CLEANING METHOD AND APPARATUS

Filed Aug. 11, 1965 3 Sheets-Sheet 1

Fig. 1.

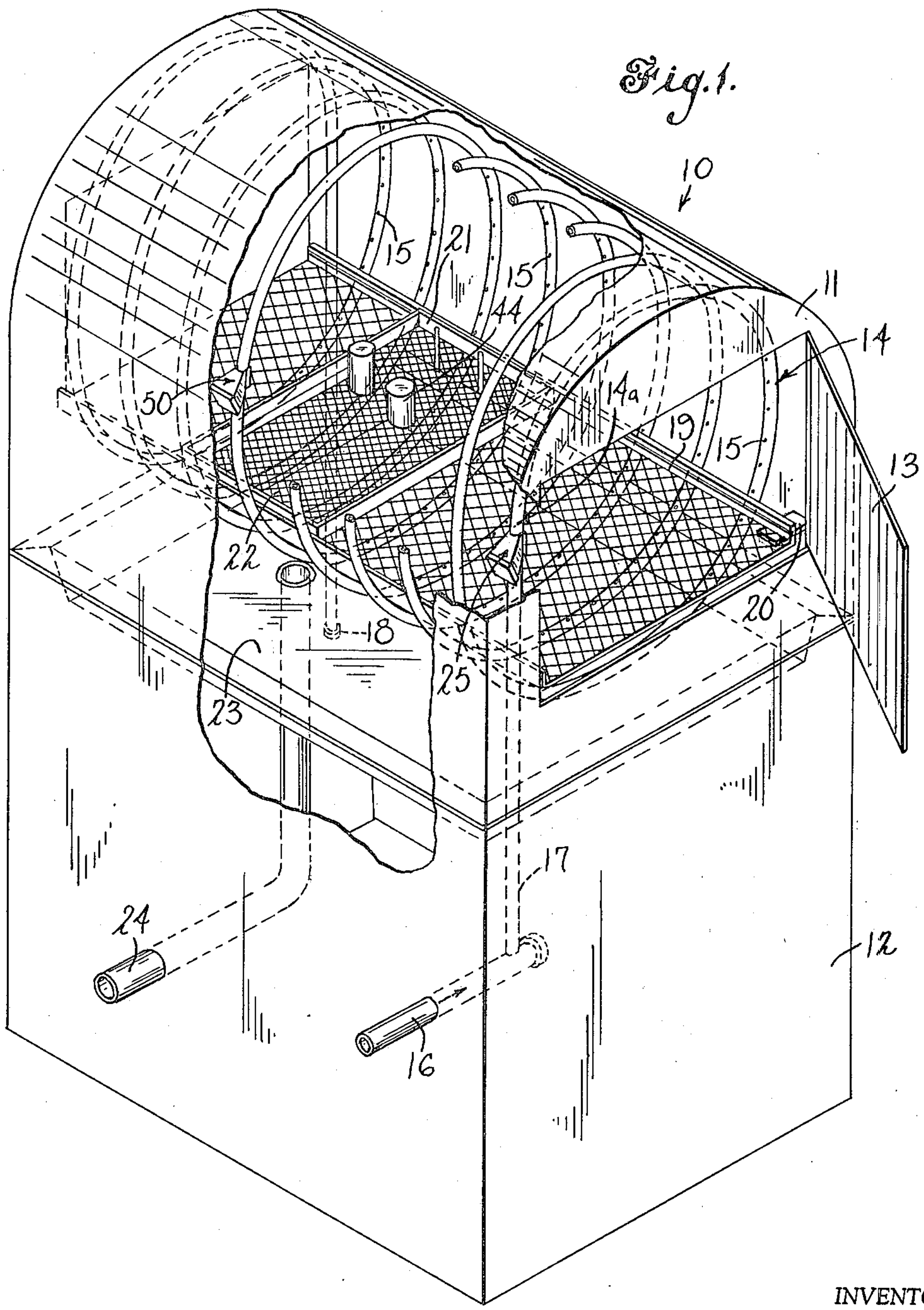

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Fig. 2.

