Jan. 29, 1929. **1,700,457**

A. L. THURAS

ACOUSTIC DEVICE

Filed Aug. 2, 1926

Fig.1

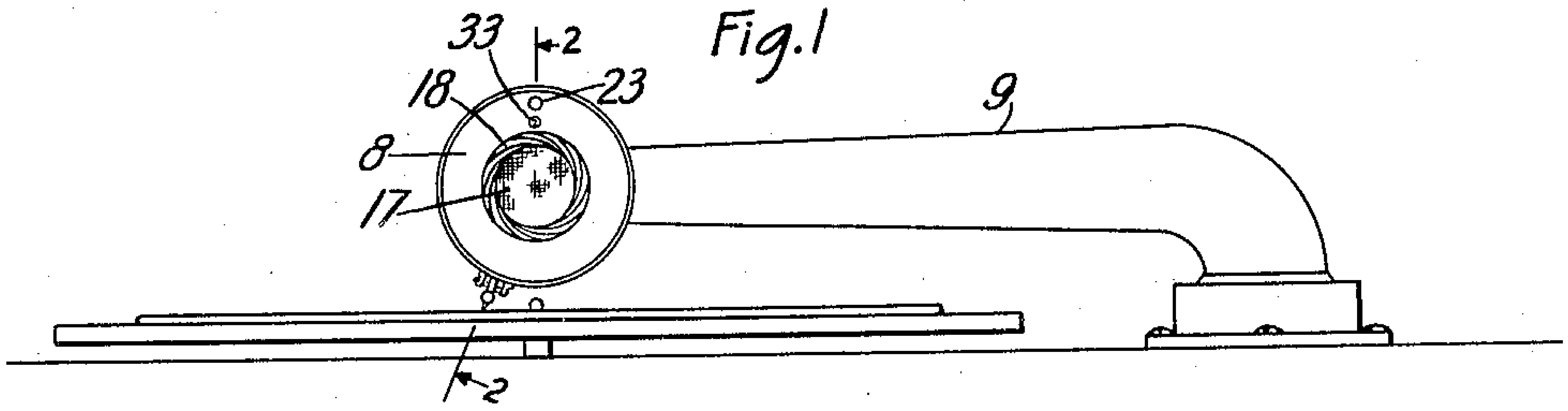


Fig.2

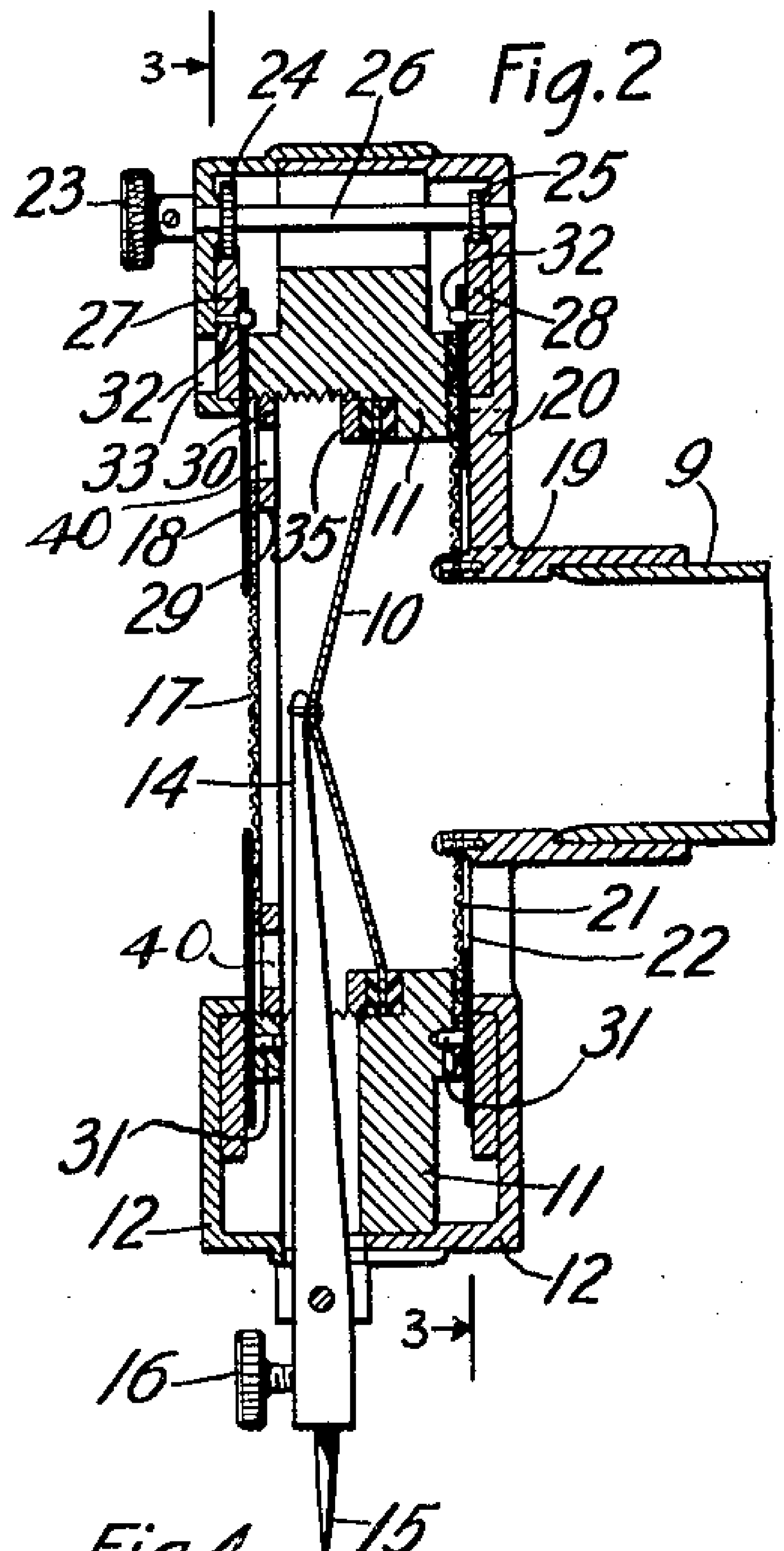


Fig.3

