

Nov. 14, 1950

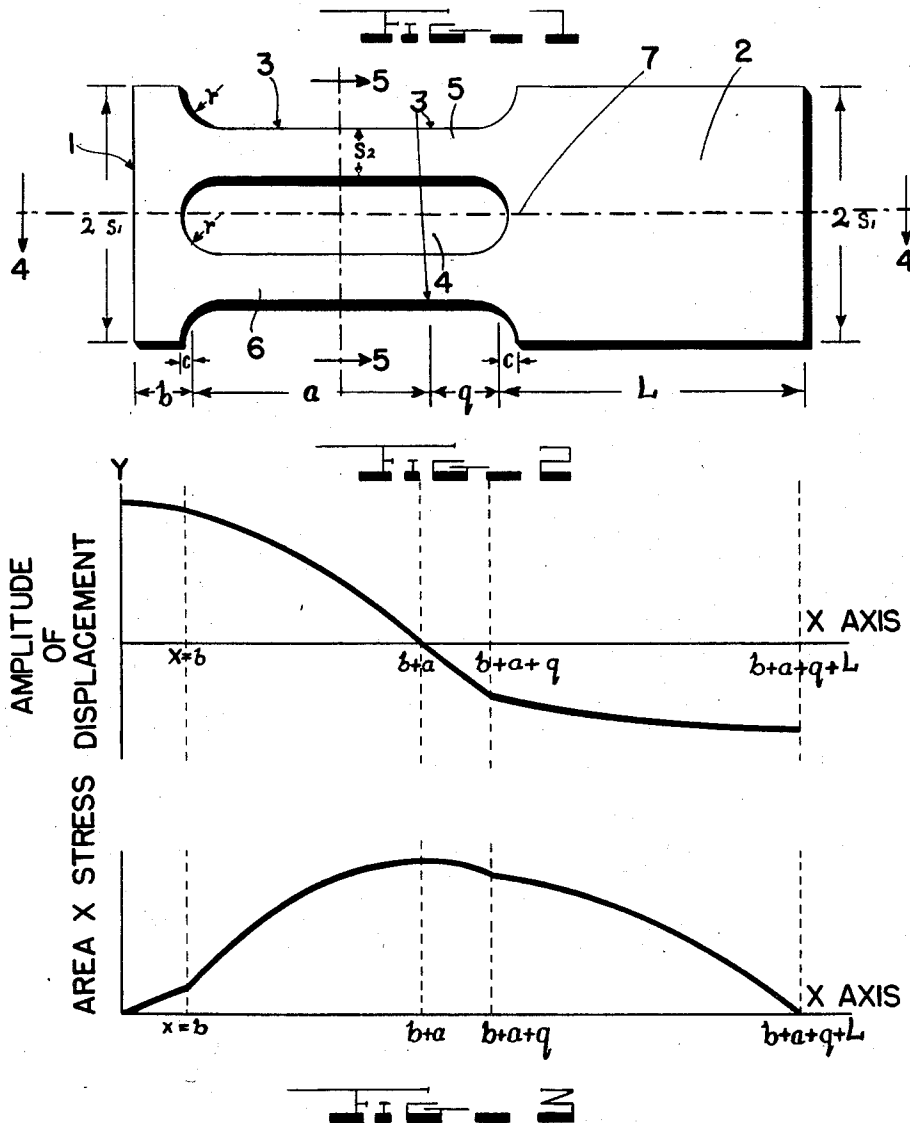
L. W. CAMP

2,530,224

MAGNETOSTRICTION TRANSDUCER

Filed Aug. 2, 1949

2 Sheets-Sheet 1



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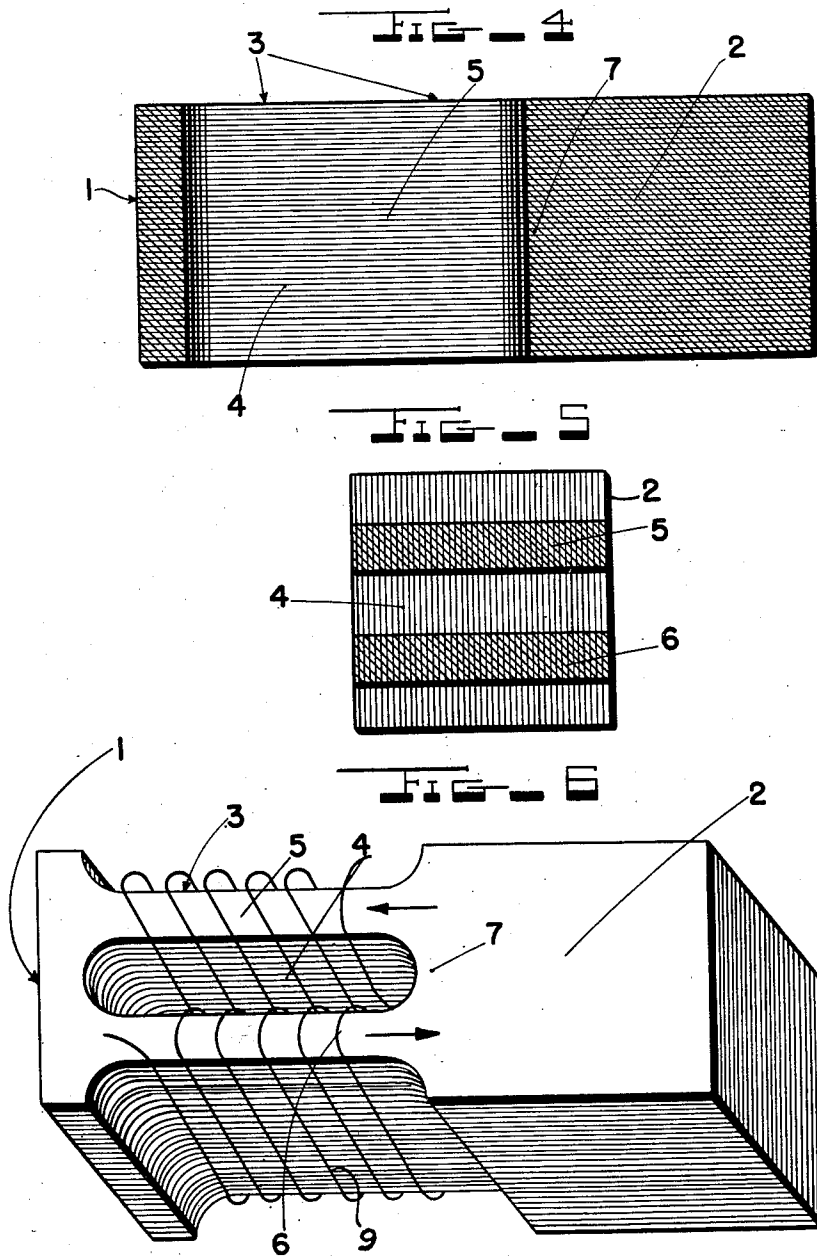
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2 Sheets-Sheet 2



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2,530,224

MAGNETOSTRICTION TRANSDUCER

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Application August 2, 1949, Serial No. 108,211

8 Claims. (Cl. 171-209)

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My invention relates broadly to electro-acoustic systems and more particularly to an improved method of constructing magnetostriction transducers and to an improved construction of magnetostriction transducer.

This application is a continuation in part of my application Serial Number 39,770, filed July 20, 1948 for Magnetostriction Transducer.

One of the objects of my invention is to provide a method of producing magnetostriction transducers by which an increased efficiency is obtained in the production of electro-acoustic energy.

Another object of my invention is to provide an improved construction of magnetostriction transducer by which a higher acoustic efficiency is obtainable than has heretofore been possible.

A further object of my invention is to provide an improved construction of lamination for magnetostriction transducers by which the rearward change in cross section of the lamination is related to the location of the center of mass of the lamination whereby vibration of the lamination imparts the maximum amount of useful motion to the face of the consolidated laminated stack.

Still another object of my invention is to provide an improved construction of magnetostriction lamination comprising forward and rearward equivalent quarter-wave sections interconnected by a constricted portion and wherein the point of maximum compression and flux density occurs in the constricted portion a short distance from the change in cross section.

A further object of my invention is to provide an improved construction of magnetostriction transducer using a minimum of magnetic material and compactly arranged but providing adequate space for the driving coils which may be centered over the region of maximum flux change for producing high acoustic efficiency.

Still another object of my invention is to provide a construction of magnetostriction transducer which may be readily reproduced with mathematical accuracy for production of magnetostriction transducers inexpensively on a quantity production basis for operation according to a predetermined specification.

A further object of my invention is to provide a construction of magnetostriction transducer developed according to predetermined parameters for producing electro-acoustic vibrations at relatively large amplitude.

