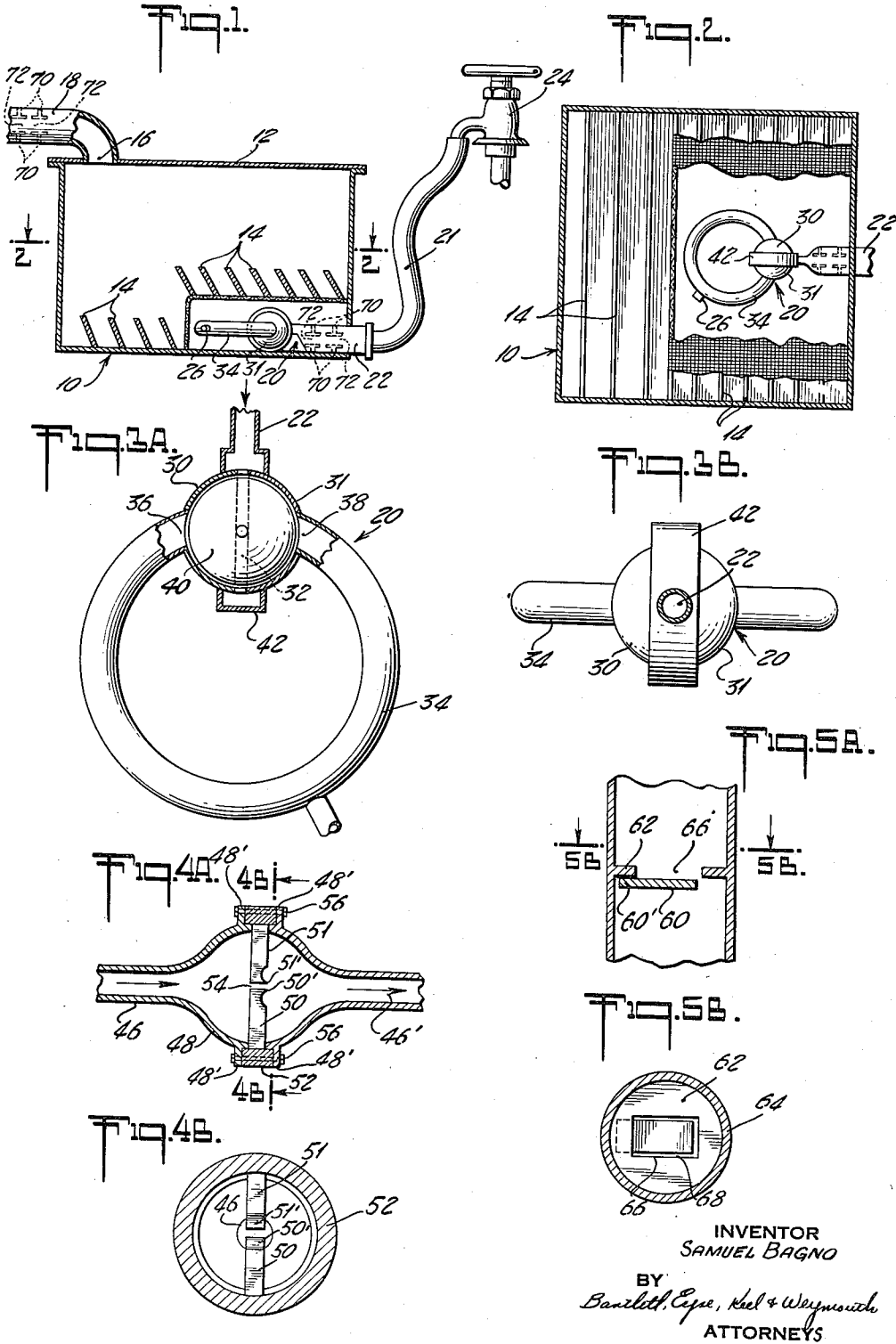


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METHOD AND APPARATUS FOR WASHING ARTICLES BY
SUPERSONIC VIBRATION IN A FLOWING LIQUID
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METHOD AND APPARATUS FOR WASHING
ARTICLES BY SUPERSONIC VIBRATION IN
A FLOWING LIQUID

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This invention relates to the removal of foreign matter from the surfaces of articles such as dishes and the like.

