been stated, a particular object of the present invention is to solve the problem of efficiently transferring sound vibrations from one vibratory body to another where these vibratory bodies have different amplitude-to-force ratios. To this end the dual chamber is especially designed. The solution of the problem consists in providing a dual chamber in which in each individual compartment the amplitude-to-force ratio of the sound vibrations is made to reach or approximately reach or correspond to the amplitude-to-force ratio of the vibratory body next to it. This amplitude-to-force ratio in each compartment is determined by the size of the compartment. Furthermore, by suitably dimensioning each compartment the damping effect thereof may be made to reach a desired magnitude. The required size of each compartment may be determined either by experiment or calculation or both.

Other and further features of the invention will be described hereinafter in the specification and be more particularly pointed out in the annexed claims.

The invention will now be described, by way of example, with reference to the accompanying drawing, in which like reference letters and numerals in the several figures designate like parts.

Fig. 1 is a section of a dual chamber formed of two individual chambers or compartments that communicate with each other through a central passage.

Fig. 2 represents a section of a dual chamber with a plurality of communicating passages in its dividing wall.

Fig. 3 is a section of a dual chamber such as shown in Figure 2, but in which one of the individual compartments is next to a vibratory diaphragm while the other is next to a sound conducting tube or conduit.

Fig. 4 is a section of a dual chamber applied to a magaphone, in which one of the individual compartments is next to a vibratory diaphragm while the other flares out into the open air.

Fig. 5 is a section of a dual chamber system formed of two dual chambers coupled

together in series, the central compartment of the system in this case being common to the two dual chambers.

In Figure 1, e_1 and e_2 designate the individual compartments of a dual chamber constructed in accordance with the invention, and o designates the communicating or connecting passage between the two compartments. L_1 is a sound conducting conduit or pipe, and L_2 is a similar pipe of larger diameter connected to the former by the vibratory unit that the dual chamber constitutes. The purpose of the dual chamber in the arrangement shown in this figure is to transfer sound from the small conduit or pipe L_1 to the larger conduit or pipe L_2 . The walls of the chamber e_1 are preferably shaped, as shown, so as to converge toward the sound passage o , in order that as little resistance as possible is offered to the oscillations and that the oscillations will be concentrated toward the sound passage o . Since the conduit L_1 is of smaller sectional area than the conduit L_2 , it will be observed that the compartment e_1 is of smaller volume than the compartment e_2 .

In the dual chamber shown in Fig. 2, instead of one communicating passage o there are a plurality of such passages distributed over a relatively large area of the partition wall. In this type of dual chamber it is not absolutely necessary to converge the walls of the individual compartments toward the communicating passages as in Figure 1, although this may be done if desired. By distributing the communicating passages over the partition wall the advantages are gained that the total distances traversed by the oscillating medium are reduced and this medium is prevented from passing straight through the compartments. In this figure, as in Figure 1, the conduit L_1 is smaller than the conduit L_2 ; and, therefore, in accordance with the invention, the compartment e_1 must be, as shown, smaller than e_2 .

The embodiment of the invention shown in Figure 3 is the same as that shown in Figure 2, except that the compartment e_1 is closed off by a diaphragm d instead of being in communication with a conduit or pipe L_1 . This diaphragm d carries or forms the armature a of an electromagnet m . Because of the mass and elastic force of the diaphragm d it is necessary to make the compartment e_1 quite small.

As a rule the size given to each of the two individual compartments will preferably be short with reference to the wavelength of the sound transferred, so that the waves that occur in them are quasi stationary, i. e., that the motions of all parts of the medium in each compartment are substantially in phase with each other.

In regard to the dimensions of the dual chamber, a point to be invariably observed

is that the external surface area of the circular wall of an imaginary cylinder whose length and cross-sectional area correspond to the depth of either compartment of the dual chamber and to the cross-sectional area of the communicating passage respectively, must be at least as large as the cross-sectional area of the said communicating passage itself; and, in addition, the cross-sectional area of the sound passage must not be greater than the cross-sectional area of either compartment at any point taken on a plane parallel to the cross-sectional plane of the sound passage, because if this is not so the greatest motion of the sound conducting medium will not take place as it should in the said sound passage, but at the point of smaller cross-section.

In Fig. 4 a form of the invention is shown in which the one compartment e_1 is arranged to contain a quasi-stationary wave, while the medium in the other compartment e_2 is not in a strict sense quasi-stationary. The compartment e_2 is here formed by the flaring trumpet or megaphone piece t . A condition, somewhat analogous to a quasi-stationary condition, may be said to be produced in the compartment e_2 due to the inertia of the outside medium. The complete apparatus of Fig. 4 constitutes an improved megaphone, the voice being directed into the mouthpiece h against the diaphragm d , which latter excites the dual chamber e_1, e_2 , whose trumpet shaped compartment e_2 then throws the sound into the air.

