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ULTRASONIC CLEANING APPARATUS

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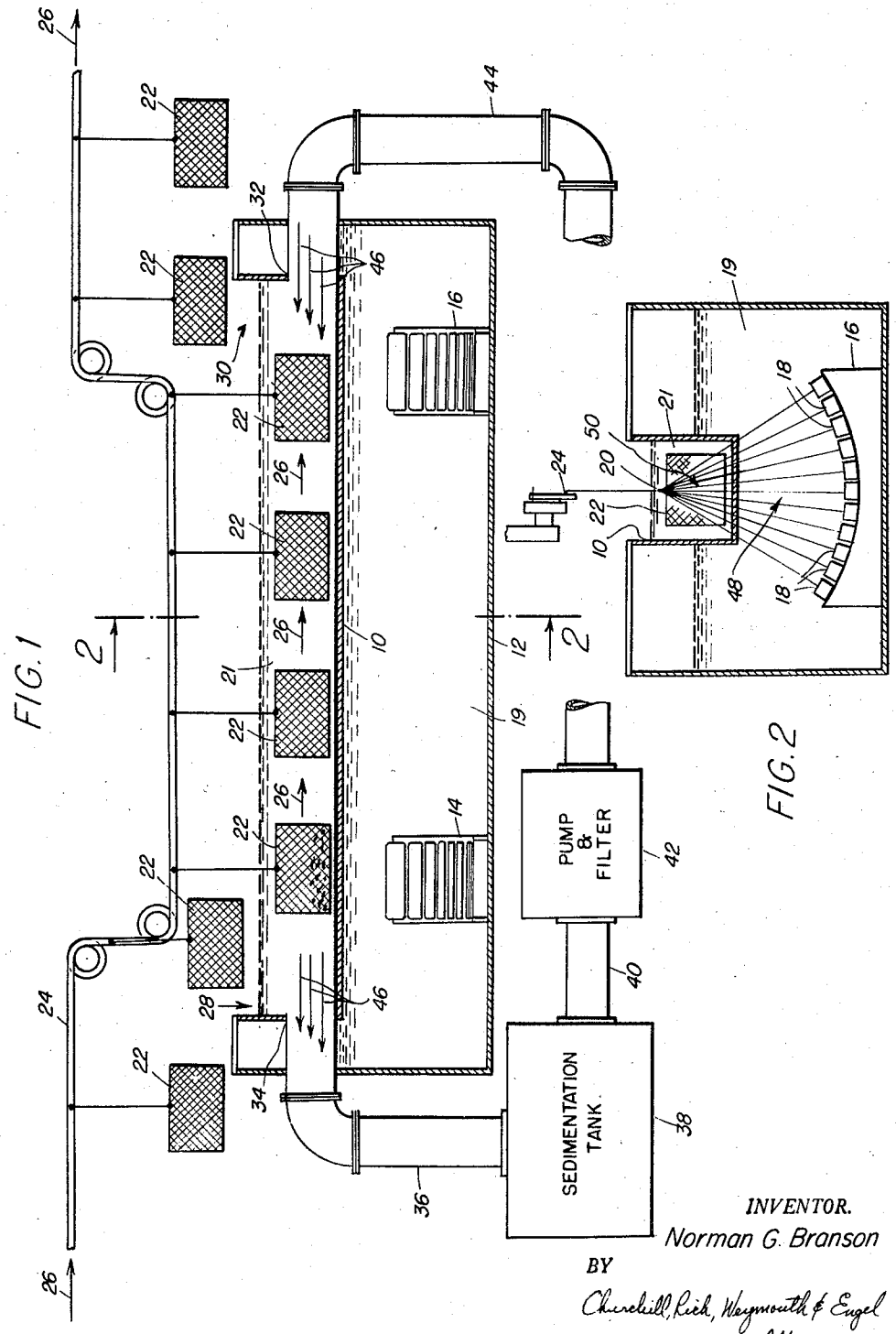


FIG. 1

FIG. 2

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ULTRASONIC CLEANING APPARATUS

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The present invention relates to ultrasonic cleaning apparatus.

