

Sept. 4, 1951

L. L. BERANEK
VOICE SILENCER

2,566,975

Filed Jan. 18, 1947

2 Sheets-Sheet 1

Fig. 1.

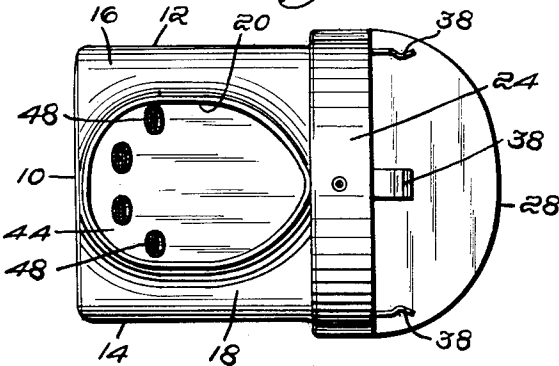


Fig. 2.

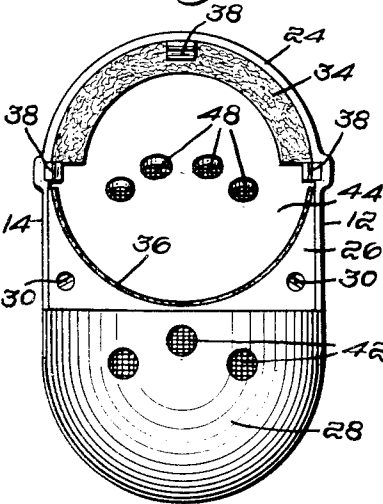
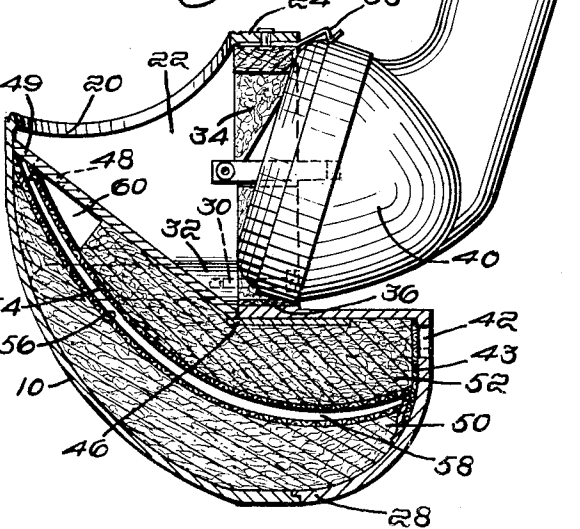


Fig. 3.



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2 Sheets-Sheet 2

Fig. 4.

