Sept. 13, 1966 H. M. RUTTER 3,272,281

TRANSDUCER

Filed Dec. 4 1964 2 Sheets-Sheet 1

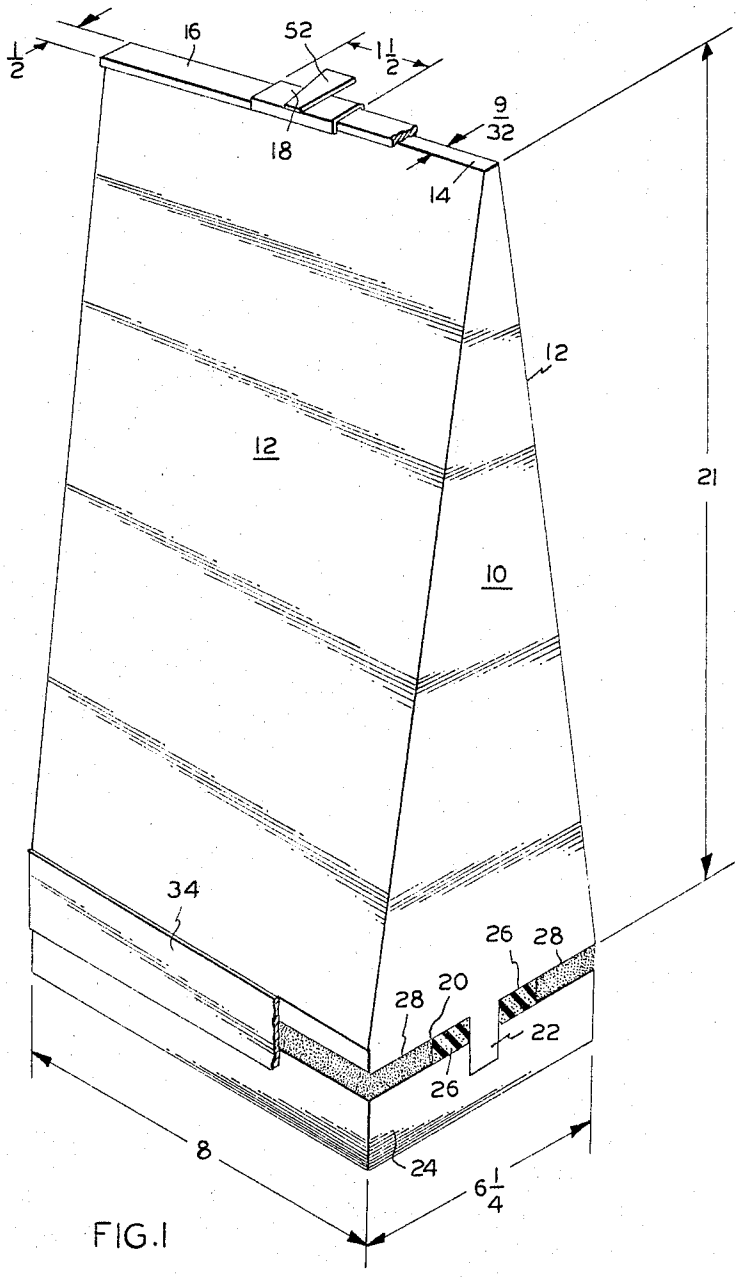


FIG.1

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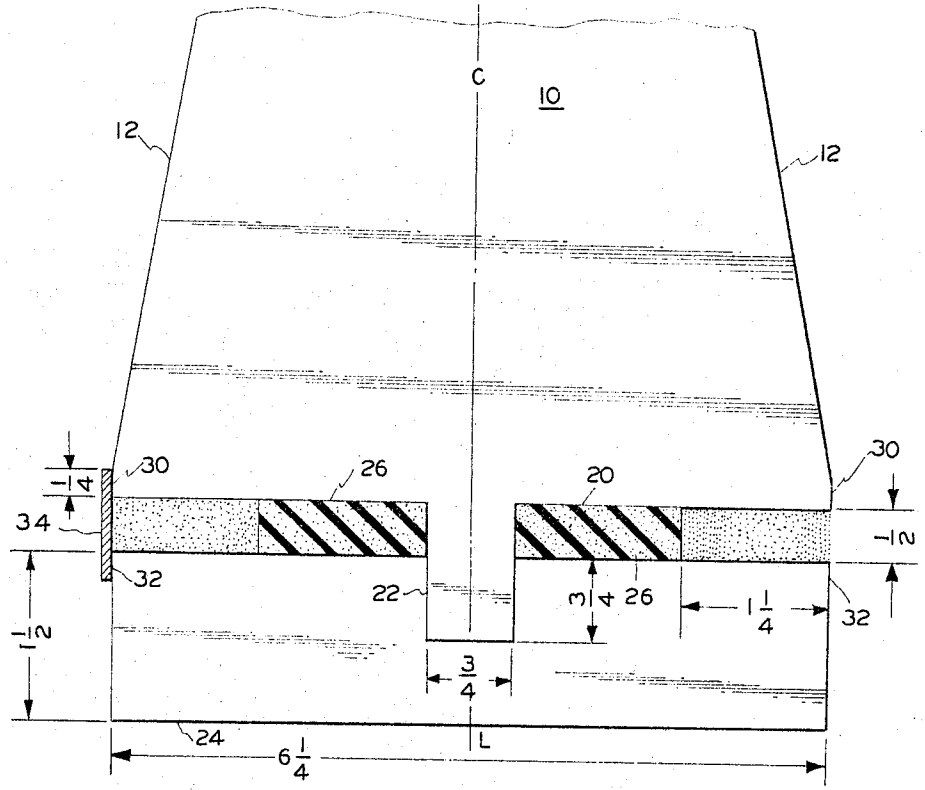


FIG. 2

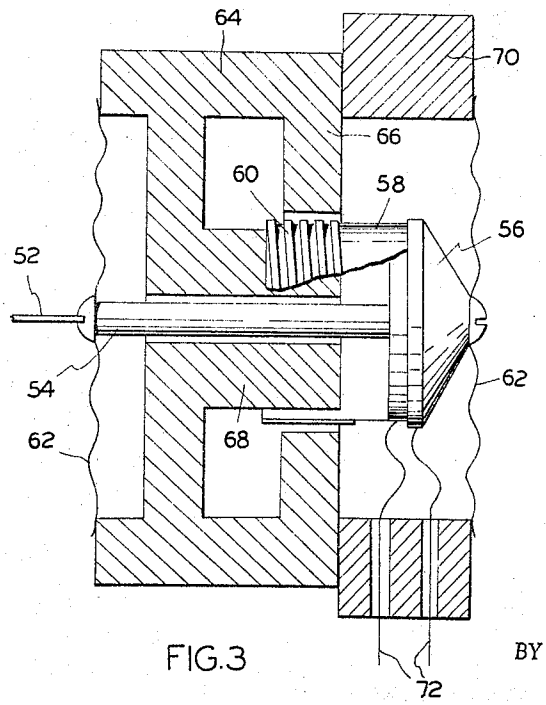


FIG. 3

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19 Claims. (Cl. 181—31)

In the reproduction of music, it is found that there is a wide variation in the style and quality of manufacture of commercially available recordings, and also in the degree of fidelity with which the original music was recorded. It is a premise of the following discussion that presently accepted music reproduction is not faithful to the recording itself, and therefore cannot be a reproduction of the original music, whether or not it was faithfully recorded. A number of electrical and mechanical components and processes are necessary to the art of recording and reproducing music, including what is generally known in the art as the "loudspeaker," which finally radiates the audible sound. Obviously, if the "loudspeaker" does not perform ideally, there is no means for critically evaluating the other components and processes involved, for we must depend upon the radiated sounds as we hear it.

There is at present a great variety of devices generally known as "loudspeakers." However, there is general disagreement among those skilled in the art, as to which of these produces the desired sound. Different loudspeakers of comparable quality produce very different musical sound when connected to the same signal source, and, since the object of the loudspeaker is to reproduce sonically the electrical input signals, which should have only one result, there is an implication that at least part of the accepted theory of loudspeaker design is invalid.

This invention provides means for the expansion and exploitation of a controlled combination of certain natural vibration phenomena. These phenomena are present at random in conventional loudspeakers, but they are not an integral part of, and indeed could not be incorporated into, accepted loudspeaker theory and practice.

It is an object of this invention to provide a sound reproduction system having a unique sound reproducing element and a unique mounting for said element, the element and its mounting coacting, when the element is excited by the application of energy impulses, to project into the atmosphere audible sound waves corresponding with exactitude, to the frequency and other attributes of the impulses by which it is excited.

