

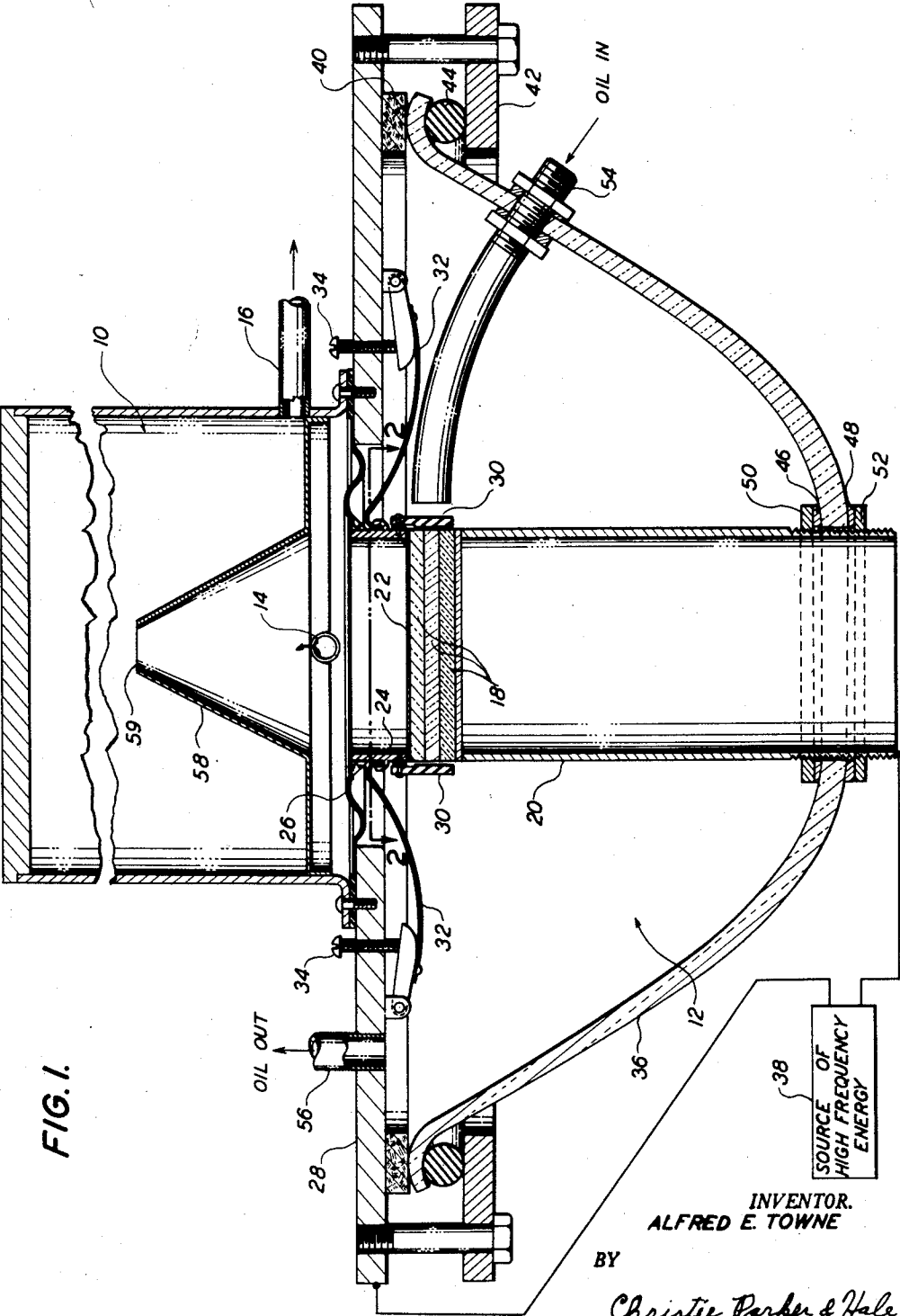
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ULTRASONIC APPARATUS