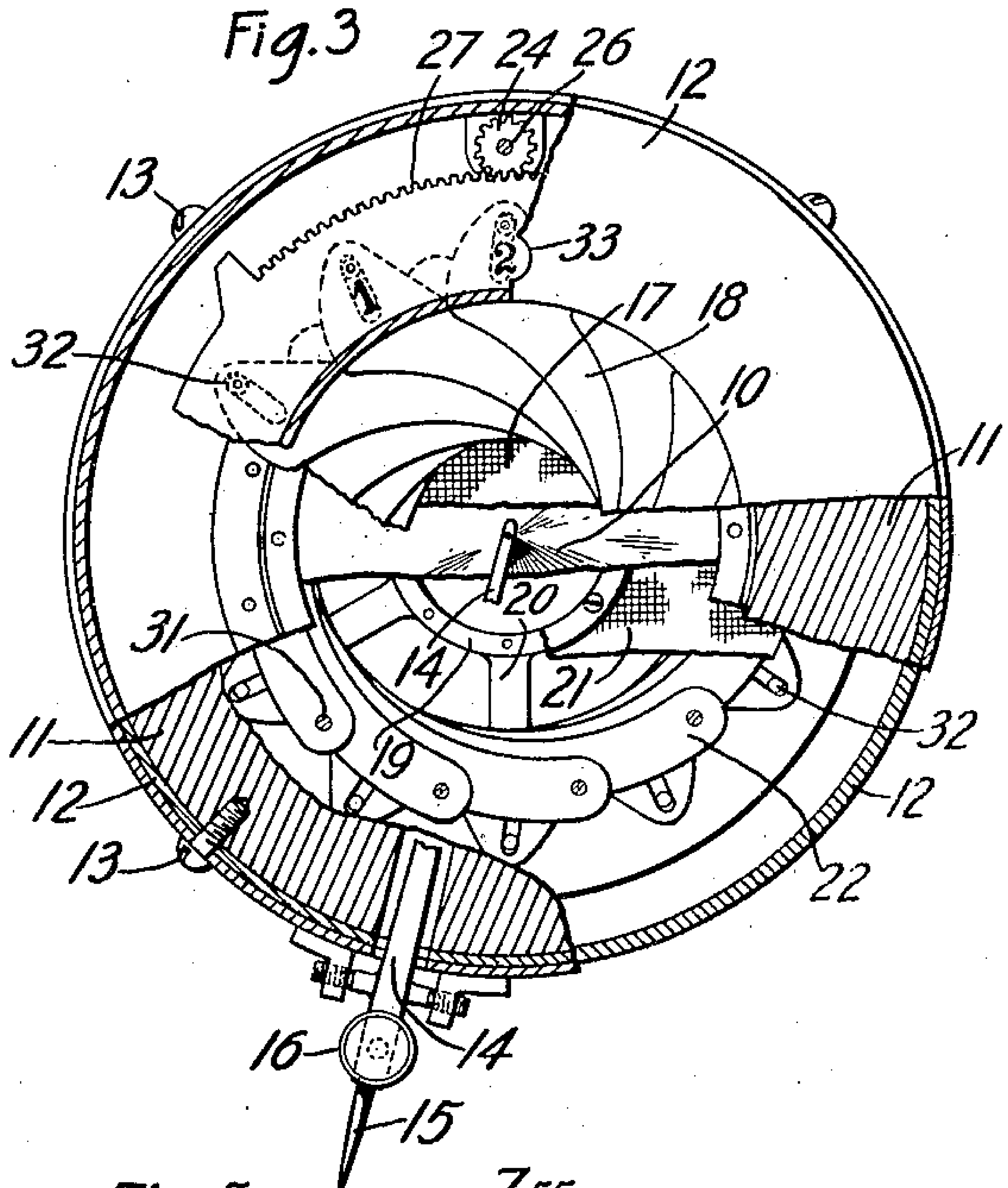


Fig.4

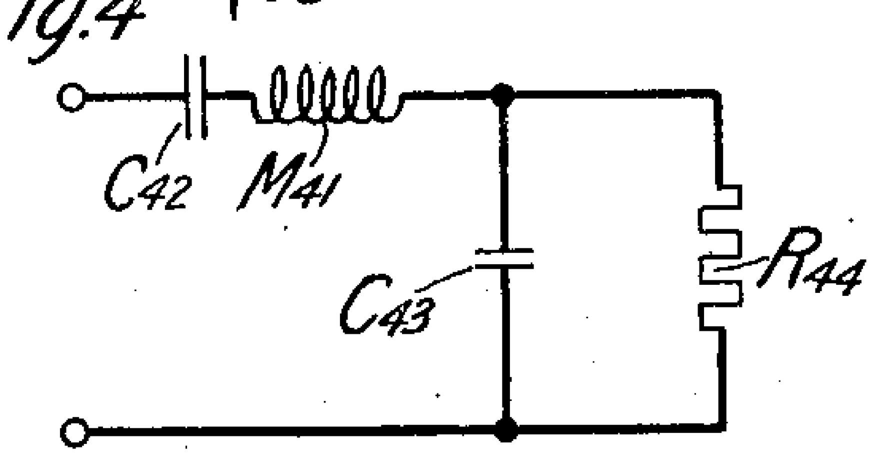


Fig.5.

