A mobile floor cleaner that includes a moveable housing, a cleaning head operably supported by the moveable housing, one or more solution generators configured to receive a feed liquid and to generate a cleaning solution from the feed liquid by application of acoustic energy and/or nanobubble generation, and control electronics configured to operate the one or more solution generators.
FIG. 2
MOBILE FLOOR CLEANER WITH CLEANING SOLUTION GENERATOR

CROSS-REFERENCE


FIELD

[0002] The present disclosure relates to cleaning machines, such as mobile floor cleaners. In particular, the present disclosure relates to mobile floor cleaners that incorporate acoustic energy and/or nanobubble generation.

BACKGROUND

[0003] Floor cleaning in public, commercial, institutional and industrial buildings have led to the development of various specialized floor cleaning machines, such as hard and soft floor cleaning machines. These cleaning machines generally utilize a cleaning liquid dispensing system and a cleaning head to perform a cleaning operation.

[0004] The cleaning liquid dispensing system generally dispenses a cleaning liquid that includes water and a chemically based detergent. The detergent typically includes a solvent, a builder, and a surfactant. The cleaning head typically includes one or more disc-type scrubbing brushes, which may be located in front of, under or behind the floor cleaning machine. The scrubbing brushes typically include nylon bristles, pads or other fibers. The scrubbing brushes are motorized to rotate during cleaning operations. The rotation of the scrubbing brushes causes the brushes to scrub the surface being cleaned as they engage the surface.

[0005] While detergents increase cleaning effectiveness for a variety of different soil types, such as dirt and oils, these detergents also have a tendency to leave unwanted residue on the cleaned surface. Such residue can adversely affect the appearance of the surface and the tendency of the surface to re-soil. Additionally, the detergents may not be environmentally friendly. Some mobile floor cleaning machines have been fitted with electrolysis cells for producing an electrochemically-activated cleaning liquid by electrolyzing a feed liquid such as tap water.

[0006] Improved floor cleaning heads, mobile floor cleaners, and floor cleaning methods are desired for reducing the use of detergents during cleaning operations, while maintaining the efficacy of the floor cleaning operation.

SUMMARY

[0007] An aspect of the present disclosure is directed to a mobile floor cleaner that includes a moveable housing, a cleaning head operably supported by the moveable housing, a liquid source configured to provide a feed liquid, and a conduit configured to relay the feed liquid from the liquid source. The mobile floor cleaner also includes one or more solution generators configured to receive the feed liquid from the conduit, and to generate a cleaning solution from the feed liquid by application of acoustic energy (e.g., via ultrasonic waves) and nanobubble generation (e.g., via electrolysis). The mobile floor cleaner further includes control electronics configured to operate the one or more solution generators.

[0008] Another aspect of the present disclosure is directed to a method for cleaning a surface. The method includes providing a mobile floor cleaner having a cleaning head and a solution generator, directing a flow of a feed liquid to the solution generator, and generating a cleaning solution by applying acoustic energy to and generating nanobubbles in the feed liquid in the solution generator. The method also includes dispensing the generated cleaning solution to the surface, and agitating the dispensed cleaning solution with the cleaning head.

[0009] Another aspect of the present disclosure is directed to a mobile floor cleaner that includes a moveable housing, a liquid source configured to provide a feed liquid, a conduit configured to relay the feed liquid from the liquid source, and a scrubbing brush operably supported by the moveable housing. The scrubbing brush includes a backing portion, one or more sub-units each configured to retain a set of bristles, and one or more transducers supported by the backing portion and configured to vibrate the one or more sub-units and retained sets of bristles. The mobile floor cleaner also includes control electronics configured to operate the one or more transducers.

DEFINITIONS

[0010] Unless otherwise specified, the following terms have the meanings provided below:

[0011] The terms “preferred” and “preferably” refer to embodiments of the invention that may afford certain benefits, under certain circumstances. However, the embodiments may also be preferred, under the same or other circumstances. Furthermore, the recitation of one or more preferred embodiments does not imply that other embodiments are not useful, and is not intended to exclude other embodiments from the scope of the present disclosure.

