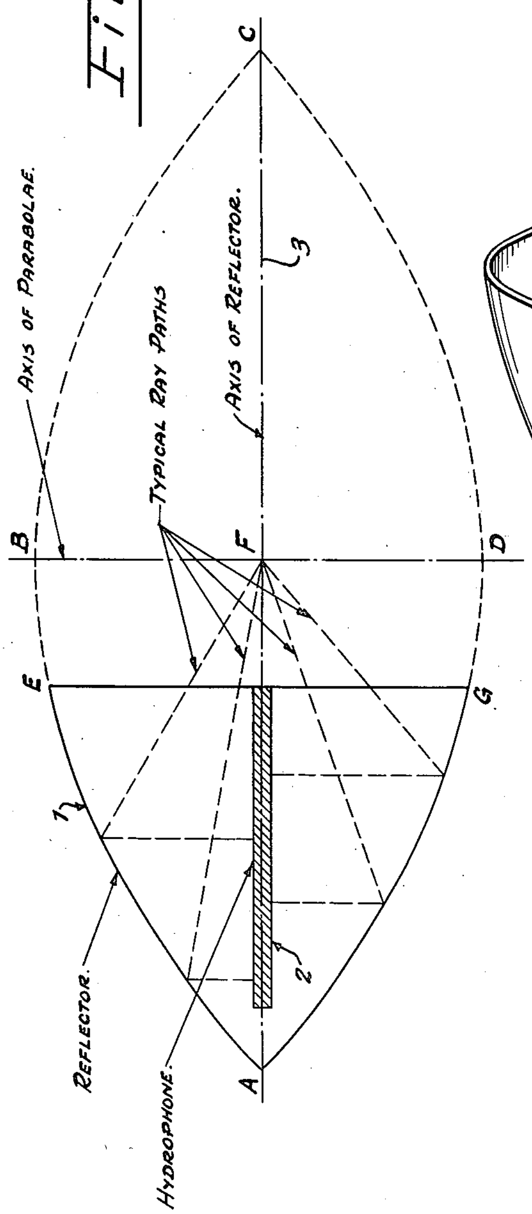
Nov. 11, 1952 W. H. LEWIS **2,617,874**

SYSTEM FOR THE PRODUCTION OF A HIGH-PRESSURE SOUND FIELD

Filed Feb. 16, 1950 2 SHEETS—SHEET 1

Fig. 1.



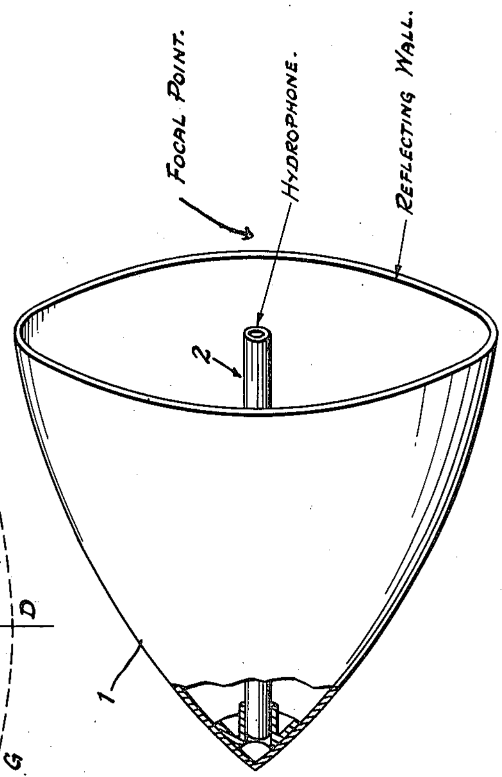


Fig. 2.