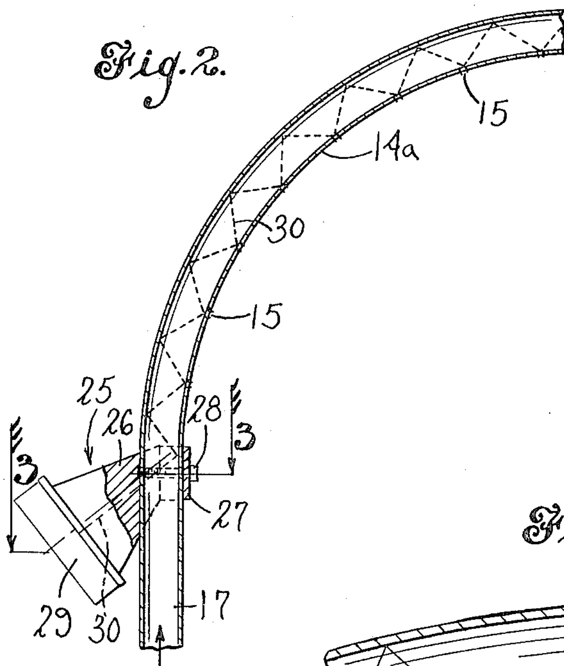


Fig. 3.

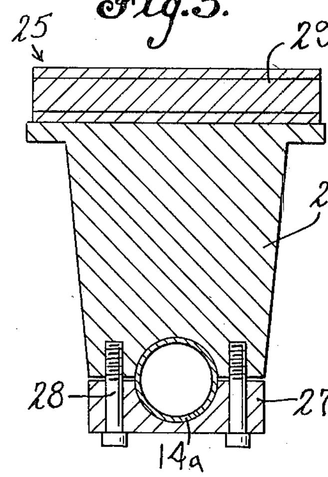


Fig. 4.

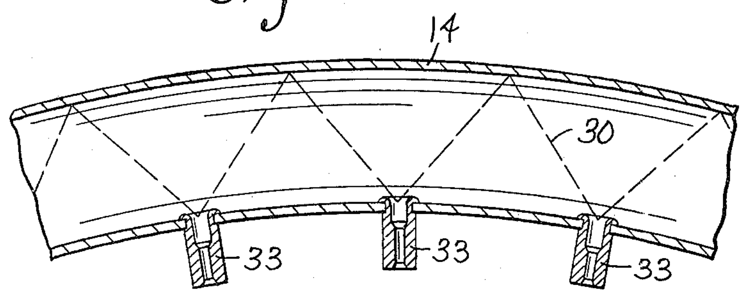


Fig. 5.

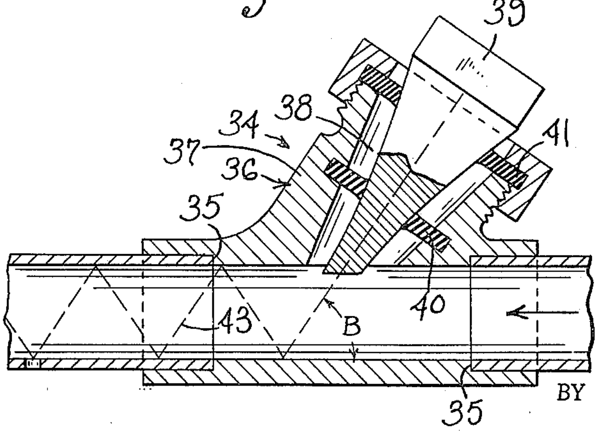
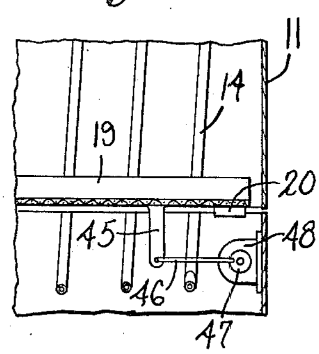


Fig. 6.



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CLEANING METHOD AND APPARATUS

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Fig. 8.

