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TRANSDUCER PLATE FOR HIGH ACOUSTICAL-MECHANICAL
ENERGY TRANSFER TO LIQUIDS

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2 Sheets-Sheet 1

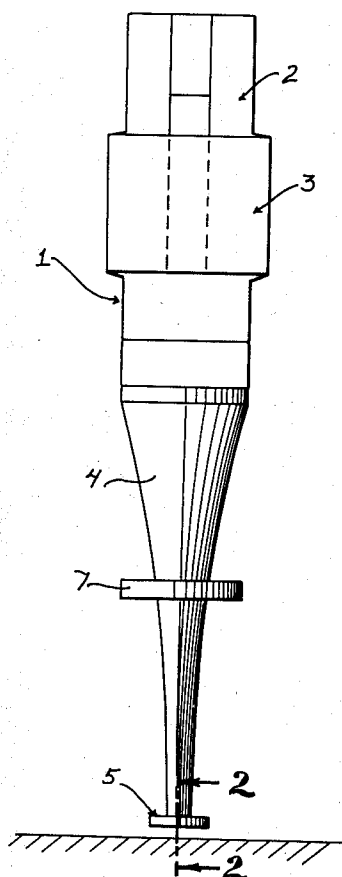


FIG. 1

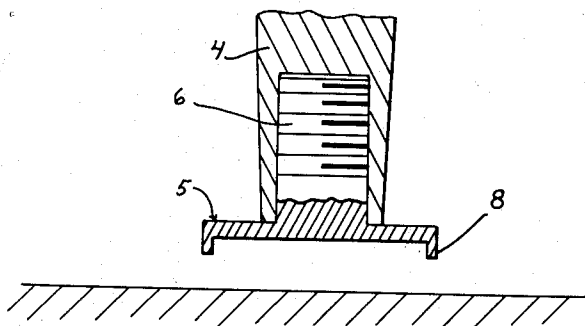


FIG. 2

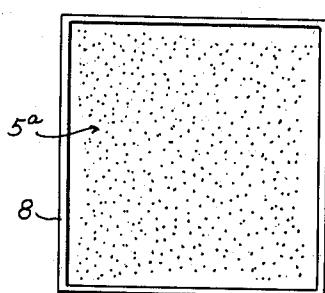


FIG. 3

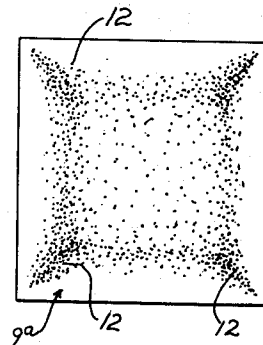


FIG. 5

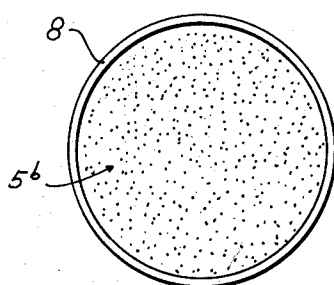


FIG. 4

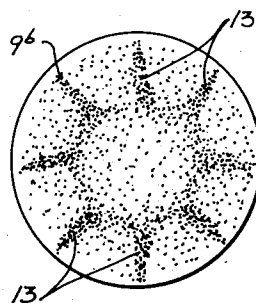


FIG. 6

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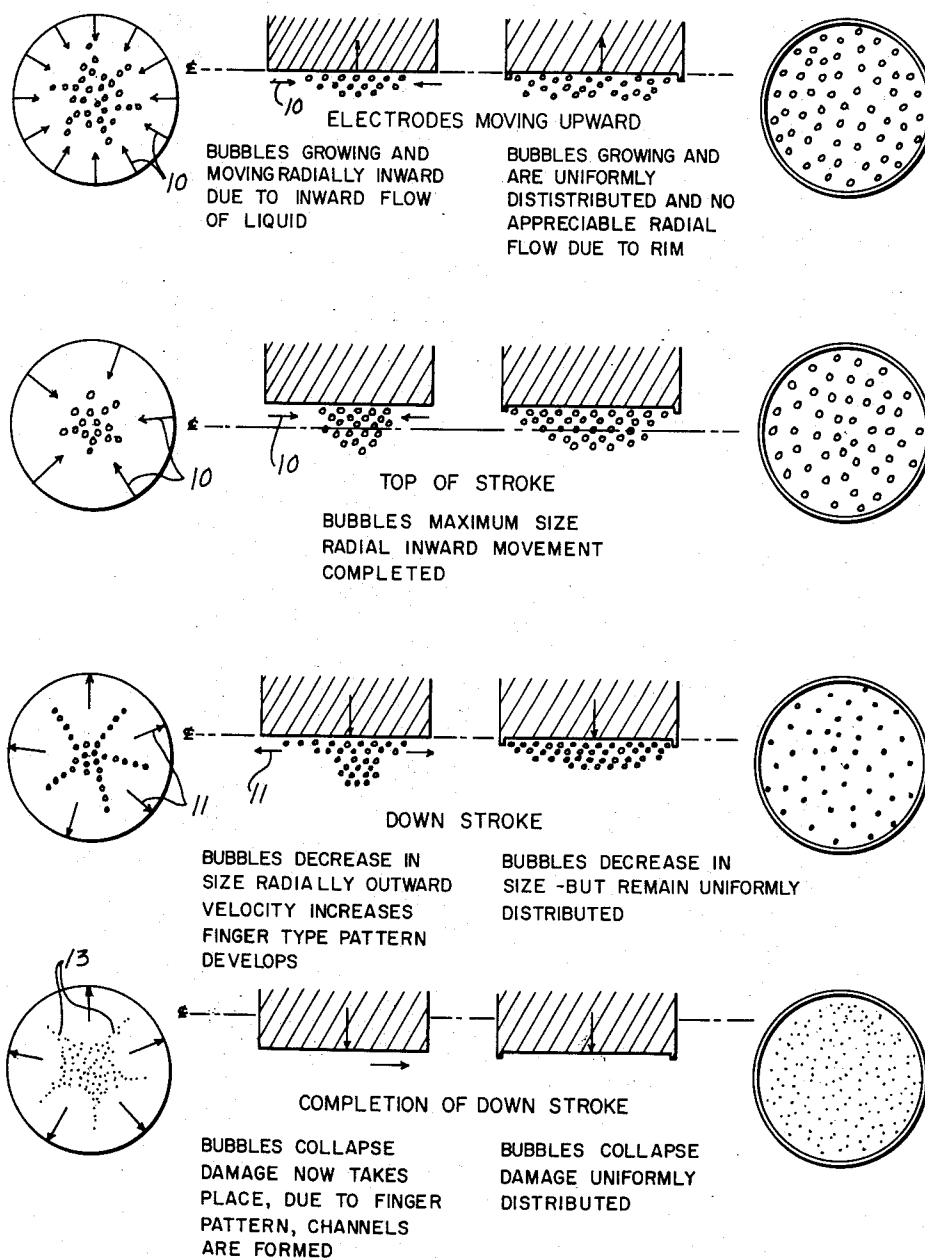


FIG. 7

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TRANSDUCER PLATE FOR HIGH ACOUSTICAL-MECHANICAL ENERGY TRANSFER TO LIQUIDS

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This invention relates to acoustic-mechanical transducer plates, particularly adapted for high energy transfer to a liquid under conditions wherein cavitation occurs.

The cavitation produced by high energy operation of transducers takes the form of small bubbles which form an irregular and intermittent cloud over the surface of the transducer plate. That is, the vibration of the transducer plate produces pressure fluctuations of substantial magnitude. As a consequence bubbles containing vapor and gas are formed when the pressure is at a minimum and collapse when the pressure is at a maximum. The energy release on collapse of the individual bubbles is enormous and when this occurs in close proximity to a surface, erosion of the surface will occur. This phenomenon is used in high energy acoustic-mechanical transducers for purposes such as cleaning or other applications requiring energy transfer to a liquid in the action on contiguous areas exposed to the energy. However, the transducer plate, too, is subject to erosion by the collapsing bubbles.

The erosion which occurs on a conventional transducer plate is not evenly distributed but displays various typical patterns of channels or pits. Once these channels or pits begin to form, not only does the efficiency of the transducer plate drop but the erosion is increasingly concentrated in these regions. While some improvement is found in the use of hard metals or alloys such as tungsten carbide, still the life of transducer plates under cavitation conditions is relatively short.

A primary object of this invention is to provide a transducer plate for high acoustic-mechanical energy transfer wherein erosion is minimized and wherein the erosion which does occur is uniformly distributed so that the useful life of the transducer plate is materially increased or so that the energy output may be increased.

A further object of this invention is to provide a transducer plate wherein the effective transmitting area is increased.

A still further object is to provide a transducer plate which may be readily substituted for a conventional transducer plate without changing the apparatus associated therewith.

With the above and other objects in view as may appear hereinafter, reference is directed to the accompanying drawings in which:

FIGURE 1 is a side view of a transducer unit showing a transducer plate thereon, the electrical connections and mounting means for the transducer unit being omitted.

FIGURE 2 is an enlarged fragmentary, sectional view through 2—2 of FIGURE 1.