Other and further objects of my invention reside in a new principle of lamination and transducer construction as set forth more fully in the

specification hereinafter following by reference to the accompanying drawings, in which:

Figure 1 is a plan view showing the construction of the individual laminations employed in the magnetostriction transducer of my invention; Fig. 2 is a curve diagram illustrating the theoretical displacement of any point from a rest position along the length of the lamination during the compression part of the cycle and progressively along the length of the lamination and with respect to the portions thereof designated in Fig. 1; Fig. 3 shows a curve diagram of the theoretical internal stresses in the material of the lamination corresponding to the conditions of Fig. 2 and the structure of Fig. 1;

Fig. 4 is a longitudinal cross sectional view through the assembly of a stack of laminations forming the magnetostriction transducer of my invention, the view being taken substantially on line 4-4 of Fig. 1 with the laminations thereof superimposed in a stack;

Fig. 5 is a transverse sectional view taken substantially on line 5-5 of Fig. 1 with the laminations arranged in a stack; and

Fig. 6 is a perspective view of the magnetostriction transducer assembly of my invention.

My invention is directed to a method of constructing and an improved construction of magnetostriction transducer which has many applications, among which I mention systems of electro-acoustic depth sounding; systems used in locating schools of fish; supersonic systems of radar for exploring ocean-beds in locating lost treasures; systems for detecting flaws in materials; methods of homogenization and sterilization of milk; the production of vibrations in confined areas applicable in producing agitation for use in cleansing and laundry operations; the preparation of emulsions and suspensions in fluids employing supersonic vibrations; and the destroying of vermin and insects by the production of supersonic vibrations.

My invention provides a new design for and a method of producing a magnetostriction transducer where the laminations forming the transducer element are each provided with a front portion and a rearward portion with a restricted portion therebetween which is longitudinally slotted and provides parallel extending legs which connect with the solid plane of the laminations (at the center of mass of the transducer element) and where the rearward change in cross section and the center of mass coincide. That is to say the laminations have their center of mass located substantially in the plane of the change

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of cross sectional area in the rearward portion of the lamination. The overall dimensions of the lamination are determined by the physical properties of the material, the frequency of the vibrations desired, the mechanical quality factor or "Q" at which the system is to operate, and the directional patterns desired for the emerging sound beam. All of these factors may be varied as desired without affecting this design principle.

Referring to the drawings in detail, reference character 1 designates the forward quarter-wave section, and reference character 2 designates the rearward quarter-wave section interconnected by the constricted section 3. The constricted section 3 extends longitudinally between the forward and rearward quarter-wave sections 1 and 2. A longitudinally extending slot 4 is formed in the constricted section 3, and extends from a position behind the vibration emanating face 1 to a position 7 in rearward extending portion 2 which is substantially coincidental with a plane extending through the center of mass of the lamination.

The slot 4 divides the transducer formed by a stack of the laminations into two legs, 5 and 6, which are adequately spaced to enable the electrical windings 8 and 9 to be wound over each of the legs and through the slot 4.

The point of maximum compression and flux density occurs in the constricted portion 3 a short distance from the change in cross section at 7. The center of mass of the lamination coincides with the plane of the change of cross sectional area. The relationship of the dimensions of the laminations are shown in Fig. 1 of the drawings, and which I have designated as follows:

2S₁=width of forward vibrating face portion
S₂=width of each leg in constructed portion
b=length of forward vibrating end portion of the lamination
a=length of restricted portion adjacent forward vibrating portion
q=length of restricted portion adjacent the rearward portion where a+q=entire length of restricted portion
L=length of rearward section of lamination
r=radius of curvature of slot and edge of constricted portion
c=r(1+π/4)

The mathematical relationship of the dimensions of the lamination are as set forth in the following equations:

$$\cot kq \cot kl = m; m = S_1/S_2$$

$$L^2 = b^2 + 2b(a+q) + 1/m(a+q)^2$$

in which

k=constant for the properties of the particular material of the laminations expressed as

$$\frac{2\pi}{\lambda}$$

where λ is the wavelength of sound in the magnetostrictive material at the frequency for which the lamination exhibits its fundamental mode of resonance;

m=ratio of the cross-sectional area of section b with respect to the cross sectional area of section a.

This relationship establishes the location of the junction of the constricted section 3 with the rearward section 2 of length L according to the

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foregoing equations for obtaining the lengths q and L.

Fig. 2 is a curve showing the displacement Y from rest position of any point along the length of the lamination during the compression part of the cycle. The curve is not intended to show a mathematically correct representation. If such is required, the following functions must be plotted: With the X-axis along the length of the lamination and its origin at the left end of Fig. 1

$$a \leq X \leq b, Y = A \cos kX$$

$$b \leq X \leq b+a+q; Y = A \frac{\cos kb}{\sin ka} \sin k(b+a-X)$$

$$b+a+q \leq X \leq b+a+q+L; Y = -$$

$$A \frac{\cos kb \sin kq}{\sin ka \cos kL} \cos k[X - (b+a+q+L)]$$

Fig. 3 is a curve of internal forces in the material corresponding to the condition of Fig. 2. This curve may be properly plotted by using the foregoing equations and the relationship:

$$F = -S\rho v^2 \frac{\delta Y}{\delta X}$$

Where F is the total internal force across the width S of the lamination, this force assumed to be in the direction of the X-axis. ρ is the density of the lamination material and v is the velocity of sound in that material. S in this case is a variable depending on the lamination section under consideration. The quantity S will equal twice S₂ if the two-legged lamination is considered as a whole and F is the sum of the forces in the two legs. The exciting coils 8 and 9 are located one around each of legs 3 and 6 and do not extend beyond the longitudinal limits of the constricted section of the stack. The solid or more massive end of the stack is that referred to as "fixed."

The polarities indicated are selected for illustrative purposes only and it will be understood that the polarities may be reversed without adverse effect to the operation.

The construction of the lamination according to the foregoing principles places the junction of the constricted section 3 and the rearward section 2 in a plane coincident with the center of mass of the lamination.

I have found numerous advantages resulting from the coincidental location of the connection of the constricted section of the lamination with the rearward portion through the center of mass among which I summarize the increased magnetostriction activity of the device; the increased electrical efficiency and the increase in magnitude of the vibrations emanating from the front end of the device.

While I have described my invention in one of its preferred embodiments, I realize that modifications may be made, and I desire that it be understood that no limitations upon my invention are intended other than may be imposed by the scope of the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is as follows:

1. In a magnetostriction oscillator system, a magnetostriction transducer element comprising a stack of laminations acoustically vibratory through one end thereof, a constricted section intermediate the ends of said stack and a slot extending through the constricted section longitudinally of said stack one end of the slot being disposed substantially in a transverse plane

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through the center of mass of the stack of laminations to a position adjacent the acoustically vibratory end thereof.

2. In a magnetostriction oscillator system, a magnetostriction transducer element comprising a stack of laminations, said stack including an acoustically vibratory end face and an elongated end section, and a constricted portion extending between said elongated end section and said acoustically vibratory end face for receiving windings thereon, said constricted portion being longitudinally slotted from a position aligned with a transverse plane through the center of mass of said stack of laminations to a position located adjacent said acoustically vibratory end face.

3. In a magnetostriction oscillator system, a magnetostriction transducer element comprising a stack of laminations, said stack including an acoustically vibratory end face and an elongated end section, and a constricted portion extending between said elongated end section and said acoustically vibratory end face, said stack being longitudinally slotted from a position aligned with a transverse plane through the center of mass of said stack of laminations to a position adjacent the acoustically vibratory end face for forming legs adapted to receive windings thereon within said constricted portion.

4. In a magnetostriction oscillator system, a magnetostriction transducer element comprising a stack of laminations, said stack including an acoustically vibratory end face and an elongated end section, and a constricted portion extending between said elongated end section and said acoustically vibratory end face, said stack being longitudinally slotted from a position aligned with a transverse plane through the center of mass of said stack of laminations to a position adjacent the acoustically vibratory end face for forming legs adapted to receive windings thereon within said constricted portion, said legs having a width less than the width of the slotted portion of said stack.

5. In a magnetostriction oscillator, comprising a magnetostriction element formed by a stack of laminations, each of said laminations having an acoustically vibratory end face and an opposite elongated end section, a longitudinal slot extend-

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ing from a position aligned with a transverse plane through the center of mass of said stack of laminations to a position adjacent said acoustically vibratory end face and a constriction formed in said stack adjacent the slot therein.

6. A magnetostriction oscillator, comprising a magnetostriction element formed by a stack of laminations, each having an elongated section at one end extending to the center of mass of said stack and an acoustically vibratory face portion at the other end, said face portion and said solid portion being interconnected by a constricted portion, said constricted portion having a slot extending therethrough from a point aligned with a lateral plane through the center of mass of said stack of laminations to a position adjacent said acoustically vibratory face portion.

7. In a magnetostriction oscillator system a magnetostriction transducer element comprising a stack of laminations each comprising forward and rear equivalent quarter-wave sections each of which consists of a face portion and a constricted portion substantially perpendicular to the face portion, the two equivalent quarter-wave sections being joined at their constricted ends so that the junction of the constricted portion and the enlarged portion of the rearward quarter-wave section falls substantially in a plane extending laterally through the center of mass of the lamination.

8. A magnetostriction device comprising a magnetostriction element formed by a stack of laminations each of said laminations including two end sections joined by a slotted section, said slotted section being constricted over a portion of its length and interconnecting the end section in a lateral plane that passes through the center of mass stack of laminations.

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The following references are of record in the file of this patent:

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