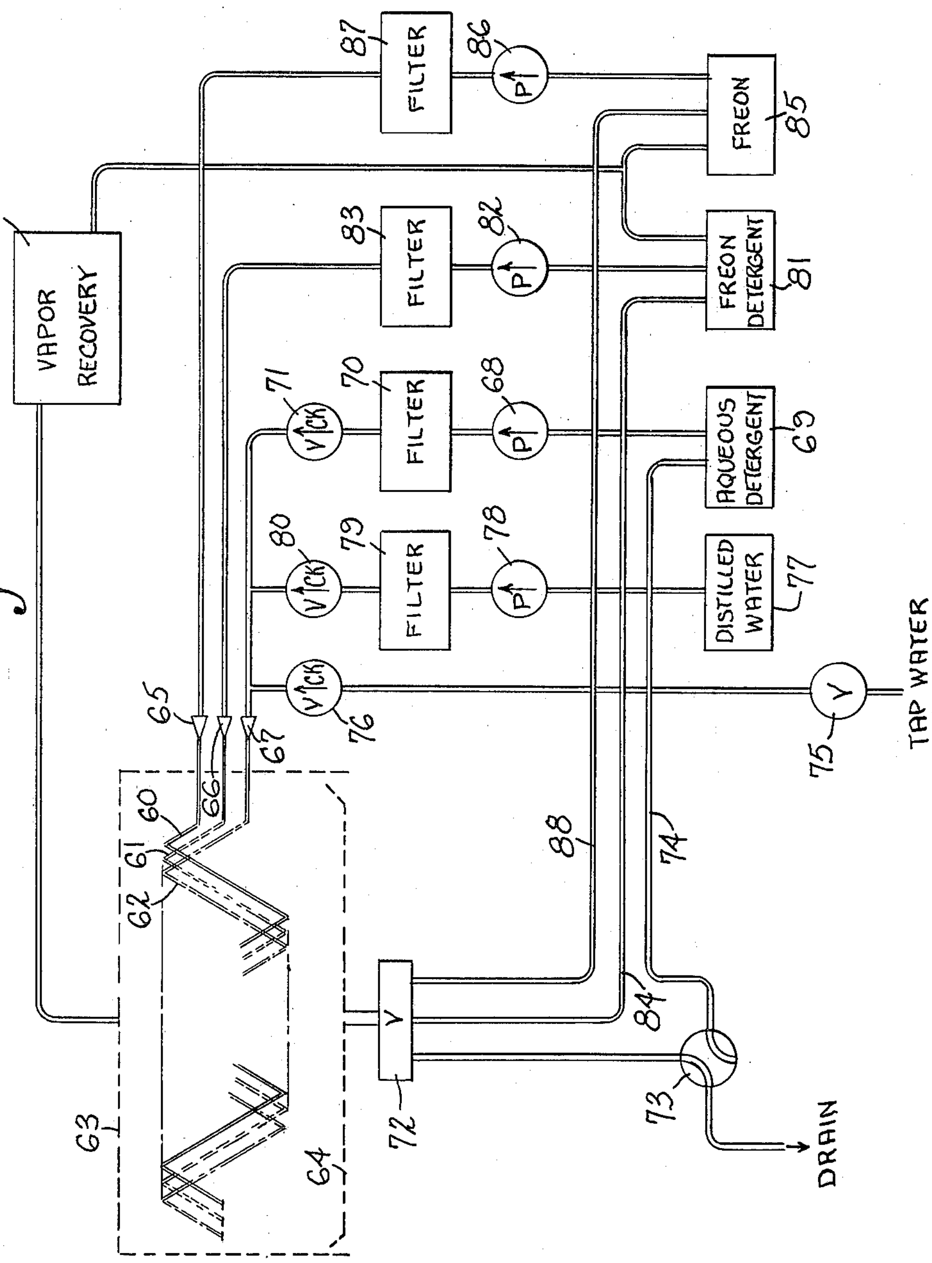
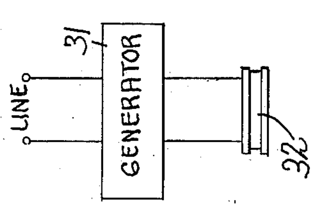


Fig. 7.



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CLEANING METHOD AND APPARATUS

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U.S. Cl. 134—1 11 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus for cleaning the surface of an article which comprises a length of tubing having orifices spaced along the length thereof and means for forcing liquid under pressure into the tubing to produce jets of liquid emanating from the orifices. Ultrasonic energy is introduced into the liquid in the tubing so that a wave of ultrasonic energy is transmitted through the liquid and produces cavitation in the jet streams emanating from the orifices.

This invention relates to a method and apparatus for cleaning objects and more particularly relates to an improved method and apparatus for cleaning or washing objects which utilize ultrasonic energy.

The use of ultrasonic energy in immersion cleaning of articles is quite well known. Known ultrasonic cleaning units generally comprise a cleaning tank containing a liquid with transducers mounted at the bottom or side of the tank. An article or articles to be cleaned are immersed in the liquid in the tank. The transducers convert electrical energy into mechanical vibrations which are transmitted through the liquid. Ultrasonic vibrations in the liquid cause rapid formation and collapse of millions of microscopic bubbles or cavities. The implosion or collapse of these cavities causes a violent inrush of adjacent mass at extreme pressures which pulls dirt, soil and contaminants free from the parts immersed in the liquid. This phenomenon is called cavitation. Ultrasonic energy, when transmitted through a liquid, cleans the most delicate and complex parts immersed in the liquid thoroughly, rapidly and efficiently.