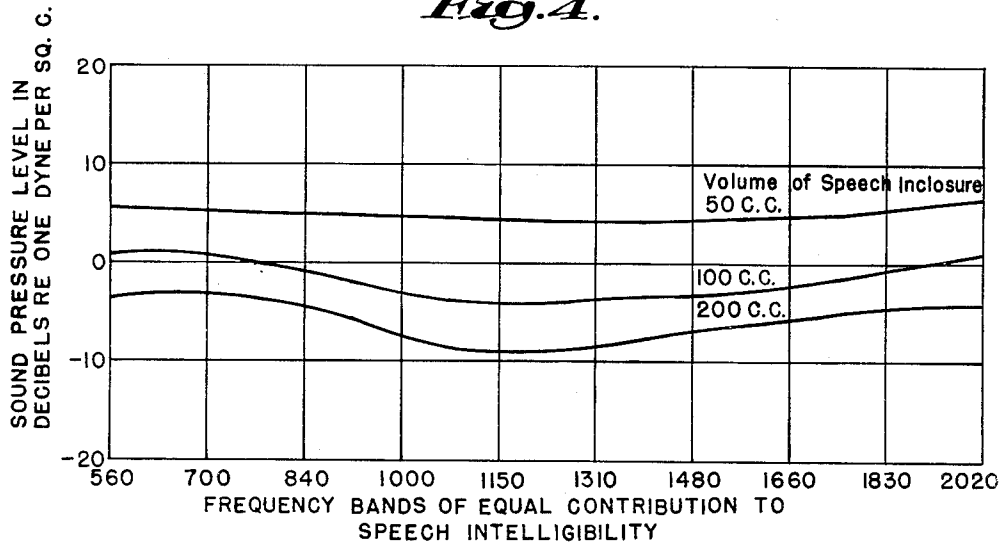
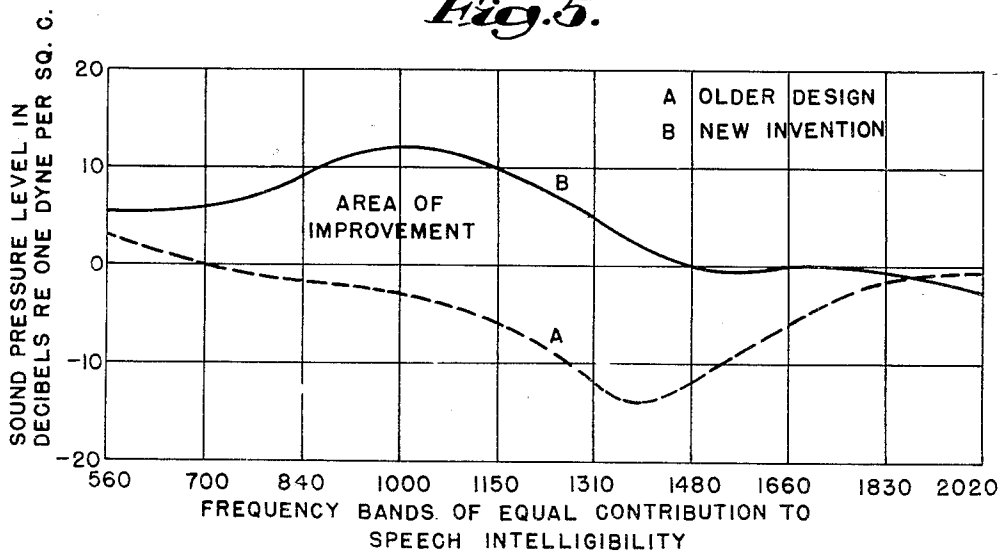


Fig. 5.



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UNITED STATES PATENT OFFICE

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VOICE SILENCER

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6 Claims. (Cl. 181-34)

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This invention is primarily concerned with an acoustic filtering and shielding device for use in speech transmission. More particularly, the invention relates to an arrangement of sound insulating bodies and an acoustic filter combined with transmitter devices such as telephones so as to produce a selective silencing system by means of which words spoken into the transmitter are communicated in a highly intelligible state to a party listening at the receiver station, while to those listening at all other points, and especially in the immediate vicinity of the transmitter, the spoken words are rendered indistinct and effectively muffled.

Speech as produced by the human voice is made up of relatively low frequency components, i. e. frequencies below 500 cycles per second, and relatively high frequency components, i. e. frequencies above 500 cycles per second, running up to 15,000 cycles per second or higher. It has been determined that those frequencies lying between 500 and 2000 cycles per second contribute most to the intelligibility of speech.

These facts are of significance in connection with silencing devices heretofore proposed in the art. Thus it has been proposed to reduce the intensity of speech, as heard from points outside of the immediate vicinity of the transmitter, by providing various types of mouth pieces, all of which are designed to surround the transmitter and to extend outwardly in a position in which they may be contacted by those portions of the face immediately surrounding the mouth and thus secure a sealing effect.

In the use of such devices several difficulties are present. It is known that a mouthpiece may seriously reduce intelligibility owing to the fact that the low frequencies of the voice are appreciably intensified by the presence of the enclosed volume of air in the mouthpiece casing. This intensification, if allowed to become too great, reaches a point at which it produces distortion in the microphone transmitter and renders transmitted speech difficult to understand. Moreover, when one speaks into a relatively small volume of air such as furnished by a mouthpiece, back pressure builds up almost at once, affecting both speech production and breathing. On the other hand, if too large air outlets are provided, there may be a failure to produce effective silencing of speech.

In addition to these known limiting factors, we have observed that there is another hitherto unknown factor further involving the relation of an inclosure volume to intelligibility levels of

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transmitted speech and consisting essentially in the effect of such inclosure volume upon some of the high frequencies of the voice.

