July 3, 1956 W. H. RYMES 2,753,543

TRANSDUCERS

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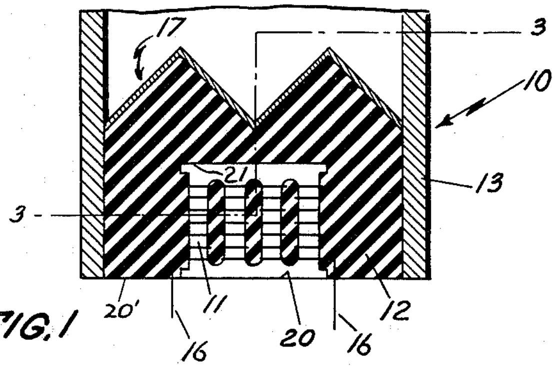
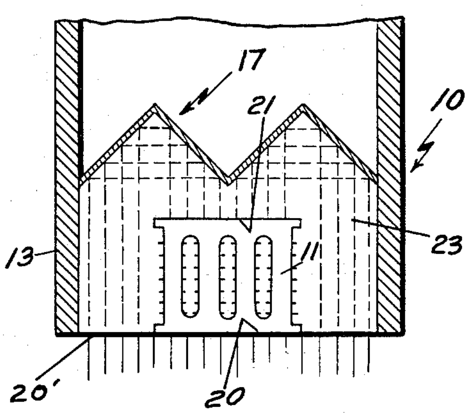