[0012] The term “providing”, such as for “providing a mobile floor cleaner”, when recited in the claims, is not intended to require any particular delivery or receipt of the provided item. Rather, the term “providing” is merely used to recite items that will be referred to in subsequent elements of the claim(s), for purposes of clarity and ease of readability.

[0013] The terms “about” and “substantially” are used herein with respect to measurable values and ranges due to expected variations known to those skilled in the art (e.g., limitations and variabilities in measurements).

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. 1 is a side schematic illustration of an example mobile floor cleaner of the present disclosure.

[0015] FIG. 2 is a top perspective view of a cleaning head of the mobile floor cleaner.

[0016] FIG. 3 is an exploded top perspective view of a scrubbing brush of the cleaning head shown in FIG. 2.

[0017] FIG. 4 is a side schematic illustration of the scrubbing brush with a solution generator having a transducer unit located upstream of a hydrogen cell.

[0018] FIG. 5A is a side schematic illustration of the scrubbing brush with an alternative solution generator having an electrolysis cell located upstream from a transducer unit.

[0019] FIG. 5B is a side schematic illustration of the example mobile floor cleaner of FIG. 1 showing an alternative solution generator configuration.

[0020] FIG. 6 is a top schematic illustration of an alternative scrubbing brush of the cleaning head, which includes radial rows of multiple solution generators.
FIG. 7 is a side schematic illustration of the alternative scrubbing brush shown in FIG. 6.

FIG. 8 is a side schematic illustration of an alternative cleaning head having multiple front-located solution generators.

FIG. 9 is a top schematic illustration of the alternative cleaning head shown in FIG. 8.

FIG. 10 is a top schematic illustration of an alternative scrubbing brush having bristles secured to multiple transducer sub-units.

FIG. 11 is a side schematic illustration of the alternative scrubbing brush shown in FIG. 10.

FIG. 12 is a side schematic illustration of a second example mobile floor cleaner of the present disclosure having multiple solution generators separate from the cleaning head.

FIG. 13 is a schematic illustration of a third example mobile floor cleaner of the present disclosure having multiple solution generators separate from a dual-roller cleaning head.

FIG. 14 is a front perspective view of an alternative cleaning head having a cylindrical member.

FIG. 15 is an exploded perspective view of the alternative cleaning head shown in FIG. 14.

FIG. 16 is an illustration of an example portable cleaning stick that includes a solution generator for applying localized cleaning fluid.

DETAILED DESCRIPTION

The present disclosure is directed to a mobile floor cleaner that includes an acoustic transducer (e.g., an ultrasonic transducer) and/or a nanobubble generator (e.g., with an electrolysis cell or other nanobubble generator), which produce a cleaning solution from an aqueous feed liquid, such as water. As discussed below, the acoustic transducer and/or the nanobubble generator, in combination with a floor cleaning head, allows the mobile floor cleaner to clean floor surfaces effectively with little or no additives (e.g., detergents), and preferably with low power consumption. The lower power consumption correspondingly allows the mobile floor cleaner to incorporate smaller and/or fewer batteries with sustainable operating durations.

FIG. 1 illustrates an example mobile floor cleaner 10 of the present disclosure, which may be designed for use by an operator that walks behind the machine or rides on the machine. Examples of suitable cleaning units for mobile floor cleaner 10 include the “T”-series scrubbers from Tennant Company, Minneapolis, Minn., which are modified to operate as discussed below. Alternatively, mobile floor cleaner 10 may be configured to be towed behind another vehicle.

As shown, mobile floor cleaner 10 includes housing 12, which is supported by wheels 14 that advance mobile floor cleaner 10 in the direction of arrow 16 along a surface to be cleaned, such as surface 18. One or more of wheels 14 are correspondingly rotated by motor 20 based on operator commands, where motor 20 may include one or more electric motors and/or an internal combustion engine. Motor 20 may also be configured to rotate wheels 14 in the opposing directions to reverse the movement of mobile floor cleaner 10.