An object of the invention therefore is to deal with the problems indicated and to provide an improved voice silencing structure which includes means for carrying on muted speech transmission without departing from satisfactory intelligibility levels and without subjecting the user of such instruments to unpleasant back-pressure effects. It is also an object of the invention to combine an acoustical element with a voice-silencing casing in a manner such that undesirable sounds may be excluded where speech is to be transmitted from regions of high ambient noise. Other objects will appear from the following description.

In seeking means to realize these objectives to the fullest extent, I have discovered that in the important voice frequency range noted above as lying between 500 and 2000 cycles per second, an increase in volume of inclosure produces an unexpectedly pronounced drop in intelligibility levels. I have also determined that there is a reasonably well defined optimum inclosure volume, consistent with adequate volume for speech production, where interference with frequencies in the 500 to 2000 cycle per second range is at a minimum.

With the foregoing considerations in mind, I have devised a voice silencing unit which includes a unique acoustic filter element combined with a hollow casing and sound absorbent bodies in such a manner as to provide, on the one hand, low frequency filtering and sound absorption with suitable air outlets; and on the other hand, a speech inclosure characterized by a relatively small volume, so chosen as to be acoustically suited to the more important voice frequencies lying in a frequency range of from 500 to 2000 cycles per second.

The voice silencing unit is constructed with a transmitter receptacle formed in the casing, and is adapted to be detachably fastened to the transmitter end of a telephone of the type commonly referred to as a "hand set." The casing member includes a rigid thin-walled body of relatively high acoustic insulating value, having a speech inclosure which communicates with the transmitter receptacle. The upper part of the inclosure is defined by concave edges of the casing adapted to conform to the shape of the face at those portions immediately surrounding the mouth. The lower portion of the inclosure is

formed by an acoustic filter element supported within the casing.

The acoustic filter element consists essentially of a thin plate or disc arranged in an inclined position so that it determines the volume of the speech inclosure and also functions somewhat in the nature of a baffle member. The plate is formed along one side with several closely grouped openings or passageways carefully chosen for number, diameter and length according to acoustic filter principles.

The inclination of the plate is designed so that these openings are uppermost and nearest to the mouth and so that speech energy entering the speech inclosure may to a great extent be directed first against these openings. This arrangement furnishes an opportunity for the plate to exercise an excellent filtering action and to separate low frequencies of speech from the high frequencies with the former passing through the passageways in accordance with acoustic filter principles.

The close proximity of the passages to the mouth when the device is in use, taken in conjunction with the fact that the passageways are designed so as to be short in length, results in rapid passing of the breath through the plate with a minimum of inertial effects and thereby substantially eliminates back pressure and facilitates breathing. With the filter plate in the inclined position described, the speech energy in the high frequency region entering the inclosure from the mouth is directed against the plate at an angle less than 90 degrees and is then reflected in the direction of the microphone in a highly efficient manner.

The unusual nature of the filter construction lends itself to formation of an exceptionally effective sound absorbing chamber in which an air duct is brought up to a point where it is closely adjacent to the mouth and may rapidly carry away expelled air. At the same time the duct is made to follow a curved path along either side of which are arranged masses of acoustic material against which the sound must be deflected. Because of the curved nature of the duct, sound waves, which tend to travel in straight lines, are certain to penetrate into the masses of acoustical material. Moreover the acoustical properties of the absorbing material are chosen in such a way that they are matched to the volume of the sound absorbent chamber and afford a maximum deadening effect.

The accompanying drawings illustrate a preferred embodiment of these features, of which

Fig. 1 is a plan view of the voice silencer of the invention, looking directly down into the speech inclosure;

Fig. 2 is an end elevational view looking through the receiver opening into the speech inclosure;

Fig. 3 is a symmetrical vertical cross-section taken centrally of the voice silencer, with the transmitter end of a telephone shown engaged in an operating position; and

Figs. 4 and 5 are graphs representing acoustic values.