2,916,265

Filed Nov. 22, 1954

3 Sheets-Sheet 1



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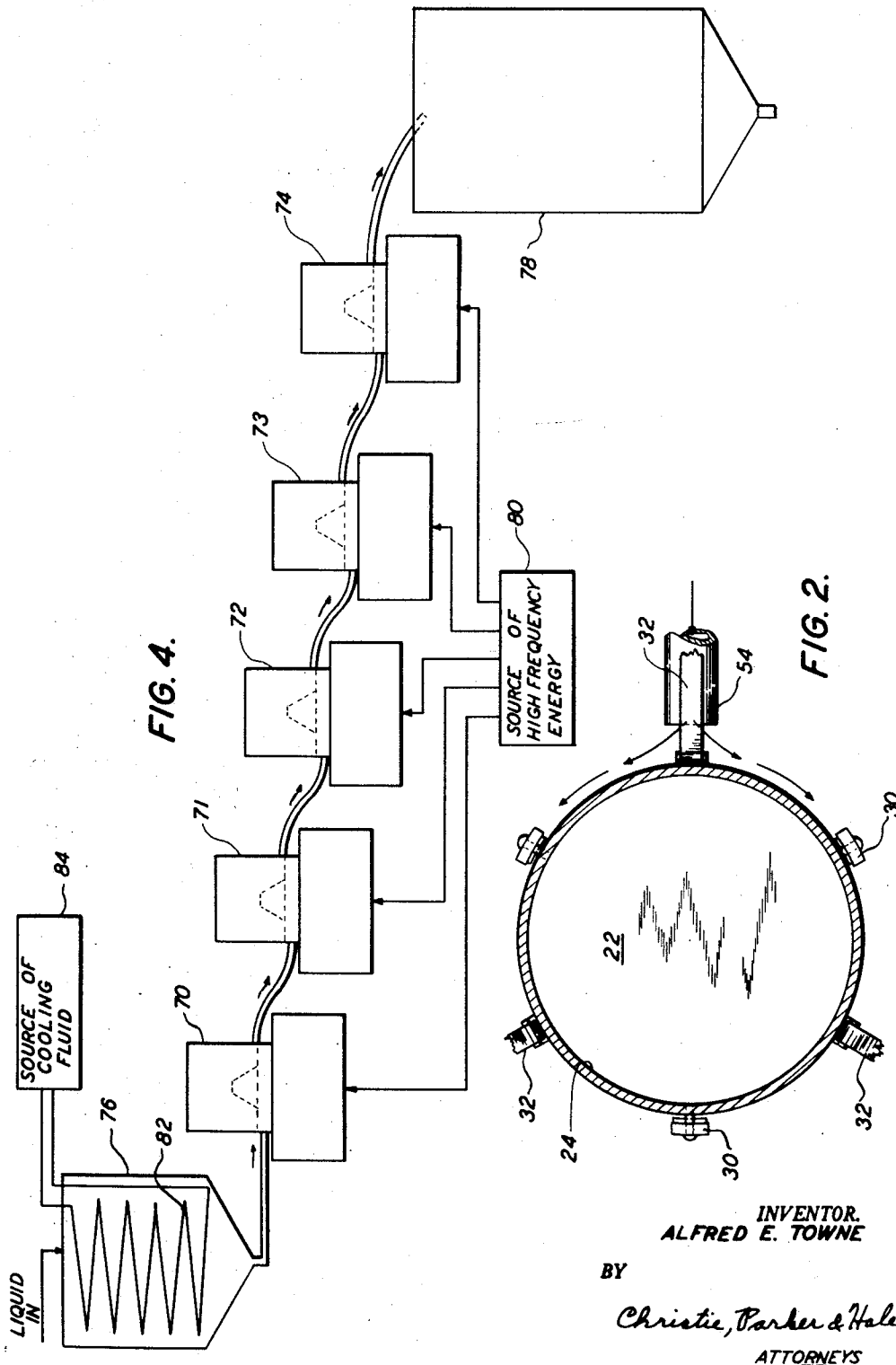
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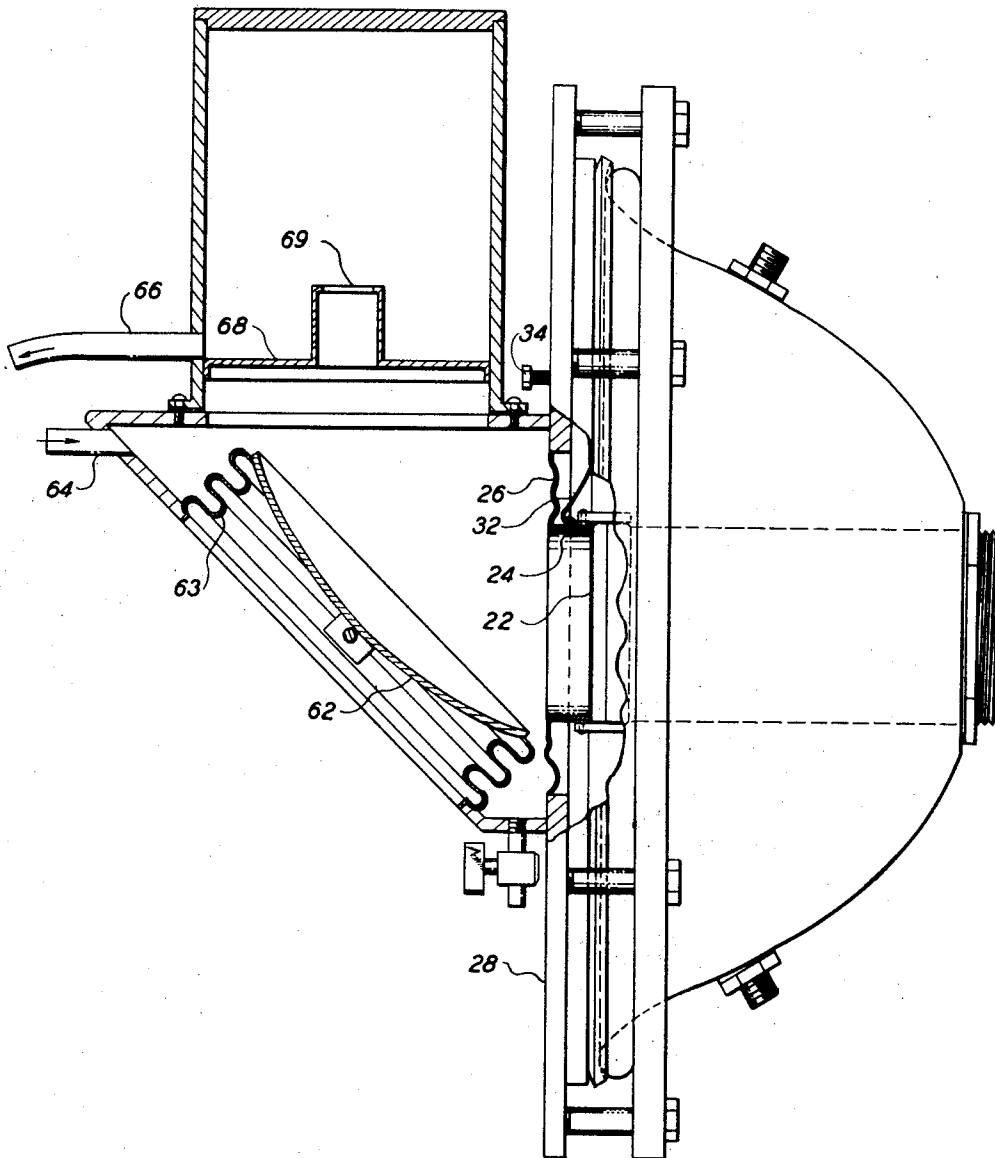
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3 Sheets-Sheet 3