Almost any rigid and elastic body, of whatever proportions or material will radiate audible sound to the atmosphere when excited by energy impulses in sonic frequencies. There appear to be three distinct modes in which this propagation and radiation of sound occurs. For the purpose of this discussion, the first of these is called "molecular vibration" and is believed to be a phenomenon of molecular strain without deformation or displacement of the body itself. When this occurs, there is an apparent wave propagation and audible sound is radiated, but there is otherwise no perceptible disturbance of the surface of the sound radiating body. The second mode will be referred to as "surface deformation" in which case the surface may have any number of separately but sympathetically vibrating areas separated by distinct nodes, in a manner similar to the harmonic vibration of a taut string. The third mode will be termed "monolithic" or "massive vibration" of the body as a whole, and this occurs either by deflection or displacement.

Depending on the material, the proportions and the mounting of the radiating body, any of the three modes or any combination of two or more modes may occur. However, they may occur at random; one may interfere with the other; they will be reflections and standing waves,

and the amplitudes of the separate frequencies may be relatively altered. Also, any radiating body tends to respond resonantly to certain frequencies, resulting in unauthorized and exaggerated sounds. Thus the total radiated sound will not correspond to the exciting impulses.

With such random and uncontrolled behavior in mind, it is a major object of this invention to design a radiating body, and a mounting therefor, which will be free of the undesirable vibrations, while accommodating the said three modes in proper relation to the excitation, and thereby provide accurate reproduction throughout the audible range of the widest variety of tones and frequencies or combinations thereof.

Loudspeakers, for the most part, are designed to operate by vibrational displacement of the radiating element as a whole, or what has been referred to above as "massive" vibration, whereas this invention provides means for utilizing all three natural vibration modes as described above, in a single radiating element. In loudspeaker design, much effort is devoted to providing rigidity of the radiating element, so that it will move as a whole without either internal or surface vibrations, whereas in this invention, the radiating element is intended to be stressed, deformed and deflected.

The above and other objects will be made clear in the following detailed description, taken in connection with the annexed drawings in which:

FIGURE 1 is a perspective view partially in section, of the improved sound reproducing element and its mounting;

FIGURE 2 is a transverse cross-section of the base of said element and its mounting; and

FIGURE 3 is a partial schematic cross-section through an electromagnetic device for applying mechanical impulses to the sound radiating body.

Briefly, the present invention may be described as a rigid but resilient plate mounted as a cantilever and excited at its free end. At its base the plate is subject to restraint and damping by an amorphous, semi-fluid mass interposed between portions of the base and its mounting. The plate is preferably made of low density brittle material having a low modulus of elasticity. Excitation is by mechanical connection of the free end to a conventional loudspeaker voice coil. It cannot be too strongly emphasized that the manner and means of excitation are immaterial so long as excitation occurs at or near the free end. It matters not at all whether the source is connected by electromagnetic, elastrostatic, mechanical or other means. A presently preferred excitation means is shown in FIGURE 3 and this means offers certain overall design advantages in connection with the music radiator hereinafter discussed. FIGURE 3 must be taken, however, as illustrative rather than definitive or limiting.

As noted, the fundamental concept is of a cantilever excited at its free end and restrained rather than "fixed" at its base. The term "cantilever" ordinarily calls to mind a horizontally protruding beam having one end firmly fixed in a vertical wall and the opposite end perfectly free. The term "cantilever" is used in this case, however, as a matter of convenience, in the absence of a word more aptly describing the particular structure of this invention. True, the sound radiating body has its major dimensions vertical rather than horizontal and its base end is "restricted" rather than "fixed." Nevertheless, regardless of its angle to the vertical, and regardless of its "restraint" as against "fixation" the stress-strain distribution under sonic frequency excitation adjacent the free end so far approximates that of the conventional "cantilever" that use of the term is deemed justified. The form and proportions shown are what *thus far* have been

found to be optimum and for full compliance with the statute, the unusual step has been taken of dimensioning the drawings. These dimensions, though optimum in the light of present knowledge, are not critical and form a "concrete example" rather than a limitation. Although, in any given case, the form, proportions and dimensions are critical relative to each other, the overall size of the device may be varied within wide limits.

