

**July 26, 1938.**

J. Q. TIEDJE

**2,124,597**

ACoustic DEVICE

Filed Jan. 31, 1934

2 Sheets-Sheet 1

*Fig.1.*

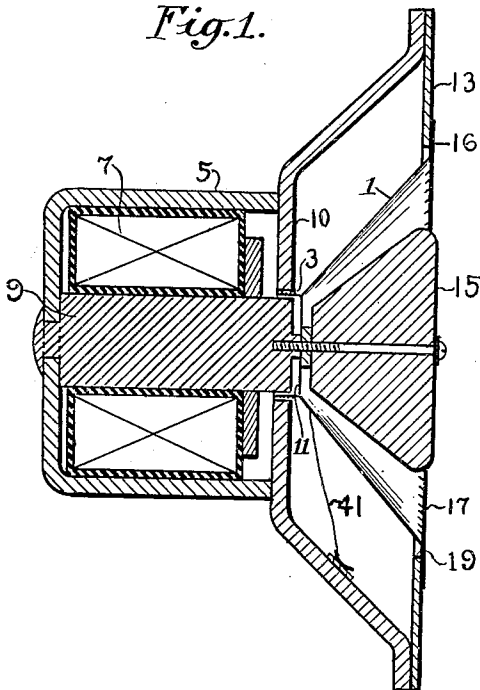


*Fig. 2.*

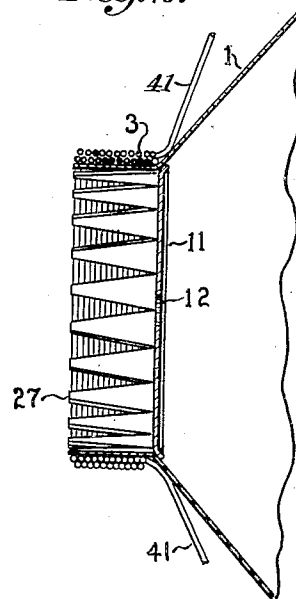


*Fig. 3.*

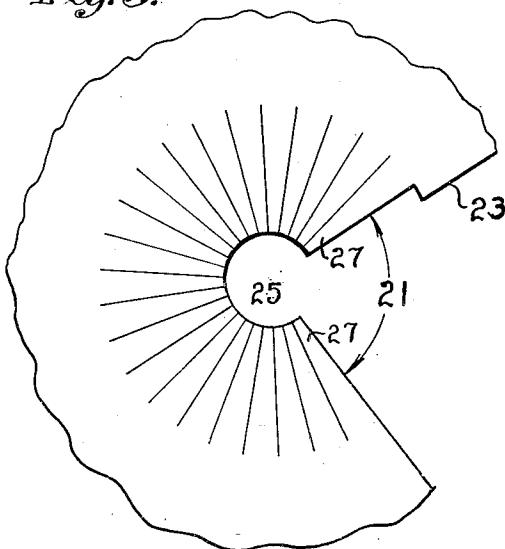
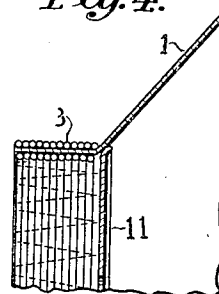


