

Jan. 26, 1960

W. T. HARRIS

2,922,483

ACOUSTIC OR MECHANICAL IMPEDANCE

Filed June 3, 1954

2 Sheets-Sheet 1

FIG. 1.

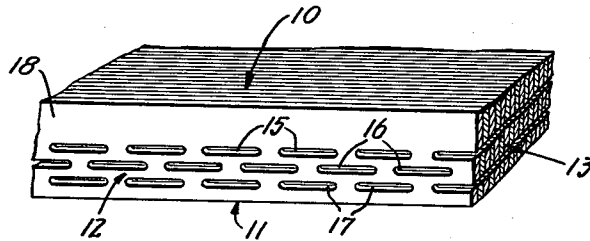


FIG. 2.

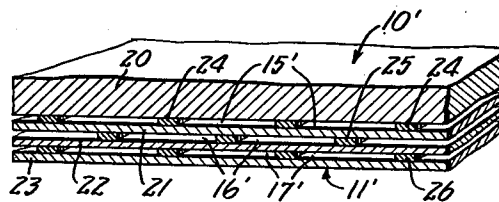


FIG. 3.

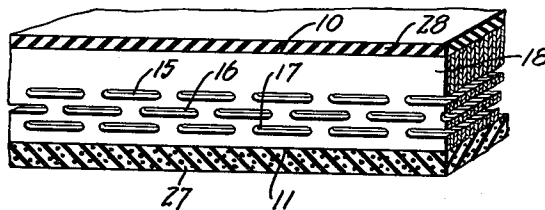


FIG. 4.

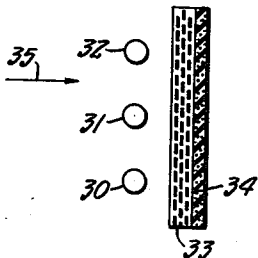


FIG. 5.

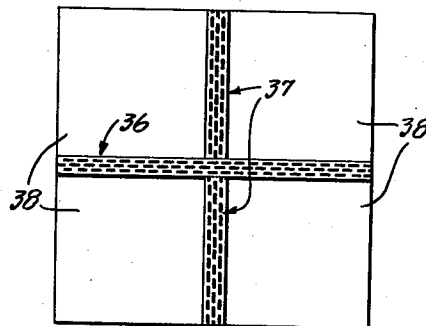


FIG. 6.

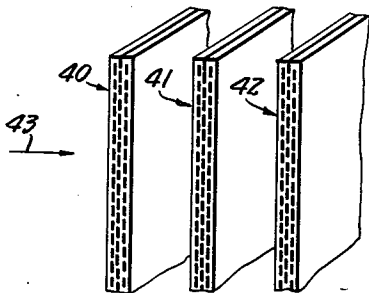
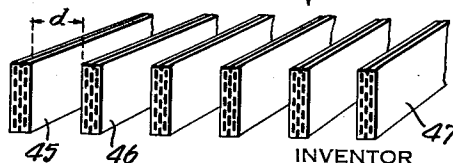


FIG. 7.



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FIG. 8.

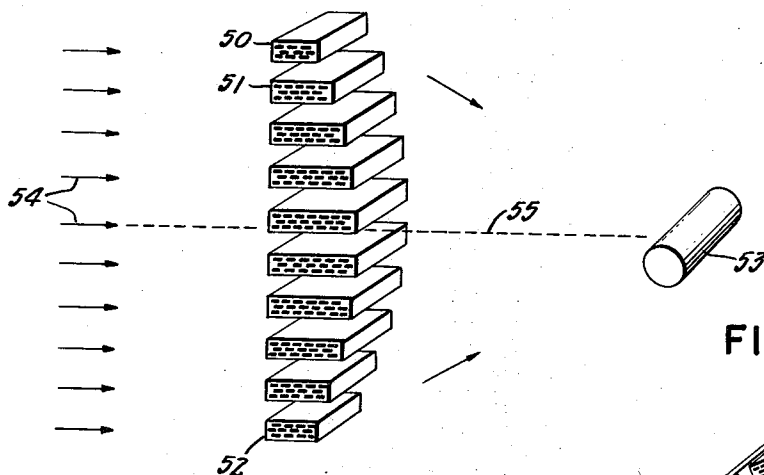


FIG. 10.