The general arrangement of speech inclosure receptacle and sound absorbing chamber is apparent from an inspection of Fig. 3. One important feature of the structure shown is the choice of volume of the speech inclosure. I find that a volume of from 100 to 300 cubic centimeters, such as has commonly been employed on mouthpieces, results in a loss of from 15 to 20

decibels in the important frequency range between 500 C. P. S. and 2000 C. P. S. The need for a small volume of speech inclosure of a substantially optimum value, is evidenced by the curves illustrated in Fig. 4. The data employed in the curves were obtained from a standard type of acoustical testing procedure on which speech energy from an artificial voice was supplied to a telephone transmitter, using three different volumes of speech inclosure. Sound pressure established at the transmitter was determined as a function of frequency.

These figures indicate the desirability of decreasing the speech inclosure volume below 100 cubic centimeters, and I have found that the volume may successfully be decreased down to approximately 75 cubic centimeters. From a practical standpoint it is not desirable to reduce the volume much below 50 cubic centimeters since smaller volumes will not provide adequate space for the lips and the transmitter of the telephone. A volume of substantially 75 cubic centimeters was employed in the speech inclosure described below.

Referring more in detail to the drawings, 10 denotes a hollow casing member which is formed of an acoustic insulating material such as hard rubber, Bakelite or similar substances. The casing is formed with an irregularly curved under-surface from which extend two opposite flat sides 12 and 14. Upper casing portions 16 and 18 are curved inwardly to form a mouthpiece and terminate along concaved edges 20 which define an aperture opening into a speech inclosure 22 as may be more clearly seen in Fig. 3.

At points immediately adjacent to the speech inclosure the casing body is formed with a semi-circular frame portion 24. Arranged below the frame portion 24 is a second semi-circular frame portion 26 which forms a part of a separate casing section 28 secured to the main body of the casing by means of bolts 30 engaged in threaded projections 32. Located around the inner peripheral surfaces of the frame portions 24 and 26 are strips 34 and 36 of sound absorbent material such as felt. Also attached to the frame portions at separated intervals are spring clips 38. The frame portions, strips and spring clips combine to form a transmitter receptacle in which the transmitter end 40 of a hand set may be detachably secured in an inclined position such as has been illustrated in Fig. 3.

The separate casing section 28 is of a generally rounded shape as is indicated in Figs. 1 and 2 and extends outwardly below the transmitter end of the receiver to substantially increase the amount of space within the casing. Through the end of the casing section 28 are formed outlets 42 and against these openings at the inner side of the casing material is arranged a screen member 43 of wire mesh or other reticulated body, overlying the area included by the outlets 42.

Numeral 44 denotes the acoustic filter element of the invention, consisting of a thin plate preferably composed of a material such as fibreboard or similar fibrous substances. The plate is supported between the walls of the casing and is arranged in an inclined position chosen so as to provide a volume of speech inclosure of the magnitude already indicated. The lower end of the plate may, if desired, rest against a retaining edge 46 formed along an inner surface of the frame portion 26. Other suitable means for maintaining the plate in an inclined position may however be desired to be employed.

At the uppermost edge of the plate 44, as viewed in Fig. 3, I have further provided openings 48 arranged in a curved path as shown, in a position such that they occur very near to the mouth. These openings are of such a diameter that the plate can be formed of a thin material and yet act as a suitable filter element so that the length of openings 48 is very short, a feature which is essential in reducing the back pressure of the acoustic filter element.

The plate 44 serves not only as a filter element and reflecting surface but also acts as a dividing wall for separating the casing cavity into the speech inclosure 22 and a lower sound absorbing chamber. This sound absorbing chamber extends upwardly to the under side of the plate 44 and therefor air and low frequencies are furnished with a highly accessible path through which they may rapidly escape from the speech inclosure.

Within the sound absorbing chamber are combined sections or layers of sound insulating material 50 and 52 which occupy a substantial part of the space therein. The two layers 50 and 52 are arranged in spaced-apart relation and supported by two reticulated elements 54 and 56 which may for example consist of wire screening bent into a curved formation as noted in Fig. 3, to define a curved air duct 58. The upper extremities of the screen elements extend to a point just below the plate 44 and a space 60 is maintained just below the openings 48 so that the latter openings directly communicate with the air duct 58, which in turn leads to the screen 43 and outlets 42, forming a continuous passageway.