As further shown, mobile floor cleaner 10 also includes cleaning head 22, which, in the shown example, is a disc-type, scrubbing brush head that includes cover or shroud 24 and rotatable scrubbing brush 26. Scrubbing brush 26 is rotated about an axis of rotation 28 relative to cover 24 by motor 30. Motor 30 may include one or more electric motors that generate rotational power for a drive shaft or other mechanism (not shown) that extends along axis 28. Preferably, axis 28 is substantially perpendicular to the surface 18 being cleaned, allowing scrubbing brush 26 to rotate parallel to the surface 18 being cleaned.

Mobile floor cleaner 10 also includes control electronics 32, which include one or more control circuits configured to monitor and operate the components of mobile floor cleaner 10 over one or more control lines (e.g., electrical, optical, and/or wireless lines, not shown). Control electronics 32 and the components of mobile floor cleaner 10 are preferably powered from batteries 34, which are one or more rechargeable batteries, allowing mobile floor cleaner 10 to move freely without requiring a physical connection to a fixed electrical outlet. Accordingly, control electronics 32 may direct the operation of motors 20 and 30 respectively over control lines 36 and 38.

One or more of the control functions performed by control electronics 32 can be implemented in hardware, software, firmware, or a combination thereof. Such software, firmware, and the like may be stored on a non-transitory computer-readable medium, such as a memory device. Any computer-readable memory device can be used, such as a disc drive, a solid state drive, CD-ROM, DVD, flash memory, RAM, ROM, a set of registers on an integrated circuit, and/or the like. For example, the control circuit can be implemented partly or completely in a programmable logic controller and/or a processing device such as a microcontroller and/or another processor that executes instructions stored in a memory device, where the instructions configure the processor to perform the steps of the control process when executed by the processor to convert the processor into a special purpose computer.

Mobile floor cleaner 10 also includes liquid source 40, which is one or more reservoirs or tanks for storing a feed liquid 42 for cleaning, and/or may include a fitting or other inlet for receiving feed liquid 42 from an external source (e.g., from an external hose). Feed liquid 42 is an aqueous liquid, preferably regular, untreated tap water or other water that is commonly available. In some embodiments, feed liquid 42 may include one or more electrolytes to assist in an electrolysis reaction.

In some alternative situations, feed liquid 42 may also include one or more additives, such as detergents, which preferably do not leave post-cleaning residues and do not chemically attack the cleaned surface 18. However, as indicated above, in preferred embodiments, feed liquid 42 is substantially free of any residues-forming additives, such as detergents.

Feed liquid 42 may exit liquid source 40 by conduit 44, which may include one or more actuable valves (e.g., valve 46) and/or pumps (e.g., pump 48) for supplying feed liquid 42 to cleaning head 22. Control electronics 32 may direct the operation of valve 46 and/or pump 48 respectively over control lines 50 and 52. In alternative embodiments, feed liquid 42 may be supplied from liquid source 40 by the operation of a gravity, without pump 48.

Conduit 44 directs feed liquid 42 to solution generator 54, which, in the shown embodiment, includes transducer unit 56 and nanobubble generator (e.g., electrolysis cell) 58. As discussed below, transducer unit 56 includes one or more acoustic transducers configured to generate high-frequency acoustic waves through the received feed liquid 42. The acoustic transducers may be any suitable transducer, such as piezoelectric transducers and/or magnetostrictive transduc-
ers, and preferably generate ultrasound waves (e.g., from about 20 kilohertz to about 400 kilohertz).

The generated acoustic waves create compression waves in the received feed liquid 42 that flows through transducer unit 56, which produce microscopic voids or bubbles. Feed liquid 42 preferably fills the volume of transducer unit 56 at all times during operation to prevent the formation of air pockets that can otherwise potentially disrupt the acoustic waves.

After passing through transducer unit 56, the resulting liquid flows through nanobubble generator 58. Nanobubble generator 58 can be implemented as an electrolysis cell that generates nanobubbles in the flowing liquid through electrolysis. Examples of suitable cells for an electrolysis cell nanobubble generator 58 include those disclosed in U.S. Pat. No. 8,156,608. In alternative embodiments, nanobubble generator 58 may be replaced with other nanobubble generators, such as mechanical nanobubble generators (e.g., air infiltration sieves, venturi nozzles, swirl nozzles). These nanobubble generators can generate nanobubbles through shear forces without application of electrical energy. Therefore, although various example configurations described herein are described as having an electrolysis cell 58, the configurations may be implemented using a mechanical nanobubble generator in addition to or in lieu of electrolysis cell 58 without departing from the scope of the disclosure.