FIG. 1

FIG. 2



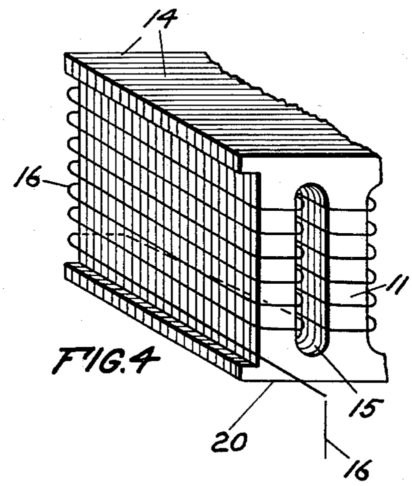


FIG. 4

FIG. 3

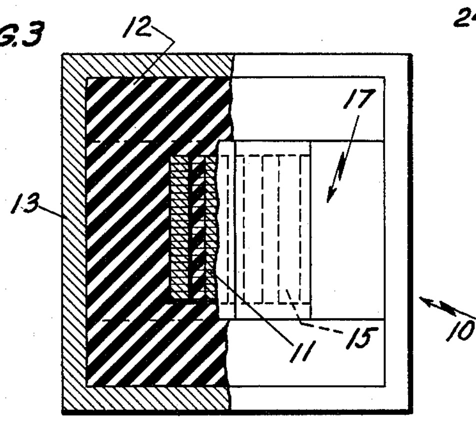


FIG. 5

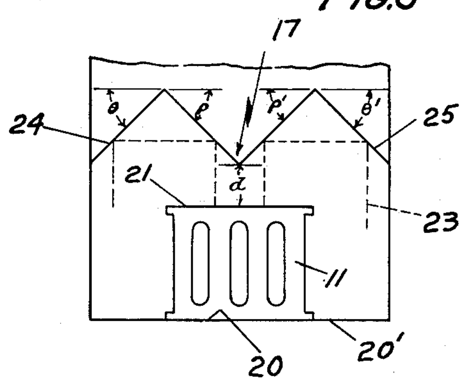


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FIG.7

FIG.6

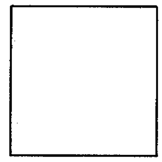


FIG.9

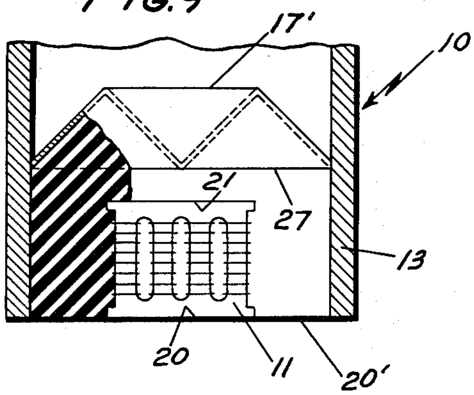


FIG.8

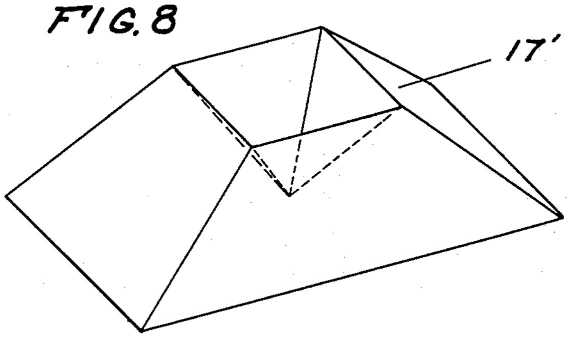


FIG.10

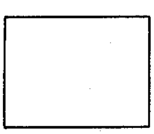
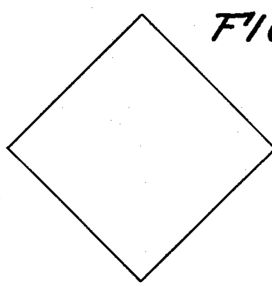


FIG.11



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TRANSDUCERS

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Application August 28, 1952, Serial No. 306,875

4 Claims. (Cl. 340—11)

This invention relates to a compressional wave transducer and, more particularly, relates to means for increasing the effective driving surface of a transducer to achieve greater directivity of the energy radiated therefrom.

An object of this invention is to provide means for increasing the effective driving surface of a compressional wave transducer.

Another object of this invention is to provide a compressional wave transducer having improved directivity for a given size.

A further object of this invention is to provide means for varying the focal length of the beam of a compressional wave transducer as a function of the shape of a reflector mounted near one face of said transducer.

As is well known in the art, the intensity of compressional wave energy at different points equidistant from a transducer is dependent upon the dimensions of the driving surface compared with the wave length of said energy. The energy is largely confined within a diverging beam whose axis is perpendicular to the center of the driving surface. The angle of spread of the beam is proportional to the ratio of the wave length of said energy to the dimensions of the driving surface. The larger this ratio is made, that is, the larger the area of the driving surface for a given frequency, the greater the directivity from the transducer.

Pursuant to this invention, the directivity of a transducer having a first generating surface in contact with the medium through which transmission of energy is required and a second generating surface opposite said first surface is increased with the aid of one or more reflectors so positioned adjacent said second surface of the transducer that the compressional wave energy radiated from said second surface and reflected from said reflector or reflectors is in phase with the energy radiated from said first surface.

By adjusting the angle of the reflector or reflectors and thus the angle of incidence of the energy reaching the reflector after emission from said second surface, the beam of compressional wave energy may be focused at any desired depth in said surrounding medium.

In the drawings:

Fig. 1 is a central longitudinal section view of a first embodiment of a transducer assembly according to the invention;

Fig. 2 is a view in elevation of the transducer assembly of Fig. 1 illustrating certain principles of operation and omitting the transducer supporting means for the sake of clarity;

Fig. 3 is a plan view, partly in section, of the transducer assembly of Fig. 1, the section being taken through line 3—3 of Fig. 1;

Fig. 4 is a fragmentary detail view of the transducer used in the assembly of Figs. 1 to 3;

Fig. 5 is a sketch illustrating certain operating principles of the transducer assembly shown in Figs. 1 to 3;

Fig. 6 is a view illustrating the effective driving surface obtained with a conventional transducer;

Fig. 7 is a view showing the effective driving surface obtained with the transducer assembly shown in Figs. 1 to 3;

Fig. 8 is a second form of reflector which may be used in a transducer assembly according to the subject invention;

Fig. 9 is a view in elevation, partly in section, of a second embodiment of a transducer assembly according to the invention utilizing the reflector shown in Fig. 8;

Fig. 10 is a view illustrating the effective driving surface obtained with a conventional transducer having an area equal to the base of the pyramidal re-entrant portion of the reflector of Fig. 9; and

Fig. 11 is a view showing the effective driving surface of the transducer assembly shown in Fig. 9.

