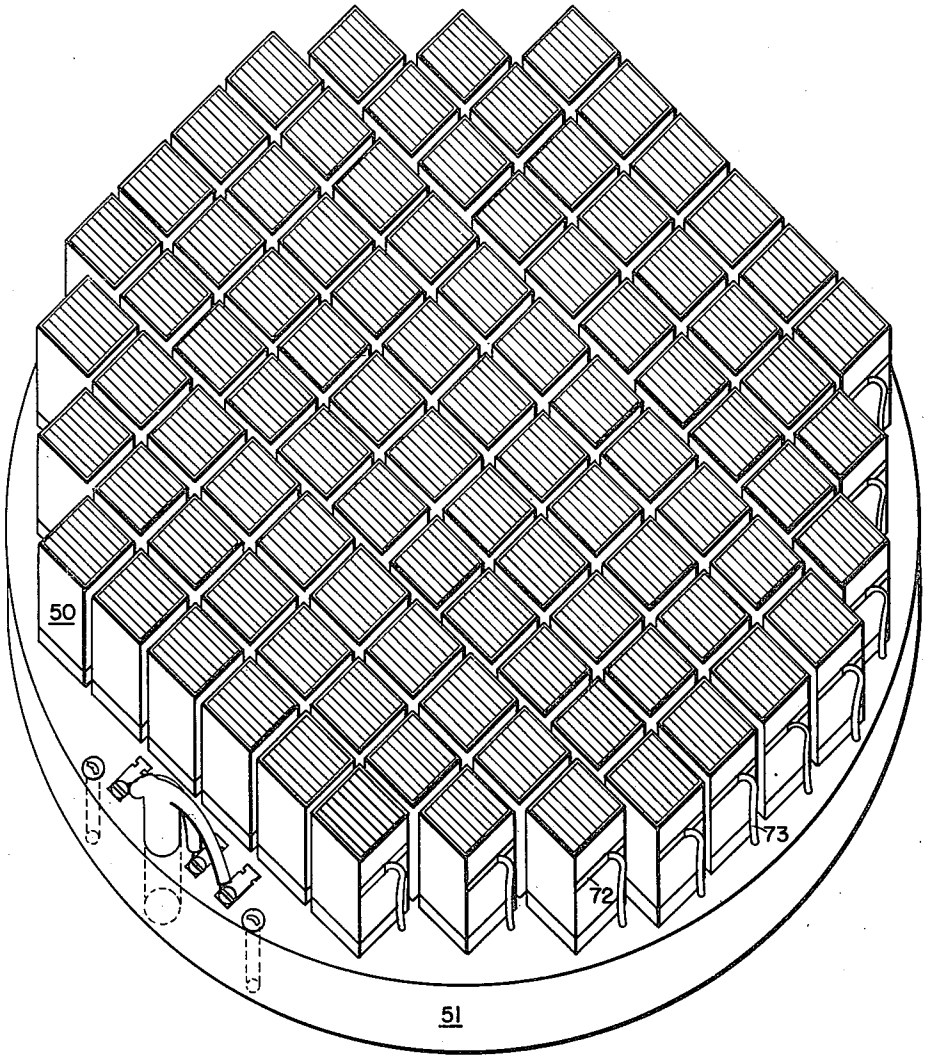
June 24, 1952 E. KLEIN 2,601,300

ELECTROACOUSTIC TRANSDUCER

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Fig. 1



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FIG. 2

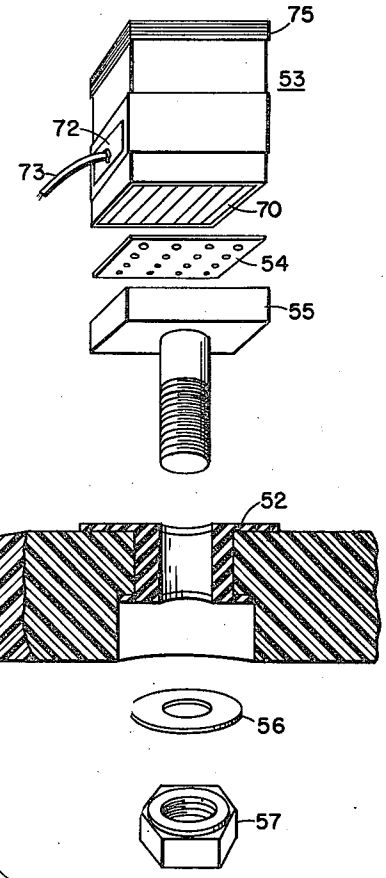