*Fig. 4.*



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2 Sheets-Sheet 2

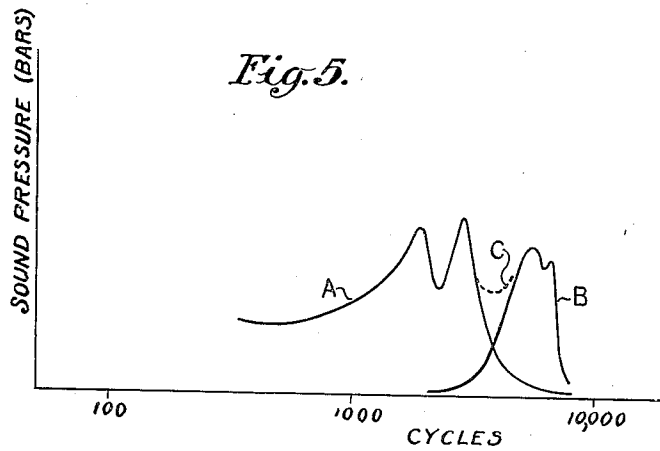


*Fig. 6.*

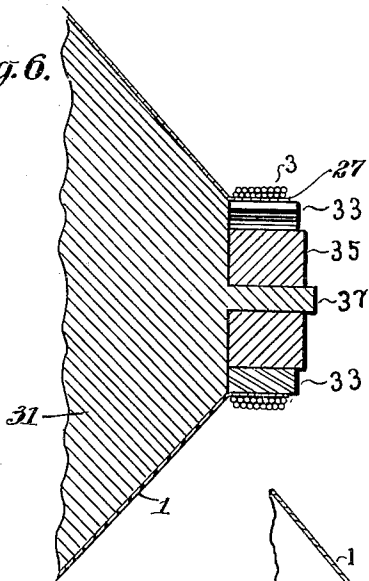


*Fig. 7.*

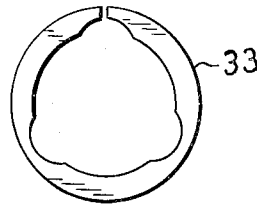
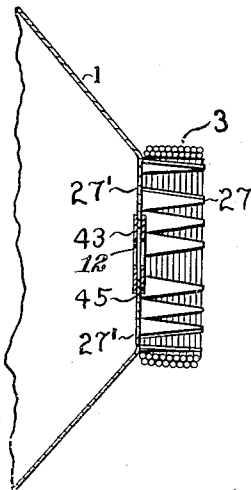


*Fig. 9.*



*Fig. 8.*



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## UNITED STATES PATENT OFFICE

2,124,597

## ACOUSTIC DEVICE

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Application January 31, 1934, Serial No. 709,081

9 Claims. (Cl. 179—115.5)

My invention relates to improvements in acoustic devices and more particularly to dynamic or moving coil loud speakers or microphones, and has particular relation to an improved voice coil construction of such speakers, as well as to a method of making the same.

In loud speakers of the moving coil or dynamic type a diaphragm, usually in the form of a frustum of a cone, is driven by a coil of wire wound on a cylindrical form which in turn is attached to the small end of the diaphragm. The coil structure, known as a voice coil, is resiliently suspended in an intense magnetic field set up across a narrow airgap formed by spaced poles of a magnetic field structure. Variable currents, in accordance with music or speech to be reproduced as sound, are fed into the coil causing it to vibrate in the magnetic gap in a direction parallel to the pole faces. For most efficient operation in an acoustic device it is necessary that a vibratory structure shall have the characteristics of rigidity, reduced dimensions, low inertia, and stability under adverse conditions of temperature and humidity.

Voice coil structure of one type heretofore used extensively, has comprised a cylindrical support form of stiff paper on which the coil has been wound. In order to strengthen the coil form and to properly attach it to the small end of a frusto-conical diaphragm, it has been customary to reinforce the form adjacent the diaphragm with one or more layers of paper in the form of a collar cemented around the form. A serrated edge has been provided on the end of the coil form, or on the added paper layers, to constitute contiguous surface areas for cementing the coil form to the diaphragm. In slightly modified arrangements the serrated edge has been formed on the small end of the cone for engaging a separate coil form and the reinforcing collar. Such constructions increase the number and complications of manufacturing operations, occasion delay in assembly of parts and, of course, appreciably add to the weight of the moving elements of the acoustic device. I also am familiar with numerous other constructions that have been designed in an attempt to obtain a maximum of lightness, simplicity and strength but none of these has been satisfactory for my purposes.

It is, accordingly, an object of my invention to provide a voice coil and diaphragm assembly of novel construction having, in a marked degree, the foregoing desirable characteristics.

Another object of my invention is to provide a voice coil of novel construction that has a small

moment of inertia and, at the same time, a desirable degree of rigidity.

Another object of my invention is to greatly simplify the voice coil construction and to make a lightweight and durable connection between the coil structure and the diaphragm while employing the minimum number of parts.