The present invention combines the advantages of ultrasonic cleaning with jet stream cleaning. In jet stream cleaning apparatus and methods, high velocity streams of cleaning media are caused to impinge on the article or articles to be cleaned, thus effectively washing away exposed dirt, contaminants, etc. on the articles. An example of jet stream cleaning is the household dishwasher.

The present invention provides a new and improved method and apparatus of combining ultrasonic and jet stream cleaning to achieve a very efficient cleaning action which may be ultilized not only in cleaning articles, but also in sterilization thereof.

Briefly stated, the invention provides a technique of producing cavitation in jet streams of liquid through the use of ultrasonic energy, which jet streams are directed on the articles to be cleaned. In one form, this technique of cleaning is achieved by providing a tubular spray head having a plurality of equally spaced orifices along the length thereof directed toward the articles to be cleaned. A cleaning media under pressure is forced into the spray head creating jet streams emanating from the orifice towards the object to be cleaned. Ultrasonic energy is introduced into the cleaning media and reflected along the length of the tubular spray head from the walls thereof. The point of reflection of the ultrasonic energy is so selected that there is a point of reflection at some or all of the orifices. This introduces cavitation in the jet stream with a very efficient cleaning action on the articles to be cleaned resulting.

A further feature of the invention is the provision of

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new and improved means for introducing ultrasonic energy into and creating cavitation in a liquid-cleaning media, and particularly in jet streams. The invention further provides a new and improved liquid cleaning and rinsing operation including economy in the recirculation of cleaning media.

Accordingly, an object of this invention is to provide a new and improved method of surface cleaning articles.

Another object of this invention is to provide a new and improved method of surface cleaning articles which combines the efficiency of ultrasonic cleaning with jet stream cleaning.

Another object of this invention is to provide new and improved means for surface cleaning articles using ultrasonic energy.

Another object of this invention is to provide new and improved means for providing a jet stream cleaning device with facility for producing cavitation in the jet streams.

A further object of this invention is to provide surface cleaning apparatus including new and improved means for introducing ultrasonic energy into the cleaning media.

A further object of this invention is to provide a new and improved multi-cycle cleaning system utilizing jet sprays having cavitation produced therein.

A further object of this invention is to provide a new and improved jet spray cleaning system in which several spray heads may be utilized to spray different cleaning or rinse media in a minimum of space, and further where some or all of the media may be recirculated for reuse.

A still further object of this invention is to provide a new and improved jet spray head.

The features of the invention which are believed to be novel are set forth with particularity and distinctly claimed in the concluding portion of this specification. However, the invention both as to its organization, operation and method of practice, together with further objects and advantages thereof, may best be appreciated by reference to the following detailed description taken in conjunction with the drawings, in which:

FIG. 1 is a perspective view partially cut away, which shows features of the apparatus embodying the invention;

FIG. 2 is a view in half section of a section of tubing of the apparatus of FIG. 1 as seen from the right-hand end of the apparatus of FIG. 1 immediately inside thereof;

FIG. 3 is a sectional view seen in the planes of line 3—3 of FIG. 2;

FIG. 4 is a fragmentary view of a portion of the tubing of FIG. 2 illustrating jet stream producing means associated with the tubing;

FIG. 5 illustrates in half section a coupling member which may be inserted in the tubing of the foregoing figures and illustrates mounting of an ultrasonic transducer thereto;

FIG. 6 is a fragmentary view of a portion of the apparatus of FIG. 1 illustrating schematically the manner in which an article-holding rack may be reciprocated;

FIG. 7 is a schematic view in block form of an apparatus utilized to produce ultrasonic energy; and

FIG. 8 is a schematic diagram of a multi-cycle cleaning system embodying the invention.