Referring now to the drawings there is shown a sound radiating element **10** having plane radiating surfaces **12**. These are symmetrical about a central, vertical plane C–L (FIGURE 2). The free edge **14** has secured thereto a stiffening strip **16** of wood or similar material to which, in turn, is secured a metal clip **18** to which a voice coil **60** (shown in FIGURE 3) is mechanically connected by a strap **52**. The strip **16** and the clip **18** are designed to excite, equally, the entire extent of the free end **14** of the radiating element **10**.

The radiating element **10** may be defined as a body having uniform length, uniform width and varying thickness. The thickness is greatest at the restrained end, and the element is tapered in such a manner that the stress, produced by a static load at the free end, is least at the restrained end and progressively increases toward the free end. This tends to make the propagation of induced vibrations unidirectional, which is a requirement for proper operation, because the vibrations tend to propagate from a region of high stress to a region of lower stress. The taper further allows increased deflection of the element for radiation of low frequency vibrations. The element is tapered in thickness rather than in width so that the full width is available, at the region of maximum deflection, for maximum coupling to the surrounding air when radiating low frequency vibrations, and this requirement would not be met if the radiating face had, for example, a triangular shape.

At the restrained end **20** of the element **10** there is formed an integral central tongue **22**, a part of which occupies a slot in the base member **24** which forms part of the ultimate frame of the device. Framing for loudspeakers of all types is largely conventional, forms no part of this invention, and is not disclosed herein.

Because the tongue **22** is longer than the depth of the slot in the base member **24**, there is a gap between the end **20** of the radiating element **10** and the base member **24**. The tongue **22** fixes the lateral position of the radiating element **10** in relation to the base member **24**, and it has only sufficient stiffness to define the central position of the radiating element **10** as the plane C–L (FIGURE 2). Since, in normal vibration there is no significant stress in the region of the tongue, it plays no active part in the operation of the device, except to tend to retain the radiating element in this central position.

Blocks **26** of sponge rubber or other low strength, resilient material are placed in the space between the end **20** of the element **10** and the surface of the base member **24** adjacent each side of the tongue **22**. Since the amplitude of the movement of the end **20** relative to the base member **24** is so small as to be negligible in the area of the blocks **26**, these blocks function only to prevent inward migration of the semi-fluid damping compound next to be described. In length the blocks **26** are coextensive with the width of the element **10**.

The semi-fluid material above referred to is of high viscosity and is extremely adhesive. By way of specific example, a preferred material is 97% polybutenes and 3% hydrogenated castor oil. As a genus, the term "butene" includes all of the isomers of butylene, hence the term "polybutene" as used herein is intended to cover any and all polymers of any and all of the isomers of butylene. Any substance having similar flow characteristics and similar physical and chemical stability may be used, or there may be substituted any flexible solid material provided it has the required damping characteristics.

This material is used at **28** to fill the spaces between the blocks **26** and the outer faces **30** and **32** of the element **10** and the base member **24** respectively and is held in place by woven fabric tapes **34**. The viscous coupling of the radiating element **10** to the base member **24** is fundamental to the operation of the device. A similar but solidly mounted radiating element would tend to respond only to certain frequencies in a resonant manner, after the manner of a taut string in harmonic vibration. By the base mounting herein described, these resonant harmonic vibrations are damped to the required level and it is then found that, with this construction, the radiating element responds similarly to all frequencies, as if it did not actually have a fixed length. One important function of the viscous material is to prevent reflection of vibrations from the base of the radiating element, and this damping effect makes the radiating element substantially nonresonant. Another important function is to provide resistance so that force applied at the free end causes deflection by bending of the element rather than by simple displacement.

The element **10** is formed of foamed or expanded polystyrene which seems the best material currently available. New materials, however, make their appearance almost every week and it not only is possible but probable that better materials will become available. It is not intended therefore, to limit this invention to foamed polystyrene.

Referring now to FIGURE 3, which is illustrative and not definitive of the power portion of the apparatus, the strap **52**, which, in FIGURE 1 is shown as having one end attached to the free end **14** of the element **10**, is shown in FIGURE 3 as having its opposite end attached to a nonmagnetic rod **54**. The opposite end of the rod **54** has a head **56** which supports a shell **58** on which a voice coil **60** is wound. Each end of the rod **54** is secured to a diaphragm **62**. Each of the diaphragms **62** is marginally secured to a magnet **64** of which a portion **66** surrounds the voice coil **60** and another portion **68** penetrates the voice coil **60** and surrounds the rod **54**. The magnet **64** is mounted on a suitable support **70** through which freely pass lead wires **72** for delivering electrical impulses to the voice coil **60**.