My invention also contemplates a novel method of forming the voice coil and assembly thereof with the diaphragm.

Another object of my invention is to provide in a speaker of the dynamic or moving coil type, a voice coil and diaphragm assembly which is extremely light in weight and adapted to reproduce particularly well the higher audio frequencies.

A further object of my invention is to provide a highly efficient dynamic speaker by means of a novel method and construction which insure that the voice coil walls shall inherently be in accurate parallel alignment in the active air gap whereby, in a production design, the air gaps may be made quite narrow, no allowance or tolerance being necessary for misaligned coils.

More specifically it is an object of my invention to provide, in connection with a dynamic speaker of the frusto-conical diaphragm moving coil type, a method of forming a cone diaphragm and coil structure whereby, during manufacture, the cone and coil will be in accurate coaxial alignment.

Other objects of my invention will become evident from the following detailed description taken in connection with the accompanying drawings in which

Figure 1 is a side view in elevation, partly in section, of a dynamic speaker of the electromagnetic type embodying my invention, drawn to scale and about three-quarters full size.

Fig. 2 is a side elevation view in section and in enlarged form of the voice coil structure and a section of the cone diaphragm shown in Fig. 1.

Fig. 3 is a plan view in development stage of the central section of the diaphragm structure prior to forming.

Fig. 4 is an enlarged view in section of a modified voice coil structure made in accordance with my invention.

Fig. 5 is a characteristic response curve of my speaker shown in relation to that of the ordinary dynamic speaker made in accordance with the teachings of the prior art.

Fig. 6 is a side elevation view in section and on an enlarged scale, illustrating the apparatus used in forming my novel structure.

Fig. 7 is an end view of one of the elements of the forming apparatus.

Fig. 8 is a side elevation view in section, and in enlarged form, of a modified form of voice coil and centering spider structure made in accordance with my invention.

Fig. 9 is a side elevation view, in fragmentary form, partly in section of a still further modification of my invention.

Referring to an embodiment of my invention as illustrated in Fig. 1, it comprises a sound producing diaphragm 1, preferably frusto-conical in shape and of fibrous material, e. g. hard surface paper, a driving or voice coil structure 3, fixed to the small end of the diaphragm and supported in co-operative relation to a field structure comprising a yoke 5 of magnetic material energized by a field coil 7 disposed on a central pole piece 9. The parts of the field yoke structure may be assembled and secured together by welding, in accordance with the teachings of Creager et al, 2,027,473, issued Jan. 14, 1936, although any other form of magnetic field construction of appropriate form may be employed. In some cases it is desirable to use a permanent magnet field structure, as shown for example in Warnke, 2,085,721, issued June 29, 1937.

The driving coil 3 is resiliently suspended in an intense magnetic field in a narrow air gap formed between the spaced poles 9 and 10 of the magnetic field structure. The coil is maintained central in the air gap by means of a spider in the form of a flexible centering disc 11 that is secured at its periphery to the small end of the cone and clamped at its center to the inner-pole piece. While ordinarily it is desirable to employ spiders provided with slots for greater flexibility, the present diaphragm operates at small amplitude of vibration for high audio frequencies, and I have found the plain centering disc to be sufficient.

The base of the cone is resiliently supported for vibration in an axial direction by means of a plate 13 that is secured to the magnetic yoke structure. For the purpose of providing an annular flexible support for the base of the cone a peripheral portion of the base is angularly bent at 16, having been radially slit at 17 and is cemented to the plate 13 around a large central opening 19 therein.

A deflector 15 is preferably disposed centrally within the cone diaphragm, supported by the central pole piece, for spreading the high frequency sound waves to reduce the beam effect.

Referring more in detail to my invention, as illustrated in Fig. 3, a sheet of paper, or other desirable material is provided with a cut-away section or sector 21 for forming into a frustum of a cone. A radial tab 23 is provided along an edge of the sector to provide the usual seam for cementing the edges of the sector together to maintain the cone. The central portion of the cone paper is apertured at 25 and radially slit at 27 to form a plurality of tabs, or serrations of tapered form, for attachment to the voice coil, as shown clearly in Fig. 2, in a manner hereinafter described. The ends of the tabs are cut off the desired length in the blanking operation, as shown by the size of circular opening 25.