Fig. 5 shows a dual chamber system formed of two dual chambers coupled together, one of these dual chambers being composed of compartments e_1 and e_2 and connecting passage o , and the other dual chamber being composed of compartments e_2 and e_3 and connecting passage o . In this arrangement, it will be observed, the compartment e_2 is common to the two dual chambers, in the same way as in the device disclosed in copending application, Serial No. 435,563, previously referred to, a mass may be common to two coupled vibratory structures. Where the common compartment e_2 is relatively large, as shown, a loose coupling between the dual chambers is secured. Of course, more than two dual chambers could be coupled together.

A certain portion of the total amount of vibratory energy operating in the entire dual chamber arises in each of the two compartments e_1 and e_2 , and the quota of energy in each is determined by the relative sizes of the compartments. The energy in each of the compartments is in the form of pressure energy, while taking the form of motional or kinetic energy in the communicating passage or passages. The ratio of the magnitudes of the pressure amplitudes in

compartments whose size is e_1 and e_2 is determined by the ratio of these sizes, the smaller compartment having the higher pressure and the larger compartment the lower pressure.

To make sound communication apparatus efficient, attention must be given to certain special requirements concerning the damping thereof.

It is known to be desirable in sound receiving apparatus to have the so-called useful damping of the apparatus (due to actuating the apparatus) equal to the so-called radiation damping of the apparatus (due to the reflection or radiation of energy back into the sound propagating medium). On the other hand, in sound sending apparatus it is known to be desirable to have the radiation damping of the highest possible magnitude. In acoustic apparatus heretofore, however, these conditions have not been satisfied. But with the invention of the present dual chamber or two-compartment resonator, a convenient means is provided whereby, by the suitable dimensioning of the individual compartments, the radiation and useful dampings may be regulated or adjusted to meet desired conditions or magnitudes. The required sizes of the individual compartments in each case to effect certain damping conditions may be determined either by experiment or calculation.

If the air in the dual chamber is the only vibratory element or body in the entire apparatus that is to have a pronounced natural rate of vibration, then this chamber itself, and this chamber only, must be tuned to the frequency of the sound to be received or sent out. This also holds in cases in which the elastic element gas in the chamber cooperates and works as a unit with another elastic vibrating element, but in such cases these two elements must be conceived as forming one. The damping is then adjusted to the proper amount while the tuning of the resonator is kept constant. The proper damping may be determined either by calculation or experiment. The number of resonators used may be one or more.

Considerations on the physical properties of a dual chamber lead to the following:

From the analogy between the invention disclosed in copending application, Ser. No. 435,563, and the dual chamber, which was pointed out in the opening paragraphs, it follows that in the first place the dual chamber is a monotone (single wave) structure. As in the structure disclosed in said copending application, the vibratory energy sometimes resides in the two masses or weights in the form of kinetic energy, and at other times in the stretched or compressed connecting rod between the two masses in the form of potential energy, so in the dual chamber it resides sometimes in the two compart-

ments in the form of potential energy (causing increased pressure in one compartment and decreased pressure in the other) and at other times in the form of kinetic energy in the flowing medium in the communicating passage. This statement also holds in cases in which the vibrating medium in one or both of the compartments of the dual chamber is not quasi stationary, and even when these compartments individually act as resonators, although in such a case the resonance effect produced independently by one or both compartments would affect the natural rate of vibration of the dual chamber to a very great extent.

Another fact that may be drawn from comparison with the device of copending application, Ser. No. 435,563, is that when a series of dual chambers are coupled together as in Figure 5, a bi-resonant or multi-resonant system is produced which in regard to tuning and damping is subject to the laws applying to coupled vibratory systems.

Formulas have been found by means of which the sizes of the compartments of a dual chamber can be determined in accordance with the invention in each particular case. This will now be elucidated by a few examples:

If E_1 denotes the amount of vibratory energy operating in the one compartment e_1 , and E_2 the vibratory energy in the other compartment e_2 then, according to the law stated above,

$$\frac{E_1}{E_2} = \frac{e_2}{e_1}.$$

Let it be assumed that the problem to be dealt with is to continually transmit or transfer sound energy from one tube L_2 (of larger diameter) to another tube L_1 (of small diameter). In Fig. 1, for example, this would be in the direction from right to left. In such a case the compartments e_1 and e_2 are made of such sizes that the damping of the dual chamber e_1-e_2 due to L_1 is equal to the damping caused by L_2 . Since the tube L_2 of larger diameter produces the greater damping effect, the vibratory energy operating in e_2 must be made proportionately smaller, i. e., the compartment e_2 must be made proportionately larger than e_1 , or in other words so much larger that the damping of the dual chamber that is to be attributed to L_1 is equal to the damping produced by L_2 . If for some reason, as in order to obtain a resonance curve of a certain breadth, the said individual damping is to have a certain prescribed value, it will also be necessary not to make the compartment e_2 too large in comparison with e_1 , so that the amount of energy that can be damped in e_2 may not be too small. The considerations on which the determination of the size of e_2 are based

are as follows: According to a known law the damping d is always equal to one half of the ratio of the amount of energy (E_n) yielded per second by a vibratory structure to the total amount of energy E operating in the structure, i. e.,