FIGURE 3 is an end view of a transducer plate constructed in accordance with the present invention and

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shown as rectangular in form and indicating thereon the uniform distribution of erosion.

FIGURE 4 is a similar end view showing a transducer plate thus constructed which is circular in form and indicating a typical uniform erosion distribution pattern which develops after continued use of the transducer plate.

FIGURE 5 is an end view of a conventional transducer plate showing thereon a conventional, rectangular transducer plate corresponding in shape to FIGURE 3 and showing a typical erosion pattern.

FIGURE 6 is a similar end view of a circular conventional transducer plate corresponding to FIGURE 4 and showing a typical erosion pattern.

FIGURE 7 comprises a series of diagrammatical views to illustrate the sequence of events which occur during a vibration cycle of a conventional transducer plate and a plate constructed in accordance with the present invention.

The transducer plate which is the subject of this invention may be adapted to various types of transducer units. For purposes of illustration the transducer plate is shown as adapted for use in conjunction with a magnetostrictive type of transducer. Such a transducer unit designated 1 comprises a laminated core or stack 2 provided with energizing coils 3 connected in a conventional manner to an electrical energy source of appropriate frequency.

The magnetic core is connected to a velocity transformer 4 which may be in the form of a tapered member, the area of which varies exponentially. The smaller end of the velocity transformer is joined to a transducer plate 5 which may be substantially larger in diameter.

For purposes of illustration, the transducer plate is shown attached by a screw threaded stud 6 seated into a mating socket provided in the end of the velocity transformer. The transducer unit may be supported in any suitable manner; for example, by a mounting flange 7 located at a node point of the velocity transformer.

The transducer plate 5 which is the subject of this invention corresponds in dimension and shape to a conventional transducer plate. It is distinguished from a conventional transducer plate by a marginal rib 8 projecting from the active face of the transducer plate. If the transducer plate is rectangular as indicated by 5a in FIGURE 3, the marginal rib 8 is also rectangular. If the transducer plate is circular as indicated by 5b in FIGURE 4, the marginal rib 8 is also circular.

In order to understand the function of the marginal rib 8, it is essential to compare the transducer plate shown in FIGURES 3 and 4 with a conventional transducer plate such as the rectangular transducer plate 9a shown in FIGURE 5 or the circular conventional transducer plate indicated by 9b in FIGURE 6.

The conventional transducer plate is flat and without a marginal rib 8. It is operated while immersed in a liquid. Under this condition when the transducer plate accelerates away from the liquid, tension is produced in the liquid. If this tension is great enough; that is, if the acceleration away from the liquid obtains high enough magnitude, then cavitation bubbles in the form of a cloud appear in the liquid in the neighborhood of the transducer surface.

At the same time, the transducer plate is moving away from the liquid, there is generated in the liquid in the

neighborhood of the transducer a component flow velocity directed radially inward as indicated by arrows 10 in FIGURE 7. This radially inward flow produces some tendency toward concentration of the cavitation bubbles about the central portion of the transducer plate.

During the remaining half of the vibration cycle, the transducer surface is accelerated into the liquid and during this phase of the motion of the transducer plate, there is produced a component of flow which is directed radially outward as represented by the arrows 11 in FIGURE 7. Because of the previous concentration of the cavitation bubbles near the central portion of the transducer plate, there is an area consisting of a mixture of liquid and cavitation bubbles near the central portion of the plate and a liquid mass free of bubbles toward the radially outward portion of the plate. This creates a situation in which a light liquid; i.e. (liquid plus cavitation bubbles) is accelerated into a heavy liquid; i.e. (liquid without bubbles) because of the outward radial motion generated during this part of the cycle.

It is a well established physical law that a motion in which a lighter fluid is accelerated into a heavier fluid will produce an unstable condition. The boundary between the lighter fluid and the heavier fluid in this situation of acceleration breaks up so as to develop fingers or needles of lighter fluid penetrating into the heavier fluid.

This is borne out when the erosion patterns which occur on a conventional transducer plate are studied; for example, in FIGURE 5 the diametrically disposed grooves 12 are formed at the corners of a square or rectangular transducer plate 9a. On a circular conventional transducer plate 9b radial grooves or fingers 13 appear. These are usually randomly disposed. In either case, however, the exact location of the propagation of finger or needle-like penetration of the lighter fluid is a matter of chance, but is most apt to occur where there exists some slight irregularity in the surface. If a slight irregularity does not exist initially, it is soon produced on the surface of the conventional transducer plate and once established, these fingers or needles of the lighter fluid will tend to reestablish in the same place with each cycle of operation.