The sheet of paper is formed into a cone 1 in any desired manner, for example as shown in Fig. 6 on a conical mandrel 31, then the tabs 27 are bent outwardly into a cylindrical configuration along a removable mandrel element 33 shown more in detail in Fig. 7. Next, one or

more layers of wire 3, preferably of light weight metal, e. g. enameled aluminum wire, are wound over the tabs and firmly secured thereto by the application of cementing material, such as shellac or lacquer. For still higher efficiency, if desirable, the coil may be wound with flat ribbon in edgewise relation. In the case of aluminum, an oxide coat may be formed, as by the electrolytic anode process, for insulating the turns. Such a coating is quite thin and is very durable and is as effective an insulator as enamel. Beryllium, or an alloy thereof with aluminum, may be used for the voice coil in view of the fact that it has a lower specific gravity than aluminum and a lower specific resistance as disclosed by Thuras 1,707,544. After the coil has been wound and the cementing material has sufficiently set, the structure is removed from the mandrel.

It will be noted that the cylindrical mandrel element 33 is a resilient split ring provided with a removable core 35. This split ring is forced on over the plain ring prior to winding and it is caused to expand to a circumference appreciably greater than its unsprung dimension. When the inner ring 35 is removed after the winding operation, the outer one 33 contracts and is readily removed from the interior of the voice coil structure, as will readily be understood. The removable mandrel elements 33 and 35 are coaxially mounted on an axial extension 37 of the mandrel 31.

By reason of the fact that the coil is wound on an integral extension 27 of the cone and because the cone and the extension are mounted on a common mandrel structure during the winding operation, the coil and cone are truly coaxial in relation. It will, therefore, be seen that when this structure is assembled into a speaker field structure the voice coil will be in true parallel alignment with respect to the pole faces, in the air-gap. Heretofore, in the constructions employing a separate voice coil structure it has been difficult to insure the coaxial relation, with the result that it has been necessary to provide considerable tolerance by making the air gap in the field structure wider than it should be for efficient operation. As additional assurance of proper alignment the flexible base portion 16 of the cone, Fig. 1, can be formed on the same mandrel.

In assembly, shellac may be applied to the support plate 13 around the opening therein and allowed to dry. The coil is then centered in the air gap in an unrestrained manner, and a hot press is caused to force the base of the cone against the plate 13, softening the shellac and cementing the cone in place.

If desired, the spider 11 may be cemented in place prior to winding the coil, by placing the disc 11 between the mandrel 31 and elements 33, 35, the central aperture 12 on the spider fitting around the mandrel extension 37, thereby assuring proper alignment.

The ends 41 of the voice coil are brought out directly for attachment to an external circuit. Because of the extremely small amplitude of vibrations of the cone involved in the present speaker, when used for high audio frequency purposes, it was found unnecessary to provide the usual separate flexible leads for soldering to the voice coil at the cone or coil form. This improvement greatly increases the lightness of the acoustic moving structure.

The number of the tapered serrations 27 re-

quired is determined by the necessary opening at the small end of the cone as well as by the design required to give a proper mechanical transition from the cone to the cylinder. From the standpoint of lightness and strength, it is an inherent feature of my invention that the tabs are narrow at the extreme end and become wider nearer the cone where the total driving force of the coil becomes greater.

The rigidity of the several wire turns in combination in the coil form serve to maintain the coil in circular form. The sections 27, which are cemented along the voice coil, serve, in addition to the cement between turns, to hold the turns securely together in the direction of the axis of the cylindrical coil structure. If desired, the tab sections 27, prior to winding of the coil thereon, may be saturated with an uncured phenol resin, e. g. liquid "bakelite". After the coil is wound thereon, the structure is baked and the phenol resin polymerized, thereby resulting in an extremely durable rigid structure. In such an arrangement, it is also desirable to treat the coil and the end of the cone adjacent the coil structure with phenol resin. In some cases the entire cone except the outer support flange 16 is treated with phenol resin in order to stiffen the cone and render it waterproof. On the other hand, it is desirable to keep the mass of the moving structure to the lowest possible minimum so therefore it is desirable to use a cone coating material sparingly. I have found that a light application of lacquer is sufficient and gives the cone a smooth hard surface which is desirable for radiation and for high speed of propagation along the cone at high audio frequencies.

