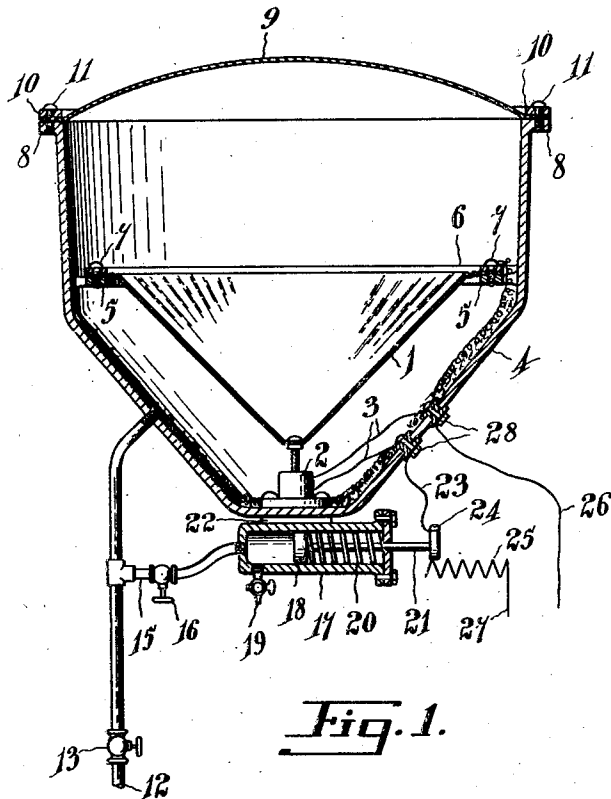
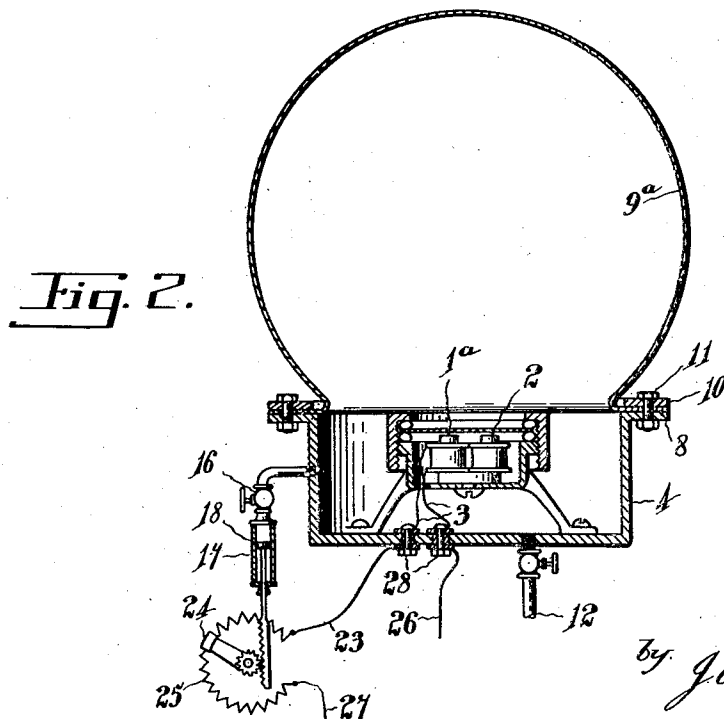


Oct. 8, 1929.

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ACOUSTIC TRANSFORMER
Filed Nov. 30, 1928

1,730,531



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ACOUSTIC TRANSFORMER

Application filed November 30, 1928. Serial No. 322,898.

When a loud-speaker diaphragm is vibrated, work is expended upon it. This work is divided between accelerating and retarding the movement of the mass of the diaphragm, bending the material of which it is made against the internal forces which give the material rigidity and elasticity, and in agitating air particles in contact with the diaphragm.

The useful effort is the agitation of the air particles, but the efficiency of the diaphragm in performing this useful work is limited by factors which depend upon necessary rigidity, elasticity, durability and weight of the diaphragm itself.

The power impulses are usually applied at or near the center of a diaphragm and the diaphragm must be strong enough and stiff enough to spread the impulses over a large part of its area without undesirable distortion of its shape.

For any given tone or pitch there is a given number of vibrations per second and each vibration of the reproducing diaphragm must be made within the time interval between sound waves or impulses. In case of reproducing the sounds of an orchestra the diaphragm must vibrate slowly, say to the notes of the bass-drum, and at the same time it must vibrate rapidly to the shrill notes of a violin or flute.

Thus the diaphragm must be stiff enough to carry the vibrations of the drum over its entire surface and at the same time be flexible enough to break up into nodes and antinodes over its entire surface to accommodate the shrill pitch vibrations. Thus the diaphragm must be a compromise between the requirements for all ranges of pitch and shapes of sound waves.

These conditions require a delicate adjustment between mass, internal strength, elasticity, durability and dimensions.