It is now known that if a compressional wave generator is arranged to set up compressional wave energy in a body of liquid, and that if the generator is suitably energized, a phenomenon known as cavitation will be observed. Cavitation has been explained as the bursting of bubbles which are formed in the liquid due to the compressional wave energy. Usually the cavitation is confined to a particular region or zone where the wave energy is concentrated. If an object to be cleaned is located in this zone the liquid will exert a scrubbing action upon the article.

A typical cleaning setup may be provided with an ultrasonic transducer, which may be nothing more than a piezoelectric crystal, located at the bottom of a tank containing a cleaning solution and arranged to direct its compressional wave energy upward through the liquid. The article to be cleaned can be inserted or immersed into the liquid within the zone or region of compressional wave energy and after a short time all foreign matter or dirt adhered to its surface will be removed by the scrubbing action. The important thing, however, is that cavitation must take place within the zone for satisfactory cleaning or any cleaning at all to take place.

A well known cleaning liquid which is extremely suitable for de-greasing is trichloroethylene. Unfortunately, trichloroethylene is a very poor propagator of compressional wave energy. Thus, when the ultrasonic apparatus is intended for use with a bath of trichloroethylene it is necessary to use an excessive number of transducer units or employ excessive power. But excessive power results in the additional adverse characteristic of producing cavitation at the surface of the transducer and cutting down the cleaning effect, not to mention possible damage to the transducer. Also for reasons of economy it is desirable to keep down the input power required for a given cleaning effect. For the purposes of this discussion the relationship between the input power and the resulting cleaning effect will be referred to as the input power-to-cleaning ratio. Thus, it is an object of the present invention to produce apparatus whereby the input power-to-cleaning ratio may be decreased.

It is often essential in cleaning operations that the articles when removed from the cleaning bath be substantially completely devoid of foreign contamination. This condition can not be guaranteed if thte cleaning bath in the vicinity of the article at the moment it is removed therefrom contains such foreign matter. It is, therefore, a further object of the present invention to insure that the cleaning bath in the vicinity of the article at the moment the article is removed therefrom is almost or substantially devoid of such undesirable contamination. By thus improving the cleaning efficiency of the apparatus there is achieved a further decrease in the input power-to-cleaning ratio.

In order to provide apparatus which is expressly suited for use with cleaning solutions having poor compressional wave propagating properties, there is provided a combination comprising focused compressional wave generating means associated with an enclosure for containing both the cleaning liquid and the object to be cleaned with the enclosure disposed so that the generating means lies without and the focal point lies within its confines. In order to communicate compressional wave energy from the generating means to the enclosure, liquid confining means is provided for supporting another liquid so as to encompass the entire path of energy transmission between the generating means and said enclosure. The other liquid should be selected so as to have good compressional wave energy propagating properties. Such a liquid may, for example, be water. In this manner the enclosure which contains the cleaning liquid can be made as small as possible commensurate with the size of the objects to be cleaned. However, focused compressional wave generating means may still be employed by filling the remaining space between the generating means and the enclosure with a liquid such as water which has good compressional wave energy propagating properties.

In addition to the aforementioned structure, means are provided for causing the cleaning liquid to circulate through the cleaning enclosure in one direction along a cleaning path therein. The articles to be cleaned are inserted or immersed in the bath and moved through the bath in the opposite direction along the same path. In this manner the foreign particles or contaminants, as they are removed from the objects, are carried by the stream of cleaning liquid in a direction away from the point of emergence of the article from thte bath. By the combination of the various features already mentioned and others to be discussed in the following detailed description the present invention is characterized by a low input power-to-cleaning ratio.

The various objects and advantages of the present invention will best be understood in the light of the following detail description of the present preferred embodiment, taken in connection with the accompanying drawings in which:

Fig. 1 is an elevation, partly in section, of ultrasonic cleaning apparatus constructed in accordance with the invention and shown more or less schematically; and

Fig. 2 is a sectional view taken on line 2—2 in Fig. 1.