One object of the invention is the method and apparatus for cleaning articles without the aid of abrasives, soaps and other conventional mechanical cleaning equipment.

Other objects of the invention will become apparent in the following description and accompanying drawings forming part of this application.

Fig. 1 is a side view of one embodiment of the invention;

Fig. 2 is a plan view taken along the lines 2—2 of Fig. 1;

Figs. 3A and 3B are plan and side views of apparatus in accordance with the invention;

Fig. 4A is a cross-sectional view of another form of the invention;

Fig. 4B is a sectional view taken along the line 4B—4B of Fig. 4A; and

Fig. 5A is another form of the invention.

Fig. 5B is a sectional view taken along the line 5B—5B of Fig. 5A.

This invention contemplates the cleaning of articles as for instance dishes and cooking utensils by means of high frequency pressure waves of the order of 20 to 50 kc. generated in the fluid in which the articles are immersed. In this way I am able to thoroughly cleanse the dishes without the need of warm or hot water or even solvents and abrasives such as soaps, abrasive cleansers and the like, and in addition attain a relatively high degree of sterilization even when using domestic cold water. I am also able to generate these high frequency waves by means of the water power available in conventional domestic water supply systems and thus provide simple, inexpensive and long-lasting equipment that will operate silently and effectively to both clean and sterilize the articles.

For a more detailed description of the invention, reference is made to the drawings and particularly to Figs. 1 to 3B inclusive, wherein 10 denotes a closed container for housing the articles to be cleaned having a removable top 12 and a rack 14 for supporting the articles in a suitable position for cleaning. In cleaning dishes, for instance, it is desirable to support them in a substantially vertical position so that the food particles and grease when removed can either fall to the bottom of the container or be carried by the water through an outlet 16 in the top and discharged through conduit 18 connected with the drain.

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In the bottom of the container is located a pressure wave generator 20 having an inlet pipe or conduit 22 connected by a hose 21 to a suitable source of fluid under pressure as for instance the water faucet 24 of a domestic cold water system. The pressure of the fluid flowing through the inlet pipe 22 and into the generator 20 is discharged into the container through the generator outlet 26. The continuous discharge of water fills the container and is then discharged through the outlet 16 at the rate of admission through the inlet 22. The generator 20 in discharging fluid through the outlet 26 periodically interrupts the flow and thereby creates a succession of pressure waves in the fluid which travel through the fluid as well as the articles immersed therein, and it is the action of these waves or vibrations which removes particles that may be clinging to the surfaces of the articles.

I have found that if these pressure waves are generated at ultrasonic frequencies and preferably at frequencies between 20 to 40 kc. per second, good results will be obtained.

The removal of the particles by ultrasonic pressure waves may be referred to as cavitation and is actually effected by the travel of the waves through the particles and into the article or dish to which the particle adheres. A pressure wave consists of two zones—one in which the medium through which the wave is passing is compressed so that its density is greater than normal, and another in which the density of the medium is less than normal. As the wave proceeds through a homogeneous body stresses are set up which first compress a part of the medium and then cause it to be expanded or pulled apart. In the present instance the pressure wave passes through the boundary between two relatively homogeneous mediums—the particle and the article to which the particle adheres—and in so doing actually causes the particle to be forcibly pulled from the surface, whereupon it is either carried by the water or falls to the bottom of the container by the force of gravity.