"Loudness" of tone depends upon the amplitude of vibrations at the ear of the listener, and the loudness of tone emitted by a diaphragm depends upon the number of air particles acted upon by the diaphragm and the degree of violence with which the air particles are vibrated. Loudness may therefore be increased by increasing the area of the dia-

phragm and maintaining a fixed amplitude of vibration: by retaining a fixed area but increasing the amplitude of vibration: by crowding a greater number of air particles into contact with the diaphragm: or by providing a gas heavier than air to receive the vibrations from the diaphragm.

Diaphragms of large size are sometimes used, but their increased size involves greater thickness and weight to make them proof against distortion and their mass becomes so great that they vibrate feebly or not at all in response to shrill notes and overtones. If a diaphragm is retained of a small size and vibrated with a greatly increased amplitude of vibration the accelerating force must be greatly increased and the application of this force may distort the diaphragm or break its vibrations up into undesirable overtones causing rattling or screeching. To guard against this the diaphragm must be made stiffer and therefore less responsive.

Various attempts have been made to maintain the advantage of a light flexible diaphragm by subjecting it to a tension stress by means of a distending gas pressure applied to one side of the diaphragm. A characteristic of a diaphragm must be elasticity, and any application of gas pressure to one side distorts and stretches the diaphragm and interferes with the delicate adjustment between it and its actuating magnet of stylus.

To overcome these objections by immersing the diaphragm completely in a dense gaseous medium, and no matter what variations may be made in the pressure of the immersing gas, there is no distortion or stretching of the diaphragm.

Any diaphragm has fixed mechanical strength, elastic characteristics, weight and area, and when operated in air at atmospheric pressure it produces a certain degree of vibration or sound, depending upon the intensity of the actuating force. If now this same diaphragm be immersed in a dense atmosphere and be vibrated with the same intensity as previously, using the same actuating force, there will be only a small change in the inertia stresses within the structure

of the diaphragm or in its elastic characteristics or in its mass.

Owing to the greater number of air particles being agitated, the amplitude of vibration will be less than previously, but the total amount of work done will be the same as before, but in the dense atmosphere more work will be done upon the air particles and less upon the diaphragm, and thus the efficiency of the diaphragm will have been increased.

This may be expressed by symbols thus: If W is the total work done at atmospheric pressure and a is the work done upon the air, and d the work done upon the diaphragm, then $W = a + d$. If the amplitude of vibration of the diaphragm be reduced the work done upon it will be less and may be represented by d' , so it follows that if the diaphragm be immersed in dense air and vibrated at a less amplitude of vibration owing to the density of the air and the total input of power to the diaphragm is not changed then $W = a' + d'$, where a' is the work done upon the dense air particles. As d' is less than d it follows that a' is greater than a . Thus the efficiency of the diaphragm has been increased.

If we now increase W until the amplitude of vibration of the diaphragm is the same in the dense air as it was in the free air, the amount of work expended upon the diaphragm will still be d , as neither the mass nor other characteristics of the diaphragm have been changed.

The equation then becomes:

$$W + \text{increase} = (a' + \text{increase}) + d$$

and thus the entire increase in total work is expended upon the air particles, and none of the increased work is wasted upon moving the diaphragm. This is only broadly true as a slightly different set of internal stresses would be involved within the structure of the diaphragm when vibrating in a dense atmosphere owing to the increased load of air particles. These forces would vary according to the formula Mv^2 , where M is the mass of air particles and v is the velocity of acceleration. The velocity has not been changed so v is constant, and hence the stresses will only be increased by an increment due to the increase in the mass of the air.

Manufacturing and ordinary handling and usage require that the diaphragm shall have an excess of mechanical strength and in the combined mass of diaphragm and air particles, the weight of air is very small compared to the weight of the diaphragm, so even a considerable increase in the mass of the air will impose but a small increment upon the stresses within the diaphragm, and the result shown by the above equation will be approximately true.

The ability to transform a greatly increased

amount of mechanical or electrical energy into sound energy or air vibration, in the case of any diaphragm, is a very desirable accomplishment. The increased efficiency indicated is not all gained however, for the sounds propagated through the dense atmosphere must in turn pass through the second or outer diaphragm with a loss of energy due to reflection and work done upon the second diaphragm.

The second diaphragm may be made very large in comparison with the first diaphragm and may be made of very thin metal, quartz glass, paper, or other suitable material. The force required to overcome the mass of the second diaphragm is equivalent to Ma , where M is the mass and a the rate of acceleration. The total force propagated through the dense atmosphere to the second diaphragm will therefore be reduced by whatever amount is required to vibrate the second diaphragm.

Owing to the large area of the second diaphragm it will have a comparatively short amplitude of vibration when transmitting the sound-waves, and this short amplitude will result in the rate of acceleration being very small. With a spherical shape the second diaphragm may be made very thin as it has to resist tension only, and thus its mass will be quite small. With a low value for the acceleration factor " a ", and a low value for the mass factor " M " in the equation, the value of the force necessary to do the work on the diaphragm must necessarily be very small.