Referring now to the drawing the enclosure for the cleaning liquid is shown at 10. It is in the form of an elongated trough open at the top and positioned horizontally. The trough 10 is supported within a larger enclosure 12 adjacent the top thereof. A plurality of compressional wave generating means 14 and 16, as many as may be desired, are positioned at the bottom of the enclosure 12 and spaced along its length so as to lie beneath the trough 16. In Fig. 2 it can be seen that the generating means 16 is of the focused type. It will be assumed for the present discussion that the means 14 will have generally the same construction. That is, both are formed from a plurality of individual transducing elements, designated by the numeral 18, which are mounted on an arc or a parabola so as to project their wave energy towards a focal point 20. In operation the enclosure 12 will contain a liquid which has high compressional wave propagating properties such as water, designated by the numeral 19 in Fig. 2. The enclosure or trough 10 may then be filled with a cleaning solution such as trichloroethylene which has relatively poor compressional wave propagating properties. The cleaning liquid is designated in the drawing by the numeral 21.

The articles to be cleaned are placed in suitable holding means such as the baskets 22 which are supported from a conveyor belt or chain or the like 24 and conducted in the direction of the arrows 26 into the trough 10 near one end designated 28 and then carried through

the cleaning liquid towards the other end from which they emerge at **30**.

The trough **10** is provided with an inlet for the cleaning solution at **32** and with an outlet for the solution at the opposite end at **34**. The outlet **34** is connected by a conduit **36** to a sedimentation tank **38**. From the sedimentation tank **38** the fluid is conducted through a pipe **40** to a pump and filter **42** (a still, if desired) and then through the conduit **44** to the inlet **32**. This produces a continual counterflow of cleaning liquid in the direction of the arrows **46**.

The separate elements **18** of the compressional wave generating means will be electrically energized by a conventional power oscillator. With the present arrangement the power can be so adjusted that in the region designated **48** in Figure 2 insufficient energy will be present to produce cavitation in the water. However, cavitation will be produced in the trichloroethylene **21** in the region **50**. It is to be understood that any form of focused compressional wave generating means may be employed in practicing the present invention.

Although only two compressional wave generating means **14** and **16** are illustrated in Figure 1 it is feasible and sometimes desirable to include more than two spaced along the length of the trough. For purposes of illustration the bottom of the trough **10** has been shown as flat. However, the bottoms of the baskets may be curved as well as the bottom of the trough. It may also be desirable to curve the bottom of trough **10** in order to "tune" the space between the trough and the generating means.

In the embodiment illustrated, the compressional wave generating means are located below the trough. This causes the compressional wave energy to enter the trough through its bottom wall and thus the space between the baskets and the bottom wall is preferably kept at a minimum. However if the compressional wave generating means are located to one side of the trough then the space between that side of the basket and the adjacent side wall should be maintained at a minimum.

As best seen in Fig. 2, the focal point **20** of the compressional wave energy is located on the side of the baskets remote from the point of entry of the compressional wave energy into the trough. This provides a substantial cavitation zone within the cleaning liquid.

In Fig. 2 it is also seen that the level of the water **19** in the outer enclosure **12** is maintained below the upper surface of that enclosure. This is merely optional and may vary from installation to installation. For maximum efficiency the water, or other liquid having good compressional wave propagating properties, should encompass the entire path of energy transmission between the compressional wave generator and the cleaning trough or enclosure **10**. Thus the liquid confining means **12** should be so designed that it will contain or hold the liquid or water so as to completely encompass the entire energy transmission path.

To summarize the operation, the articles to be cleaned will be placed in the baskets or supports **22** and conveyed into the cleaning bath at the end **28** of the trough **10**. The circulating system including the pump **42** and the connecting plumbing will cause a steady flow of the cleaning liquid through the trough **10** in the direction of the arrows **46**. As the conveyor conducts the articles in the direction of the arrows **26** against the stream of cleaning liquid, they will pass through the zones of cavitation generated by the compressional wave generating means and the foreign or contaminating material will be removed from the articles. Due to the counterflow of the cleaning liquid the contamination will be carried behind the articles being cleaned so that they progress into cleaner and cleaner liquid. Thus, as the supports or baskets **22** approach the end **30** of the trough **10** the cleaning liquid in this region as well as the articles are substantially free of contamination. This insures that the articles are completely clean as they emerge from the trough **10**.

It is to be understood that the specific structure disclosed in the drawing has been chosen solely for the purpose of illustration to show an exemplary embodiment of the invention. As will be clear to those skilled in the art the structure may be modified without departing from the spirit of the invention.