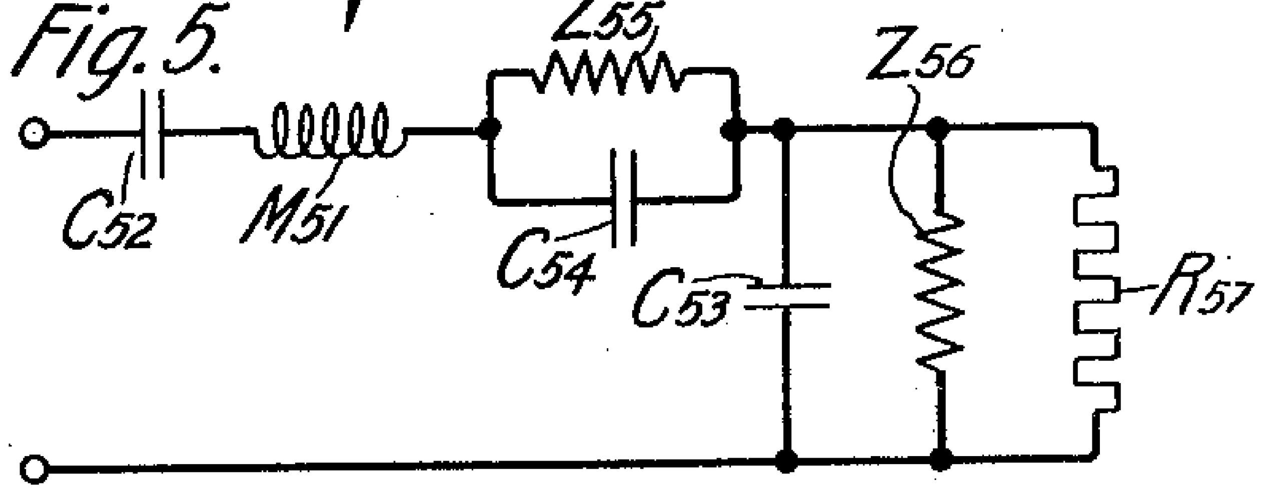


Fig.6

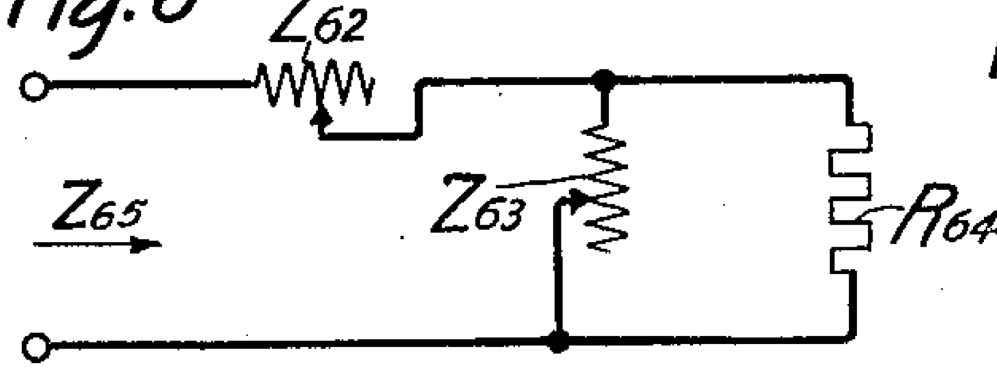
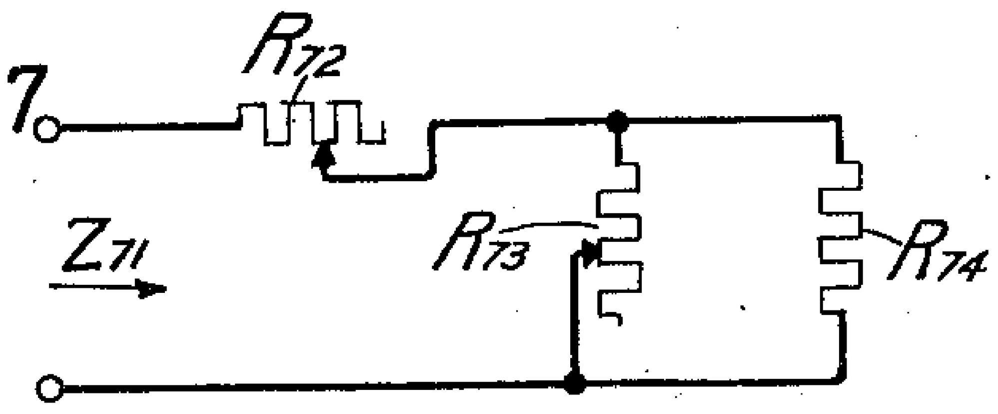


Fig.7



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UNITED STATES PATENT OFFICE.

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ACOUSTIC DEVICE.

Application filed August 2, 1926. Serial No. 126,523.

This invention relates to acoustic devices and particularly to attenuators for acoustic apparatus.

The principal object of the invention is to attenuate sound energy without introducing appreciable distortion.

A more specific object is to control the sound output of phonograph reproducers, loud speakers and other acoustic devices.