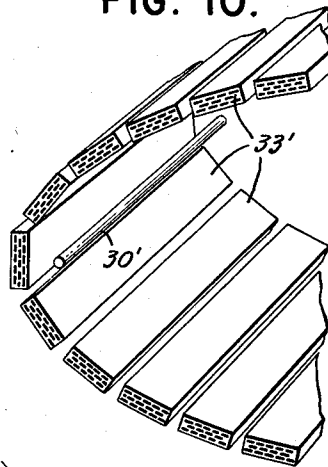


FIG. 9.

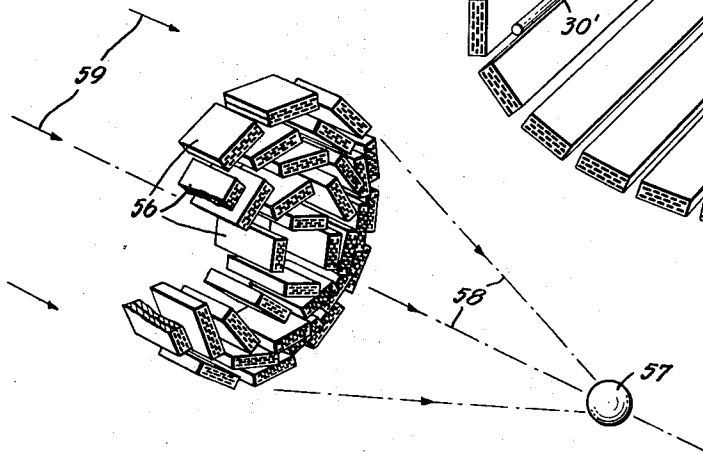
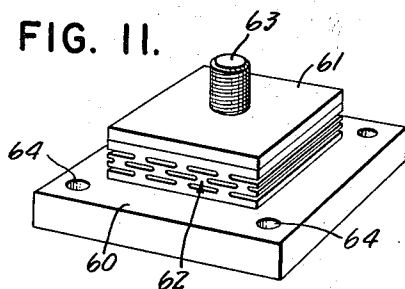


FIG. 11.



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ACOUSTIC OR MECHANICAL IMPEDANCE

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Application June 3, 1954, Serial No. 434,278

7 Claims. (Cl. 181—5)

My invention relates to acoustic or mechanical impedances and, in particular, to a construction lending itself to underwater acoustic use or to industrial application.

It is an object of the invention to provide improved means of the character indicated.

It is another object to provide an improved acoustic or mechanical impedance construction which may be the mechanical analogy of a capacitor or of a capacitor plus series resistors.

Another object is to provide novel configurations of such impedance elements, for a variety of applications including underwater acoustics and load-supporting shock-mounts or plates.

Other objects and various further features of novelty and invention will be pointed out or will occur to those skilled in the art from a reading of the following specification in conjunction with the accompanying drawings. In said drawings, which show, for illustrative purposes only, preferred forms of the invention:

Fig. 1 is a fragmentary view in perspective, taken through a transverse section and partly broken away to show the basic elements of one form of acoustic or mechanical impedance of the invention;

Figs. 2 and 3 are similar views illustrating modifications;

Fig. 4 is a simplified sectional view schematically illustrating a specific application of my acoustic impedance as a combination reflector and shield, for use with an underwater acoustic transducer;

Fig. 5 is a side elevation illustrating a triplane application of the invention;

Figs. 6 and 7 are fragmentary views in perspective, schematically illustrating low- and high-pass filter applications of the invention;

Figs. 8 to 10 are similar views illustrating acoustic-lens applications; and

Fig. 11 is a perspective view of a shock mount incorporating features of the invention.