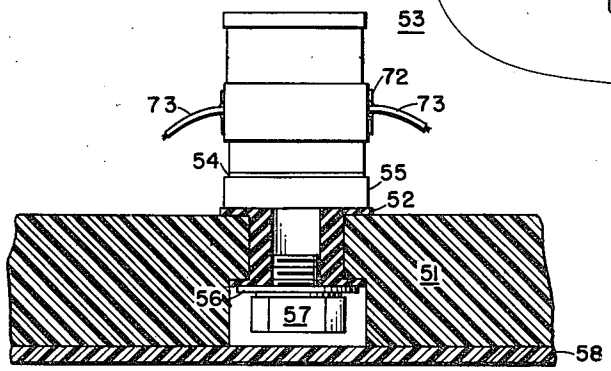


FIG. 3



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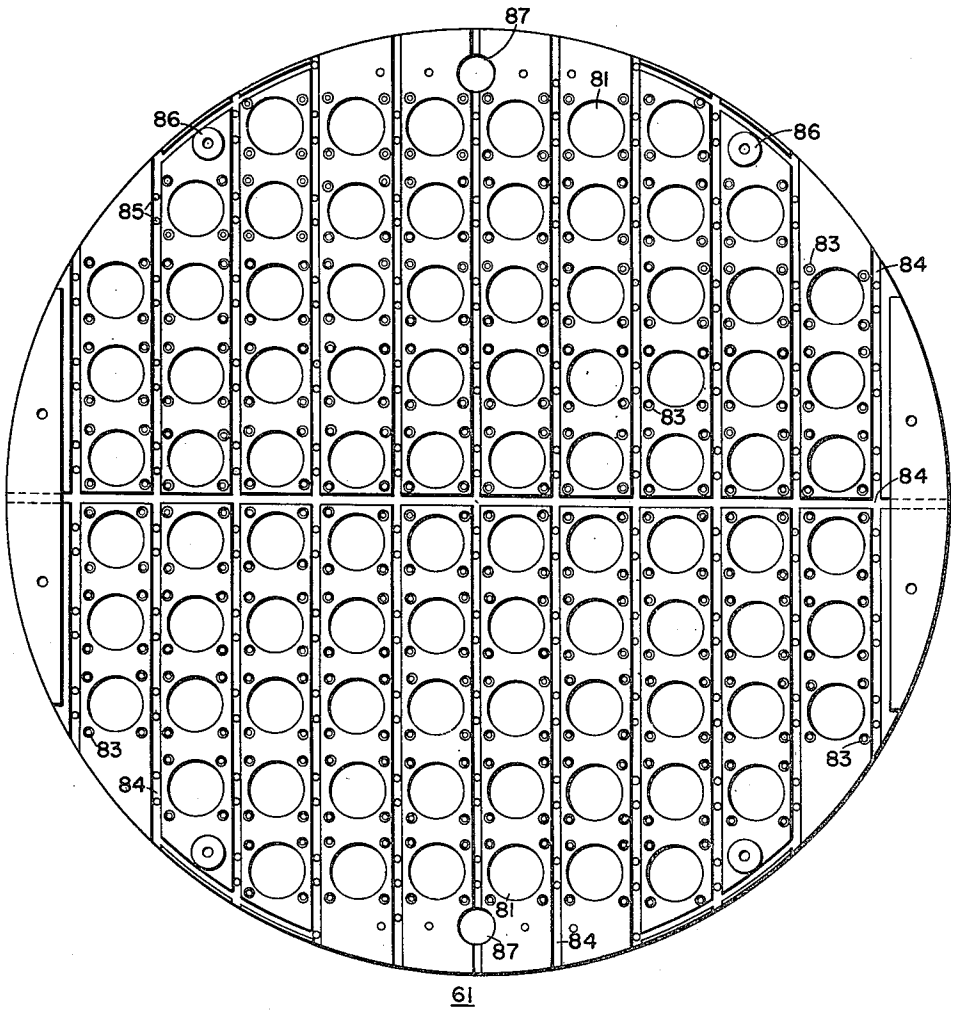
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ELECTROACOUSTIC TRANSDUCER