An apparatus in which the invention may be practiced and embodied is indicated by the reference character **10**, and generally comprises a cleaning housing **11** carried on a base member **12**, and having an excess door **13** at the end thereof. Disposed within housing **11** and extending along the length thereof is a jet stream spray head **14** having a plurality of orifices **15** spaced along the length thereof. The spray head is preferably in the form of a helix with the orifices **15** directed towards the longitudinal axis of the helix. The orifices **15** are provided with nozzle means (FIG. 4) for creating a concentrated jet stream, as will hereinafter be described. The tubing of the helical spray head **14** is preferably of stainless steel and is connected to a liquid supply conduit **16** which receives a cleaning media or liquid under pressure, as will hereinafter be schematically described. Liquid entering conduit **16** passes through lead-in section **17** to the first helix of spray head **14** and through the helical tubing. The spray head is terminated in any suitable manner as at **18.** Therefore, the liquid must exit through the orifices **15.** Disposed within the helix is a perforate rack **19** adapted to be reciprocated parallel to the axis of the helix as hereinafter described. Rack **19** may be slidably mounted on support means or rails **20** mounted to the inside of housing **11** (only one shown). Carried on rack **19** is a tray **21** having a perforate bottom **22**, adapted to hold the articles to be cleaned. For reasons hereinafter described, the rack **19** and tray **21** are disposed beneath the axis of the helix. The apparatus of FIG. 1 further comprises a liquid-collecting member or sump **23** disposed beneath the helix to collect liquid emanating from the orifices **15**, and a drain tube **24** communicating therewith.

Reference is now made to FIG. 2 which more clearly shows in half section a portion of the first turn **14***a* of the helical spray head **14**. Disposed about the tubing is a transducer mounting member **25** comprising a mounting portion **26** and a securing portion **27**, both formed with semi-circular channels adapted to fit about the tubing. Bolts **28** secure the portions together on the tubing. Mounted on member **25** is an ultrasonic transducer **29** which is so directed and arranged in association with mounting member **25** as to direct a wave of ultrasonic energy into the tubing at a predetermined angle as shown by the broken line **30**. This wave of ultrasonic energy is transmitted through mounting member **25** through the walls of the tubing and reflected from the walls of the tubing as it travels along the length thereof with every other point of reflection occurring at an orifice **15**.

The ultrasonic transducer **29** of any one of the three general classes of transducers is generally available. These are the electro-strictive type, the magneto-strictive type, and the sandwich type. The electro-strictive or piezoelectric type are generally composed of polarized ceramic such as barium titanate or lead zirconate, which is excited by an electric field. The magneto-strictive type is of a material such as nickel which is excited by a magnetic field. The sandwich type is essentially a higher frequency piezoelectric transducer loaded down with metal to lower its operating frequency. These types of ultrasonic transducers may be mounted on the member **25** in such relation thereto that ultrasonic energy will be transmitted through the member **25** and the walls of the tubing and reflect along the length of the tubing as indicated by the broken lines **30**. In energizing the transducers, a generator **31**, FIG. 7 converts line power into high frequency electrical power which is applied to a transducer **32** and the transducer vibrates naturally at the same frequency. These mechanical vibrations produce the ultrasonic energy which is transmitted to the fluid in the tubing.

The term "ultrasonic" as used herein refers to that range of frequencies in which fluids can be made to cavitate. It has been determined that cavitation of the fluid may be made to occur in frequencies ranging from 10 kilocycles to several megacycles. The term "cavitation" refers to the phenomena which produces the formation and collapse of millions of microscopic bubbles. The collapse or implosion of these tiny cavities creates a violent inrush of the adjacent mass at extreme pressure which effectively sucks matter off solids upon which the jet spray impinges.

Cavitation threshold levels tend to occur at lower power inputs at the lower frequency end of the aforementioned frequency spectrum. However, in some cases, the audible portion of the aforementioned spectrum (10 to 18 kilocycles) has been found objectionable to the operator. Accordingly, cleaning at frequencies at 20 kilocycles, or above, is generally preferred.

FIG. 4 represents an enlarged view in section of the tubing and illustrates a means for concentrating the liquid emanating from the orifices and producing jet streams directed towards an object to be washed. Positioned in each of the orifices is a nozzle **33** of decreased diameter along its length arranged to concentrate and focus the stream forced from the tubing. In FIG. 4, as in FIG. 2, it will be noted that the wave of ultrasonic energy reflected along the length of the tubing has reflection points at each of the nozzles **33**, which produces cavitation in the streams emanating from the orifices.

The nozzles are provided to prevent diffusion of the liquid streams emanating from the orifices. The liquid in the streams should be concentrated to prevent loss of cavitation in the streams. If too much diffusion of the streams occurs the cavitational phenomena in the streams will be diminished.

FIG. 5 illustrates another technique of introducing ultrasonic energy into the fluid in the tubing and comprises a coupling member **34** having a generally cylindrical body portion provided with means such as internal shoulders **35** at either end thereof for receiving the tubing and further includes an extending, generally upstanding, portion **36** having walls **37** defining a transducer-receiving bore **38**. An ultrasonic transducer **39** is supported in bore **38** by resilient mounting and sealing members **40** and **41** such that its axis of vibration forms an angle B with the tubing and the generally cylindrical portion of coupling member **34**. The members **40** and **41** damp out or alternate transmission of ultrasonic vibrations to coupling member **34** and the tubing, and further provide a liquid seal and transducer support. Transducer **39** is so constructed and arranged as to concentrate and focus ultrasonic vibrations at the end thereof into the liquid in coupling member **34**.

