July 28, 1959 W. T. HARRIS 2,897,475

MOVABLE ACTUATING COIL TRANSDUCER ARRAY

Filed April 13, 1954

FIG. 1.

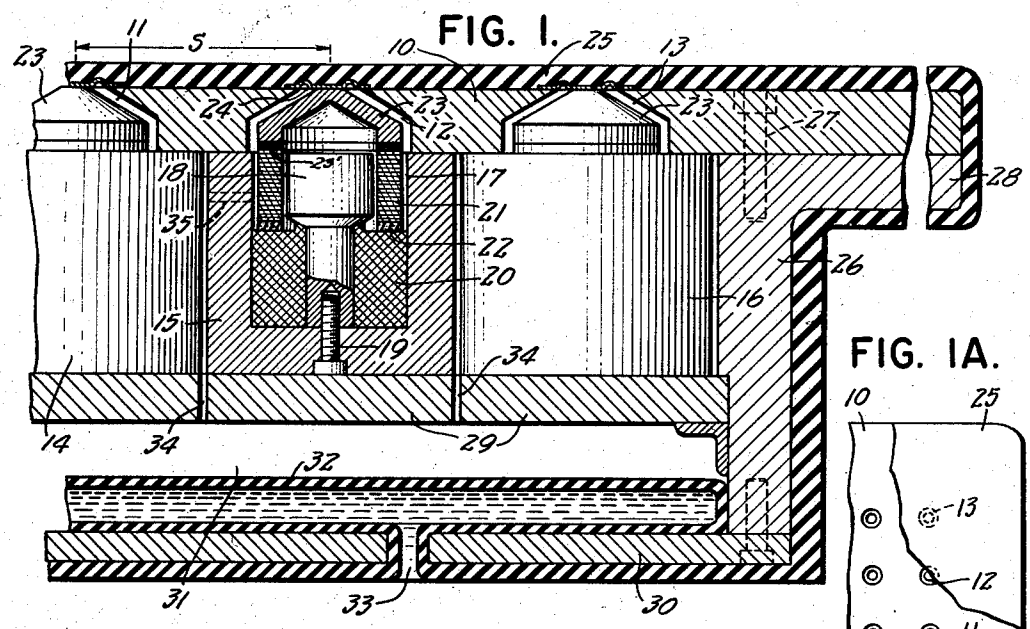


FIG. 1A.

FIG. 2.

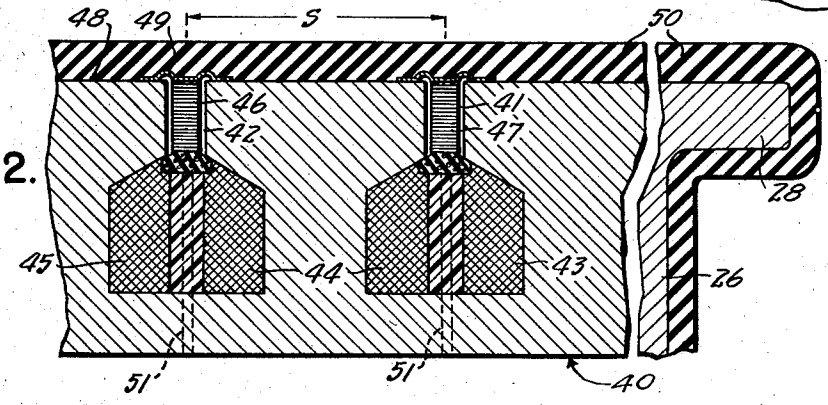
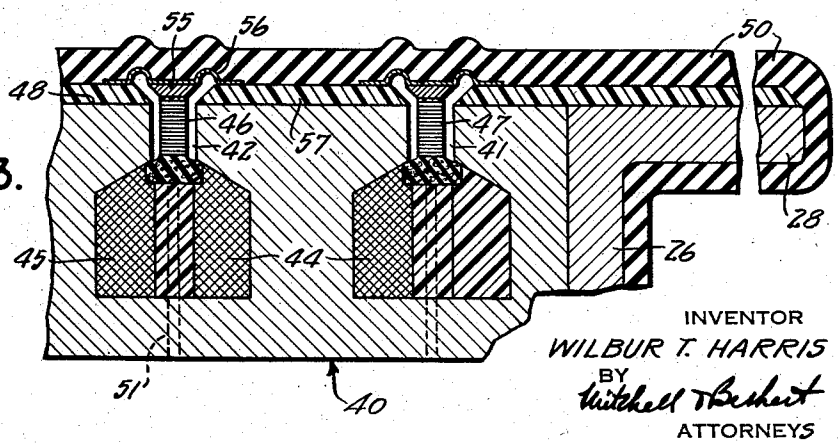


FIG. 3.