Referring to the modified form of my invention in Fig. 4, the split end sections or tabs of the cone are sandwiched in between the layers of the voice coil in intimate contact with the adjacent walls of the layers. In this arrangement, one coil layer is wound upon the mandrel, then the tabs 27 are placed in position over this layer, and the outer layer is wound in place. Cement material is applied during the process in the usual manner. The resulting structure is unusually strong and light in weight in spite of the absence of the usual voice coil form.

Referring to a still further modification, the ends of the tabs need not be cut away as indicated at 25, Fig. 3. They may, for example, in either Figs. 2 or 4 be folded back along another wall of one or more of the coil layers as shown at 28 in the modification in Fig. 9. Other modifications of this nature will readily occur to those skilled in the art.

Referring to a modified form of my invention, shown in Fig. 8, certain of the voice coil tabs 27' taken from spaced points, say any sixth or eighth tab, are employed for centering the voice coil, in place of the spider 11, Fig. 2, thereby providing a unitary compact and light-weight construction. This structure is formed by bending the selected tabs 27' inwardly on the mandrel, toward the base of the extension 37, prior to inserting the voice coil mandrel members 33 and 35 in place. For the purpose of holding the selected tab members in proper position, and to complete the spider, an apertured disc 43 is placed on the mandrel extension 37, then the selected tab portions are bent inwardly as shown and another apertured disc 45 is inserted in place, cement being applied to hold the parts in position. The mandrel members are then inserted in position and tightly against the circular discs, and the

voice coil is wound upon the remaining tabs 27 as in the manner shown in Fig. 6. If desired the tabs 27' may be bent in an outward direction to form an outside spider, as will be readily obvious.

My novel speaker is designed primarily to operate over the higher audio range, say in the neighborhood of 4,000 to 10,000 cycles. Referring to the characteristic curve in Fig. 5, curve A, represents the response characteristic of the usual cone diaphragm dynamic loud speaker. Curve B, represents the characteristics of my improved loudspeaker. The composite curve, comprising the dotted line portion C results from the use of my improved speaker in conjunction with a speaker of the usual type, in the manner developed by M. E. Karns and M. W. Scheldorf. In the foregoing arrangement, one of my improved speakers, for high frequencies, and another speaker of conventional type are mounted on the same baffle and the rear portion of the high frequency speaker is enclosed in a housing to prevent the diaphragm thereof from being deleteriously influenced by sound waves emanating from the rear of the other speaker. Attempts have been made in the past to build radio sets with two speakers, one a large and one a small speaker, but it has been found in most cases with which I am familiar, that when the small speaker, made in the usual way except with small dimensions, is disconnected, there is substantially no difference in the character of acoustic output. By reason of my novel construction, it will be seen that the output audio range has been extended 1,000 to 3,000 cycles more toward the higher range. I am aware of the fact that ribbon type dynamic loud speakers, forms of which are shown by Rice and Kellogg in A. I. E. E. Proceedings, September 1935, page 937, Fig. 12, and Gerlach Patent 1,557,356, by way of illustration, have been employed in combination with ordinary speakers for reproducing the higher audio range, but this type is relatively expensive and has not proven satisfactory under certain conditions.

While I have specified fibrous material for the cone, my novel construction is particularly adapted for the use of metallic thin sheet material such as aluminum foil, beryllium foil or the like. I have found light weight metal diaphragms of this nature to have good characteristics for high audio frequency work. The construction of the coil attachment means 27 is such as to minimize eddy currents in the case when metal is used. If desirable the tabs 27, when of aluminum, may be oxidized to provide insulation against the turns of wire of the coil, particularly in case oxidized wire is used for the voice coil as above disclosed.