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SYSTEM FOR THE PRODUCTION OF A HIGH-PRESSURE SOUND FIELD

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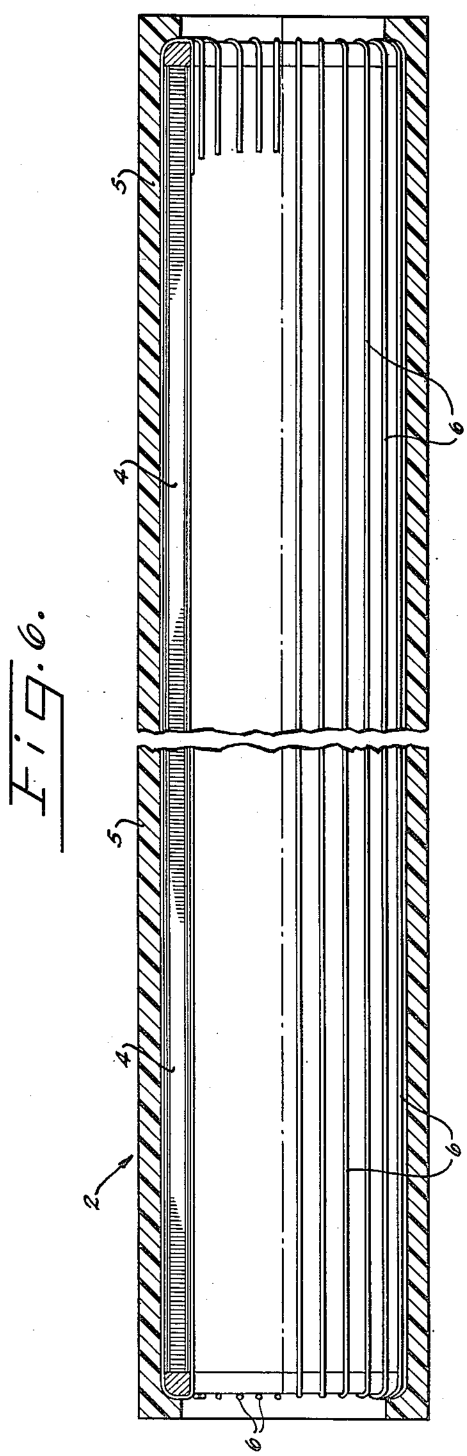

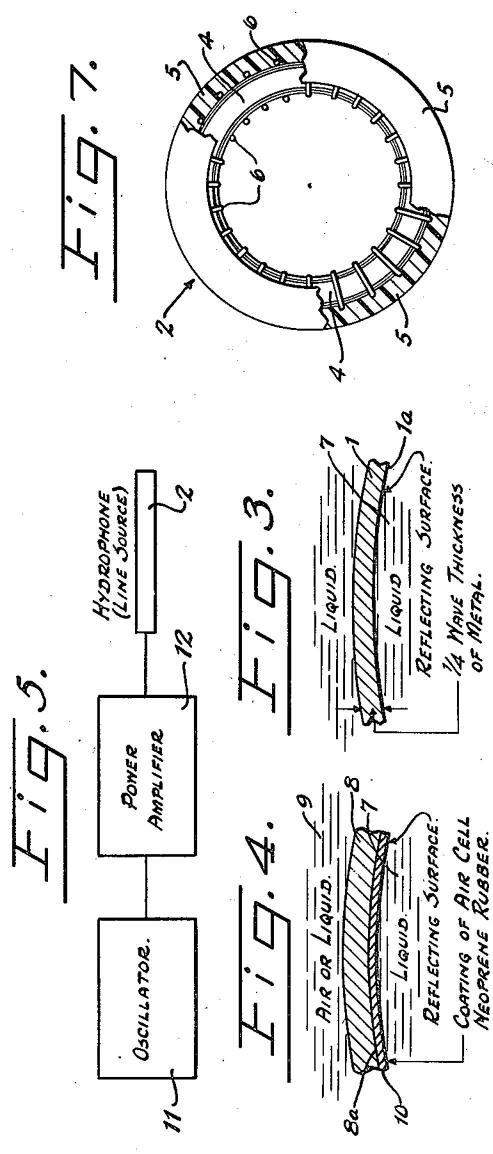

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SYSTEM FOR THE PRODUCTION OF A HIGH-PRESSURE SOUND FIELD

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1 Claim. (Cl. 177—386)

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My invention relates to a system for the production of a high-pressure sound field, and more particularly to a hydrophone transmission and reception system.

One of the objects of my invention is to provide a system for the production of a high-pressure sound field in which sound pressure variations may be established in an amount in excess of the pressures necessary to produce cavitation.

Another object of my invention is to provide a system for the production of a high-pressure sound field in which approximately cylindrical waves of energy may be established in a surrounding medium and focused to produce a very substantial energy density and sound pressure.

Another object of my invention is to provide a system for the production of a high-pressure sound field in which sound energy may be concentrated at a remote location with minimum loss in efficiency of operation and with minimum distortion of the output wave forms.

A still further object of my invention is to provide an arrangement of hydrophone system of high acoustic efficiency by which extremely high energy densities useful in the emulsifying and homogenization of normally non-miscible liquids, or solids and liquids, may be produced.

A still further object of my invention is to provide a system for the production of a high-pressure sound field over an extremely wide band of frequencies essentially independent of the frequency and point of origin of the energy causing cavitation.

Still another object of my invention is to provide a system for the directional transmission and reception of sound waves employing a radiating or receiving element disposed linearly on an axis coincident with the axis of a reflector formed by the revolution of a parabolic segment about the axis of the radiating or receiving element.