In accordance with the invention, the filter orifices are selected so that their positive acoustical reactance is just equal to and, hence, cancels the negative acoustical reactance of the inclosed volume of the sound absorbing chamber. The method by which I determine the proper size and number of holes in the filter plate necessary to bring the net reactance to zero, is as follows:

Use is made of a publication standard in the acoustic art entitled: "Acoustic Design Charts by Frank Massa," published by the Blakiston Co., 1942. In particular, reference is made to charts numbered 41 and 43 therein. Chart No. 41 sets forth the acoustic reactance (positive) of a circular orifice formed in a wall or partition whose thickness is small compared with the diameter of the orifice. If more than one orifice is used, the reactance is divided by the number of holes. Chart No. 43 gives the acoustic reactance (negative) of an inclosed volume whose maximum linear dimension is small compared with the wave length of sound at the frequency of operation.

In designing a filter, the frequency at which the filtering starts to take place, i. e. the change-over frequency, is found when the acoustic reactance (positive) of the holes equals the acoustic reactance (negative) of the inclosed volume of the sound-absorbent chamber. In the case of the telephone silencer of the invention, the change-over frequency was chosen at approximately 500 C. P. S. Calculations made from the above noted charts furnish the data that four orifices, each having a diameter of $\frac{1}{8}$ of an inch, would bring the net reactance to zero and, hence, would make a suitable filter when used with an inclosed volume of 300 cubic centimeters.

Having selected the diameter of the orifices, it is necessary to provide that the thickness of the plate in which they are formed be small compared with the diameter of the orifices. If the thick-

ness of the plate is too small, it will vibrate under the influence of speech, thus nullifying the advantage of the holes. Hence, a compromise thickness of approximately $\frac{1}{8}$ inch was selected as satisfying both requirements. This may be varied to some extent.

In figuring the volume of the inclosed air space in the sound-absorbing chamber, the effect of the added absorbing material should be included because chart No. 43 assumes that no absorbing material is present. I have found that the actual volume of the inclosed space must be considered to be enlarged by approximately 40 per cent when it is filled with acoustical material of the type specified in the preferred embodiment of my invention, if chart No. 43 is to be applicable. Some variance in this percentage figure is permissible. Material supporting this fact is found in an article under my name entitled: "Acoustic Impedance of Porous Materials," published in the Journal of the Acoustical Society of America, vol. 13, pages 248-260, January 1942. Hence the actual volume of the inclosed air space should, for example, be approximately 250 cubic centimeters where four orifices, having a diameter of $\frac{1}{8}$ of an inch, are employed. Similar reducing of the net reactance to zero can be achieved, using other volumes which would require orifices having different diameters and employed in different numbers.

The acoustical absorbing material constituting the layers 50 and 52 are chosen so that they are "matched" to the volume of the sound-absorbing chamber. By this is meant that for any given size of chamber there is an optimum range of values for the flow resistance of the acoustic absorbing material placed therein. An acoustical material can be specified in terms of weight, thickness and more particularly by its flow resistance. The latter term denotes a characteristic of the material which is related to the degree of opposition that the material offers to the flow of air through it.

In determining an optimum range of values for the flow resistance of the material to be placed in my sound-absorbing chamber, the volume of the chamber was taken to be 250 cubic centimeters with a depth of approximately three inches. Larger volume could be used but practical limitations on size and weight forced a compromise.

The acoustical impedance of an inclosure in which there is an acoustical material is known to be as follows:

$$\text{Acoustical impedance} = Rfd/3 \\ - j(230,000/rd) = Z$$

where R_r is the acoustical flow resistance of one centimeter thickness of the material; d is the depth of the chamber in centimeters; f is the frequency in cycles per second at which absorption is desired; $j = (-1)^{1/2}$; and Z is the acoustical impedance.