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FIG. 4



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FIG. 5

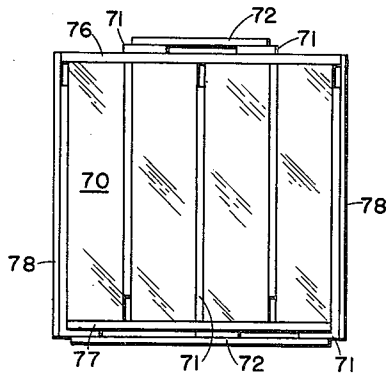


FIG. 7

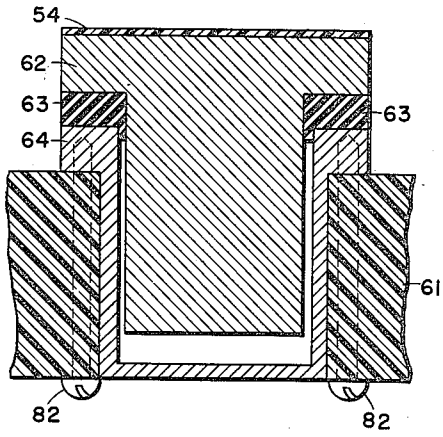


FIG. 6

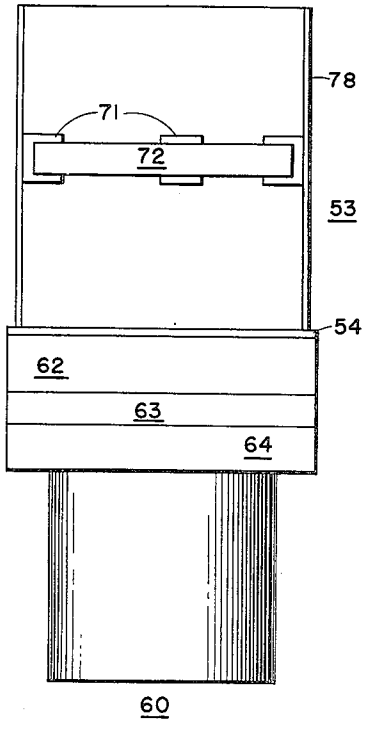
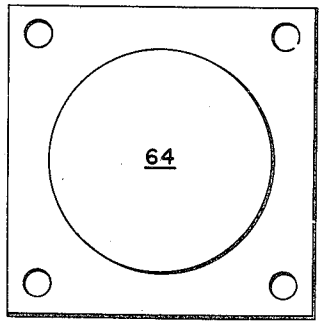


FIG. 8



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ELECTROACOUSTIC TRANSDUCER

Elias Klein, Washington, D. C.

Application February 20, 1946, Serial No. 649,103

2 Claims. (Cl. 177—386)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

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This invention relates to electroacoustic transducers for the radiation and reception of underwater sound waves. It has particular application to a directive transducer which has the form of an array of piezoelectric units.

Objects of the present invention are to provide a directive piezoelectric transducer involving an array of independent piezoelectric transducer units, which will have minimized coupling between unit transducers, great flexibility for adjustment of directional properties, controllable phase, frequency, and amplitude conditions of any part of the vibrating array without interference of one part on the other, greater ease of attaining high radiating power levels over a large range of frequencies, a more satisfactory response characteristic over a large range of frequencies, lighter weight and properties of ease of construction, modification and repair not hitherto achieved in devices of this class.

Features of the invention are the use of a combination of piezoelectric crystals and metal backing member as an individual vibrating unit transducer which has its own sealed off air back space, so that a plurality of such isolated units may be mounted in a base plate of light material to form an array, any particular selection of subarray within the whole, or any selective vibrating condition for any subarray being accomplished by a switching of electrical connections. The invention contemplates a closely similar combination of magneto-striction unit transducers, in which each transducer vibrates in front of its own air space, although in the following description attention will be confined to piezoelectric devices.

In a known construction of piezoelectric projector which may be regarded as standard, an array of crystals is cemented to a single metal backing plate. The crystal vibrating system is matched to the acoustic impedance of the liquid medium in which the compressional disturbances are transmitted. The acoustic impedance looking back from the vibrating system of crystals and metal plate must be a violent mismatch, in order to prevent back radiation, and this is achieved by providing an air space behind the plate. If in addition the projector is designed for high directivity in the beam pattern, the ratio of transverse dimension to wavelength of the compressional disturbance is high. To reduce unwanted side lobes, different parts of the array are driven to vibrate with different amplitudes.