$$d = \frac{1}{2} \frac{E_n}{E}$$

In order that this amount may be yielded, the quota of vibratory energy E_2 operating in the compartment under consideration must be larger than E_n and hence it follows that the upper limit for the size of this compartment is defined by the inequation

$$e_2 \geq 2dE.$$

Another example will now be explained with reference to Fig. 3 of the drawing. Suppose that the diaphragm d is excited by the electromagnet m , and that sound energy is to be conducted out of the dual chamber through the tube L_2 . The first problem to be faced here is to cause such an amount of the particular form of vibrations produced in the diaphragm by the exciting magnet to pass into the air compartment e_1 as is given by the desired damping of the sender. This is accomplished by selecting the proper relation between the size of this compartment (small coupling chamber) and the diaphragm. Then it is necessary to conduct into the tube an amount of the said vibratory energy which is given by the desired damping. This function is performed by the compartment e_2 . In this instance we have to deal with two vibratory bodies or units, one of which consists of the diaphragm and the compartment e_1 , while the other consists of the dual chamber e_1, e_2 . The two are coupled together by e_1 . Therefore, at a given coupling, there should be a certain relationship between the size of the compartment e_1 and the elastic force of the diaphragm on the one hand, and between the sizes of e_1 and e_2 on the other hand. The damping of the vibratory system should be produced at e_2 by the tube, the form of damping meant here being the useful damping due to the propagation of sound energy through the tube.

Dual chambers as contemplated herein are of particular importance in the construction of submarine sound receivers in which a diaphragm abutting on the water transfers the sound energy it receives to the other parts of the apparatus through a small chamber bounded by the diaphragm. The practice adopted heretofore has been to cause the said small chamber to act directly, or indirectly through a resonator, upon the sound-conducting tube, and no particular points were observed regarding the specific properties of the resonator used. In ac-

cordance with this invention it is preferable to interpose between the diaphragm and the tube a dual chamber comprising air compartments of such a kind that the sound waves operating in them are quasi stationary, the size of the compartment next to the diaphragm being selected with due consideration to the desired coupling between the dual chamber and the diaphragm, and the ratio of the compartment next to the diaphragm to the compartment next to the tube being chosen so as to conform to the damping to be produced in the dual chamber by the tube.

It will be obvious that the field of application of the invention is not limited to the examples illustrated and described herein, but that one or more of the described arrangements can be employed in sound apparatus of any kind and for any purpose, so as to enable sound energy to be transmitted or transferred at the greatest possible efficiency.

The term "vibratory body" is used in the claims in its broadest sense, including for example a vibratory body or column of gas; and the word "passage" used therein is intended to designate not only a passage formed by a single aperture as in Fig. 1, but also a passage formed of a plurality of apertures as in Fig. 2.

We claim:—

1. A resonator formed of two individual compartments connected by a sound passage, and having each compartment of predetermined size dependent upon the amplitude-to-force ratio of the vibratory body next to the particular compartment.

2. A resonator formed of two individual compartments connected by a sound passage, and having each compartment of predetermined size dependent upon the damping effect to be produced in the particular compartment.

3. A resonator formed of two individual compartments connected by a sound passage, and having each compartment of predetermined size dependent upon the amplitude-to-force ratio of the vibratory body next to the particular compartment, the cross-sectional area of said passage being not greater than the smallest cross-sectional area of either compartment taken on a parallel plane, and the external surface area of the circular wall of an imaginary cylinder having the same cross-sectional area as the passage and having a length equal to the length of either compartment being at least as large as the cross-sectional area of said passage.

4. Means for transferring sound between two vibratory bodies, comprising a dual chamber formed of two individual compartments connected by a sound passage and tuned as a whole to the frequency to be transferred, and having each compartment of

predetermined size dependent upon the amplitude-to-force ratio of the vibratory body next to the particular compartment.

5 Means for transferring sound between two vibratory bodies, comprising a dual chamber formed of two individual compartments connected by a sound passage and tuned as a whole to the frequency to be transferred, and having each compartment
10 of predetermined size dependent upon the damping effect to be produced in the particular compartment.

6. Means for transferring sound between a conduit of relatively small cross-section
15 and a conduit of relatively large cross-section, comprising a dual chamber formed of two individual compartments connected by a sound passage, and having each compartment of predetermined size dependent upon
20 the amplitude-to-force ratio of the vibra-

tory body next to the particular compartment, the compartment next to the conduit of relatively small cross-section being the smaller compartment.

7. Means for transferring sound between 25 a conduit of relatively small cross-section and a conduit of relatively large cross-section, comprising a dual chamber formed of two individual compartments connected by a sound passage, and having each compartment
30 of predetermined size dependent upon the damping effect to be produced in the particular compartment, the compartment next to the conduit of relatively small cross-section being the smaller compartment. 35

In testimony whereof we affix our signatures.

WALTER HAHNEMANN.
HEINRICH HECHT.
BERNHARD SETTEGAST.