These objects are attained in accordance with the features of the present invention by means of a variable acoustic attenuator composed of impedance elements, in series and shunt relation to the line of energy propagation, which elements are arranged to be varied in such a way that the impedance of the attenuator remains substantially constant for all values of attenuation and that, for a given setting, the loss introduced by the attenuator is substantially uniform over the major portion of the sound frequency range. While this network may be designed to have a constant impedance over the sound frequency range and a substantially uniform frequency loss characteristic when employing impedance elements having reactance components rather than being pure resistances, it is preferable to employ elements consisting of substantially pure resistance.

In accordance with a preferred form of the invention the resistance elements consist of gauze discs placed on each side of the sound generating device or diaphragm and shutters are employed to regulate the effective areas of the gauze discs to vary the attenuation.

The invention is particularly applicable to acoustic devices employing a diaphragm contained in a partly enclosed case, one side of which is connected to a horn or other sound-radiating device. Sound volume regulators for such devices have been devised in the past, as disclosed, for example, in Patent No. 1,229.780 granted to W. Opel, June 12, 1917. This patent shows a volume regulator comprising two superposed perforated discs one on each side of a layer of felt inserted in the diaphragm case between the diaphragm and the sound transmitting passage, these perforated discs being rotatable to vary the volume of the radiated sound. However, as far as applicant is aware there have been no volume regulators having variable impedance elements and which give the same impedance for different attenuation settings and have uniform attenuation characteristics over a fairly large frequency range.

The invention may be better understood by referring to the accompanying drawing in which: Fig. 1 shows the attenuator of this invention applied to a phonograph reproducer; Fig. 2 is a detail sectional view of the device shown in Fig. 1 taken along the line 2—2; Fig. 3 a sectional view taken along the line 3—3 of Fig. 2 and having portions broken away to better show the invention; and Figs. 4 to 7 inclusive are diagrammatic representations of the impedance relations which exist in the device.

Referring to the drawing, the phonograph reproducer 8 employing the attenuator of this invention is connected to the tone arm 9 which leads to a horn (not shown). The peripheral portion of the conical metallic diaphragm 10 is clamped, by means of a threaded ring 35 to the ring 11 which is secured to the case 12 by the screws 13. The diaphragm is driven at its apex by the stylus arm 14 to the other end of which the needle 15 is secured by the set screw 16. Slightly spaced from one side of the diaphragm is a thin metallic gauze member 17 having extremely fine perforations, a material employing 250, 0.004″ parallel wires to the inch in one direction and 28, 0.009″ wires to the inch extending intersectingly to the 0.004″ wires having been found satisfactory. Such a member has a substantially pure resistance impedance. This gauze member is rigidly secured to the ring 29 which is joined to the ring 30 by metallic spokes 40—40, as illustrated in Fig. 2, the ring 30 in turn being threaded into the ring 11. With this arrangement the air space between the diaphragm 10 and the gauze member 17 communicates directly with the outside air through the opening between the rings 29 and 30 when the adjacent shutter 18 is entirely open. This shutter is also used to cover a portion of the gauze member 17 to vary its resistance, the resistance being increased as a greater portion of the gauze is covered. On the other side of the diaphragm the tone arm 9 is fitted into the metallic tube 19 which is connected to the case 12 by means of the metallic spokes 20. Slightly spaced from this side of the diaphragm and about the opening through the tube 19 is positioned a ring-shaped gauze member 21 which is of similar material to that employed in the gauze member 17. A shutter 22 is positioned adjacent to the gauze member 21 to vary its impedance. The shutters 18 and 22 are operated simultaneously by movement of the thumb screw 23 transmitted through the gears 24 and 25 respectively. These gears are connected to the common shaft 26 and mesh with the toothed wheels 27 and 28 respectively. The relative movement of the shutters is proportional to the diameters of the gears 24 and 25. The operation of the shutters is so adjusted that the shutter on one side of the diaphragm is closed when the one on the opposite side is open, the relative rate of opening and closing of the two shutters being such that the impedance into which the diaphragm works remains substantially constant over the sound frequency range for all values of attenuation. When the shutter 18 is set for maximum opening and shutter 22 is closed, the minimum attenuation or maximum sound radiation takes place and, conversely, when the shutter 18 is entirely closed and the shutter 22 is set for its maximum opening, the device gives a maximum attenuation. The shutters 18 and 22 may be of any type, the ones shown in the drawing being of the type commonly employed in cameras as the iris diaphragm. Each shutter is made up of a number of curved sectors which are pivoted at one end and moved simultaneously at the other end so as to enlarge or decrease the size of the opening at the center of the shutter. These sectors are pivoted at one end to the ring 11 by means of the pins 31 and are slotted at the other end to receive the pins 32 which are secured to the wheels 27 and 28. The wheel 27 has the numerals 1, 2, etc. painted upon it, these numerals being visible through the hole 33 in case 12. The attenuator can therefore be set for a given volume attenuation by turning the thumb-screw 23 until the corresponding number appears in the opening 33.