Briefly, my invention contemplates acoustic or mechanical impedances producible in the form of sheets or blanks and possessing the properties of substantially pure compliances or, alternatively, compliances with resistance or damping features. In electrical analogy, the impedance elements correspond to capacitors, or to capacitors plus series or parallel resistors, respectively. Various applications and combinations of these elements are described.

Two basic forms of impedance elements according to the invention are shown in Figs. 1 and 2 and, in both cases, the basic construction is applicable to manufacture of the consolidated impedance in large sheets. In the form of Fig. 1, the construction is essentially defined by two spaced surfaces 10—11, which may be substantially coextensive and integrally joined by a body including a stiffly compliant section designated generally 12. The body of the impedance may be formed by consolidating a stack of like laminations, only one of which is shown in full along the face of Fig. 1. Edges of further lamina-

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tions appear along the broken side 13 and top surface 10 of the construction shown.

The compliant section of each lamination may comprise a plurality of rows of elongated slots 15—16—17, the slots in adjacent rows being staggered so that, insofar as the transmission of force from one surface 10 to the other surface 11 is concerned, reliance is made on numerous cantilevered, resiliently bendable sections. The plurality of these sections is such that, taken over the substantial area of the opposed surfaces 10—11, an essentially uniform compliant action is achieved. If desired, and particularly for the case in which force application to the surface 10 is localized, the body of the impedance immediately adjacent the surface 10 may be somewhat thicker, as by forming the compliant slotted region 12 predominantly away from said surface 10, and defining a uniformly thick load-equalizing section 18 between the surface 10 and the compliant section 12.

The laminations making up the impedance of Fig. 1 may, as indicated above, be of exactly the same plan-form and may be assembled in register and consolidated to form a uniform slab of any desired length. The laminations may be of metal or of plastic and, in the event plastic is used, I prefer to employ a fabric-reinforced or a fiber-reinforced plastic.

In the mass-production of the impedances of Fig. 1, the laminations may be repetitively punched in an automatic power press and this applies whether the material is steel, aluminum, magnesium or other metal, or plastic. After punching, the strips may be coated with a liquid adhesive, clamped together and baked to form the compliant sheet. An epoxy-type adhesive is usually preferred.

In Fig. 2, the construction is somewhat different, but the result may be essentially the same. The impedance may still be said to comprise, between opposed substantially coextensive surfaces 10'—11', a stiffly compliant region of extensive but essentially uniform cantilevered support, defined by staggered rows of slots 15'—16'—17'. The only difference is that continuous sheets are employed in place of like slotted transverse laminations. Thus, the impedance of Fig. 2 may comprise a plurality of spaced sheets 20—21—22—23. One of these sheets, say, the outer sheet 20, may be thicker than the others for the purpose of load distribution, and the others may be of the same or different thickness, but preferably sufficiently thin to provide yieldable support. A first pair 20—21 of these sheets may be spaced by a first set of spacers 24. A second pair 21—22 of these sheets may be spaced by a second set of spacers 25, the spacers 24—25 of adjacent rows being staggered to promote cantilever action. Likewise, the third pair of sheets 22—23 may be spaced by a further set of spacers 26, again staggered with respect to the adjacent row 25 to promote cantilever action. Depending upon the impedance characteristics desired, the materials of the construction of Fig. 2 may be metallic or plastic, as discussed in connection with Fig. 1.

For many applications, as for underwater acoustic applications, it is desirable to cover and fully seal the impedance with suitable material, such as rubber or neoprene, to avoid filling the interstices of the impedance and thus to retain compliant effects. If the sealing material is essentially acoustically transparent, the compliant effects remain essentially unchanged, but if it is resistive or absorptive, then resistive properties are added to the compliance.

In the arrangement of Fig. 3, I illustrate that, for certain applications, my compliant sheets or slabs may be combined with resistive material to promote combined capacitance-resistance properties. The particular compliant sheet shown happens to be of the Fig. 1 variety, and

to the back surface 11, I have applied a slab 27 of resistive material. As described in greater detail below, such material may be shot or flake-filled rubber, neoprene or the like, readily bonded to the surface 11. For underwater applications, it may be desirable to bond a further rubber or plastic layer 28 to the other surface 10.