The flowing liquid received from transducer unit 56 also preferably fills the volume of electrolysis cell 58 at all times during operation to maintain the electrolysis reaction. Accordingly, transducer unit 56 and electrolysis cell 58 are each preferably sized based on the volumetric flow rate of feed liquid 42 to solution generator 54, which is accordingly dependent on the dimensions of conduit 44 and operational rate of pump 48.

The resulting cleaning solution that is generated may then exit electrolysis cell 58 (or other nanobubble generator) via a dispensing nozzle or orifice 60. The dispersed cleaning solution preferably provides a suitable path for conducting the acoustic waves (e.g., ultrasonic waves) from transducer unit 56 to the surface 18 being cleaned, through the dispersed cleaning solution. The dispersed cleaning solution also preferably carries the entrained nanobubbles to the surface 18 being cleaned.

Control electronics 32 may direct the operation of solution generator 54 (i.e., transducer unit 56 and electrolysis cell 58) over control line 62. In the shown embodiment, solution generator 54 is retained by scrubbing brush 26 of cleaning head 22 at its axial location. While not wishing to be bound by theory, it is believed that having the flow of the cleaning solution traverse around conduit corners or other conduit bends can adversely affect the stability of the generated cleaning solution, which can potentially reduce its cleaning efficiency. Therefore, solution generator 54 is preferably located close to and directed towards the surface being cleaned (e.g., surface 18) to provide the cleaning effectiveness. This is believed to provide a suitable path for conducting the acoustic waves (e.g., ultrasonic waves) and for carrying the entrained nanobubbles from solution generator 54 to the surface 18 being cleaned, through the dispersed cleaning solution.

The arrangement shown in FIG. 1, with solution generator 54 at the axial location of scrubbing brush 26, provides a suitable arrangement for dispensing the cleaning solution directly onto surface 18, and then agitating the cleaning solution with the rotating scrubbing brush 26 after the initial dispensing. This is believed to allow the generated bubbles from transducer unit 56 and electrolysis cell 58 to attract to and/or dislodge the contaminants (e.g., dirt) on surface 18 prior to being agitated with the rotating bristles of scrubbing brush 26. The rotating bristles may then abratively remove the contaminants along with the cleaning solution to clean surface 18.

As discussed below, solution generator 54 may rotate with scrubbing brush 26 while scrubbing brush 26 is driven by motor 30. As such, solution generator 54 may be a sacrificial unit that is permanently attached to the scrubbing brush 26, and the elements of transducer unit 56 and electrolysis cell 58 may be integrated within scrubbing brush 26 such that the brush and solution generator 54 are fabricated together as a single, unitary part. Alternatively, solution generator 54 may be fabricated as separate components that are secured to scrubbing brush 26.

Mobile floor cleaner 10 may also include a recovery system 64, which, in the shown embodiment, includes one or more vacuum units 66, one or more vacuum extractor tools 68, one or more vacuum squeegees 70, a vacuum path selector 72, and one or more waste recovery tanks 74. Vacuum unit 66 is used in combination with vacuum extractor tool 68 and/or vacuum squeegee 70 to remove liquid and solid waste (i.e., soiled cleaning liquid) from surface 18. Control electronics 32 may direct operation of vacuum unit 66 over control line 75.

Vacuum extractor tool 68 may be used for removing liquid and solid debris from soft surfaces 18, whereas vacuum squeegee 70 may be used for removing liquid and solid debris from hard surfaces 18, for example. Other types of liquid and debris recovery tools and methods can also be used for use on hard surfaces, soft floor surfaces, or both. Mobile floor cleaner 10 may also include one or more lift mechanisms (not shown) operated by control electronics 32 to independently raise and lower vacuum extractor tool 68 and vacuum squeegee 70.