Figs. 4 to 7 inclusive are diagrammatic representations of the mechanical impedance relations which exist in the sound reproducer. Figure 4 shows these relations for the condition in which the shutter 22 on the horn side of the diaphragm is entirely closed and the shutter 18 at the back of the diaphragm is entirely open. Under these conditions, there is no attenuation introduced by the gauze members 17 and 21 and the device functions as if the attenuator were not present. In Fig. 4 the mass of the diaphragm is represented by M_{41} and its compliance, i. e., the reciprocal of its stiffness, by C_{42}. The compliance of the air on the horn side of the diaphragm is indicated by C_{43} and the impedance looking into the horn at the throat end, which is a substantially pure resistance, is represented by R_{44}. Compliance may be defined as the ratio of displacement to applied force. The terms mass, compliance, and resistance, applied to a mechanical impedance diagram, are analogous to the inductance, capacity and resistance, respectively, of an electrical impedance diagram.

Fig. 5 represents diagrammatically the impedance relations in the device when the attenuator is set so as to introduce a certain amount of attenuation into the sound transmitting path. For this condition the shutter 22 is partly opened and the shutter 18 is partly closed. In this figure M_{51} represents the mass of the diaphragm, C_{52} its compliance and R_{57} the impedance looking into the horn, at the throat end. I have in addition, for this setting of the attenuator, a series arm comprising the compliance C_{54} of the air space in back of the diaphragm and the impedance Z_{55} of the gauze member 17 in parallel with each other and a shunt arm comprising the compliance C_{53} of the air space in front of the diaphragm and the impedance Z_{56} of the gauze member 21 in shunt with one another.

The compliances C_{53} and C_{54} are made of such a size that they may be neglected in making design computations covering a large portion of the frequency range employed in speech and music. However, at some of the higher frequencies of the sound frequency range, the effect of their presence may become noticeable.

Neglecting the effect of these compliances the impedance diagram is shown in Fig. 6 in which Z_{62} and Z_{63} represent the impedance of the gauze members 17 and 21, respectively, and R_{64} the throat impedance of the horn. In operating the shutters the attenuation is increased by closing the shutter 18 and opening the shutter 22, which operation is equivalent to increasing the impedance Z_{62} and decreasing Z_{63}. In order to maintain the impedance Z_{65} looking away from the diaphragm equal to R_{64} for all values of attenuation, it is essential that

$$Z_{65}=Z_{62}+\frac{Z_{63}R_{64}}{Z_{63}+R_{64}}=R_{64}$$

or that

$$Z_{63}=\frac{R_{64}(1-Z_{62})}{Z_{62}+R_{64}}$$

Figure 7 is the same as Figure 6 except that the impedances Z_{62} and Z_{63} are shown as resistances R_{72} and R_{73} respectively. In view of the relative difficulty of correctly proportioning reactive impedance elements in the attenuator of this invention, it is preferable to employ impedance elements having a negligible reactance component thus approaching the condition shown in Fig. 7. It has been found that the impedance of thin gauze members having very fine perforations is practically a pure resistance. Under these conditions in order to maintain the input impedance Z_{71} of the attenuator equal to the horn impedance R_{74} it is necessary to maintain the following relation between the various elements,

$$Z_{71}=R_{72}+\frac{R_{73}R_{74}}{R_{73}+R_{74}}=R_{74}$$

or

$$R_{73}=\frac{R_{72}(1-R_{72})}{R_{72}+R_{74}}$$

It is seen that the acoustic attenuation networks of the general form shown in Fig. 7 are substantially distortionless since the network impedance is maintained substantially constant for all values of attenuation and for a given setting, the loss introduced by the attenuator is substantially uniform over a large portion of the sound frequency range.

