June 28, 1938. S. BALLANTINE 2,121,781

SOUND TRANSLATING DEVICE

Filed April 13, 1936 2 Sheets-Sheet 1

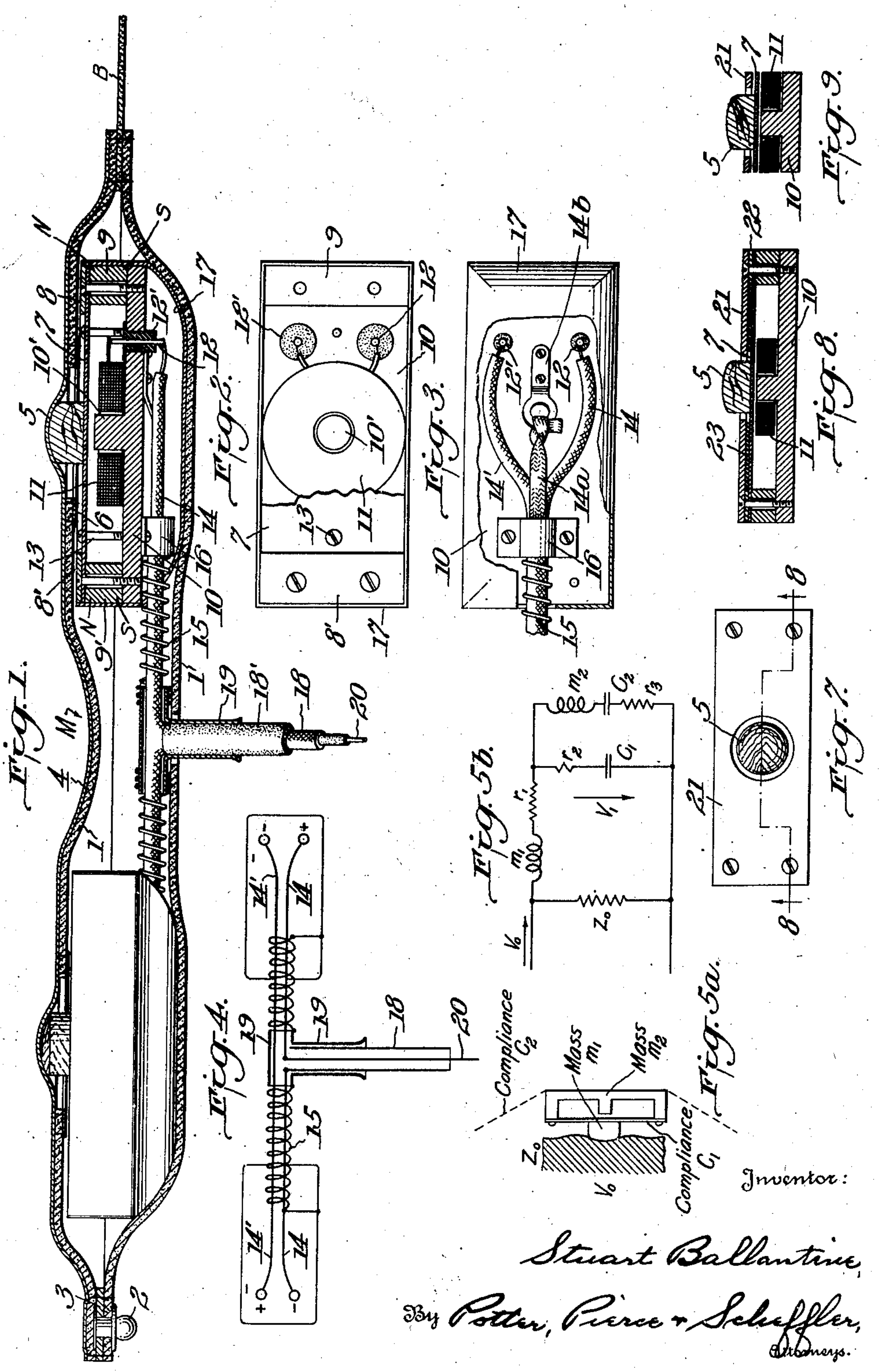

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Fig. 10.

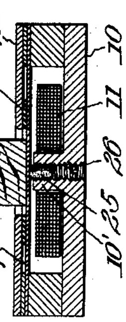


Fig. 11.