The strap **52** is of spring steel and its function is similar to that of a cross-head and connecting rod. The vibrations of the rod **54** are axial and linear; the motion of the free end **14** of element **10** is essentially arcuate, and both motions are accommodated by the strap **52**.

Disclosure has been made of a form of this invention which seems optimum in the light of the current knowledge and experiment. As the drawings make clear the element **10** is trapezoidal in transverse cross-section and has plane sound radiating surfaces symmetrical on opposite sides of a central plane. That is, the element **10** has substantially uniform length and substantially uniform width, but has varying thickness. The *average* thickness, however, is substantial as compared to either length or width so that the element **10**, though sufficiently resilient to reproduce energy impulses in the form of mechanical vibrations in compound and multiple sonic frequencies, is, nevertheless, a substantially rigid body. Quite possibly it may be found that some proportions may be altered or that the element may be made asymmetrical or that the radiating surfaces **12** may be given some curvature instead of being made plane as disclosed. The invention is not, therefore, to be limited to the details of the disclosure, but only as set forth in the subjoined claims.

What is claimed is:

1. A device for converting energy impulses into audible sound comprising: a sound radiating element of substantially uniform length and width of varying thickness having one end substantially restrained and the opposite end substantially free and means for exciting the free end of said element in response to said energy impulses.

2. A device as set forth in claim **1** in which the sound radiating element has a generally tapered longitudinal

cross-section having its greatest thickness adjacent its restrained end.

3. A device as set forth in claim 1 in which the sound radiating element has a trapezoidal longitudinal cross-section in planes parallel to its deflection.

4. A device as set forth in claim 2 in which said sound radiating element is made of substantally rigid cellular material.

5. A device as set forth in claim 2 in which the sound radiating element is symmetrical in cross-section about a central longitudinal plane perpendicular to its base.

6. A device for converting energy impulses into audible sound comprising a sound radiating element, mounted as a cantilever, substantially restrained at its base and substantially free at its opposite edge; a base member; said sound radiating element having, at its base, a tongue fixed to said base member, the thickness of said sound radiating element at its base exceeding that of said tongue and vibration damping means adjacent the free margins of said base between said base and said base member.

7. A device as set forth in claim 6 in which said sound radiating element is formed of foamed polystyrene.

8. A device as set forth in claim 6 in which said damping means comprises, essentially, a polybutene.

9. A device as set forth in claim 7 in which said damping means comprises, essentially, a polybutene.

10. A device as set forth in claim 8 including solid bodies of deformable, essentially elastic material between said tongue and said damping means.

11. A device as set forth in claim 9 including bodies of deformable, essentially elastic material between said tongue and said damping means.

12. A device for converting energy impulses into audible sound comprising: a sound radiating element mounted as a cantilever having one end substantially restrained and the opposite end substantially free, said element having a generally tapered longitudinal cross-section with its greatest thickness adjacent its restrained end, said element being formed of foamed polystyrene and means for loading the free end of said element in response to said energy impulses.

13. A device for converting energy impulses into audible sound comprising: a sound radiating element, said element having major, generally rectilinear surfaces and minor, generally trapezoidal surfaces and being substantially restrained at its base and substantially free at its opposite edge; a base member; said base and said base member having mutually confronting surfaces generally normal to the major surfaces of said sound radiating element; means connecting the base of said sound radiating element to said base member, said means having a cross-sectional area less than the area of the confronting surfaces of said base and said base member; vibration damping means interposed between said confronting surfaces; and means for exciting vibrations in the sonic range at said opposite edge.

14. A device as set forth in claim 13 in which said sound radiating element is formed of foamed polystyrene.

15. A device as set forth in claim 13 in which said damping means comprises, essentially, a polybutene.

16. A device as set forth in claim 14 in which said damping means comprises, essentially, a polybutene.

17. A device as set forth in claim 15 including solid bodies of deformable, essentially elastic material between said connecting means and said damping means.

18. A device as set forth in claim 16 including bodies of deformable, essentially elastic material between said connecting means and said damping means.

19. A device as set forth in claim 13 in which said damping means comprises at least one substantially solid flexible body cooperating with a viscous fluid.

References Cited by the Examiner

UNITED STATES PATENTS

2,063,945	12/1936	Pierce	181—31
3,046,362	7/1962	White	181—32 X

FOREIGN PATENTS

614,175	9/1926	France.

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