While I have illustrated my invention in connection with a diaphragm of the cone type, it should be obvious to those skilled in the art that other forms may be used, e. g. a substantially flat diaphragm. Furthermore, although I have disclosed a sound reproducer, any other form of transducer, e. g. or microphone of the dynamic type may embody my invention. Because of the extreme lightness of the moving elements, my construction is particularly adaptable for use as a microphone. While my novel construction is especially adapted for high audio frequency work, it has equal advantages for general use for sound reproduction over other portions of the audio range.

It will readily be seen that, in accordance with my invention, there has been provided an extremely light weight diaphragm and voice coil structure, particularly adapted for reproduction

of the higher audio frequencies and that the construction is such that there has been minimum sacrifice of strength and rigidity of construction.

The advantages of my novel construction are summarized as follows:

(a) Lightness of construction by reason of the elimination of a seam or joint at the juncture of the cone and voice coil with the usual load of cement binder, strips, etc. at or near this juncture;

(b) Substantial reduction in the number of separate elements used in the diaphragm and voice coil structure particularly by reason of the integral relation of elements;

(c) Substantial strength and rigidity of voice coil and cone structure considering the lightness of the structure;

(d) Accuracy of coaxial alignment of cone and voice coil structure thereby overcoming one of the serious sources of trouble in production and making it possible to employ a narrow, higher efficient air-gap.

Although I have shown and described certain specific embodiments of my invention, I am fully aware that many modifications are possible and I desire therefore, that only such limitations shall be imposed thereon as are indicated in the appended claims.

I claim as my invention:

1. In a sound translating device, a unitary vibratory structure comprising a conical diaphragm, a plurality of serrations integrally formed in an end portion of said diaphragm and arranged cylindrically, voice coil turns secured directly upon said serrations, said serrations constituting the sole support and driving connection for said coil turns.

2. The invention as set forth in claim 1 wherein said serrations are coextensive with said coil form and tapered, being wider adjacent the end of the coil where the driving force is greatest.

3. In a sound translating device, a unitary structure comprising a cone type diaphragm having its small end slitted and arranged to constitute a coil form, a voice coil secured directly upon said coil form, the slitted portions of said form being secured along a wall of said coil, and extending beyond the end thereof, and bent backward along another wall of said coil.

4. The method of making a unitary voice coil form and cone diaphragm assembly which com-

prises taking a sheet of material, slitting it radially adjacent its center, forming a plurality of integral tabs, bending the sheet into a conical form, forming the tabs into a substantially cylindrical form, and winding and securing a voice coil directly on the surface of said tabs.

5. The method of making a diaphragm and voice coil assembly for a dynamic speaker from a circular sheet which comprises cutting a multiplicity of radial slits on said sheet at the central portion and around the periphery thereof thereby forming a plurality of tabs, bending some of said tabs at an angle for receiving a voice coil thereon, forming other of said tabs into a flexible means for supporting said diaphragm and said coil.

6. A diaphragm and voice coil assembly comprising a frusto-conical diaphragm having its small end radially slit at spaced intervals and forming thereby a plurality of integral tabs, certain of said tabs being bent into substantially a cylindrical form for receiving a voice coil thereon, and other of said tabs being bent into a plane at substantially right angles to said cylindrical form thereby forming a centering spider.

7. A diaphragm and voice coil structure comprising a frusto-conical diaphragm having its ends thereof radially slit at spaced intervals forming thereby a plurality of integral tabs, said tabs being bent substantially into planes at right angles to the axis of said cone for flexibly centering said cone and coil structure.

8. In a sound transducer of the moving coil type, yoke and pole piece structure defining a magnetic air gap, a voice coil and centering spider assembly comprising a coil, spaced strips secured axially along a wall of said coil, a plurality of strips integrally connected with said other strips and disposed at an angle with respect thereto, said last named strips being fastened to the yoke or pole structure for centering said coil.

9. In a sound transducer of the dynamic or moving coil type, a yoke and pole piece structure defining a magnetic air gap, a diaphragm, a multi-turn voice coil attached to said diaphragm and disposed in said magnetic air gap, spaced strips secured in axial relation to said coil and bridging the turns thereof, and flexible means integral with said strips for centering said coil for vibration in said gap.

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