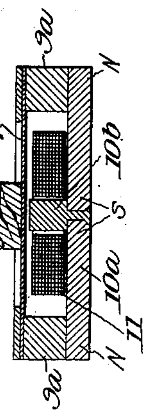


Fig. 13.

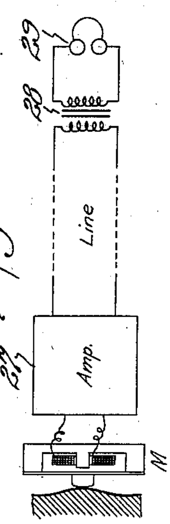


Fig. 6.

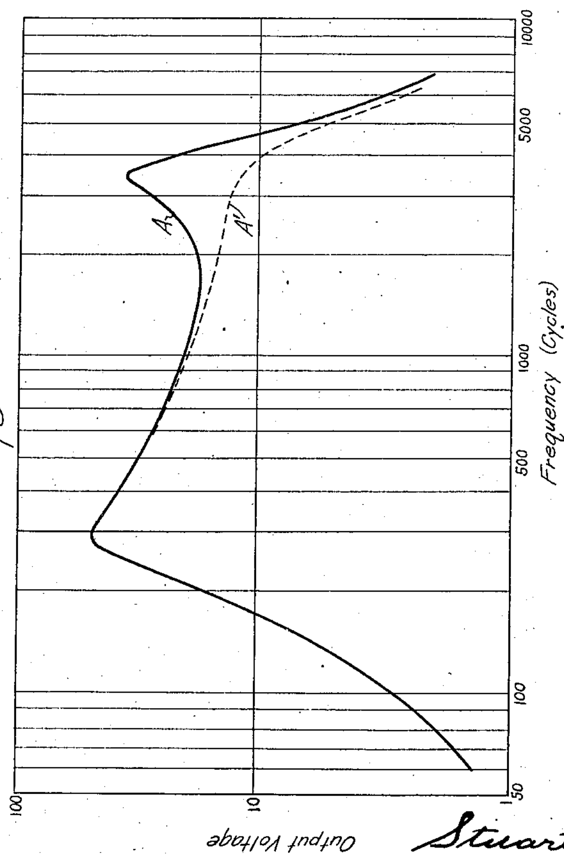
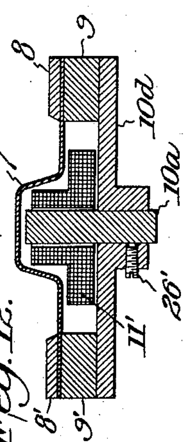


Fig. 12.



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UNITED STATES PATENT OFFICE

2,121,781

SOUND TRANSLATING DEVICE

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Application April 13, 1936, Serial No. 74,201

9 Claims. (Cl. 179—114)

This invention relates to apparatus for translating mechanical vibrations of the body in the region of the throat due to the voice into articulate speech sounds or into electrical currents which yield articulate speech sounds when reproduced.

Apparatus and methods for this general purpose have been described in my copending applications Ser. Nos. 6,245 and 6,246, filed Feb. 12, 1935; Ser. No. 8,392, filed Feb. 26, 1935, and Ser. No. 54,347, filed December 13, 1935.

An object of the invention is to provide a device of novel construction for converting acoustical vibrations of the body due to the voice into electric currents for transmission in an electrical communication system. An object is to provide a microphone, of the character stated, which operates on the electromagnetic principle and which therefore does not require the battery ordinarily used with microphones of the carbon granule type.

Further objects are to provide a larynx microphone which is characterized by a simple and rugged mechanical construction and by an electrical output which compensates, in part at least, for the deficiency of the higher frequency constituents in the mechanical vibrations of the larynx.

These and other objects and advantages of the invention will be apparent from the following specification when taken with the accompanying drawings in which:

Fig. 1 is a sectional view of an embodiment of the invention;

Figs. 2 and 3 are front and rear views, respectively, with parts broken away, of one of the transducer units;

Fig. 4 is a schematic view of the wiring connections and shielding of the microphone shown in Fig. 1;

Figs. 5*a* and 5*b* are corresponding mechanical and electrical impedance diagrams;

Fig. 6 is a curve sheet showing typical output voltage-frequency characteristics which may be obtained with embodiments of the invention;

Fig. 7 is a front view of another transducer construction which is particularly adapted for oil damping;

Fig. 8 is a longitudinal section on line 8—8 of Fig. 7;

Fig. 9 is a central transverse section;

Fig. 10 is a longitudinal section through a transducer which includes adjustable elements for controlling the air gap;

Fig. 11 is a sectional view of a transducer which includes another form of magnet structure;

Fig. 12 is a longitudinal section through a transducer which includes a different form of vibratory armature; and

Fig. 13 is a fragmentary circuit diagram of a complete electrical system which embodies the invention.