Referring to Figs. 1 to 4, a transducer assembly, generally indicated by reference numeral **10**, comprises a magnetostrictive transducer **11** molded in a substance **12** having an acoustical impedance substantially equal to that of the medium into which the transducer is to operate. For example, if the medium is sea water, the substance **12** may be a type of rubber whose wave impedance is substantially equal to that of the aforesaid medium.

Although substance **12** is shown as a solid mass, it is possible to use castor oil or other liquids having a suitable acoustical impedance, in which case it is necessary to provide proper supporting means for transducer **11**.

The molded mass **12** is encased in a housing **13** which, although shown as rectangular in Fig. 3, may be any convenient shape, such as rectangular, circular or oval. Housing **13** may be made of any material having sufficient rigidity and mechanical strength.

Transducer **11** is illustrated in detail in Fig. 4; the body portion **11** comprises a plurality of laminations **14** having elongated slots **15** through which winding **16** may be inserted. The terminals of winding **16** are adapted to be connected to the usual receiving and transmitting means, as is well known in the art.

The transducer need not be limited to the exact details shown in Fig. 4, and other types of magnetostrictive transducers may be used. Moreover, crystal transducers may be used in lieu of magnetostrictive transducers, if desired.

Transducer **11** has two opposed radiating surfaces **20** and **21**; surface **20** is adapted to contact a medium through which the compressional wave energy is to be propagated.

A multi-surface reflector **17**, which is opaque to compressional wave energy, is positioned in housing **13** adjacent surface **21** of transducer **11**. Reflector **17** may comprise a solid metallic plate, as shown in Figs. 1–3, or may comprise a metallic backing plate to which a coating having good reflecting properties is cemented or otherwise attached. This coating, for example, may consist of a combination of cork and neoprene having several air cells. Since air is a good reflector of compressional wave energy, the reflecting power of reflector **17** may be enhanced.

Energy radiated from surface **21** impinges upon reflector **17** and is reflected therefrom. The path of the compressional waves radiated from surfaces **21** of transducer **11** is shown by the broken lines **23** of Fig. 2. An inspection of Fig. 2 indicates that not only the energy from surface **20** but also that from surface **21** is available for propagation into the desired transmission medium in contact with surface **20'**.

The radiating surface **20'** resulting from the transducer of Figs. 1 to 3 when reflector **17** is omitted is shown in Fig. 6. The effective radiating surface **20'**, resulting when transducer **11** is provided with a reflector, is shown in Fig. 7. For a reflector whose sides are positioned at an angle of forty-five degrees with surfaces **20** and **21**, as shown in Figs. 1 to 3, the area of the driving surface is doubled when a reflector is used.

Since the angle of incidence and reflection of the compressional waves for the reflector of Figs. 1 to 3 is forty-five degrees, the path lengths of the compressional waves from the various points of surface **21** are all equal. This insures that the energy at all points along surface **21** is in time phase.

The phasing of the compressional waves leaving surface **21** with respect to the waves leaving surface **20** is adjusted by varying the distance *d* shown in Fig. 5. In other words, the time required for the compressional waves from the various points on surface **21** of transducer **11** to travel to reflector **17** and be reflected back to surface **20'** is dependent upon the degree of spacing between the reflector and the transducer. By moving the entire reflector up and down, an optimum distance *d* is reached at which the reflected compressional waves emerge from surface **20'** in time phase with the compressional waves radiated directly from surface **20** of transducer **11**. By adjustment of the angles θ shown in Fig. 5, a focusing of the beam may be accomplished. For example, if angles ρ and ρ' are equal to forty-five degrees, and if either of angles θ or θ' or both are made larger than forty-five degrees, the compressional waves reflected from surfaces **24** and **25** will be bent inward toward the center of the transducer. At some point in the transmitting medium, dependent upon angles θ or θ' or both and also dependent on the angles ρ and ρ', the beam will be focused. Since the wave length of the compressional waves is of the order of four inches, the amount of change in angle θ necessary to focus the beam at a distance, say 100 feet, will be only a fraction of a degree. For this reason, therefore, the adjustment of angles θ and θ' is somewhat critical. It is preferable, therefore, to preset the angle θ which surfaces **24** and **25** of reflector **17** make with either surfaces **20** and **21** of transducer **11** to correspond to the focal length desired and build this angle into the transducer.