A still further object of my invention is to provide a construction of sound pressure generator or receiver associated with a reflector of circular cross section, any axial section of which consists of segments of two parabolae, the axes of which are coincidental and the foci of which lie on the axis of the reflector.

Other and further objects of my invention reside in a system for the production of high-pressure sound fields in which cylindrical wave fronts are caused to impinge on a compositely curved reflector for producing at remote positions acoustic energy having a high concentration factor, as set forth more fully in the specification hereinafter following by reference to the accompanying drawings in which:

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Figure 1 is a schematic diagram showing the manner of mounting a sound generator in accordance with my invention in association with the reflector; Fig. 2 is a perspective view partially broken away to illustrate the mounting of the hydrophone of my invention in association with the reflector; Fig. 3 is a fragmentary sectional view of the wall structure of the reflecting shell employed in the system of my invention wherein the frequency used bears a specific relationship to the shell thickness; Fig. 4 shows a structure of wall for the reflecting shell employed in the system of my invention as applied to any acoustic or ultrasonic frequency; Fig. 5 is a block diagram showing the driving system for the hydrophone for the development of cylindrical pressure waves; Fig. 6 is a longitudinal sectional view showing one form of the hydrophone employed in the system of my invention; and Fig. 7 is an end view of the hydrophone shown in Fig. 6 with a portion thereof broken away and illustrated in section.

Referring to the drawings in detail, Fig. 1 illustrates an axial section of the reflector designated by reference character **1** and the association of the hydrophone therewith designated by reference character **2**. The arcs A, B, C and A, D, C are segments of parabolae having their axes coincident (BFD) with noses at B and D and focal points coincident at F. Since the axes and focal points of the curves are coincident and the openings opposing, the two curves intersect each other at A and C in right angles. The reflecting surface of the shell illustrated in Fig. 2 is formed by rotating the parabolic segment EAG of these intersecting parabolae about the line AFC as an axis. This line will be known as the axis of the reflector and designated by reference character **3**.

It is a basic characteristic of the parabola that rays or plane wave fronts perpendicular to the axis of the parabola and traveling toward the concave face of the parabola in a direction parallel to the axis thereof will, upon specular reflection from the surface, be condensed or brought to a focus at the focal point F of the parabola, with all points on any wave front remaining in phase with each other and arriving simultaneously at the focal point. A radiator which emits energy radially located with its axis of symmetry on the line AFC sets up the condition described above. Energy from the radiator travels in directions parallel to the parabolic axes BFD until striking the reflecting surfaces. If the radiating hydrophone is located along the reflector axis **3** but does not include the point F, the reflected energy will be condensed to a theoretical point or very small volume at F in a field free of any interfering structures, with an energy density and sound pressure far in excess of that existing at the face of the hydrophone 2. In this way, sound pressure variations up to and in excess of the pressures necessary to produce cavitation, that is, the mechanical breaking up of a liquid into its vapor due to acoustic or low mechanical pressures in the liquid, may be produced at an easily observable point at a free field in a liquid. The driving energy supplied to the hydrophone **2** can be insufficient, however, to produce cavitation at any other surface. Thus there is not the loss in efficiency of operation and the distortion of the output wave form at the face of the hydrophone which is common when driving normal transducers at high levels. The allowable proximity of the reflector **1** and hydrophone **2** to the focal point F must depend upon the size of the free field required in a particular operation.

A hydrophone capable of producing approximately cylindrical waves of energy in surrounding medium is illustrated more particularly in one form in Figs. 6 and 7. This form consists of a conventional ring stack transducer **4** shown as covered with a cast plastic shell **5**. The transducer **4** is well insulated by a suitable kraft paper or other insulation material over which the exciting winding **6** is wound upon the cylindrical transducer **4**. The winding extends longitudinally of the cylindrical transducer and is protected by the cast plastic shell **5**. I have successfully employed ring stacks constructed according to my invention of various dimensions over a range having an approximate outside diameter of one inch to three and four inches. The length to diameter ratio of this hydrophone should exceed five in order that a close approximation of cylindrical wave fronts be emitted by it. The hydrophone may be supported in the shell either by a socket at the vertex of the shell or by spider supports sufficiently thin as not to appreciably block the normal paths of flow of the sound energy. The transducer operates as a magnetostriction oscillator and by virtue of the cylindrical contour of the transducer pressure waves having approximately cylindrical wave fronts move in a direction perpendicular to the axis of the reflector **1**.