FIG. 3.



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1

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ULTRASONIC APPARATUS

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4 Claims. (Cl. 259—1)

This invention relates to improvements in apparatus for generating ultrasonic waves, and it has particular reference to apparatus and methods for treating fluids with ultrasonic waves.

Compressional waves having a frequency which is higher than the frequencies which are audible to the human ear are termed ultrasonic waves. Such waves have been successfully employed in apparatus for cleaning objects and in apparatus for testing materials.

It has been proposed that such waves be employed to treat fluids so as to sterilize them and so as to form colloidal suspensions and the like in certain liquids. However, ultrasonic waves of high intensity must be employed in order to treat fluids in this manner. It is difficult to produce such waves, and the apparatus which has been devised heretofore for producing such waves generally has been unreliable.

These difficulties are overcome in the present invention by the use of an improved ultrasonic transducer which may be employed to produce ultrasonic waves of high intensity over long periods of time.

In accordance with the present invention, the ultrasonic waves are produced by crystal means which is excited with high frequency electrical energy. The crystal arrangement is supported at one end by a mechanical arrangement having a high impedance to ultrasonic waves, and a movable diaphragm is located at and floats on the other end of the crystal arrangement. Preferably, the diaphragm is disposed in direct contact with the fluid to be treated. With such apparatus, the high impedance support at one end of the crystal apparatus causes substantially all of the ultrasonic energy to be propagated from the other end of the crystal apparatus. With the diaphragm being located in direct contact with the fluid to be treated, substantially all of the ultrasonic energy is propagated into the fluid.