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United States Patent Office 2,897,475 Patented July 28, 1959

2,897,475

MOVABLE ACTUATING COIL TRANSDUCER ARRAY

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Application April 13, 1954, Serial No. 422,787

11 Claims. (Cl. 340—9)

My invention relates to improved electroacoustic transducer means and in particular to electromagnetic transducers, as of the character described in greater detail in my copending patent application, Serial No. 241,470, filed August 11, 1951.

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

It is another object to provide an improved means for coupling a transducer of the character indicated to the medium into which the transducer is to radiate or is otherwise to respond.

It is a further object to provide means for vastly improving the radiating efficiency of transducers of the character indicated.

Another object is to provide a transducer with improved high efficiency and broadband characteristics.

A further object is to provide an improved transducer utilizing an acoustically hard structure over a substantial part of the radiating face thereof, whereby the prospect of damage due to mishandling may be minimized.

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 sectional view of a transducer incorporating features of the invention;

Fig. 1A is a simplified fragmentary plan view on a reduced scale and partly broken-away, to illustrate the array configuration in Fig. 1; and

Figs. 2 and 3 are views similar to Fig. 1, but illustrating modifications.

Briefly stated, my invention contemplates the creation of a highly efficient broadband transducer from an acoustically hard structure, which presents to the radiating medium, such as water, an acoustically hard, essentially continuous plate; I term this plate a baffle because of its property to reflect acoustic signals. At spacings substantially less than a wavelength, preferably less than one-tenth wavelength at the desired response frequency, relatively small openings are provided in the baffle, and electrically driven force elements are supported for reciprocation in these openings. In the forms to be described, the force elements are essentially electrodynamic coils, which, if formed of sufficiently wide laminated-strip material, may themselves effectively constitute the radiating or driving areas. Alternatively, various area-transforming piston configurations may be applied to the coils in order to assure greatest efficiency of force application within the areas of baffle openings.

In one general form to be described, the baffle openings are circular and provided in a two-dimensional array, there being a separate electrodynamic force coil for such opening. In another general form, the openings are parallel slots, spaced as indicated with respect to the wavelength, and elongated racetrack-shaped force coils are provided, with opposed stretches in adjacent slots.

Referring to Figs. 1 and 1A of the drawings, my invention is shown in application to an electrodynamic transducer, in which the baffle plate **10** is a separate member of extensive area and provided with a plurality of openings **11—12—13** therein, said openings being spaced by an amount S, representing something substantially less than a wavelength at the desired response frequency; for example, the spacing S may be less than one-tenth of a wavelength. Adjacent the non-radiating side of the baffle **10**, I provide for each of the openings **11—12—13** a separate magnetic-core structure **14—15—16**, defining, symmetrically with respect to each of such openings and adjacent the non-radiating side of baffle **10**, an air gap such as the annular air gap **17** in the case of magnet **15**. The air gap **17** is defined between the enlarged head or pole piece **18** of an upstanding central member secured, as by bolt **19**, in the base of a generally cup-shaped magnetic core; the core **15—18** may be permanently magnetized, but I show that polarizing flux is established in the gap **17** by coil means **20**. It will be understood that the coils **20** for each of the magnet structures **14—15—16** may be energized in series or in parallel, depending upon their impedance with respect to that of the power supply.

Supported for reciprocation in each of the air gaps, as at **17**, I provide electrodynamic-coil means, and for the case shown in section in Fig. 1, the coil **21** is a helical development of laminated conductive strips suitably consolidated into unit-handling relation and supported on the core structure **20**, as by readily yieldable acoustically absorbent means **22** (such as air-filled rubber). In order to provide area transformation for efficient application of electrodynamically generated forces in the relatively restricted area of opening **12** at the radiating face of baffle **10**, I have shown a piston **23** carried by each of the coils, the connection being through suitable incompressible insulating means **23'**. The piston **23** is preferably of lightweight construction, as of magnesium or aluminum, and is excavated as much as tolerable, as suggested in the drawings. The piston **23** may be in effect a truncated cone, with the smaller or truncated area substantially in the plane of the radiating face of baffle **10**. Additional locating support for the coil may be provided by a relatively thin sheet-metal diaphragm **24**, peripherally secured at the opening **12** and centrally secured to the truncated face of piston **23**. For sealing purposes, and to present a clean appearance, a boot or outer layer **25** of acoustically transparent material may be bonded to the diaphragms **24** and baffle **10**.