The waste is passed through vacuum path selector 72 and into waste recovery tank 74. Vacuum path selector 72 allows a single vacuum unit 66 to selectively couple to vacuum extractor tool 68 and vacuum squeegee 70. Alternatively, separate vacuum units 66 may be individually used for vacuum extractor tool 68 and vacuum squeegee 70. In this alternative embodiment, vacuum path selector 72 may be optionally omitted.

During a cleaning operation, control electronics 32 may energize motor 30 (via control line 38) to rotate scrubbing brush 26 about axis 28, open valve 46 (via control line 50), and energize pump 48 (via control line 52) to supply the feed liquid 42 through conduit 44 to solution generator 54. Control electronics 32 may also energize the acoustic transducers in transducer unit 56 to generate acoustic waves (e.g., ultrasonic waves) through the feed liquid 42 flowing through transducer unit 56.

Control electronics 32 may also energize electrolysis cell 58 to generate nanobubbles in the liquid that passes through the cell 58 via electrolysis. In particular, control electronics 32 may energize electrolysis cell 58 by applying a suitable voltage across the electrodes contained in the cell. Electrolysis cell 58 accordingly generates an electrolyzed cleaning liquid that is dispensed directly onto surface 18 at an axially-central location along axis 28 (via dispensing nozzle
The electrically-charged nanobubbles of the resulting cleaning solution then attract and dislodge contaminants from surface 18, allowing the contaminants to then be abrasively removed by the rotation of scrubbing brush 26. The resulting soiled solution with the contaminants may then be collected with recovery system 64. [0053] While not wishing to be bound by theory, it is believed that the combination of the acoustic energy (via transducer unit 56) with the generated nanobubbles at electrolysis cell 58 (or other nanobubble generator) generate a cleaning solution that is effective for attracting and dislodging contaminants from surfaces (e.g., surface 18). Additionally, transducer unit 56 and electrolysis cell 58 are each low power-consuming devices. As such, solution generator 54 is suitable for generating cleaning solutions (free of detergents) without consuming substantial amounts of electrical power. This accordingly preserves the operating duration of mobile floor cleaner 10 and/or allows smaller or fewer batteries 34 to be used.

[0054] In addition, although the combination of acoustic energy and nanobubbles generated at electrolysis cell 58 can be used to provide an efficacious cleaning solution, it should be appreciated that mobile floor cleaner 10 can be configured to clean using acoustic energy without generated nanobubbles or generated nanobubbles without acoustic energy. Depending on the application, the cleaning efficacy provided by the acoustic energy enhancement or nanobubbles enhancement of feed liquid 42 alone may be sufficient to adequately clean a desired surface (e.g., surface 18). Therefore, although mobile floor cleaner 10 in the example of FIG. 1 is described as using the combination of the acoustic energy (via transducer unit 56) with the generated nanobubbles at electrolysis cell 58, it should be appreciated that the disclosure is not limited to this combination of features.

[0055] In practice, it is believed that dispensing the generated cleaning solution directly onto surface 18 without initially flowing into the rotating bristles of scrubbing brush 26 preserves the cleaning effectiveness of the generated cleaning solution for attracting and dislodging contaminants from surface 18. Shortly after being dispensed onto surface 18, scrubbing brush 26 may then further assist in the cleaning efforts through mechanical abrasion. This results in a clean surface 18 that is substantially free of film-forming residues.

[0056] FIG. 2 illustrates an example embodiment for cleaning head 22 with the integrated solution generator 54, and where cleaning head 22 is configured to carry a single, disc-type scrubbing brush 26. As shown, cover 24 is attached to a stationary part of motor 30. Cover 24 has a substantially closed upper surface 76, and a substantially open lower surface 78 facing the surface 18 to be cleaned. Scrubbing brush 26 is carried underneath cover 24 and is connected to a drive shaft or other mechanism (not shown) of motor 30, which extends through an aperture 80 at the axial center of upper surface 76.