The force exerted at the boundary of two different mediums can be determined by relating the impedances of the two mediums. The impedance of a medium, whether it be a fluid or a solid, is

$$\sqrt{\frac{C}{K}}$$

where C is the density and K the compressibility of the medium. If Z_2 is the impedance of one medium, as for instance a dish, and Z_1 is the impedance of another medium, say a food par-

ticle, then the force P tending to separate the particle from the dish can be expressed as

$$P = \frac{Z_2 - Z_1}{Z_2 + Z_1}$$

Since in the cleaning of dishes the difference in the impedance of the two mediums is relatively large, the pressure or force tending to separate them is also large.

In addition to the removal of particles by cavitation, a certain degree of removal is effected by the agitation of the particles produced by the mere passage of the pressure waves through the particles. This occurs to a greater extent particularly when the waves travel through a particle in a direction other than normal to the surface to which it is attached, whereupon the particle is vibrated relative to the surface and falls away.

Moreover with my invention, oils and fats are emulsified by the high frequency pressure waves and are therefore readily removed from the container by the continuous flow of water through it.

One novel and improved method for generating ultrasonic pressure waves by means of water pressure is illustrated in Figs. 1 to 3B inclusive and comprises a pair of hemispheres 30—31, spaced to form a circumferential gap 32. A circular conduit or resonant loop 34 connects opposing openings 36—38 in the hemispheres and is provided with a discharge port 26. A spherical oscillating member 40 is disposed within the opening provided by the hemispheres 30—31 and centered therein by means of a plurality of pins fastened at one end to the sphere and secured in the gap 32 by welding or brazing. The spacing between the sphere and the hemispheres is maintained sufficiently small so that upon expansion of the sphere in a direction normal to the mounting axes it will alternately open and close the openings 36 and 38 in the hemispheres.

The circumferential gap 32 is closed by a circumferential channel member 42 connected with the inlet pipe 22. In this way the incoming fluid under pressure enters the space between the sphere and the hemispheres by means of the gap 32 and flows through the conduit 34 for discharge through the outlet port 26 into the container 10.

The sphere 40 and the conduit 34 are preferably made to resonate at the same frequency in order to obtain an efficient conversion of water energy to wave energy. The sphere for frequencies of the order of 30 kc. should have a thin wall structure and be formed of a hard material, as for instance titanium oxide, stainless steel, or the like. It may also be desirable to fill the sphere with hydrogen or other similar gas to obtain the desirable resonant frequency. The conduit 34 will resonate with the frequency of the sphere when its total length is equal to an odd number of half wavelengths of the waves generated by the sphere, and the outlet 26 may be placed at any velocity point on the resonant conduit 34 as for instance any half wavelength point thereon.

In operation of this novel and improved generator, the water rushing through the inlet pipe 22 will enter the gap 32 and fill the space about the sphere. The noise and turbulence produced by the rush of the water causes the sphere to periodically expand and contract. Since bodies when set into motion will normally oscillate at their natural or resonant frequency, the pulses of energy supplied by the water set the sphere and conduit into oscillatory motion whereupon

they continue to oscillate at the designed frequency.

As the sphere expands and contracts, water is periodically permitted to flow into the conduit 34 at a rate equal to the frequency of oscillation of the sphere. Since the length of the conduit 34 is an odd number of half wavelengths, the pulses or waves produced by the sphere 40 will be amplified and water will be discharged through the port 26 at the resonant frequency of the sphere and at a relatively high amplitude. The area of the port 26 should, however, be small relative to the area of the conduit 34. For instance, if the conduit 34 has an area of about one square inch, then the port 26 should preferably be of the order of three-eighths of a square inch.

In the foregoing fluid pressure operated generator, the entire water supply is interrupted to produce the pressure waves in the fluid within the container. Another method of generating pressure waves is shown in Figs. 4A and 4B, wherein only part of the water supply is interrupted. In this way the fluid flow through the tank can be materially increased and thereby effect a more complete removal of the particles from the container.

This form of the invention includes a conduit 46 having a widened spherical part 48 in which a pair of resonant bars 50—51 are placed. These bars are rigidly mounted on a heavy metallic ring member 52 and spaced one from the other so that a relatively small gap 54 is provided therebetween. The spherical part 48 of the conduit is preferably made in two parts, each provided with circumferential flanges 48' adapted to be fastened to the ring member 52 by bolts 56 or other suitable means.