During the cycle of operation in which the transducer plate is being accelerated into the liquid, there occurs a rapid rise in liquid pressure which causes the cavitation bubbles to collapse. In the instant of collapse of an individual cavitation bubble, there is released, considering the small size of the cavitation bubble, an enormous concentration of energy. When this collapse of a cavitation bubble occurs close to a surface, erosion of that surface will occur.

Inasmuch as the cavitation bubbles are concentrated in the above-mentioned needles or fingers, it follows that there is a corresponding concentration of erosion when the bubbles within the areas of these needles or fingers suddenly collapse and as a consequence grooves, ruts or pits are produced in the conventional transducer plate.

In the exercise of the present invention the relatively small marginal rib 8 prevents the radially inward and outward flow of liquid contiguous to the surface of the transducer plate. As a consequence there is no concentration of the cavitation bubbles during acceleration of the transducer plate away from the liquid and consequently no unstable outward flow of the lighter fluid comprising the bubbles and liquid during the acceleration of the transducer plate into the liquid.

Examination under operating conditions of transducer plates constructed in accordance with the present invention shows the formation of a cavitation cloud substantially uniformly distributed over the area whereas a conventional transducer plate observed under similar conditions indicates a concentration of the cavitation cloud in the central region of the plate. Still further examination of transducer plates constructed in accord-

ance with the present invention after operation fail to show the characteristic erosion patterns which exist on conventional transducer plates.

This does not imply that erosion does not occur, but rather that the erosion which does occur is uniformly distributed and being uniformly distributed insures substantially longer life of a transducer plate provided with a marginal rib 8.

One of the applications for transducer plates designed to operate under conditions where cavitation occurs in the adjacent liquid is in the field of ultrasonic cleaning in which the transducer plate is located in close proximity to the surface to be cleaned—sufficiently close to place the work piece in contact with the cavitation cloud. By reason of the fact that the cavitation cloud is more uniformly distributed throughout the cavitation plate having the rib 8 and, furthermore, by reason of the fact that the cavitation cloud tends to extend to the boundaries of the plate rather than concentrate at the central portion, the effective area of the transducer plate is substantially increased and consequently the cleaning efficiency is increased. This is true, not only when the transducer plate is new, but also becomes increasingly important during the service life of the transducer plate due to the fact that in regard to the conventional transducer plate, the formation of the ruts or channels still further decreases the efficiency of the conventional transducer plate.

Inasmuch as damage to the surface of the transducer plate can only be caused by the collapse of those bubbles which are close to the surface of the plate, the dimensions of the marginal rib may be small and, in fact, are preferably small in order that the distance between the transducer plate and the work piece may be as small as possible. More specifically, the cavitation bubbles which are developed by an oscillating transducer plate operating in the higher range of frequency are extremely small, often so small that they cannot be individually discerned without magnification. The energy released by each collapsing bubble does not extend appreciably beyond the diameter of the bubble at the instant of collapse. As an approximation the erosion effect is probably greatly dissipated at a radial distance twice the diameter of the bubble.

By way of illustration, but not of limitation, a marginal rib approximately $\frac{1}{16}$ " wide and $\frac{1}{16}$ " high bordering a transducer plate approximately 1" square proved in test to provide adequate protection for the surface of the transducer plate operating in the range of frequency of 14,000 c.p.s. As the dimensions of the transducer plate increase, the height of the rib may be increased proportionately.

It is possible, however, to create conditions in which the cavitation bubbles may be relatively large; as, for example, a condition of high energy input and lower frequency. In such case the dimensions of both the transducer plate and marginal rib are increased accordingly.

In the use of the transducer plate for the purposes of cleaning or eroding adjacent work pieces, it is essential that the height of the rib be less than the maximum depth of the cavitation cloud.

Having thus described certain embodiments of our invention, we do not wish to be limited thereto but desire to include in the scope of our invention all novelty inherent in the appended claims.

We claim:

1. The combination with a transducer plate submerged in a liquid and subjected to acoustical-mechanical vibrations of an intensity capable of producing a cavitation cloud, of a rib bordering said plate and restraining radial flow of said liquid across said transducer plate, said rib having a height approximately one-sixteenth the width of the plate within said rim.

2. A transducer, comprising: a transducer plate submerged in a liquid; means for subjecting said plate to vibrations of an intensity capable of producing a cavita-

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tion cloud over the surface thereof; a rib bordering the periphery of said plate having a height less than said cavitation cloud to prevent radial flow of liquid contiguous to the surface of said plate.

3. A transducer, comprising: a transducer plate submerged in a liquid; means for subjecting said plate to vibrations of an intensity capable of producing a cavitation cloud over the surface thereof; a wall enclosing an area of said plate, said wall having a height less than said cavitation cloud produced within said area to mini-

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mize radial flow of liquid contiguous to the surface of said plate.

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