In such known construction of projector, the

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metal back plate is of finite size. The facts that an edge exists and that in any practical system there must be supports for the plate, even though these be pliant, introduce boundary conditions on the vibration. In general, projectors are utilized over a range of frequencies which often include several resonant modes of the vibrating system, which depend on the specific boundary conditions. It may be possible to design the vibrating system so as to minimize the effect of specific boundary conditions over a determinate range of frequencies. However, because of the complex coupling through Poisson ratio in the metal plate, the amplitude distribution over the vibrating system is not altogether controllable. This becomes the more aggravated the broader the band of frequencies encompassed in any application, and particularly when such a band includes higher frequencies.

In submarine work, a directional projector of the known type described above must be of substantial construction to withstand pressures ordinarily encountered. The metal plate must itself be of sufficient thickness to withstand the force applied, and this in turn increases difficulties with the elastic properties of the plate, in addition to increasing the overall weight of the projector. Increasing the transverse dimension or diameter of the projector, for the purpose of increasing directivity, will enhance this difficulty. Some recent applications arising in connection with measurement of phase of compressional disturbances require flexibility in the operating characteristics of the projector. For example, in receiving, the array of crystals may have to be effectively split in order to afford means of measuring the deviations off the sound beam axis through indication of phase differences between the waves reaching the one and the other half. For maximum efficiency it is necessary that any coupling between halves be a minimum.

In the known type of projector involving a single metal back plate, isolation is not possible due to the coupling through the metal plate. Ordinarily, reception takes place over a range of frequencies covering some of the resonant modes of the vibrating system, which modes tend to introduce spurious phase relations between the two halves. Such difficulties are multiplied if further division of the projector is undertaken, as for example for the measurement of phase relations of an incoming wave in reference to a number of planes. The difficulties are further

enhanced if the range of frequencies includes high frequencies. In other applications, the projector is required to be an even more flexible instrument in that it may be utilized as a single piston to radiate compressional waves, in addition to the receiving functions involving phase discrimination, as mentioned above. It may be further required to radiate in some complex mode, being driven with differing amplitudes in different parts of the radiating face. It is clear that all the difficulties heretofore enumerated will be encountered in this situation.

In known types of piezoelectric array projectors, such as have been described, to remove elements of the crystal array for purposes of maintenance or repair is a tedious and difficult task. It involves roughly the steps of removal of projector, and extraction of the crystal to be removed by means of heating the whole assembly of base plate and crystals in order to weaken the glue or cement with which the crystal is secured to the plate, or by means of chipping the crystal out with a chisel or other such instrument. In either case it is generally found that the projector characteristics are not the same after the operation has been performed. The process of insertion of one or more new crystals obviously immobilizes the whole projector for the length of time required to bring the projector to a condition satisfactory for operation.

As will appear hereinunder, it has been found entirely practicable to construct a projector which greatly reduces many of the difficulties heretofore encountered, including those mentioned above. Being composed of units, which can be made to predetermined specifications, production in quantity of projectors of a variety of vibratory characteristics is entirely possible. The invention has the added advantage of particular ease of construction, modification and repair, as will appear from perusal of the following description and drawings, of which:

Fig. 1 depicts a face of one embodiment of projector,

Fig. 2 is an exploded view of a unit transducer and a section of its mounting plate,

Fig. 3 is an assembled view of the same transducer, in its mounting plate,

Fig. 4 shows a rear view of a mounting plate for a second type of unit transducer,

Fig. 5 depicts a top view of the second type of unit transducer,

Fig. 6 shows a side view of the same transducer,

Fig. 7 shows a section of the backing member and air cell of the same transducer, and

Fig. 8 shows a bottom view of the type of transducer of Figs. 5 to 7.