Usually a plurality of crystals is required to produce the desired amplitude of vibrations. The crystals are stacked one adjacent the other, and it is desirable that the crystals all have substantially the same resonant frequency and be poled so that their vibrations reinforce one another to produce ultrasonic waves of high intensity. Also, it is desirable to provide an arrangement for adjusting the pressure on the crystals to provide acoustic impedance matching between the crystals and the fluid to be treated, so that the apparatus may be adjusted to operate at maximum efficiency.

In order to obtain vibrations of maximum amplitude from the crystals it is necessary to apply a high voltage electrical signal between the two ends of the stack of crystals. Oil is circulated past the crystals so as to cool them, and the flow of oil also reduces the tendency for electrical arcs to form. I prefer to employ a bowl-shaped member composed of an insulating material having low dielectric losses for providing a container around the crystals through which the cooling oil is pumped. The bowl-shape of the container provides a large surface area between the electrodes across which the high

2

frequency energy is applied, thereby reducing corona losses.

If desired, the ultrasonic waves which are produced by the crystals and the diaphragm may be concentrated or focused by employing a cone-shaped member or by employing a parabolic reflector aligned with the diaphragm.

The invention is explained in more detail with reference to the drawings, in which:

Fig. 1 is a sectional view showing one form of the ultrasonic apparatus of the invention;

Fig. 2 is a sectional view along line 2—2 of Fig. 1;

Fig. 3 is a view, partially in section, of an alternative embodiment of the ultrasonic apparatus; and

Fig. 4 shows how a plurality of the ultrasonic fluid treating devices may be connected in series to treat a continuous flow of liquid.

In the apparatus of Fig. 1, the housing defines a pair of chambers 10 and 12. The upper chamber 10 serves to contain the liquid which is to be treated, and it is provided with an inlet conduit 14 and an outlet conduit 16.

The apparatus for generating the ultrasonic waves is located in the lower chamber 12. A plurality of crystals 18 stacked one adjacent the other serve to generate the waves. The crystals are supported at the lower end by a hollow tubular member 20, which is preferably made of a conductive material such as brass so that the member may be employed as one of the electrodes for applying an electrical signal to the crystals. The air inside the tubular member offers a high impedance to ultrasonic waves, so that the support for the crystals provides a high impedance to the propagation of ultrasonic waves in the direction of the support and thereby causes substantially all of the ultrasonic energy to be propagated from the other end of the stack of crystals.

A movable diaphragm 22 is located at the other end of the stack of crystals, and it is arranged to contact the end of the crystals on one side and to contact the fluid to be treated on its other side. The diaphragm is composed of a conductive material, and it serves as the other electrode for the crystals.

An annular ring 24 is affixed to the outer periphery of the diaphragm, and an annular corrugated member 26 is coupled between the annular ring 24 and a closure plate 28. A plurality of guide members 30 are affixed to the annular ring 24, and they extend along the crystal stack to maintain the crystals in proper position. The annular ring 24, the annular corrugated member 26, and the closure plate 28 are composed of conductive material so that they may be employed to conduct electrical energy to the diaphragm 22.

A plurality of springs 32 are affixed to the annular ring 24, and they are provided with adjustments 34 located outside the two chambers for adjusting the pressure of the annular ring on the stack of crystals.

Thus, the diaphragm floats on top of the stack of crystals and it is free to move with the vibrations of the crystals. Acoustic impedance matching between the crystals and the fluid to be treated is attained by adjusting the pressure of the springs 32 on the stack of crystals. The adjustment for maximum output of ultrasonic waves may be ascertained by observing the coloration or the movement of the liquid in the upper chamber 10.

Since the diaphragm forms part of the fluid-tight seal between the upper and lower chambers 10 and 12, and since the diaphragm is disposed in direct contact with the fluid to be treated, substantially all of the ultrasonic energy is propagated into the liquid to be treated and very little of the energy is dissipated in the lower chamber 12.

A source 38 of high frequency energy has its output

3

coupled between the tubular member 20 and the closure member 28, so that the high frequency electrical energy is applied to the two ends of the crystal stack by the tubular member 20 and by the diaphragm 22.

