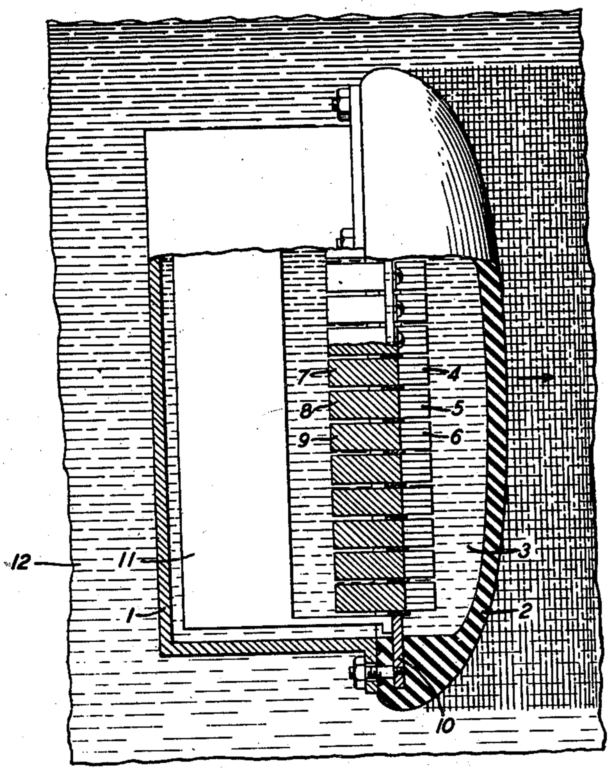
Feb. 24, 1948. H. B. BRIGGS ET AL 2,436,377

ULTRASONIC COMPRESSIONAL WAVE TRANSMISSION

Filed Dec. 27, 1943

FIG. 1



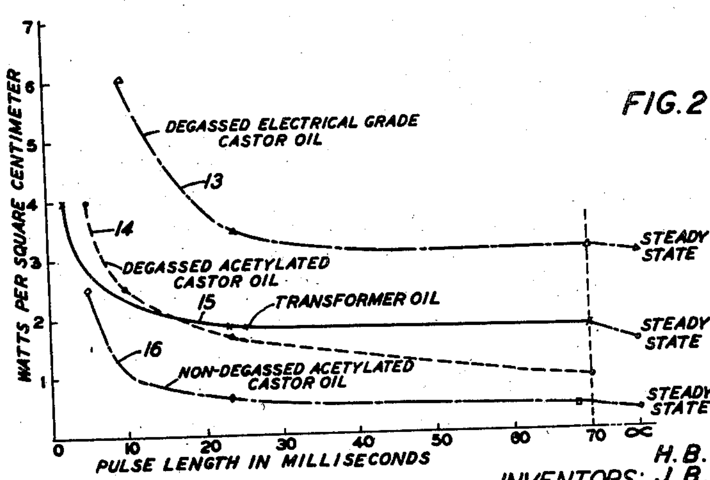


FIG. 2

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ULTRASONIC COMPRESSIONAL WAVE TRANSMISSION

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3 Claims. (Cl. 177—386)

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This invention relates to ultrasonic compressional wave transmission and has for its object the provision of a method for transmitting high power compressional waves.

It is known that the phenomenon of cavitation imposes a limit on the amount of power which may be transmitted in a liquid by a transducer regardless of the capability of such transducers.

One form of transducer in common use consists of an array of piezoelectric crystals which respond to electrical excitation to produce compressional waves in a surrounding medium such as sea water; but it has been found that sea water will not transmit a great concentration of power before the phenomenon of cavitation sets in and imposes a practical limit thereto and it has also been found that besides limiting the power which may be transmitted, cavitation leads to rapid physical destruction of the transducer.

Some advance in the means to transmit greater power has been made by immersing the transducers in another liquid which will support a greater power than sea water and then interposing between such surrounding liquid and the sea water a diaphragm having a much greater area than the effective area of the faces of the transducers so that the power transmitted thereby per unit of area is comparatively small. In this way the total power transmitted may be greatly increased. However, even in this case, the power transmitted by the transducer has to be limited a reasonable amount below the point at which cavitation will begin so as to avoid destruction of the transducer should the power be momentarily raised above the danger point.

Further advance in the art has been made by providing a liquid medium to surround the crystals of the transducer which will have the peculiar effect of preventing destruction of the crystals even though the limit has been overstepped and cavitation has been established. This advance is based on the discovered fact that the phenomenon of cavitation may be roughly divided into two regions—one known as false cavitation and the other known as true cavitation. False cavitation is the evolution of gas and in a medium wherein gas may be evolved easily generally precedes true cavitation as the power is increased. When gas is evolved the collapse of the voids is nowhere near as violent as in true cavitation and therefore the destructive effect is not as great. A mixture of liquids has therefore been devised in which one liquid having a high vapor pressure will not through such admixture with another adversely affect the otherwise excellent properties

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of such other liquid but will provide a means for the rapid evolution of gas and thus enhance the false cavitation effect. With such a liquid a transducer may be worked at a higher power intensity much nearer the limit than heretofore since an occasional operation beyond the limit will not endanger the transducers.