The spacing of the orifices **15** and the angle B are chosen so that points of reflections of the ultrasonic wave **43** occur at orifices **15**.

In the operation of the device thus far, the liquid cleaning media is forced under pressure through the lead-in pipes **16** and **17** into spray head **14**, and the transducer on mount **25** generates ultrasonic energy which is directed into the tubing through mounting member **25**. The ultrasonic wave is reflected from the walls thereof as the ultrasonic energy travels along the length of the tubing. As previously pointed out, the points of reflection are so chosen that the ultrasonic energy impinges at the orifices **15** and the nozzles **33** which may be therein. This produces jets of liquid containing ultrasonic energy, which in turn produces cavitation in the jets and provides very efficient surface cleaning of the objects **44** on tray **21**. Simultaneously, rack **19** is reciprocated by any suitable mechanism as, for example, that illustrated in FIG. 6. Rack **19** may be provided with a depending arm **45** pivotally connected by a mechanism comprising a rod **46** and crank **47** driven at a predetermined speed by a suitable drive means **48**, such as a low speed motor or a geared down shaft. The rack **19** is slowly reciprocated within the spray head to ensure total exposure of the surfaces of articles **44** to the jet streams.

In some instances it may be desirable to introduce ultrasonic energy into the spray head at more than one point to compensate for the energy loss due to attenuation as the energy travels along the length of the tube. As illustrated in FIG. 1 a second transducer mount **50** is mounted on the spray head and so positioned that every other point of reflection of the ultrasonic energy introduced into the spray head impinges at each orifice.

The shape of the spray head, helical, provides improved exposure of the articles to be cleaned to the multiplicity of jets to ensure more effective cleaning action. If desired, some of nozzles **33** may be dissimilarly directed in a predetermined pattern toward the axis of the helix. For example, the center of three nozzles 33, shown in FIG. 4, may be directed directly at the axis of the helix while the other two nozzles are directed toward such axis at an angle, in opposite directions. Such directional pattern may be repeated along the length of the helix.

In an alternate arrangement, both transducer mounts 25 and 50, or two coupling members 34, could be mounted on the same turn of the helix and each transmit a wave of ultrasonic energy which alternately impinge at every other orifice and associated nozzle.

The liquid cleaning media falls into sump 23 from whence it drains through drain pipe 24 either for discharge or for recirculation, as hereinafter explained. The rack 19 is mounted below the axis of the helix to allow the articles 44 to extend toward the axis thereof. Also, such positioning of rack 19 is preferable inasmuch as the lower sprays must work against gravity while the upper sprays are aided by gravity.

This invention provides many versatile arrangements for effecting surface cleaning of articles. For example, various cleaning or rinsing media may be utilized in the same spray head, as exemplified in FIG. 1, and either recirculated or dumped. Additionally, a plurality of substantially similar helical spray heads may be utilized to carry different cleaning or rinsing media. In such case, either some or all of the spray heads may be arranged to have ultrasonic energy introduced therein. As an example of such versatility, reference is now made to FIG. 8 which exemplifies a multi-cycle cleaning system embodying the invention.

In the apparatus of FIG. 8, an article to be surface cleaned is inserted within the helical spray heads 60, 61 and 62 which are essentially the same in configuration, have essentially the same axis, and are arranged in nested relation. The spray heads 60, 61 and 62 are disposed within housing 63 above a sump 64. Various cleaning and rinsing media are introduced into the spray heads in a predetermined sequence and in successive washing or rinsing cycles. As illustrated, transducers 65, 66 and 67 are associated with each of the heads 60, 61 and 62, respectively. However, it is to be understood that this is for purposes of illustration only, and one or more of the cleaning heads may be utilized only for jet stream cleaning without ultrasonic assist. Alternatively, the same spray head may be used in one cleaning media in which ultrasonic energy is introduced into the cleaning head and, also, with a second cleaning or rinsing media in which ultrasonic energy is not introduced into the cleaning head, and cleaning or rinsing is performed by jet stream action only. It is to be understood that dependent upon the type of article to be surface cleaned and the number of cycles in an overall cleaning operation, the number of cleaning heads may vary, as well as the different types of cleaning media.