For the slab 27 of Fig. 3, a suitable composition having desirable absorptive properties could comprise aluminum pellets imbedded in rubber. However, I prefer a mica-filled compound, both for underwater acoustics and industrial-supporting applications, somewhat as follows:

	Parts
Polychloroprene -----	100
Softeners -----	3
Stearic acid -----	0.5
Zinc oxide -----	5
Magnesia -----	4
Mica flake -----	20 to 50

The acoustic properties of a slab of compliant material immersed in water cannot be deduced by treating the simple boundary-value problem, as is done in many textbooks. However, the acoustic impedance, or radiation impedance, of an immersed planar slab of a given size and a simple shape can be approximated by known methods. Having done this, the compliant slab and acoustic load then can be treated mathematically as two masses connected by a spring, or compliance, plus a damping device. Thus, a definite mass, resistance, and compliance can be associated with each unit of area. Electrically, the analog has the form of a low-pass filter element. Functionally, the slab becomes virtually opaque to normally incident sound or other vibrational frequencies above the resonant frequency of the mechanical oscillator formed by the water loading and the compliance. In this frequency region they are nearly perfect reflectors, probably the most important application. For lower frequencies, the slab becomes transparent. Multiple parallel slabs increase the discrimination, and, if placed close together, react on each other to alter the cut-off frequency. If maximum acoustic shielding for all frequencies is desirable, damping-type covers may be employed on the acoustic impedance elements.

If slabs, or strips or rings or blocks from such slabs, are disposed so that sound passes between them and substantially parallel to the compliant faces, such an array may produce a high-pass filter, a high-pass diffraction grating, or a Fresnel lens for the passed frequencies. The sound of frequencies at or below the resonance mentioned above is scattered and reflected, whereas for the pass band the sound is transmitted. A generally cylindrical or spherical staggering produces lens effects, and diffraction effects are obtained in manners similar to those in physical optics by inclining planar or curved two-dimensional arrays. By surrounding a volume with both high-pass and low-pass elements, the interior of the volume may be shielded from sound except for a definite frequency band.

In the remaining figures, I show certain of the specific applications of my impedance as outlined in general terms above. Fig. 4 schematically suggests combination of my impedance with an underwater-sound transducer 30 or with an array of such transducers 30—31—32. The impedance 33 may be essentially as described in connection with Fig. 3, that is, comprising a slotted body to present a compliance facing the transducers 30—31—32, and backed by slab 34 of resistive material which is sometimes desirable. The arrow 35 designates the general direction for which principal response may be achieved upon a proper spacing of the elements 30—31—32 from the impedance 33 and upon a proper choice of compliance constants in the design of the impedance 33. The softer the compliance the lower the frequencies

at which the reflecting property is extended; resistive material is useful for attenuating frequencies below the critical frequency, where the compliance alone would otherwise begin to transmit, to define a low-pass region.

In Fig. 5, I show application of my invention to an underwater acoustic triplane comprising three mutually perpendicular surfaces 36—37—38 intersecting more or less centrally of their respective surfaces. For triplane applications a resistive component is undesirable.

In Fig. 6, I schematically indicate a low-pass filter construction employing a plurality of impedances 40—41—42 of like construction and presenting to sound incident from direction 43 a succession of spaced compliances. The compliances are substantially normal to the sound direction 43 and may serve to dissipate the higher frequency components and therefore to pass low-frequency components, as may be desired to improve the discriminating characteristics of low-frequency responsive hydrophone or listening apparatus.

In the arrangement of Fig. 7, I schematically show a band-rejection filter construction. This construction may resemble that of Fig. 6, in comprising a plurality of spaced generally similar impedance elements 45—46 . . . 47, but these elements are oriented in substantially parallel relation with the predominant direction 48 of incident sound. At sufficiently high frequencies, sound may pass freely between the elements; at lower frequencies, and near the resonant frequency of the system, sound will be reflected and scattered; at much lower frequencies, the array appears stiff and hence becomes transparent again. In the frequency range at which the array scatters sound, the array effectively constitutes a diffraction grating. Curved arrays of elements may provide focussing diffraction gratings.