It is to be understood that the use of the acoustic attenuator of this invention is not limited to a phonograph reproducer but may be readily adapted to other acoustic devices, as, for instance, the electromagnetic telephone receiver. While the use of metallic gauze impedance elements having a very small cross-section and extremely fine perforations is desirable, many other materials of various forms may be employed, as for instance, a transverse section of bamboo or a layer of "cellotex."

What is claimed is:

1. An acoustic attenuator comprising impedance elements in shunt and series relation to the line of propagation of wave energy, and means for simultaneously varying the impedance of said elements to vary the attenuation produced thereby.

2. An acoustic attenuator comprising impedance elements in shunt and series relation to the line of propagation of wave energy, and means for varying the impedance of said elements to vary the attenuation produced thereby while maintaining the impedance of said attenuator substantially constant.

3. In an acoustic device including a diaphragm, an acoustic attenuator comprising means positioned on both sides of said diaphragm for attenuating the sound energy generated by said diaphragm substantially uniformly over a large portion of the sound frequency range.

4. In an acoustic device including a diaphragm, an attenuator comprising an impedance element on each side of said diaphragm, and means for varying the magnitude of said impedance elements.

5. In an acoustic device including a diaphragm, an attenuator comprising impedance elements of substantially pure resistance on each side of said diaphragm, and means for varying the magnitude of said impedance elements.

6. A variable acoustic attenuator comprising an impedance network having variable impedance elements, and means for varying the impedance of said elements so as to maintain the input impedance of said network substantially constant over a wide frequency and attenuation range.

7. In an acoustic device having a diaphragm and a sound transmission path arranged to receive sound waves from one side of said diaphragm, means for attenuating the sound waves transmitted from said diaphragm to said path, said means comprising a perforated member leading into the free air from the side of said diaphragm associated with said path, a second perforated member leading into the free air from the other side of said diaphragm, and means for simultaneously varying the effective area of both of said members to vary the attenuation introduced by said attenuating means.

8. An acoustic device according to the preceding claim characterized by means for simultaneously varying the effective area of the perforated members while maintaining the acoustic impedance of the attenuating means substantially constant.

9. In an acoustic device having a diaphragm and a sound transmission path arranged to receive sound waves from one side of said diaphragm, means for attenuating the sound waves transmitted from said diaphragm to said path, said means comprising a thin gauze member leading into the free air from the side of said diaphragm associated with said path, a second thin gauze member leading into the free air from the other side of said diaphragm, and means for simultaneously varying the effective area of both of said members to vary the attenuation introduced by said attenuating means.

10. In an acoustic device having a diaphragm and a sound transmission path arranged to receive sound waves from one side of said diaphragm, means for attenuating the sound waves transmitted from said diaphragm to said path, said means comprising a thin, finely perforated gauze member and leading into the free air from the side of said diaphragm associated with said path, a second thin, finely perforated gauze member leading into the free air from the other side of said diaphragm, and adjustable shutters adjacent to each of said gauze members for simultaneously varying the effective area of both of said members to vary the attenuation introduced by said attenuating means.

11. In an acoustic device including a diaphragm, a variable acoustic attenuator comprising impedance elements of substantially pure resistance on each side of said diaphragm, said impedance elements consisting of finely perforated gauze members of relatively thin cross-section, movable shutters covering a portion of said gauze members, means for operating said shutters so that a terminal impedance of said acoustic attenuator remains substantially constant over a

large portion of the sound frequency range while the attenuation of said variable acoustic attenuator is varied.

12. In a mechanical phonograph including a sound reproducer and a sound radiator, a variable acoustic attenuator comprising a variable sound impeding element in series with the impedance of said sound radiator and a second variable sound impeding element in parallel with the impedance of said sound radiator, means for simultaneously varying the impedance of said sound impeding elements for controlling the volume of sound radiated from said mechanical phonograph without introducing appreciable distortion.

In witness whereof, I hereunto subscribe my name this 31st day of July A. D., 1926.

ALBERT L. THURAS.