A bowl-shaped member 36 provides the closure for the lower portion of the lower chamber 12. The bowl-shaped member should be composed of a good insulating material so as to minimize losses in the high frequency electrical energy which is applied between the tubular member 20 and the closure member 28. I prefer to employ Pyrex glass or polystyrene so as to reduce the dielectric losses as much as possible. The large surface area of the bowl-shaped member reduces the corona losses along the member. A shallower lower chamber 12 may be employed but with the disadvantage that higher corona losses may result.

The bowl-shaped member may be mounted in various ways. In the arrangement illustrated in Fig. 1, a cork gasket 40 is disposed between the bowl-shaped member 36 and the closure member 28, and a continuous ring 42 engages a rubber ring 44 along the underside of the bowl-shaped member and serves to secure the bowl-shaped member to the closure member 28.

The tubular member 20 extends through an opening in the center of the bowl-shaped member. A pair of cork gaskets 46 and 48, and a pair of nuts 50 and 52 serve to support the tubular member in the opening in the bowl-shaped member.

Cooling oil is admitted to the lower chamber 12 through an inlet 54, and it is discharged at an outlet 56. Preferably, the oil is caused to sweep past the crystals so as to reduce the tendency for electrical arcs to form when high frequency electrical energy is applied to the crystals. This may be effected by providing one or more oil inlets located adjacent the crystals and disposed radially with respect to the crystals so as to cause the oil to flow around each side of the stack of crystals. Other arrangements for causing the oil to sweep past the crystals may be employed if desired.

Fluid in the upper chamber 10 may be treated in various ways. In the arrangement illustrated in Fig. 1, a cone-shaped member 58 is provided in the upper chamber for focusing or concentrating the ultrasonic energy in a selected region. Preferably the base of the cone has approximately the same area as that of the movable diaphragm so as to provide maximum concentration of the ultrasonic energy. The apex of the cone-shaped member has an opening 59 in it through which the treated fluid may be discharged.

The concentration of the ultrasonic energy within the cone-shaped member 58 serves to force the liquid upwardly into the upper portion of the upper chamber 10 in a manner resembling the action of a geyser.

In addition to serving to concentrate the ultrasonic energy, the cone-shaped member 58 also provides a barrier between the treated and the untreated fluid in the chamber so as to prevent contamination of the treated fluid by the untreated fluid which is admitted through the inlet 14.

Fig. 3 illustrates an alternative embodiment of the ultrasonic apparatus wherein the apparatus for generating the ultrasonic waves is the same as that shown in Fig. 1, with the exception that it has been shifted 90° so that the diaphragm 22 is disposed vertically instead of horizontally.

In this embodiment of the invention the ultrasonic energy is directed toward a parabolic reflector 62 which serves to focus and direct the energy upwardly. Preferably a hollow space is provided behind the parabolic reflector so that it has a high impedance to the ultrasonic waves, thereby preventing propagation of the ultrasonic waves behind the reflector. One arrangement for effecting this is to provide a bellows 63 around the para-

4

bolic reflector, so that the position of the reflector can be adjusted.

Liquid to be treated is admitted through an inlet 64, and it is discharged through an outlet 66. A barrier 68 having an opening 69 at its apex is located between the inlet and outlet conduits.

In order to provide maximum energy transfer to the liquid, the liquid level should be located so that its surface is at the geometric focal point of the parabolic reflector.

As before, the ultrasonic waves cause the liquid to be forced through the opening 69 in the barrier 68 so that the treated liquid is not contaminated by the newly admitted and untreated liquid.

Various frequencies may be employed in treating fluids with the apparatus of Figs. 1 and 3. For killing bacteria I have found that a frequency of one megacycle is satisfactory, and I have applied up to 1000 watts of power at a frequency of one megacycle to the crystals. The parabolic reflector arrangement of Fig. 3 provides more effective focusing than the cone-shaped member of Fig. 1, and less power or fewer crystals are required for the apparatus of Fig. 3 in order to achieve the same ultrasonic wave intensity.

In one test conducted with the apparatus similar to that of Fig. 1, the bacteria in a sample of orange juice were completely destroyed. The orange juice was placed in a closed flask, and the oxygen in the flask was replaced by CO₂. The flask was placed in the fluid treating chamber. Cool oil was circulated through the chamber and it was subjected to ultrasonic vibrations having a frequency of one megacycle for 6¼ minutes. The power applied to the crystals was approximately 765 watts. A focusing arrangement such as the cone-shaped member of Fig. 1 was not employed in the fluid treating chamber for this test.