The microphone is adapted to be worn around the neck like a collar, as shown in Fig. 1 of my copending application Ser. No. 6,246, but other methods of support may be employed. When worn as a collar, the microphone M has the general form of a narrow band or casing in which two mechano-electrical transducers are symmetrically arranged, and an adjustable elastic band B is sewed to the casing to form a collar that may be placed around the neck in such a way that the microphone units are in contact with the neck in the region of the larynx.

The covering or elongated casing 1 for the transducer unit or units may be of any suitable material, such as glove leather, with a snap fastener 2 and fibre stiffener 3 fastened to one end of the casing. The side of the microphone which contacts with the neck will be designated, for convenience of description, as the "front" of the microphone. The front wall of the casing 1 is provided with two holes which are covered by a thin membranous material 4 which may be cemented to the front leather wall, and the actuating buttons 5 of the microphone units extend through these holes. Not all materials are suitable for the membrane 4 on account of attenuation of the higher frequency vibrations. Materials which have been used successfully are thin rubber, animal intestinal linings which may be grouped under the name of "colon leather", and ordinary leather of the order of .005" to .015" thickness. Thin glove leather has been employed in most of my constructions because of its good mechanical qualities and because its physical appearance can be made to match the rest of the leather covering. This is cemented to the covering 1 with rubber cement and extends over the entire area of the side toward the neck. In order to reduce the strain on the covering 1 and the thin protective covering 4, a thin metal grommet 6 is sewed and/or cemented around the edge of the openings in the front wall 1.

The electromagnetic transducer units may be, and preferably are, of substantially identical construction. The motion transmitting button 5 is of substantially rigid material, such as "bakelite", balsa wood, white pine, etc., and is fastened to the middle of the vibratory element 7. This vibratory element is a resilient strip of magnetic material, such as silicon steel, which may have metallic pieces 8, 8' soldered at the ends thereof to assist in defining the effective length of the vibratory strip or armature, thus rendering the resonant frequency substantially independent of the vicissitudes of assembly, screw pressure, etc. The end pieces are not essential but, when used, are usually somewhat thicker than the vibratory strip and partake of its vibrations only to a minor extent. The magnetic strip 7 bridges across the ends of a flat E-shaped magnetic yoke that, as shown in Figs. 1 and 2, comprises end pole pieces 9, 9' on a backing strip 10 which carries a central and somewhat shorter pole piece 10'. The pole pieces 9, 9' are permanent magnets of suitable material such as cobalt steel, aluminum-iron steel or the like which are magnetized, as indicated by the polar designations, N, S, to present like poles to the vibratory armature. The back piece or strip 10 is of iron having a low variational reluctance, such as pure annealed or Swedish iron. A small air gap of the order of from 0.001 to 0.010 inch is provided between the pole piece 10' and the vibratory strip 7, and a multi-turn coil of insulated wire 11 surrounds this pole and has its leads brought out through terminal pins 12 that pass through insulating bushings 12' which are held in the back piece 10 of the magnetic yoke

The vibrations of the throat are picked up by the button 5 and communicated to the armature 7 and, due to the mass of the transducer unit which prevents it from vibrating as a whole, the forces imparted to the armature 7 result in a vibration of the armature with respect to the magnetic field system. The air gap is therefore periodically altered in conformity with the vibrations and the variations in flux through the central pole 10' induce an electromotive force in the coil 11 which may be led to the external electrical circuits, amplifiers, line, etc. Due to the polarity of the permanent magnets, their flux adds up in the central pole and the two halves of the symmetrical magnetic circuit may be regarded as in parallel.