What is claimed is:

1. Ultrasonic cleaning apparatus comprising focused compressional wave generating means for setting up compressional wave energy in a surrounding medium directed toward a distant focal point, an enclosure for containing both a cleaning liquid and an object to be cleaned, said enclosure being so disposed that said generating means lies without and said focal point lies within its confines, and liquid confining means associated with said generating means and said enclosure for supporting a body of liquid therebetween encompassing the entire path of energy transmission between said generating means and said enclosure, said liquid having good compressional wave energy propagating properties, whereby the input power-to-cleaning ratio is decreased for a cleaning liquid having poorer compressional wave propagating properties than said last mentioned liquid.

2. Ultrasonic cleaning apparatus according to claim 1, wherein said enclosure is provided with liquid inlet and outlet means disposed at spaced apart points for establishing a flow of cleaning liquid in one direction along a cleaning path therein, and means are provided for conveying an article to be cleaned through the cleaning liquid in the opposite direction along said cleaning path, thereby to reduce further the input power-to-cleaning ratio.

3. Ultrasonic cleaning apparatus according to claim 2, wherein said enclosure comprises an elongated horizontal trough with said inlet and outlet means disposed in opposite end walls thereof, and a circulating pump and filtering system is coupled in circuit with said inlet and outlet means for establishing said flow of cleaning liquid along the length of said trough and for eliminating the material removed from articles being cleaned.

4. Ultrasonic cleaning apparatus according to claim 1, wherein said focal point is located within said enclosure remote from the place of entry of said compressional wave energy, whereby a substantial quantity of the cleaning liquid will be subjected to intense compressional wave energy.

5. Ultrasonic cleaning apparatus comprising a plurality of focused compressional wave generating means for setting up compressional wave energy in a surrounding medium directed toward a series of distant focal points, said focal points being so located that the regions of maximum compressional wave energy define a given path, an enclosure for containing both a cleaning fluid and an object to be cleaned, said enclosure being so disposed that said plurality of generating means lie without and said path lies within its confines, means for conveying an article to be cleaned along said path within said enclosure, and liquid confining means encompassing the paths of energy transmission between said plurality of generating means and said enclosure, said liquid confining means being adapted to hold a liquid having good compressional wave energy propagating properties, whereby the input power-to-cleaning ratio is decreased for a cleaning liquid having poorer wave propagating properties than said last mentioned liquid.

6. Ultrasonic cleaning apparatus according to claim 5, wherein the article to be cleaned is conveyed in one direction along said path, and means are provided for creating a counterflow of cleaning fluid along said straight line path, said last mentioned means comprising liquid inlet and outlet means for said enclosure disposed beyond the opposite ends of said straight line path.

7. Ultrasonic cleaning apparatus comprising an elon-

gated horizontal open top trough for holding a cleaning liquid; a conveyor supporting a plurality of means for holding articles to be cleaned, said conveyor being positioned above said trough for leading said holding means into the cleaning liquid at one end of the trough, conveying the holding means through the liquid along the length of the trough, and removing the holding means from the cleaning liquid at the other end of the trough; said trough being dimensioned with respect to said holding means such that the cleaning liquid will just surround said holding means; at least one focused compressional wave gentrating means positioned below the trough for setting up compressional wave energy in a surrounding media directed toward a focal point located within said trough above said holding means as they pass through the trough; and liquid confining means encompassing the entire path of energy transmission between said generating means and said trough, said liquid confining means being adapted to hold a liquid having good compressional wave energy propagating properties, whereby the input power-to-cleaning ratio is decreased for a cleaning liquid having poorer wave propagating properties than said last mentioned liquid.

8. Ultrasonic cleaning apparatus comprising focused compressional wave generating means for setting up compressional wave energy in a surrounding medium directed toward a distant focal point, an enclosure for containing

both a cleaning liquid and an object to be cleaned, means for supporting said object in said enclosure, said enclosure being so disposed that said generating means lies without its confines, said wave generating means being so disposed that said focal point is located on the side of said object remote from the points of entry of the compressional wave energy into said enclosure, and liquid confining means associated with said generating means and said enclosure for supporting a body of liquid therebetween encompassing the entire path of energy transmission between said generating means and said enclosure, said liquid having good compressional wave energy propagating properties, whereby the input power-to-cleaning ratio is decreased for a cleaning liquid having poorer compressional wave propagating properties than said last mentioned liquid.

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