In operation, the fluid enters the conduit 46 in the direction indicated by the arrow and passes both around the members 50—51 and through the gap 54. The aft side of each member 50—51 is recessed or cut out to provide relatively sharp edges 50'—51', and the fluid in passing these edges is diverted momentarily to produce turbulence and set the members into longitudinal vibration to alternately open and close the gap 54 and thereby produce an interrupted flow of water. The water and the generated pressure waves then pass through the conduit part 46' and into the container as shown in Fig. 1.

Still another form of generator is shown in Figs. 5A and 5B. It includes a reed 60 securely fastened at one edge 60' to a wall or disc 62 within the conduit 64, the disc being provided with an opening 66 just large enough to permit the reed 60 to vibrate therein. The gap 66 between the opening and the reed is alternately opened and closed by the rush of water through the conduit 64 and thereby generates a pressure wave which is transmitted into the tank 10.

It is desirable, in the generation of pressure waves within the tank, to prevent or retain losses at a minimum. One of the more important losses will occur in absorption of the pressure waves by the walls of container or tank 10 and I prefer, therefore, to make the walls of a relatively dense metal so that reflection rather than absorption will be obtained.

It is also desirable to prevent the transmission of waves through the outlet 16 and inlet 22 and for this purpose filters or traps are enclosed within each conduit 18 and 22. These filters are illustrated in Figs. 1 and 2 and each consists of a pair of spaced discs 70 having central flanged

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openings 72 through which the water or fluid may pass. The flanges extend from both sides of the discs and are spaced so the resonant point of the trap is substantially at the frequency of the pressure waves in the tank. In this way a substantial part of the waves reaching the traps are reflected back into the container and cannot escape and be dissipated in the connecting conduits.

With my invention I am able to thoroughly cleanse articles such as dishes and the like using any readily available and suitable fluid such as a domestic cold water supply. Moreover, substantially complete sterilization is obtained and by the elimination of electrical and conventional mechanical components I am able to operate the device at greatly improved efficiencies. Furthermore, ultrasonic frequencies are inaudible and with my novel and improved method and apparatus for generating these frequencies, the process can be carried on with little or not audible sound.

In the generation of pressure waves within a container in the manner heretofore described, standing waves of constant frequency are set up by reflection from the container walls which absorb power without producing useful work. By varying the frequency of the waves set up in the moving body of water a Doppler effect is obtained. Thus when the water impinges on the walls of the container, frequency variation will prevent formation of standing waves by reflection. By varying the fluid pressure applied to the generator a slight shift in the frequency generated within the container can be obtained. By periodically or aperiodically altering the water pressure, these standing waves can be materially reduced so that a greater part of the energy will function to perform the cleaning operation. This modulation of frequency can be accomplished by a slowly varying pressure control device, as for instance a reed operated device of the type shown in Fig. 5A that is designed for operation at a frequency preferably in the subsonic range so that no audible noise will be produced.

An alternate method of frequency variation for eliminating the effect of standing waves is to include two generators such as shown in Figs. 3, 4 and 5 arranged to oscillate at different frequencies so that the pressure wave admitted to the container produces the effect analogous to having both frequency and amplitude modulation at a frequency equal to the difference in the generator frequencies. It is preferable that the difference in frequencies between the two generators be in either the ultrasonic or subsonic ranges so that the resulting modulation will not be audible. In this way standing waves are effectively prevented.

I claim:

1. The method of cleaning articles comprising placing the articles in a container having an inlet and an outlet, continuously admitting liquid under pressure into the container and discharging it through the outlet, and producing pressure waves of ultra-sonic frequencies in the liquid in the container by periodically interrupting the admission of said liquid.

2. The method of cleaning articles placed within a closed container having an inlet and outlet comprising continuously admitting liquid into the container and discharging it through the outlet, vibrating the liquid entering the container

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and impeding the transmission of vibrations through the inlet and outlet.