In Fig. 3 I have illustrated a fragment of the wall of the reflector **1** submerged in a liquid where the thickness of the metal is equal to ¼ of the wave length in metal of the sound frequency being emitted by the hydrophone. The frequency used with the shell sectioned in Fig. 3 must bear a specific relationship to the shell thickness. The internal curved reflecting surface of the reflector **1** is designated at **1***a*. Such an arrangement, due to the mismatching of acoustic impedances between the liquid **7** and the metallic reflecting surface at **1***a*, forms a very effective reflector of acoustic energy.

In Fig. 4 I have shown a modified form of shell for a reflector designated by reference character **8** which may be either immersed in liquid **9** or merely filled with the liquid **7**. In this instance the wall thickness of the shell **8** is not critical. Any acoustic or ultrasonic frequency may be used with the shell shown in Fig. 4. The inner surface **8***a* of the shell **8** is covered with a coating of air cell neoprene rubber **10** the surface of which forms an effective acoustic reflector. There are other usable surfaces but the two illustrated in Figs. 3 and 4 have been found to operate very effectively.

The driving circuit for the hydrophone, Fig. 5, consists of a conventional oscillator **11** producing an electrical output at a frequency to which the hydrophone **2** is capable of responding. The shell is designated according to the frequency of the oscillator. The output of the oscillator is fed to a conventional power amplifier **12** which in turn drives the hydrophone **2**, as represented for example in Fig. 6. Mechanical radial vibration of the hydrophone due to the magnetostrictive response of the hydrophone laminations to the magnetic field produced by the varying currents in the windings causes acoustical energy to be transmitted to the surrounding liquid.

In the study of liquid cavitation in the presence of alternating high-pressure sound fields it is usually necessary either to cause the cavitation at the face of the hydrophone, diaphragm or other wave generator in which case one is not dealing with a free liquid, or to utilize a wave generator capable of producing a flat or nearly flat wave front, the cavitation being produced at focus of the reflector. In the latter case the wave generator must be of sufficiently large dimensions so as to produce an effectively flat wave front to impinge on the reflector with a corresponding lessening of the "concentration factor" or ratio of pressure at the point of observation to pressure at the generator face.

In operation, the wave generator produces a series of approximately cylindrical wave fronts, moving in a direction perpendicular to the axis of the reflector in an extremely narrow angular path. The path of propagation is practically linear. In the section of the reflector this is analogous with the approach of a plane wave to the curved reflector. In either case the wave is reflected to the focal point of the reflector, in this case the point F on the axis of the reflector. All the energy from the radiator is concentrated at this point if the reflector extends to or beyond the normal to the end of the radiator.

The accuracy of concentration of energy at point F depends upon the closeness of approximation of the radiated wave front to a circular cylinder. A radiator to produce an approximation to a cylindrical sound wave front at close quarters is less difficult to produce and less bulky than is one for the production of a flat wave front.

The system of my invention may be used to study the mechanical characteristics of a fluid as a function of the frequency and energy density of the acoustic signals introduced to the fluid. This is of considerable importance in the design of mechanical equipment for operation under water or in other liquid surroundings. The effective operation of such elements as propellers, pump impellers, underwater acoustic equipment, and the like depend upon knowledge of this characteristic. Such operation frequently results in cavitation of the liquid and consequent poor performance. Since relatively little is understood of the basic physics of this cavitation phenomenon, the present instrument has a wide field of application. Extremely high sound energy densities are also widely used in the emulsifying and homogenization of normally non-miscible liquids, or solids and liquids. Such a device has considerable usefulness in studies of sonic and supersonic vibrations in liquids or gases, the sound pressures existing in a free field and being variable up to values in excess of that obtainable at the face of the radiator. For certain acoustic investigations, this system of producing cavitation at the focal point may be used as a nondirectional source of white "noise" caused by the collapse of the cavitation bubbles which is accompanied by the production of noise of an extremely wide band of frequencies essentially independent of the frequency and point of origin of the energy causing the cavitation.

While I have described my invention in certain 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 claim.

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

In a system for the production of a high-pressure sound field, a curved reflector of circular cross section having a major axis extending centrally thereof and a generator of acoustic energy comprising a relatively long slender magnetostrictive transducer of toroidal construction having its longitudinal axis extending coincidental with the major axis of said curved reflector and its minor axis extending in a plane substantially normal thereto said reflector being formed by the rotation of segments of two parabolas about the axis of said transducer where the end of the transducer is displaced from the focal point of the parabolic curves, said reflector having a wall thickness equal to one-quarter of the wave length in metal of the said frequency emitted by the transducer, said reflector operating to concentrate energy from said transducer for propagating approximately cylindrical waves of acoustic energy and to focus said energy in a remote position with a high concentration factor.

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