The present inventors have found that there is a time delay between the application of power to the transducer and the establishment of the phenomenon of cavitation. Unlike certain electrical phenomena such as the breakdown of insulation when the dielectric strength thereof has been exceeded, there is here a definite time delay in the appearance of the phenomenon. Also unlike the low governing the heating of a coil of wire where the heating is proportional to the product of the intensity of the current and the time of application thereof, a peculiar relation exists between intensity of power transmitted and the period required under such conditions for cavitation to become established. This peculiar fact is employed by the present inventors to transmit a high concentration of power—very much more than can be transmitted after cavitation has been established by limiting such transmission to periods shorter than the period required for the establishment of cavitation. It has been found that high power signals may thus be transmitted periodically without undue limitation from cavitation.

A feature of the invention is the use of an ultrasonic compressional wave transmitting device for short periods at a power level above that which may be used continuously. By this means an ultrasonic direction and ranging system may be employed in a vessel or other hull moving through water at such a high rate of speed that considerable acoustic noise is developed. Due to this noise a high energy density must be used if the direction and ranging system is to be effective for any considerable distance. Since in such a system signals in the form of very short impulses are transmitted the power used may be extremely high.

The drawings consist of a single sheet having two figures as follows:

Fig. 1 is a cross-sectional view of a crystal transducer which may be suitably employed; and

Fig. 2 is a set of graphs showing the relation between energy density which may be applied to such a transducer and the pulse length in milliseconds, for various liquids.

The electromechanical transducer shown in Fig. 1 comprises a casing 1 of steel or other rigid and mechanically strong material and a cap 2 of plastic material such as that known as ρc rubber. These two elements are bolted together to form a sealed chamber housing the electrical apparatus and filled with a liquid medium 3 such as castor oil. The electrical apparatus consists of a plurality of piezoelectric crystal mosaics such as 4, 5 and 6, each with its resonator 7, 8 and 9 respectively, mounted on a plate 10. Within a housing 11, also attached to the mounting plate 10, there is contained other electrical apparatus such as filters and delay networks used when such a transducer is connected as a prism array. The device is shown as submerged in water 12 and the vertical broken lines to the righ of the ρc rubber cap represent a compressional wave as being transmitted.

Available data indicate that cavitation results from the collecting of minute bubbles of air or vapor into larger bubbles that can be seen and which affect materially the acoustic output of a transducer. This collecting or joining together of the minute bubbles is a process that takes time. The rapidity with which it occurs also depends on how much energy is put into the liquid. Hence, if a certain amount of energy is required to produce cavitation under steady state conditions, it requires a larger amount of energy to produce cavitation for a relatively long pulse, followed by a period when no energy is sent out; and a still greater energy for a shorter pulse.

Fig. 2 shows experimental results obtained for degassed acetylated castor oil, graph 14, transformer oil, graph 15, and for non-degassed acetylated castor oil, graph 16. For the degassed electrical grade castor oil, graph 13, the power went from 3 watts per square centimeter of crystal face to 6 watts per square centimeter from the steady state to 10 millisecond pulses. If this had been a plain heating effect following the usual law the rise would have been greater, for the pulse was applied for 10 milliseconds and then there was an off period of 990 milliseconds so that only 2 per cent of the energy was put in the liquid for the pulsing case as compared with the steady state. Here the rise in power, instead of being 100 times (as it should be for a heating effect) was only 2 times.

The graphs show that liquids do not all act the same, transformer oil, for example, showing smaller increase than acetylated castor oil. While no graph is shown for water, the non-degassed sea water that will be outside the projector gives about the same result as the non-degassed acetylated castor oil, graph 16.

Hence, if a projector such as that shown in Fig. 1 is used, filled with degassed electrical grade castor oil, and the pulses are limited in duration to 5 milliseconds, an energy density in the order of 10 watts per square centimeter of crystal face

could be used. The outside diaphragm 2 would have to be large enough so that the energy density at any point on the surface dropped to 2 to 2.5 watts per square centimeter before going into the water. The graph 16 for non-degassed acetylated castor oil (which is similar to sea water) shows that the water would take this power without cavitation and transmit it to the main body of water.

Heretofore, projectors have been designed on a basis of keeping the energy in the water below ⅓-watt per square centimeter (the steady state cavitation value). A projector delivering 2 to 2.5 watts per square centimeter to the water represents an increase of 6 or 7 to 1 and thus represents an appreciable increase in the distance that can be obtained by the pulsing method. Also for a system to be employed where the vessel is traveling through the water at 45 knots and hence is making considerable acoustic noise, it is imperative to get back in the echo all the energy possible in order to work through this noise. The factor of 7 to 1 in energy ratio (8.5 decibels) allows the echo ranging system to override the noise to a distance of 2.35 times the limiting distance for a projector designed on the previous steady state basis.

What is claimed is:

1. The method of increasing the effective range of sound ranging by compressional waves in sea water, consisting of the transmission of high power in pulses of such short duration that cavitation is avoided.

2. The method of increasing the life of a high power transducer subject to destruction through the effects of cavitation which consists of limiting the periods of high power transmission to values less than the delay time in the establishment of cavitation.

3. The method of preventing the mechanical failure of an electromechanical transducer operated at a power level above that which will produce the phenomenon of cavitation which consists of limiting the periods of operation thereof to periods less than the time taken for the establishment of the said phenomenon.

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