In Fig. 8, I show a further modification in which an array of impedance elements 50—51 . . . 52 serves as an acoustic lens receiving incident acoustic radiation, designated schematically at 54, and focusing at a transducer 53. The arrangement will be recognized as generally similar to Fig. 7, except that the disposition of the array of elements 50—51 . . . 52 is in a plano-convex cylindrical shape symmetrical about the acoustic axis 55. As in the case of Fig. 7, high-pass filter characteristics dominate the performance so that focusing action is achieved in the high-pass region.

The arrangement of Fig. 9 resembles that of Fig. 8, except that it applies for a generally spherical lens configuration, rather than cylindrical, as in Fig. 8. The slabs 56 are generally aligned with the direction 59 of incident radiation, and are arranged in a plano-convex spherical shape about the acoustic axis 58. Thus, focusing action in the high-pass region is analogous to that in Fig. 8, but, of course, since the focus is at a point rather than on an axis, a much smaller transducer 57 may serve to collect the incident energy.

In Fig. 10, I show arrangement of reflecting slabs 33' in the form of a parabolic cylinder to provide line-focusing action on a line hydrophone 30'.

Fig. 11 illustrates application of my invention for industrial use, and I have shown a shock mount suitable for accommodating one of the legs of a machine to be mounted on a floor. The mount comprises a base plate 60 and an upper loading plate 61 connected to each other by a compliant body 62 which may be of the transversely laminated variety discussed in conjunction with Fig. 1. For convenience, the upper plate is provided with a mounting stud 63, and the flange or projecting periphery of the base plate is provided with mounting holes 64 as for accommodation of bolts or lag screws. Both plates 60—61 may be intimately bonded to the compliant body 62 in order to provide a unit-handling assembly.

It will be appreciated that I have described a novel compliant structure of rather basic nature and having a wide variety of useful application. For industrial applications, the compliant slabs, with or without resistive

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damping, may be formed as square tile so that a whole floor area can provide compliant shock-proof base for machine or other operations; alternatively, individual shock mounts may be made for each point of support, as in Fig. 10. For underwater-acoustic applications, shielding, filtering, reflecting, refracting, and diffracting effects may be achieved as desired.

While I have described the invention in detail for the forms shown, it will be understood that modifications may be made within the scope of the invention as defined in the claims which follow.

I claim:

1. Mechanical impedance means, comprising a consolidated stack of like integral laminations defining a slab with opposed substantially coextensive surfaces to be subjected to transverse mechanical force, said laminations being oriented transversely of said surfaces and having opposed edges defining said surfaces, each lamination being slotted along a plurality of transversely spaced staggered rows to define a transversely compliant body between said surfaces.

2. A mechanical impedance according to claim 2, in which the slotted region of said laminations and therefore of said body is predominantly to one side thereof and in which the part of said body near the other side thereof is not slotted and is therefore better able to distribute a transversely applied load more or less uniformly over the compliant region defined by said slots.

3. A mechanical impedance, comprising a body consisting of a consolidated stack of transversely extending laminations, each lamination being of substantially the same planform and in registered overlap, each lamination having intermediate opposed transverse edges a plurality

of rows of staggered spaced openings defining a weakend compliant section.

4. An impedance according to claim 3, in which said laminations are of hard plastic material.

5. An impedance according to claim 3, in which said laminations are of metal.

6. A mechanical impedance, comprising two spaced substantially coextensive surfaces for subjection to a transverse force, stiffly compliant means comprising a consolidated stack of transversely slotted laminations oriented to extend between said surfaces, whereby said compliant means integrally connects said surfaces and is directionally compliant substantially transversely of said surfaces, and a pad of dissipative material bonded to one of said surfaces.

7. An impedance according to claim 6, and including a sheath of rubberlike sound-transmitting sealing material covering the other of said surfaces.

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