The thickness of the resilient strip 7, and its length between the edges of the end pieces 8, 8', are so chosen that the armature is mechanically resonant at the upper end of the range of speech frequencies to be reproduced. Good results have been obtained by making the armature resonant at frequencies above 1000 cycles and, in most of my constructions, they have been resonant between 2500 and 4000 cycles. The natural frequency of vibration of an elastic slab clamped at its ends varies as t/l^2, where t is the thickness and l the length, and is independent of the width to the first order. However, no rigorous rule can be given for the calculation of the resonant frequency on account of the presence of the button 5 which tends to lower the frequency by adding mass and to increase it by virtue of the added resistance to bending caused by the cementing of the lower planar surface of the button to the armature. The above rule does furnish a good practical guide, however, and the exact dimensions can be determined experimentally. Typical dimensions which I have employed with silicon steel for a resonant frequency in the neighborhood of 3500 cycles are l=0.8 inch, t=0.014 inch, and width varying from 0.25 to 0.6 inch. Although the resonant frequency is not greatly affected by variations in the width of the armature, the width does affect the mechanical impedance as viewed from the button 5 so that by varying this dimension the impedance of the transducer can be regulated in relation to that of the larynx with which it is in contact. With a length and thickness as given above, widths of from 0.2 to 0.7 inch are suitable for the average larynx.

The air gap may be adjusted by screws 13 which pass through the resilient strip 7 and into the back piece 10, but such an adjustment of the air gap affects the resonant period of the armature and this effect must be taken into consideration in the design. Other methods of adjusting the air gap will be described later.

Flexible conductors 14, 14' of tinsel or the like are soldered to the pins 12 and are relieved from strains by fabric tabs 14ᵃ which are woven into the cords and tied to eyelets 14ᵇ. The cords pass through shielding springs 15 that are soldered to the clamps 16 and thus grounded on the unit. The springs are of phosphor bronze, steel or other material which will stand repeated bendings. The unit itself is protected from external fields by a close fitting metallic casing 17 which has a slightly domed bottom wall to provide space for the terminal connections and the ends of springs 15. The connecting cords branch from the main cable at the middle of the microphone strap, see Fig. 4, the shielding lead or braided conductor 18 being connected to the negative terminal pin 12 of one unit and to the shield springs 15 of both units by a T-shaped metallic piece 19 that fits around the bifurcation of the cable and prevents relative movement of the cable and the branch connections. The central conductor 20 of the cable is connected to the positive terminal of the other unit by one lead 14, and the unlike terminals of the two units are connected by lead 14'. The braided lead 18 preferably has an outer covering 18' of soft rubber and the entire cable is, of course, quite flexible. The described connections place the two units in series, and this has given good results in practice but other connections could be used.

The transducer units may be protected against the weather and sea spray when used in open cockpit airplanes and seaplanes by placing the units in closely fitting bags of thin rubber having a thickness of the order of 0.002 to 0.005 inch. The open ends of the bags are cemented together and to the rubber covering 18' of the cable by rubber cement. The transducer units are then sewed into the leather covering of the microphone strap.

The microphone and its associated electrical circuits are designed and/or adjusted to have overall frequency characteristics such as described in my copending applications Ser. Nos. 6,246 and 54,347. A mechanical impedance diagram of the microphone is shown in Fig. 5*a*, and an approximate electrical circuit equivalent of the mechanical system is shown in Fig. 5*b*. In these diagrams, v_0 represents the impressed velocity due to the vibrations of the larynx, Z_0 represents the mechanical impedance of the throat structure (cartilage, muscle, etc.), and m_1 represents the mass of the button 5 and the effective mass of the armature 7. C_1 represents the compliance of the armature, that is the reciprocal of the deflection per unit force applied between the button and the transducer unit, C_2 represents the compliance due to the elastic band which supports the unit at the neck, and m_2 represents the mass of the unit, the housing and the covering. The resistors r_1, r_2, r_3 represent the effects of dissipation in the several associated elements. The compliance C_2 is probably so high as to be negligible, that is C_2 can probably be short-circuited (omitted) from consideration for all practical purposes.