The structure may be completed by employment of heavily flanged pieces **26**, constituting a housing to which baffle **10** is bolted, as at **27**. The baffle **10** may be coextensive with the outwardly extending flanges **28** of member **26**; but in any case I prefer to avoid loss of efficiency due to end effects, by providing further acoustically hard baffle radiating surface laterally outside the array of force elements, to a lateral extent substantially exceeding the spacing S between force elements.

For pressure-equalizing purposes, so as to render the transducer less depth-dependent, the side-flange pieces **26** may project substantially rearwardly of the backing plate **29** for the magnet assemblies, so as to support a back housing plate **30** spaced rearwardly of the plate **29** and defining therebetween a cavity or chamber **31**. Within the chamber **31**, I show a bag **32** of flexible material having an external opening at **33**, so as to be free-flooding. Air-bleed passages **34** (in the backing plate **29**) and **35** (in the magnet structure) provide a means for assuring ambient pressure in the region in which the electrodynamic coil is suspended, as will be understood.

In use, if the coil elements for the respective force elements are driven in phase, the described small-spot array radiates like a large diaphragm driven at larger force but

smaller amplitude; to the medium this diaphragm appears to have the size of the baffle. The forces and amplitudes are subject to a transformation ratio approximating the total-to-active area ratio, as long as one assumes the spacing S to be a relatively small fraction of a wavelength. Since the alternating acoustic pressure can never be appreciably different at two points which are separated only a very small fraction of a wavelength, the driven spots are not likely to produce cavitation effects when driven at high intensity. The impedance transformation greatly improves the electroacoustic conversion efficiency.

In Fig. 2, I show application of the principles of my invention to a parallel-gap array, as of the type disclosed in the above-mentioned copending application. This type of construction comprises essentially a magnet-core structure **40** having elongated parallel gaps **41—42**, spaced (as indicated above) by the amount S, representing a small fraction of a wavelength. The magnet-core material may itself be at least the central part of the acoustically hard baffle structure, so that no additional baffle need be provided, except at lateral flanges **28** of the housing **26**; the air gaps **41—42** are, therefore, strictly in the baffle surface. Separate coils **43—44—45** may be excited with polarizing current so as to assure the desired distribution of polarity at the respective gaps **41—42**, and in each two adjacent of said gaps I may support opposed stretches **46—47** of a single race-track-shaped coil, which may be a helical development of laminated conductive strip material. The front face of such coil **46—47** may be substantially in the plane of the radiating face of the baffle, that is, the face **48** of core structure **40**; and I have shown thin, yieldable, metal diaphragms **49** peripherally secured to the baffle face **48** at the gaps, and centrally secured to the respective stretches of the coil means **46—47**. As in the case of Fig. 1, a boot of acoustically transparent sealing material **50** may surround the structure. Also, when adapted for pressure-equalization, apertures, as at **51**, may communicate between the space behind the magnet core **40** and the region in which coil means **46—47** is supported; the pressure-equalizing means may be of the type described at **32** in Fig. 1 and is therefore not shown in Fig. 2.

In Fig. 3, I show a modification of the structure of Fig. 2, in which I employ area-transforming piston elements **55** carried by the respective coil means **46—47**, and preferably of magnesium, aluminum, or other light-weight material. The function served by the piston elements **55** is effectively to enlarge the force-transmitting area; elements **55**, therefore, may be of trapezoidal cross-section and may project slightly beyond the baffle surface **48**. It is convenient to provide a thin-metal diaphragm **56** for support of the coils, as by securing the same both to the coils and to the unexcited structure in a common plane. For this reason, I have applied a layer **57** of acoustically transparent material over the baffle area, except at the gaps **41—42**, and at these gaps the material **57** may be flared outwardly, as shown, to accommodate the sectional contour of piston elements **55**. The structure of Fig. 3 is otherwise as described for Fig. 2, and therefore the same reference numerals are used.

It will be appreciated that I have described relatively simple transducer structures lending themselves to improved efficiency and exhibiting broadband characteristics. These structures are further characterized by extreme ruggedness inasmuch as the exposed radiating surface is substantially entirely acoustically hard and may therefore be a heavy steel plate.