After treatment, this sample was retained at room temperature for approximately 11 months. At the end of this period the orange juice looked, tested and smelled like orange juice. The pulp of the orange was pulverized so that it could be placed in suspension easily by shaking the container.

Other samples which have been treated with ultrasonic waves are as follows: Lactobacillus, Bacillus Subtilis, and orange juice contaminated with mold. In each instance the bacteria in the sample were completely destroyed.

When a large volume of liquid is to be treated it is desirable to treat a substantially continuous flow of the liquid. By treating a continuous flow of the liquid, rather than recirculating it, the treated liquid is not contaminated by the untreated liquid. Fig. 4 illustrates one way in which the ultrasonic apparatus may be employed to treat fluid in a continuous flow arrangement.

Each of the ultrasonic devices 70 to 74 may be either the type illustrated in Fig. 1 or the type illustrated in Fig. 3. Liquid to be treated is located in a container 76, and it is permitted to flow through the successive ultrasonic devices 70 to 74 after which it is discharged into a container 78. A source of high frequency energy 80 provides the electrical energy for the respective ultrasonic devices.

The successive ultrasonic devices 70 to 74 are located one below the other so that the liquid being treated may flow by gravity between the successive devices.

Usually it is desirable to maintain the liquid being treated at a low temperature. The liquid in the container 76 is cooled by conduits 82 which receive cooling fluid from a source 84. If desired, the fluid treating chambers or the conduits interconnecting the successive treating chambers may be cooled so as to maintain the fluid at substantially the same low temperature throughout the treating process.

5

Any desired number of serially connected fluid treating devices may be employed.

It will be apparent that the ultrasonic apparatus of the present invention may be employed in various applications which require ultrasonic waves of high intensity, and that the apparatus is not limited to use for treating fluids.

I claim:

1. Apparatus for use in treating fluid by ultrasonic waves comprising a housing defining a pair of chambers, means for admitting fluid to be treated into one of the chambers, a movable diaphragm having an annular ring affixed to its outer periphery and having a corrugated annular seal affixed to the annular ring and disposed to provide a fluid-tight seal between the two chambers, with one side of the movable diaphragm communicating directly with the chamber for the fluid to be treated, a plurality of crystals stacked one adjacent the other located in the other chamber with one end of the stack of crystals contacting the other side of the movable diaphragm, a rigid hollow member supporting the other end of the stack of crystals and providing a high impedance to ultrasonic waves in the direction of the hollow member, and spring means coupled to the annular ring and adjustable outside the two chambers for controlling the pressure on the crystals to provide acoustic impedance matching between the crystals and the fluid to be treated.

2. In ultrasonic apparatus for treating fluids, having a plurality of crystals disposed adjacent one another in a stack and tuned to substantially the same frequency for producing the ultrasonic waves, a bowl-shaped member composed of an insulating material, a hollow tubular member having a closed end which extends through an opening in the central portion of the bowl-shaped member to provide a support at one end of the crystal stack having a high impedance to the ultrasonic waves in the direction of the tubular member, a movable diaphragm having one side contacting the other end of the crystal stack, an annular ring affixed to the outer periphery of the diaphragm, a plurality of guides affixed to the annular ring and extending along the crystal stack to keep the crystals in position, means including an annular cor-

6

rugated member connected to the annular ring providing a closure across the bowl-shaped member, and means for adjusting the pressure of the annular ring on the crystal stack to provide acoustic impedance matching.

3. The apparatus of claim 2 further including means for circulating oil through the bowl-shaped member to cool the crystals, with the oil sweeping past the crystals to reduce the tendency for electrical arcs to form when high frequency energy is applied to the crystals.

4. Apparatus for use in treating fluid by ultrasonic waves comprising a housing defining a pair of chambers, means for admitting fluid to be treated into one of the chambers, a plurality of crystals stacked in the other chamber, a movable diaphragm contacting one end of the stack of crystals on one side and disposed to contact the fluid to be treated on the other side, with the diaphragm forming part of a fluid-tight seal between the two chambers, and a cone shaped member disposed within said one chamber, the base of the cone having approximately the same area as that of the diaphragm and being located adjacent the diaphragm, the cone shaped member having its apex pointing away from the diaphragm with the apex of the cone shaped member having an opening in it through which the treated fluid may be discharged, the means for admitting the fluid to be treated being disposed adjacent the base of the cone whereby the fluid to be treated will flow from the base of the cone to the apex thereof.

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