In the apparatus of FIG. 8 a typical cleaning cycle might be as follows:

An aqueous detergent is applied to cleaning head 62 together with ultrasonic energy from transducer 67 for a predetermined period of time. During this time, pump 68 is operated to draw the aqueous detergent from reservoir 69 and apply the aqueous detergent through a filter 70 and check valve 71 to head 62. The detergent emitted by the jet streams of head 62, after impinging upon the articles to be cleaned, falls into sump 64 and is drained through a distribution valve 72 and a two-way valve 73 back to reservoir 69 over line 74. It will be understood that if desired a drain pump (not shown) may be placed in line 74 to assist recirculation of the aqueous detergent to reservoir 69.

After washing with the aqueous detergent, together with ultrasonic energy, the articles within the spray heads are rinsed with tap water which may be applied under line pressure through a valve 75, and check valve 76 to cleaning head 62. At this time it may not be desired to have the ultrasonic assist, and the articles may be rinsed with tap water only through jet stream action. The tap water is discharged to the drain through distributing valve 72 and two-way valve 73 without recirculation.

After the rinse with tap water, distilled water is drawn from reservoir 77 by pump 78 through a filter 79 and check valve 80 to head 62. Distilled water collected in sump 64 is discharged through distributing valve 72 and two-way valve 73 without recirculation. Usually it will not be desired to apply ultrasonic energy to the distilled water during this rinsing operation.

After the water rinses a cleaning media incorporating a detergent, such as a Freon detergent mix, is drawn from reservoir 81 by pump 82 through filter 83 to head 61. The Freon detergent in head 61 may have ultrasonic energy applied thereto by transducers 66, and the Freon detergent collected in sump 64 is passed through distributing valve 72 to line 84, back to reservoir 81 for recirculation. Line 84 may contain a drain pump, if necessary.

The articles to be cleaned are then subject to a final rinse of Freon which is drawn from reservoir 85 by pump 86 and applied through filter 87 to head 60. This rinsing media may or may not, as desired, have ultrasonic energy introduced therein by transducer 65. During this cycle of operation, the Freon drains from sump 64 through distributing valve 72 to line 88 and back to reservoir 85. If desired, a drain pump may be installed in line 88.

The articles whose surfaces have been cleaned may be removed from housing 63 and additional articles to be cleaned inserted and the above-described cycle repeated. Freon is exemplified as a cleaning media because of its inert chemical characteristics. Where Freon is used a vapor recovery system generally indicated by the block 89 may be utilized to condense the Freon gasses in housing 63 and return the condensation to reservoirs 81 and 85.

It may thus be seen that the invention may provide a closed circuit cleaning combining ultrasonic and jet stream cleaning system and use a multiplicity of fluids without interaction therebetween. Further, various fluids, or cleaning or rinsing media, may be utilized in the same spray head.

The number of heads utilized and the number of different fluid media will, of course, depend upon the intended utilization of the apparatus. In some embodiments, only one spray head will be used in conjunction with several liquids as exemplified by head 62. It is understood that the apparatus schematically shown in FIG. 7 exemplifies several surface cleaning systems that may embody the invention. For example, where articles requiring sterilization are to be cleaned, a sterilant such as aqueous gluteraldehyde may be utilized as a rinse in one of the spray heads.

The system shown in FIG. 8, as will be apparent, may be automatically controlled in any desired sequence, and the various cycles timed to meet the requirements of the articles to be cleaned.

While the invention has primarily been disclosed in conjunction with a helical spray head in a closed housing, it is to be understood that the invention is not limited to such construction. By way of example, the invention may be practiced with a linear spray head in which the jet streams are sonically activated to produce cavitation in jet streams in the manner described. Additionally, apparatus embodying the invention may be utilized to clean the exterior of objects such as buildings and other large objects which cannot suitably be housed within a cleaning enclosure.

It may thus be seen that the objects of the invention set forth as well as those made apparent from the foregoing disclosure are efficiently attained. While various embodiments of the invention have been exemplified for purposes of disclosure, modifications to the disclosed embodiments as well as other embodiments of the invention may occur to those skilled in the art. Accordingly, the appended claims are intended to cover all modifications of the disclosed invention as well as other embodiments thereof which do not depart from the spirit and scope of the invention.

What is claimed is:

1. The method of surface cleaning an article using a length of tubing having orifices uniformly spaced along the length thereof directed toward the article, comprising forcing liquid under pressure into the tubing to cause streams of liquid to emanate from the orifices and impinge on the article, and introducing ultrasonic energy into the liquid in said tubing transversely to the length of the tubing so as to produce reflection of the ultrasonic energy from the walls of the tubing as it travels along the length thereof with points of reflection occurring at the orifices.