While I have described the invention in detail for the preferred 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. In a transducer of the character indicated, a passive baffle plate of acoustically hard material having two relatively small laterally spaced openings in the radiating face thereof and spaced by an amount representing a small fraction of a wavelength at the desired response frequency, flexible diaphragm means peripherally secured at each of said openings and covering each of said openings, magnetic-circuit means establishing air gaps adjacent the non-radiating side of said baffle and symmetrically disposed with respect to the axes of said openings, and electrodynamic driving means in said respective gaps and extending in direct force-transmitting relation with the back side of each of said diaphragms.

2. A transducer according to claim 1, in which the lateral extent of said baffle plate outside the space of said openings substantially exceeds the space between said openings.

3. A transducer according to claim 2, and including a boot of acoustically transparent sealing material overstanding the radiating surface of said baffle plate and of said diaphragms.

4. In a transducer of the character indicated, magnetic-core means defining a plurality of spaced elongated gaps, a movable strip of conductive material including opposed stretches in the respective fields of two of said gaps, said magnetic-core means being formed with an essentially continuous surface constituting an acoustically hard baffle interrupted only at said gaps, whereby said movable conductive strip may in part fill said gaps to provide a substantially continuous radiating surface, and means flexibly supporting said strips in said gaps for reciprocation on axes generally normal to said surface.

5. A transducer according to claim 4, in which said movable strip of conductive material comprises a helical coil containing a plurality of turns of laminated strip material, there being a plurality of laminations in the field of each of said gaps.

6. In a transducer of the character indicated, magnetic-core means comprising a plurality of pole pieces oriented to define in a radiating surface a plurality of spaced elongated gaps, a moving conductive coil including two opposed stretches movably supported in two of said gaps, and piston means carried by said coil at the radiating end thereof in clearance relation with said gaps and substantially filling said gaps.

7. A transducer according to claim 6, in which said piston means has an effective cross-section of trapezoidal configuration with the base thereof secured to said coil so as to provide an area-transforming element.

8. A transducer according to claim 7, and including a layer of acoustically transparent material covering the radiating surface except at said openings, said layer being of a thickness to place the front face thereof in substantially the plane of the radiating face of said piston.

9. A transducer according to claim 7, and including acoustically absorbent supporting means for said coil on the non-radiating side thereof.

10. In a transducer of the character indicated, a baffle plate of acoustically hard material having two relatively small laterally spaced openings in the radiating face thereof and spaced by an amount less than a wavelength at the desired response frequency, flexible diaphragm means peripherally secured at each of said openings and covering each of said openings, magnetic-circuit means establishing air gaps adjacent the non-radiating side of said baffle and symmetrically disposed with respect to the axes of said openings, electrodynamic driving means in said respective gaps and extending in direct force-transmitting relation with the back side of each of said diaphragms, a rigid housing fixedly supporting said magnetic circuit means and defining between said magnetic circuit means and a part of said housing a pressure-equalizing cavity with an external opening on a side other than the radiating side of said transducer, a collapsible flexible bag within said cavity and covering said opening, whereby fluid may enter said opening and fill said bag, there being a fluid-communicating opening between one of said gaps and the other side of said collapsible bag, where-

by air within said transducer may be maintained under ambient fluid-pressure conditions.

11. In a transducer of the character indicated, an extensive acoustically hard baffle plate, an array of separate magnet assemblies adjacent one side of said plate, said magnet assemblies defining in each instance an annular air gap immediately adjacent said baffle plate, said baffle plate being locally recessed adjacent each said air gap and having for each said recess an opening to the opposite side thereof, piston means comprising an electrodynamic coil suspended for axial reciprocation in each of said gaps and including a part projecting through said baffle plate at the recess therein, said projecting part comprising a truncated conical area-transforming member secured at the base to said coil, a flexible diaphragm peripherally secured to the opening in said baffle plate and centrally

secured to said area-transforming member for supporting said member with the truncated base substantially in the plane of said other side of said baffle plate.

References Cited in the file of this patent

UNITED STATES PATENTS

1,852,068	Sykes	Apr. 5, 1932
1,872,799	Pare	Aug. 23, 1932
2,014,413	Pierce	Sept. 17, 1935
2,044,807	Noyes	June 23, 1936
2,346,655	Benioff	Apr. 18, 1944
2,380,931	Batchelder	Aug. 7, 1945
2,405,185	Benioff	Aug. 6, 1946
2,410,806	Black	Nov. 12, 1946
2,725,219	Firth	Nov. 29, 1955