[0057] In addition, cleaning head 14 includes conduit 82 having a first end configured to be connected to conduit 44 (shown in FIG. 1) for receiving feed liquid 42 from liquid source 40. A second end of conduit 82 passes through the aperture 80 to deliver feed liquid 42 to solution generator 54 (not shown in FIG. 2) incorporated into scrubbing brush 26. Cover 24 further includes an electrical terminal block 84, which provides an electrical connection to control line 62 (shown in FIG. 1) for operating solution generator 54. As explained in further detail below, cover 24 also provides a connection from terminal block 84 to corresponding electrical conductors on scrubbing brush 26.

[0058] FIG. 3 illustrates scrubber brush 26, which includes adapter 86 (also known as a disc hub or receiver), which attaches scrubbing brush 26 to the drive shaft of motor 30. Adapter 86 includes a central, female hub coupling 88, which is configured to receive and fixedly connect to the drive shaft of motor 30. Adapter 86 may be connected to the drive shaft by a bolt passing axially through the coupling 88 or a set screw within coupling 88, for example. Other methods of attachment may also be used.

[0059] Adapter 86 further includes a plurality of slots 90 configured to receive corresponding studs or cleats 92 attached to a backing portion 94 of scrubbing brush 26, by a friction fit, for example. A retaining spring 96 may also be provided to maintain the brush studs 92 engaged within slots 90. Studs 92 form a mechanical connection configured to receive a rotating driving force through adapter 86 to rotate scrubbing brush 26.

[0060] Adapter 86 also includes an annular slot 98 around coupling 88, which includes multiple reinforcing ribs. Annular slot 98 allows the received feed liquid 42 flowing from the second end of conduit 82 to fall downward past adapter 86. This allows the feed liquid 42 to reach solution generator 54 despite the high-speed rotation of scrubbing brush 26 (including adapter 86).

[0061] Scrubbing brush 26 also includes a set of bristles or other scrubbing material 100 attached to backing portion 94. Backing portion 94 can be formed of any suitable material such as plastic, synthetic material, wood, metal, and the like. In a particular example, backing portion 94 is formed of a rigid plastic material through an injection molding processes. Bristles 100 may be attached in any suitable manner to the lower surface of backing portion 94. In one example, bristles 100 are molded within the material of backing portion 94. Other attachment methods may also be used, such as adhesives or heat sealing.

[0062] Bristles 100 can be made of any suitable material such as plastic (e.g., nylon, polyester, polypropylene), natural animal hair (e.g. horse or hog hair), metal fibers, abrasives, and the like. Also, bristles 100 may be generally aligned vertically as shown in FIG. 3 or may be interconnected or layered such as in a pad form.

[0063] Backing portion 94 also includes a central aperture 102 in which solution generator 54 resides, below mesh plate 104, where mesh plate 104 may be omitted in some embodiments. During operation, the feed liquid 42 flows through annular slot 98 and mesh plate 104, and into transducer unit 56 of solution generator 54. This arrangement allows transmission of the feed liquid 42 into solution generator 54 despite the high-speed rotation of scrubbing brush 26, as mentioned above.

[0064] Backing portion 94 also includes an electrical coupling, such as first and second electrical conductors or contacts 106 and 108, which are electrically connected to transducer unit 56 and electrolysis cell 58. In this example, electrical conductors 106 and 108 are formed as coaxial, annular rings on backing portion 94. These rings are engaged by corresponding electrical brushes 110 carried by the lower surface 78 of cover portion 24, and which are connected to terminal block 84 of cover portion 24. In an alternative embodiment, the electrical conductors 106 and 108 are carried by cover portion 24, and the electrical brushes 110 are carried by backing portion 94.
As scrubbing brush 26 rotates around axis 28 within cover portion 24, the electrical brushes 110 maintain electrical contact with electrical conductors 106 and 108. The conductors 106 and 108 and brushes 110 can be located at any radius on the upper surface of backing portion 94, along the periphery of backing portion 94, and/or anywhere on adapter 86, for example. In another embodiment, the electrical connection between terminal block 86 and electrodes 106 and 108 is made by an inductive coupling, where a first member of the coupling is attached to cover portion 24 and a second member of the coupling is attached to adapter 86 or backing portion 94, for example. Other types of electrical couplings may be used in other embodiments.