2. Surface cleaning apparatus comprising a length of tubing having orifices therein spaced along the length thereof, means for forcing liquid under pressure into said tubing and producing streams of liquid emanating from said orifices and means for introducing ultrasonic energy into the liquid in said tubing through the walls thereof transverse thereto so that a wave of ultrasonic energy is reflected from opposite walls of said tubing along the length thereof with points of reflection occurring at the orifices so as to produce cavitation in the liquid emanating from said orifices.

3. Cleaning apparatus comprising a length of tubing in the form of a helix and having a plurality of orifices defined therein along the length thereof directed toward the axis of said helix, means positioned within said helix for supporting an article within said helix, means for forcing liquid under pressure through said tubing to cause streams of liquid to emanate from the orifices toward said axis, nozzle means in the orifices for concentrating the liquid in the streams into jets, and means for introducing a wave of ultrasonic energy into said tubing so as to cause reflection of said wave along the walls of the tubing with points of reflection occurring at at least some of said orifices.

4. The apparatus of claim 3 wherein the means for introducing introduces the ultrasonic energy into the liquid through the walls of said tubing.

5. The apparatus of claim 3 wherein said means for producing includes an ultrasonic transducer, said transducer extending into said tubing.

6. Surface cleaning apparatus comprising a plurality of tubes in the form of a helix, each of said tubes having orifices defined therein directed toward a common axis, means for supporting articles to be cleaned within said helix, means for forcing a liquid under pressure into each tube to produce streams of liquid emanating from said orifices, an ultrasonic transducer mounted to one of said tubes and arranged to transmit ultrasonic energy through the walls of said one of said tubes in a direction transverse to the length thereof to produce reflection of an ultrasonic wave from the walls of said one of said tubes as the wave travels along the length thereof, said orifices in said one of said tubes being so spaced and the angle of mounting of said mounting member so chosen that points of reflection of said wave occur at selected ones of said orifices.

7. Surface cleaning apparatus comprising a plurality of tubes in the form of a helix, each of said tubes having orifices defined therein directed toward a common axis, means for supporting articles to be cleaned within said helix, means for forcing a liquid under pressure into each tube to produce streams of liquid emanating from said orifices, an ultrasonic transducer carried by said at least one of said tubes and constructed and arranged to transmit ultrasonic energy into the liquid in said at least one of said tubes, a coupling member in said one of said tubes, said coupling member having an opening in the walls thereof communicating with the interior of said one of said tubes, said ultrasonic transducer being supported in said opening and arranged to transmit ultrasonic energy into the liquid in said one of said tubes at an angle to produce reflection of the energy from the walls of said one of said tubes as the energy travels along the length of said one of said tubes in the direction of liquid flow therein.

8. The apparatus of claim 7 wherein the orifices of said one of said tubes are so spaced and the angle of introduction of ultrasonic energy into said one of said tubes is so chosen that points of reflection of the energy occur at selected ones of said orifices.

9. Surface cleaning apparatus comprising a plurality of tubes, each of said tubes having orifices defined therein directed toward an object to be cleaned, means for forcing a liquid under pressure into each tube to produce streams of liquid emanating from said orifices, means for introducing ultrasonic energy into the liquid in one of said tubes to produce cavitation in the streams emanating from said at least one of said tubes, said energy being introduced into said tube transverse to the axis thereof to produce reflection of the energy along the walls of the tube with the points of reflection occurring at selected ones of said orifices, means for collecting the liquids emanating from said tubes, and means for recirculating selected ones of the liquids.

10. The apparatus of claim 9 wherein said tubes are in the form of helixes having a common axis, said orifices being directed toward said axis, and means for supporting articles to be cleaned with said helixes.

11. Surface cleaning apparatus comprising a length of tubing having orifices therein spaced along the length thereof, means for forcing liquid under pressure into said tubing and producing streams of liquid emanating from said orifices, a generally cylindrical coupling member in said length of tubing, said coupling member having an opening in the walls thereof communicating with the interior of said tubing, an ultrasonic transducer supported in said opening and arranged to transmit ultrasonic energy into the liquid in the tubing at an angle to produce reflection of the energy from the walls of said tubing as the energy travels along the length of the tubing in the direction of liquid flow therein, said orifices being so spaced that the points of reflection of the ultrasonic energy in said tubing occur at selected ones of said orifices.

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