The absorption of the sound in the inclosure is given by the well known formula:

$$\text{Absorption} = 1 - \left| \frac{Z - 42}{Z + 42} \right|^2$$

For maximum absorption, I have found by the process of maximizing the preceding equations that:

$$Rf = (3/d) [(1764) + (230,000/fd)^2]^{1/2}$$

In order that an inclosure 3 inches (7.62 cm.) in depth absorb sound in an optical manner in

the frequency range between 50 and 150 cycles per second, which is where the voice frequencies that are most difficult to absorb are located, the flow resistance R_r should be between 80 and 200 acoustic ohms per centimeter of thickness and preferably one-half way between. In the device constructed and described above, "Fiberglas AA," manufactured by the Owens-Corning Fiberglas Corporation, Toledo, Ohio, was used. This is a material made of glass fibers whose mean fiber diameter is about one micron and whose flow resistance lies in the range indicated. Other substances whose flow resistance is found to be in this range might also be employed.

In operation the device is snapped on over the transmitter end of a hand set in the manner indicated in Fig. 3, and the concaved edges 20 are placed firmly against the face. A telephone conversation is then carried on in the usual manner, with words being spoken directly into the speech inclosure 22. As this occurs, the breath and air driven by speech energy are instantly received through the openings 48 which are lying just below the lips and are rapidly passed along the duct 58 and relaxed through the air outlets 42. Two factors here contribute to substantial elimination of back pressure such as is frequently experienced in mouthpiece devices. First, the relatively short lengths of the holes 48, governed as they are by the thickness of the plate 44, allow air to be transferred from the speech inclosure to the sound-absorbing chamber without the usual inertial effects which have commonly been encountered where relatively longer passageways were employed. Secondly the location of the openings almost directly before the lips of the speaker and very close to them, initiates travel of the air at an earlier point than has heretofore been attempted, with consequent avoidance of time lag and opportunity for back pressure to build up.

Of the frequencies which enter the speech inclosure, the low frequencies, i. e. those under 500 cycles per second, are passed through the openings 48 which in this case, in combination with the sound-absorbing chamber, function in the well known manner of an acoustic filter. Here also the close proximity of these filter openings to the mouth enables the low frequencies to be very rapidly separated and passed into the sound-absorbing chamber which minimizes the possibility of such low frequencies becoming intensified by the casing to cause distortion. As they enter the chamber, the low frequencies pass to the opening 60, then through the screen elements 54 into the air duct 58. Here the sound waves are caused to strike against and to penetrate the sound-absorbent layers 50 and 52 with the curved formation of the duct insuring that passage of the sound rays will constantly be interrupted to provide an exceedingly efficient absorbing or deadening action.

Those frequencies of speech entering the speech inclosure which are not thus filtered out are caused to strike against the inclined plate 44 at an angle less than 90° and are almost instantly reflected in the direction of the transmitter, to yield as satisfactory speech intensity as would normally be the case by speaking directly into the transmitter.

The total improvement in quality of transmitted speech effected through the principles embodied in the claims of this specification is shown in the graph of Fig. 5. The upper curve B of that graph shows the intensity (sound pressure

level) of speech transmitted to the diaphragm of the telephone transmitter when the speech silencer described herein was tested. The lower curve A was obtained in the same manner except the most successful of previous telephone silencers was tested. It is seen that on the average the intensity of the transmitted speech for the invention described herein is 10 to 15 decibels higher than that for the older instrument. Under the conditions of listening at the far end of a long distance telephone line, an increase in transmitted speech level of this magnitude, in the important frequency range between 500 and 2000 cycles per second, will increase the percentage of words heard correctly by the listener from 40% (using the old device) to 85% (using the invention described herein).

I claim:

1. An article of the character described, comprising a hollow casing which is formed with a receptacle for a telephone transmitter, said casing also presenting a speech inclosure communicating with the receptacle, an acoustic element supported in the inclosure and consisting of a substantially rigid thin partition, said partition lying in an inclined position in the path of speech energy delivered to the inclosure, a portion of the partition being formed with low frequency sound filtering openings of relatively short length, said casing having a sound-absorbing chamber communicating with the openings in the said partition, a plurality of sound-absorbing elements disposed in the sound-absorbing chamber, said sound-absorbing elements lying in spaced-apart relation to define a discreet sound absorbing duct, one side of the hollow casing being formed with air outlets which communicate with the sound-absorbing chamber, reticulated members arranged in contact with the sound-absorbing elements adapted to support them in a curved formation.