As noted above, transducer unit 56 is configured to generate high-frequency acoustic waves in feed liquid 42, such as waves having a frequency greater than 20 kilohertz. In general, transducer unit 56 can be implemented using any type of acoustic wave generator that converts electrical energy into sound waves. In one example, transducer unit 56 includes one or more piezoelectric transducers that utilize the piezoelectric property of a material to convert electrical pulses into mechanical vibrations. In another example, transducer unit 56 includes one or more magnetostrictive transducers that utilize the magnetostrictive property of a material to convert electrical pulses into mechanical vibrations.

FIG. 4 is an additional simplified illustration of the engagement between solution generator 54 and scrubbing brush 26. As shown, transducer unit 56 of solution generator 54 may be secured within aperture 102 below mesh plate 104, where transducer unit 56 includes one or more acoustic transducers 112 for generating the acoustic waves (e.g., ultrasonic waves) in the received feed liquid 42, as discussed above. Beneath transducer unit 56, electrolysis cell 58 may also be secured within aperture 102, and held in place with dispensing nozzle 60, which may function as a restraining cap for solution generator 54.

Electrolysis cell 58 includes first and second electrodes 114 and 116, which in the example shown in FIG. 4, are arranged parallel to and separated from one another by a suitable gap (e.g., with spacer 118) to electrically isolate each other. Thus, electrodes 114 and 116 are oriented in planes that are parallel to the face of bristles 100 that engage the surface 18 being cleaned. In this embodiment, electrodes 114 and 116 are mesh-type electrodes, which enable the liquid from transducer unit 56 to pass through electrodes 114 and 116 by the force of gravity. In alternative embodiments, electrodes 114 and 116 may each be an annular electrode that is concentric with axis 28, allowing the liquid from transducer unit 56 to flow between the electrodes 114 and 116.

During operation, control electronics 32 activate acoustic transducers 112, and apply a suitable voltage potential across electrodes 114 and 116, via control line 62, terminal block 84, electrical brushes 110, and conductors 106 and 108. Feed liquid 42 is supplied to transducer unit 56 through conduits 44 and 82, aperture 80, annular slot 98, and mesh plate 104.

As motor 30 rotates scrubbing brush 26 about axis 28, the feed liquid 42 flows through transducer unit 56 and electrolysis cell 58 to generate the cleaning solution, as discussed above. In particular, acoustic transducers 112 preferably create ultrasonic waves through the flowing feed liquid 42, which then flow into electrolysis cell 58. At electrolysis cell 58, as the received liquid passes through the electrodes 114 and 116, the applied voltage induces an electrical current through the liquid contained in the gap and further generates nanobubbles in the liquid.

Due to gravity, the generated cleaning solution exits electrolysis cell 58 through dispensing nozzle 60, and is directly dispensed onto surface 18. As further shown in FIG. 4, after entering transducer unit 56, the feed liquid 42 preferably flows along a straight flow path though transducer unit 56, electrolysis cell 58, and dispensing nozzle 60, and onto surface 18. This allows the generated cleaning solution to be dispensed with a straight and direct flow path onto surface 18.

After being dispensed, the mechanical action of bristles 100 disperses the cleaning solution beneath brush 26 to actively clean surface 18. In a particular example, motor 30 may rotate scrubbing brush 26 from about 200 rotations per minute (rpm) to about 400 rpm, such as at about 300 rpm.

An exemplary technical effect of incorporating the solution generator 54 in the scrubbing brush 26 is that the feed liquid 42 is conditioned very close to the point of use at the surface 18 being cleaned, at the very end of the liquid flow path. This limits neutralization of the generated cleaning solution from the time at which the liquid is conditioned by solution generator 54 to the time at which the liquid contacts the surface 18 being cleaned.

In an alternative embodiment, transducer unit 56 may be separated from electrolysis cell 58, where transducer unit 56 may be retained at any suitable location upstream from scrubbing brush 26 (e.g., secured to cover 24). In this case, electrolysis cell 58 may be retained at any suitable location downstream from transducer unit 56, such as at scrubbing brush 26, as shown.