The voltage generated by the microphone is proportional to the velocity of the armature with respect to the other elements of the unit, and is represented in Fig. 5b as v_1, the current flowing in the C_1 branch. The form of the frequency response characteristic with constant impressed velocity depends upon the driving impedance of the neck, Z_0. If a piston vibrating at constant velocity be used for driving purposes, a curve of the type shown in Fig. 6 is obtained for the described unit, or pair of units. This curve is chiefly characterized by a resonant rise in output near 300 cycles and another near 3500 cycles. The first is due principally to resonance between the armature compliance C_1 and the mass m_2 of the unit. The upper resonance point at 3500 cycles arises principally from resonance between the mass of the armature m_1 and the compliance C_1. The exact shape of the characteristic curve may be controlled by adjustment of the mechanical impedances. The low frequency response, for example below 1000 cycles, may be controlled by the lower resonance. This, in turn, can be controlled by the mass m_2 of the unit and the armature compliance C_1. The latter can be modified without varying the upper resonance by varying the width of the armature. The lower resonance peak can thus be moved up and down in frequency to secure an augmented response at any desired frequency, with a sharp decrease in response below that frequency, as shown by the solid line curve A of Fig. 6. This particular curve represents the performance of a microphone having the following characteristics; armature 7 of silicon steel, 0.8 x 0.5 x 0.014 inch; button, white pine, mass=0.15 gram; mass of unit=15 grams.

The upper resonance can be controlled, as described above, by varying the length and thickness of the armature 7. It is not always desirable to have a high sharp peak, such as is present in curve A at about 3500 cycles, and this can be avoided by providing damping in addition to that arising from the internal viscosity of the metal and the cement used to fasten the button to the armature. One of the simplest and most effective methods of damping is to insert a drop or two of oil in the air gap between the pole piece 10' and the armature 7. Dotted line curve A' of Fig. 6 illustrates the effect of a drop of oil, of viscosity 30 in the standard commercial scale for automotive lubricating oils, inserted in the air gap. The oil is permanently held in place in the air gap by capillary attraction.

Another transducer construction which is particularly adapted for oil damping is shown in Figs. 7 to 9. The general construction is as previously described and parts which are, or may be, substantially identical with the elements of Figs. 1, 2 and 3 are identified by corresponding reference numerals. A cover plate 21 is arranged parallel to the armature 7 and spaced therefrom by a few thousandths of an inch by shims 22, 22', the plate having a central hole through which the button 5 projects. Damping material 23 is placed in the space between the plate 21 and armature 7, and this is preferably oil but may be cotton, cloth soaked in oil, rubber, felt, "glyptal", etc. When oil is used, it is held in place by capillary attraction. The cover plate 21 is preferably metallic, about $\frac{1}{32}$ inch thick, and it presents the advantage even when used without oil or other damping material of protecting the armature and acting as an acoustical shield to prevent wind and external acoustical disturbances from reaching the armature.

In the embodiment shown in Fig. 10, an annular piece 24 of rubber or other resilient material is placed between the armature 7 and the cover piece 21, and the central pole piece 10' is drilled and threaded to receive a cylindrical plug 25 of resilient material, such as rubber or "glyptal", and an adjusting screw 26. Pressure applied through the plug 25 tends to bend the armature upward, and this is resisted by the ring 24. By altering the dimensions of the ring 24 and the position of the screw 26, some control of the length of the air gap is obtained. The upper ring 24 may be omitted if the armature 7 is given an initial adjustment to lie against the pole piece 10', the stiffness of the armature itself being then relied upon to oppose the thrust of the plug 25 as the screw 26 is adjusted to obtain the desired air gap. Damping may be obtained, as previously described, by materials placed in the space between armature 7 and cover piece 21, or by the viscosity of the resilient materials 24, 25.

Another method of damping is to construct the armature 7 in laminar form, using a strip of damping material between two resilient strips of metal. The strips may be pressed or cemented into an integral whole which may be mounted in the same way as a solid iron armature.

The magnetic systems so far described have comprised a pair of short bar magnets 9, 9' mounted on the ends of a back piece having an integral central pole piece 10'. As shown in Fig. 11, the back piece 10ª may be a single permanent magnet having an inserted pole piece 10ᵇ, with short bars of soft iron 9ª at the ends of the bar magnet. The magnet 10ª is magnetized in a jig or fixture so that like poles (north poles N as indicated in the drawings) are at opposite ends of the bar and the opposite poles S are in contact adjacent the pole piece 10ᵇ. This construction has the advantage that a longer magnet, and correspondingly higher coercive forces, are obtained. Due to the extra length of the magnet, it is sometimes possible to obtain the required coercive force with tungsten steel in place of cobalt and like steels. The separate soft iron end pieces 9ª can be replaced by integral extensions of the bar magnet 10ª.