The invention is hereinafter more fully described and is illustrated in the accompanying drawings in which—

Fig. 1 is a longitudinal section, more or less diagrammatic, of one embodiment of my invention; and

Fig. 2 is a similar view of a modification.

In Fig. 1, 1 is a conical diaphragm receiving its power from the driving electro-magnet 2 which receives electrical impulses over the conductors 3, 3, which lead to terminals 28 extending through the wall of the chamber. 4 is an air-tight casing which has the annular ring 5—5 supported on brackets within it. The diaphragm 1 is held to the ring 5 by the junk ring 6 and the screws 7—7 in the usual manner.

An extension of the casing 4 has the annular flange 8 to which a convexly curved diaphragm 9 is held by the junk ring 10 and the bolts 11. The part of the casing 4 at the back of the diaphragm 1 is lined with felt or other sound absorbing material. Gas under pressure from any suitable source is supplied through the pipe 12 by opening the valve 13 and the entire casing 4 becomes filled with the gaseous medium under pressure.

A branch pipe 15 is controlled by the valve 16 which admits gas under pressure into the cylinder 17 which contains the close fitting

piston 18. The cylinder 17 is, for convenience, mounted upon the chamber 4 on lugs 22—22. Gas entering the cylinder 17 forces the piston 18 ahead of it compressing the spring 20, and if the valve 16 be closed and the pet cock 19 be opened the spring 20 will force the piston 18 back to the end of the cylinder 17. The piston rod 21 has an electrical contact brush 24 supported on its end to which the electrical conductor 23, leading to one of the terminals 28, is attached. As the piston 18 is forced forward, the contact brush 24 slides along the resistance coil 25, cutting out resistance as it advances.

Current for operating the cone diaphragm 1 flows along the conductor 26 leading to the second terminal 28 and 27 leading to the variable resistance 25 and as the amount of resistance 25 is varied the flow of current is varied and the intensity of action of the diaphragm therefore varies, being greater when the pressure within the chamber 4 is greatest, and least when the pressure within the chamber 4 is least.

Thus as the number of gas particles in contact with the diaphragm increases, the vibrations of the diaphragm are increased in intensity and greatly increased sound energy is propagated to the second diaphragm 9 which in turn transmits the vibrations to the surrounding atmosphere.

Figure 2 shows an arrangement in which a flat disc 1^a is used for a diaphragm, and the second diaphragm 9^a is made spherical in shape. In other respects the constructions are similar.

What I claim as my invention is:

1. An acoustic transformer comprising a closed chamber containing a gas having a greater density than air at atmospheric pressure; a diaphragm immersed in said gaseous medium; and a second diaphragm exposed at one side to the atmosphere and at the other to the gas pressure within the chamber.

2. An acoustic transformer comprising a closed chamber containing a gas at more than atmospheric pressure; a diaphragm immersed in said gaseous medium; and a second diaphragm exposed at one side to the atmosphere and at the other to the gas pressure within the chamber.

3. An acoustic transformer comprising a closed chamber containing a gas having a greater density than air and at more than atmospheric pressure; a diaphragm immersed in said gaseous medium; and a second diaphragm exposed at one side to the atmosphere and at the other to the gas pressure within the chamber.

4. An acoustic transformer comprising a closed chamber of lenticular form filled with a gas having a greater density than air at atmospheric pressure, one wall of the chamber being formed, in part at least, of a vibratable diaphragm immersed in said gaseous

medium; and a second diaphragm, opposite the first mentioned diaphragm and independent thereof, adapted to impart vibrations to or receive them from the other diaphragm solely through the medium of said gas.

5. An acoustic transformer comprising a closed chamber containing a gaseous medium having a greater power transmitting capacity than air at atmospheric pressure; a diaphragm immersed in said gaseous medium; and a second diaphragm of larger size closing an opening in said chamber.

6. An acoustic transformer comprising a closed chamber containing a gas having a greater density than air at atmospheric pressure; an electro-magnetically operated diaphragm immersed in said gaseous medium; a second diaphragm exposed at one side to the atmosphere and at the other to the gas pressure within the chamber; means for varying the gas pressure in the chamber; and means for varying the energy input to the electro-magnetic diaphragm as the gas pressure varies.

7. An acoustic transformer comprising a closed chamber containing a gaseous medium having a greater power transmitting capacity than air at atmospheric pressure; an electro-magnetically operated diaphragm immersed in said gaseous medium; a second diaphragm of larger size closing an opening in said chamber; means for varying the gas pressure in the chamber; and means for varying the energy input to the electro-magnetic diaphragm as the gas pressure varies.

Signed at Highland Park, Ill., this 15 day of November, 1928.

PERCY A. ROBBINS.