There is depicted in Fig. 1 a face view of an embodiment of projector of the invention. This embodiment is constituted of crystal transducer units **50**, each unit isolated from all other units. The units **50** are mounted in a perforated base plate **51** of Bakelite or like material, fitting through holes, or cavities, in the base plate, such as are shown in section in Fig. 2. The crystal faces shown in the units **50** are in direct contact with a liquid transmissive medium. Electrical excitation is supplied to the crystals by means of electrical leads **73**, which pass through the base plate **51** and are soldered to metal terminal strips **72** on the sides of the crystal assembly. In Fig. 2 is shown an exploded view of unit transducer **50**, as it would be fitted into the base plate **51**. The transducer unit **50** is seen to be composed of crystal assembly **53**, a thin perforated Bakelite strip **54**, a metal backing block **55** having a screw head of diameter fitting the acoustically insulating gasket **52**, a washer **56**, and a nut **57**. In Figs. 5 and 6, crystal assembly **53** has the usual interlaced electrodes **71** protruding on alternate sides corresponding to their polarity, and the tabs of the electrodes **71** soldered to terminal strips **72**, to which suitable electrical leads may be soldered. Bakelite insulating plates are glued to the sides of the crystals and may be secured by a waxed cord as shown in Fig. 2 for the crystal assembly **53**. The tabs of electrodes **71** fit through slots in the Bakelite insulating plates. The crystal assembly **53** is cemented to metal backing block **55**, the perforated Bakelite strip **54** being in between, with vulcalock or other suitable compound. Perforation of the strip **54** allows better cementing. The crystals and backing block thus form a vibrating unit. It is seen that the gasket **52** overlaps the offset in diameter of the cavity in the base plate **51**. It is seen that the enlargement in diameter of the cavity in the base plate **51** affords space for air around the nut and the end of the screw head, so that if this space is sealed off, each unit looks back into its own isolated air space. Such sealing may be accomplished by cementing or otherwise suitably securing a thin Bakelite plate **58** across the entire back plate. The plate may be thin because the force on any part of it is no larger than that on the radiating face of a single crystal assembly. It is seen that each air space is indeed isolated from all others in this construction. The coupling of the vibrating system to the base plate is through the insulating gasket **52**, and therefore may be assumed to be minimised. Since the base plate **51** serves as a non-vibrating member, it may be supported or fastened in any suitable manner, with due regard to structural strength, without this affecting the vibratory characteristics of the projector.

With such construction, manufacture is readily accomplished in a number of systematic steps. Base plates are made containing a maximal number of holes, all of which may not be used. Gaskets are fitted into the pattern of holes corresponding to the desired array. Crystal assemblies cemented to metal backing blocks, the whole having determined vibratory characteristics, are selected. The crystal units are fitted into the gaskets in desired order, nut and washer secured; a thin Bakelite plate is then sealed to the back of the base plate. Those of the holes that are unused may be blocked with Bakelite plugs. Electrical connections are then made as desired, to achieve the complex vibratory structure. The projector housing and frames may then be put on, and the housing filled with oil, as is common in projector construction.

It is easily seen that any change in any characteristic of electrical excitation of any part of the crystal array, independently of any other part, is achieved by proper switching of electrical connections. It is possible, for example, to use only one line of units as a battery of radiators excited in single phase, in order to get a very wide beam pattern in one plane dimension, and different width in another plane, or use half of the radiating face along with selected parts of the other half, in any desired phase relation.

It is likewise clear that each unit vibrates in the phase relation to the others that is set on the electrical controls, or in the phase relation of the various parts of the impinging compressional waves. Thus the uncontrollable phase conditions that appear in a known type of pro-

jector, owing to the boundary conditions and the complex coupling through the plate, particularly in use over a wide range of frequencies, are absent in the projector of the invention. As complicated a vibrating condition as desired may be set up in a projector of the invention with a minimum of interference of the vibrations of one part on that of another.

The lack of boundary conditions in the projector of the invention causes lack in the response characteristic of the pronounced resonant peaks that occurred over a range of frequencies in various known types of projector. Because of the smoothness, a more uniformly high power level over a range of frequencies is more easily attainable.

For a variation in response characteristic, unit transducers tuned to different frequencies may be inserted, without interference on other parts of the projector.