3. The method of cleaning articles within a closed container having an inlet and outlet comprising continuously admitting liquid under pressure into the container and discharging it through the outlet, and periodically interrupting the admission of the liquid to the container at a rapid and varying rate to set up vibrations in the liquid while preventing formation of standing waves in the liquid by reflection from the container walls.

4. The method of washing dishes comprising immersing the dishes in a liquid bath and setting up pressure vibrations of an ultra-sonic frequency within the liquid by constantly admitting liquid under pressure to the bath and periodically interrupting such admission.

5. The method of washing dishes placed within a closed container having an inlet and outlet comprising continuously admitting liquid into and discharging it from said container, generating pressure waves of an ultrasonic frequency in the liquid during admission to the container and impeding the transmission of said waves through the inlet and outlet of said container.

6. The method of cleaning articles in a closed container having an inlet and an outlet comprising continuously admitting liquid into and discharging it from the container, and periodically interrupting the admission of at least part of the liquid into the container to produce pressure vibrations therein of an ultra-sonic frequency.

7. The method of cleaning articles in a closed container having an inlet and outlet comprising continuously admitting liquid into and discharging it from the container, periodically interrupting the admission of liquid into the container to produce pressure vibrations therein of an ultra-sonic frequency, and blocking the transmission of said vibrations through the inlet and outlet of said container.

8. The method of cleaning articles in a closed container having an inlet and outlet comprising continuously admitting liquid into and discharging it from the container, periodically interrupting the admission of liquid into the container to produce pressure vibrations therein of an ultra-sonic frequency, and reflecting waves entering the inlet and outlet back into the container to preserve the energy generated within the liquid.

9. Apparatus for cleaning articles comprising a container having an inlet and an outlet, means including conduits for continuously admitting liquid into said inlet and discharging it from said outlet, a pressure wave generator having means actuated by the liquid flow into the container to produce pressure waves within the liquid, and pressure wave filters in said inlet and outlet to impede the transmission of said waves through said conduits, said generator being disposed between the inlet filter and the container.

10. Apparatus for cleaning dishes comprising a closed container having an inlet and an outlet and means whereby the dishes to be cleaned can be placed therein, a pressure wave generator associated with said inlet, means for supplying liquid under pressure to said inlet, said generator having means responsive to the liquid flow to produce pressure waves in the admitted liquid and said admitted liquid filling the container and being discharged at the rate of admission and band elimination filters resonant to the pressure waves being disposed in said inlet and outlet to

prevent dissipation of said waves therethrough by reflection back into the container.

11. Apparatus for cleaning dishes comprising a closed container having an inlet and outlet and means whereby dishes to be cleaned can be placed therein, means for supplying fluid under pressure to said inlet, a pressure wave generator associated with said inlet comprising means for periodically interrupting the flow of at least part of said fluid, band rejecting filters in said inlet and outlet for preventing the transmission of pressure waves therethrough, said fluid being continuously admitted into said container and discharged through said outlet at the rate of admission when the container is filled.

12. Apparatus according to claim 11 wherein said pressure waves are produced at an ultrasonic frequency.

13. Apparatus according to claim 11 wherein said pressure waves are produced at a frequency in the range of 20 to 40 kc. per second.

14. Means for cleaning articles comprising a hollow member having an inlet and an outlet for the circulation of liquid under pressure therethrough, an input pressure wave filter in the inlet, an output pressure wave filter in the outlet, a pressure wave generator between said filters and actuated by the flow of the liquid, and means for positioning an article to be washed between the generator and the output filter.

15. The method of cleaning solid articles comprising immersing said articles in a liquid container having an inlet through which liquid is admitted under pressure, vibrating the liquid at

one frequency by means of the liquid flow and then vibrating the vibrated liquid at another frequency by means of the liquid flow whereby the second frequency is constantly varied in frequency and in amplitude.

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