The shape of the beam pattern may also be varied by selection of reflectors. A second possible compound reflector **17'** for use with transducer **11** is shown in Figs. 8 and 9. Reflector **17'** comprises a metallic sheet in the form of a frustum of a pyramid having a pyramidal reentrant portion whose apex lies in the plane of the base **27** of said frustum. The angles formed by any two adjacent surfaces impinged by the compressional waves from transducer **11** are made substantially equal to forty-five degrees. Reflector **17'** is positioned adjacent to and spaced from surface **21** of transducer **11**, as in the case of reflector **17** of Figs. 1 to 3 and 5.

The distance between the base **27** of reflector **17'** and surface **21** determines the phasing between the compressional waves emitted directly from surface **20** of transducer **11** and the reflected compressional waves arriving at surface **20'**.

As in the embodiment of Figs. 1–3 and 5, the beam focus may be adjusted by varying slightly the slope of one or more of the surfaces of reflector **17'**.

The active surface of transducer assembly **10** of Fig. 9 in the absence of reflector **17'** is equal to the area of surface **20** of the transducer **11** and is shown in Fig. 10, while the active surface obtained when reflector **17'** is used with the same transducer is shown by Fig. 11. Because of the reflection of energy from the surfaces of the pyramidal reentrant portion, as well as from the surfaces of the frustum of the pyramid, in the reflector **17'** of Figs. 8 and 9, the effective driving surface of the transducer assembly of Figs. 8 and 9 is of square configuration, rather than rectangular, and furthermore, is oriented at an angle of forty-five degrees with respect to that obtained without the use of the reflector **17'**. For this reason, the effective driving surface shown in Fig. 11 is positioned at an angle of forty-five degrees relative to that shown in Fig. 10. A comparison with Fig. 10 indicates that the surface area and hence the directivity of transducer **10** of Fig. 9 is increased over that for a similar transducer without a reflector.

The reflectors herein shown and described are merely illustrative; other reflectors may be used besides the two types shown and described to accomplish an increase in the effective driving surface of the transducer.

This invention is not limited to the particular details of construction, materials and processes described, as many equivalents will suggest themselves to those skilled in the art. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. A device for transmission of compressional wave energy through a medium comprising a transducer having a pair of opposed vibrating surfaces, said transducer being mounted within a body of material having a wave impedance substantially equal to that of said medium and having one of said surfaces in physical contact with said medium, a multi-surface reflector secured to said body and positioned adjacent the other of said opposed surfaces, said reflector being in the form of a frustum of a pyramid having a pyramidal reentrant portion whose apex lies in the plane of the base of said frustum, said reflector being adapted to reflect incident energy from said other surface in phase with the energy radiated from said one surface, thereby increasing the effective driving surface of said device to obtain greater directivity therefrom.

2. A device as recited in claim 1 wherein said surfaces of said reflector are disposed at an angle of forty-five degrees with said opposed transducer surfaces.

3. A device for transmission of compressional wave energy through a medium comprising a transducer having a pair of opposed vibrating surfaces, said transducer being mounted within a body of material having a wave impedance substantially equal to that of said medium and having one of said surfaces in physical contact with said medium, a multi-surface reflector secured to said body and positioned adjacent the other of said opposed surfaces, said reflector being in the form of a frustum of a pyramid having a pyramidal reentrant portion whose apex lies in the plane of the base of said frustum, said reflector being adapted to reflect incident energy from said other surface in phase with the energy radiated from said one surface, thereby increasing the effective driving surface of said device to obtain greater directivity therefrom, said portions of said reflectors forming said frustum being disposed at an angle with respect to said opposed vibrating surfaces differing from forty-five degrees by a slight amount so that said beam is focused.

4. A device for transmission of a beam of compressional wave energy through a medium comprising a transducer having a pair of opposed vibrating surfaces, said transducer being maintained within a body of material having a wave impedance substantially equal to that of said medium and having one of said surfaces in physical contact with said medium, a reflector secured to said body and positioned adjacent the other of said opposed surfaces, said reflector having a first pair of adjacent surfaces arranged at an angle of substantially forty-five degrees with said other opposed surface and a second pair of angularly adjustable surfaces, said second pair of surfaces being inclined at an angle with respect to said vibrating surfaces differing slightly from forty-five degrees such that the beam is focused at a point whose distance from said transducer is dependent upon the deviation of said angle from forty-five degrees.

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