Fig. 12 illustrates another structure which offers certain advantages. In this construction, the button and armature are formed in one piece, the button being pressed out as a boss on the armature strip 7'. This avoids the possibility of the button becoming loosened. Also by utilizing the space below the button section, a greater number of turns can be accommodated on the coil 11', thus increasing the voltage output. A method of adjusting the air-gap is also shown which may be applied to the other constructions as well. This is accomplished by sliding the central pole piece 10ᶜ through the back plate 10ᵈ and fastening the pole piece by means of a set-screw 26'. The other parts of this construction are designated by the reference numerals of the previous figures.

A complete electrical system incorporating the microphone is shown schematically in Fig. 13. Only one unit is shown as the microphone M, and this works into an amplifier 27 of the type which is described in detail in copending application Ser. No. 54,347; the circuit diagram appearing as Fig.

4 of that application and its frequency response characteristic as Fig. 5. The overall frequency response of the microphone and amplifier, when the microphone unit is clamped and driven by a constant velocity piston, is shown in Fig. 9 of the earlier application. The amplifier 26 may work into a radio transmitter or, as shown, into a transformer 28 and headphones 29.

I am aware that microphones operating on the electromagnetic principle were proposed as early as 1884, but the constructions herein described have novel mechanical and electrical characteristics which particularly adapt this type of microphone for use as a throat microphone. It is to be understood that the invention is not limited to the exact constructions herein illustrated and described as many variations which will occur to those familiar with this art fall within the spirit of the invention as set forth in the following claims.

I claim:

1. An electromagnetic transducer comprising an E-shaped field magnet structure magnetized to have end poles of one polarity and an intermediate pole of the opposite polarity, an armature consisting of a resilient strip of magnetic material extending between said like end poles and over but spaced from the intermediate pole, a coil on the intermediate pole, and means consisting of a fluid medium between said resilient strip and a rigid member for damping the vibrations of said resilient strip.

2. An electromagnetic transducer as claimed in claim 1, wherein said fluid medium of the damping means is in the gap between said resilient strip and the intermediate pole.

3. An electromagnetic transducer as claimed in claim 1, wherein the rigid member of said damping means comprises a relatively rigid cover plate extending in spaced relation over said resilient strip.

4. A throat microphone of the electromagnetic type adapted to be actuated by mechanical vibrations of the body due to the voice, said microphone comprising a permanent magnet, a yoke and pole piece, a coil surrounding said pole piece, a resilient magnetic strip positioned to complete the magnetic circuit except for a small air-gap between said strip and said pole piece, said resilient magnetic strip being mechanically resonant above 1500 cycles, and means for transmitting vibrations of the throat to said resilient strip.

5. A throat microphone of the electromagnetic type comprising a permanent magnet, a yoke and pole piece, a coil surrounding said pole piece, a resilient magnetic strip positioned to complete the magnetic circuit except for a small air-gap between said strip and said pole piece, said resilient magnetic strip being mechanically resonant between 2500 and 4000 cycles, and means for transmitting vibrations of the throat to said resilient strip.

6. A throat microphone of the electromagnetic type comprising a permanent magnet, a yoke and pole piece, a coil surrounding said pole piece, a resilient magnetic strip positioned to complete the magnetic circuit except for a small air-gap between said strip and said pole piece, said resilient magnetic strip being mechanically resonant above 1500 cycles, means for critically damping the vibrations of said resilient strip, and means for transmitting vibrations of the throat to said resilient strip.

7. In a contact microphone adapted to translate vibrations of the throat due to the voice and of the type comprising a vibration element having compliance and mass, and supporting means having mass; the method of reducing frequency distortion due to the mechanical vibratory characteristics of the throat which comprises tuning the natural vibration frequency due to the cooperation of the mass of said supporting means and the compliance of said vibrating element to a frequency between 100 and 1000 cycles, and simultaneously tuning the natural frequency due to the cooperation of the mass of said vibrating element and its compliance to a frequency above 1500 cycles.

8. A throat microphone comprising a resilient vibration member to which the vibrations of the throat are transmitted, and means for supporting said vibration member on the throat, the compliance of said resilient vibration member being resonant with the mass of said supporting means at a frequency of the order of between 100 and 1000 cycles, and said resilient vibration member being resonant at a frequency above 1500 cycles.

9. A throat microphone as claimed in claim 8 in combination with means damping said vibration member at said resonant frequency above 1500 cycles.

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