A second and preferred embodiment of the invention is constituted of the transducer units **53** depicted in Figs. 5 to 7, mounted in the base plate shown in rear view in Fig. 4. Fig. 4 shows circular holes **81** in the base plate **61**, in which the units **60** fit. The units **53** are secured as shown in Fig. 7, by means of four screws **82**, fitted through holes **83** in the base plate **61**, shown in Fig. 4. The base plate includes regular depressions **84** to effectively guide electrical connections. The paired holes **85** are to allow the passage of electrical leads through the base plate **61**. Extensions **86** and the holes **87** are for purposes of securing the plate **61** to a supporting frame. Fig. 5 shows a face view of the unit, with crystals **70**, electrodes **71**, the crystals being sandwiched between electrodes and the tabs on electrodes of opposite polarity taken out on opposite sides of the crystals, through slots in upper and lower Bakelite side plates **76** and **77** respectively. Metal strips are soldered to the tabs of the electrodes, and in turn serve as soldering terminals for electrical connections **73**. The sides of the crystals may be silvered, or tinned, according to known art, for better electrical contact to the electrodes. Bakelite side plates **78** help to contain the crystal assembly, and may be secured with a waxed cord as shown in Fig. 2 at **75**.

This description of structure of crystal assembly **53** may serve also for the crystal assembly of the first described unit transducer **50**, so that these are given the same designation. Considerable variation in crystal width and length, depending on the particular usage, is possible in such assemblies. The side view of unit transducer **53** shown in Fig. 6 depicts the crystal assembly **53**, with the metal strip **72**, and the tabs of electrodes **71** protruding slightly on both sides of the strip **72** to which these are soldered. The crystal assembly is cemented through perforated Bakelite strip **54** to the metal backing block **62**. The strip **54** is the same as described in connection with the first transducer unit **50**. The backing block **62** is sealed in the air cell contained in the metal cup **64** by means of insulator **63**, which may be of rubber or like acoustically insulating material. It is seen that the metal cup **64** is merely for the purpose of supplying a sealed air cell, and is not included in the vibrating system, so that vibration is confined in the unit. When electrically excited, the system of crystals and backing block form a vibrating unit.

In Fig. 7 is shown a section view of the base of the unit transducer, with Bakelite strip **54**, metal backing block **62**, insulator **63**, and metal cup **64**, fitted in base plate **61** of Bakelite or similar material, and secured thereto by means of screws **82**. This part of the transducer, namely, backing member sealed in the air cell, is tested to the specification of the pressures anticipated, in order that effective insulation is assured at the maximum pressures. Fig. 8 shows a rear view of the unit transducer, which is the same as that of the metal cup **64**.

It should be noted that with this construction of unit transducer the manufacture of projectors is accomplished in an even simpler sequence of steps than in the first embodiment. Base plates are selected as before. Transducer units are fitted in the plates in the desired array, and electrical connections made thereto. Change in vibrating characteristics of the projector, for example introducing units of different frequency characteristics, may be made by means of a simple replacement of units, involving removal of electrical connections, and withdrawing four screws.

It should be noted that the face view of this embodiment of the projector will be highly similar to that shown in Fig. 1.

It should be clear that the vibrating characteristics of this embodiment are at least as flexible as that of the first embodiment, and that the advantages mentioned for the one hold also for the other.

As has been pointed out already, parallel principles may be applied to a magnetostrictive unit transducer.

Numerous and new applications and advantages of the invention will occur to those skilled in the art. No attempt to exhaustively cover all applications and point out all advantages of these principles has here been made. The scope of the invention is defined in the following claims.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

What is claimed is:

1. An underwater transducer comprising a linearly vibrating piezoelectric crystal transducer element having opposite flat parallel vibrating faces, an individual relatively massive backing block fixedly secured to one of said vibrating faces, a base member for said transducer element having formed therein an air chamber open at only one end, said transducer element being mounted with its backing block across the open end of said chamber in overlapping relation with said open end, and a sealing gasket element interposed between the overlapping portions of the backing block and base member and constituting the sole mechanical connection between the backing plate and the base member.

2. An electromechanical transducer unit comprising an electromechanical transducer element having opposite flat vibrating end faces, a metal backing block having a rearward extension of reduced area of transverse cross section leaving a shoulder around the extension, a relatively thin sheet of hard electrical insulating material interposed between one of said end faces and the front of the backing block and cemented both to the end face and the block to bind the whole solidly together, a rimmed metal cup member encasing said rearward extension of the backing block with an air space clearance between the back of the extension and the bottom of the cup member, and an acoustically insulating sealing member interposed between said shoulder and

the rimmed portion of the cup member, said sealing member constituting the sole mechanical connection between the backing block and the cup and said cup member being cylindrical in outside contour with the rim portion extending radially outwardly to form a shoulder whereby the cup may be fitted as a shouldered plug into a cylindrical bore.

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