2. An article of the character described comprising a hollow casing which is formed with a receptacle for a telephone transmitter, said casing also presenting a speech inclosure communicating with the receptacle, an acoustic element supported in the inclosure and consisting of a thin plate, said plate lying in an inclined position in the path of speech energy delivered to the inclosure, a portion of the plate being formed with low frequency sound filtering openings of relatively short length, said casing having a sound-absorbing chamber communicating with the openings in the said plate, a plurality of sound-absorbing elements disposed in the sound-absorbing chamber, said sound-absorbing elements lying in spaced-apart relation to define a discreet sound absorbing duct, one side of the hollow casing closely adjacent to an outlet end of the duct being formed with air outlets which communicate with the sound-absorbing chamber.

3. An article of the character described comprising a hollow casing which is formed with a receptacle for a telephone transmitter, the casing having formed therein a speech inclosure communicating with the receptacle and provided with a speaking aperture, an acoustic element forming one side of said inclosure and comprising a substantially rigid thin partition positioned so as to tend to reflect toward said receptacle high frequency components of the sound delivered through said aperture, said partition having a plurality of low frequency sound filtering openings extending therethrough, the casing includ-

ing a sound absorbing chamber communicating through the partition openings with the speech inclosure, the sound absorbing chamber having breath outlets leading therefrom, and low frequency sound absorbing material disposed in the sound absorbing chamber in spaced-apart formation to form a discreet duct through the sides of which the filtered low frequency sound may pass and be absorbed and through which the breath of the talker may be passed from said partition openings to said breath outlets.

4. A voice silencer comprising a hollow casing formed with a receptacle for a telephone transmitter, the casing having provided therein a speech enclosure communicating with the receptacle and formed with a speaking aperture, said speech enclosure having a volume between 50 and 150 cubic centimeters, an acoustic element forming one side of said enclosure and comprising a substantially thin partition positioned at an angle so as to tend to reflect toward said receptacle high frequency components of the sound delivered through said aperture, said partition having a plurality of low frequency sound filtering openings extending therethrough and communicating with a sound absorbing chamber, the dimensions of the filtering openings being so chosen that the positive acoustical reactance of all of the orifices substantially equals and tends to cancel the negative acoustical reactance of the sound-absorbing chamber volume at some frequency lying between 200 and 1000 cycles per second, the sound absorbing chamber having breath outlets leading therefrom and low frequency sound absorbing material disposed in the sound absorbing chamber in spaced-apart formation to form a discreet duct, through the sides of which the filtered low frequency sound may pass and be absorbed and through which breath of the talker may be passed from said partition openings to the breath outlets.

5. An article of the character described comprising a hollow casing which is formed with a receptacle for a telephone transmitter, the casing having formed therein a speech enclosure communicating with the receptacle and provided with a speaking aperture, the speech enclosure having a volume of from 50 to 150 cubic centimeters, an acoustical element forming one side of said enclosure and simultaneously one side of a sound absorbing enclosure, said acoustical element comprising a substantially thin partition positioned at an angle so as to reflect toward said receptacle or the frequency components de-

livered through said speaking aperture, and having a plurality of low frequency sound filtering openings extending therethrough, the dimensions of said filtering openings being so chosen that the positive acoustical reactance of all of the orifices substantially equals and tends to cancel the negative acoustical reactance of the sound absorbing chamber volume at some frequency lying between 200 and 1000 cycles per second, said frequency being the change-over frequency of the acoustical filtering action, the sound absorbing chamber having breath outlets leading therefrom and containing sound-absorbing material, the sound absorbing material having a flow resistance optimal for the absorption of sound in the frequency range between 50 and 300 cycles per second and being disposed in the sound absorbing chamber in spaced-apart formation to form a discreet duct through the sides of which filtered low frequency sound may pass and be absorbed, and through which the breath of the talker may be passed from said partition openings to said breath outlets.

6. A voice silencer comprising a hollow casing which includes a receptacle for a telephone transmitter, a sound absorbing chamber and a speech enclosure, means located between the speech enclosure and the sound absorbing chamber for selectively passing low frequency sound from the speech enclosure to the sound absorbing chamber and reflecting high frequency sound toward said receptacle, and said chamber having a curved duct provided with acoustically porous sides along which the low frequency sound may be absorbed and the breath of the talker passed out of the casing.

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