FIG. 5A illustrates an alternative embodiment for solution generator 54, where nanobubble generator 58 (e.g., an electrolysis cell) is located upstream relative to transducer unit 56. In this embodiment, the received feed liquid 42 initially undergoes electrolysis to generate nanobubbles in electrolysis cell 58, and the resulting liquid is then subjected to the ultrasonic waves of transducer unit 56 before being dispensed.

In a further embodiment, electrolysis cell 58 may be separated from transducer unit 56, where electrolysis cell 58 may be retained at any suitable location upstream from scrubbing brush 26. For example, electrolysis cell 58 may be retained at a location along conduit 44 and/or secured to cover 24. In this case, transducer unit 56 may be retained at any suitable location downstream from electrolysis cell 58, such as at scrubbing brush 26, as shown.

FIG. 5B illustrates an alternative embodiment of mobile floor cleaner 10 where like reference numbers refer to like elements discussed above in connection with FIGS. 1-4. In the example of FIG. 5B, mobile floor cleaner 10 includes a solution generator 54 that has a transducer unit 56 which does not contain a nanobubble generator (such as electrolysis cell 58). Transducer unit 56 is located in fluid communication with feed liquid 42 via conduit 44. In operation, transducer unit 56 can receive feed liquid 42 from liquid source 40 and impart acoustic energy to the feed liquid to generate an acoustically-enhanced liquid. For example, operating under the control of control electronics 32, transducer unit 56 can generate acoustic waves that are passed into feed liquid 42 flowing through solution generator 54. The acoustically-enhanced liquid generated by solution generator 54 can then be dispensed onto a surface to be cleaned via dispensing nozzle or orifice 60.
The acoustic energy imparted to feed liquid 42 can enhance the cleaning efficacy of the liquid as compared to when the liquid is not treated with acoustic energy. Acoustic waves generated by transducer unit 56 can propagate through feed liquid 42 as longitudinal waves that compress and decompress in the direction of travel. The compression and decompression of the acoustic waves can generate cavitation bubbles or void spaces within feed liquid 42. These cavitation bubbles or void spaces, which may or may not have a mean diameter less than 1 nanometer, can increase cleaning efficiency by agitating feed liquid 42 and creating a scrubbing action. For example, when the cavitation bubbles or void spaces implode, which can occur when the acoustically-enhanced liquid contacts a surface to be cleaned, the implosion can generate an intense localized shockwave. The shockwave can provide a force sufficient to overcome contaminant-to-substrate adhesion forces, releasing contaminants and cleaning the target surface.

When solution generator 54 is configured with transducer unit 56 but without a nanobubble generator as shown in FIGS. 5A, one or more acoustical transducers can be positioned in a number of different ways to direct acoustic energy into feed liquid 42. For example, the transducers can be positioned adjacent to and, in some examples, in contact with feed liquid 42 as it flows from liquid source 40 to dispensing nozzle or orifice 60. In such examples, the transducers can direct acoustic energy into feed liquid 42 after the liquid has been applied to a surface to be cleaned. In such examples, the liquid can be discharged via dispensing nozzle or orifice 60 onto a surface to be cleaned and thereafter impacted with acoustic energy generated by transducer unit 56. FIGS. 6 and 7 illustrate an alternative embodiment for scrubbing brush 26, which includes multiple solution generators 54 arranged radially around backing portion 94 between groups of bristles 100. As further shown in FIG. 7, backing portion 94 may also include conduits 120 for directing the received feed liquid 42 from aperture 102 to the individual solution generators 54 via centrifugal force and gravity.

In this embodiment, the number, sizes, and arrangements of the multiple solution generators 54 may vary depending on the particular cleaning requirements. As can be appreciated, due to the increased number of solution generators 54 in this embodiment, they each may be smaller in size than the single, axially-located solution generator shown in FIGS. 1-5. Furthermore, the number of radial rows of the multiple solution generators 54 may vary, such as from one row to ten rows, or from two rows to six rows, or from three rows to five rows.

Additionally, while illustrated as linear rows of multiple solution generators 54, each radial row may alternatively extend in any suitable arrangement, such as with spiral arms. This embodiment shown in FIGS. 6 and 7, and its variations, allow the generated cleaning solution to be dispensed in situ with the rotating bristles 100. For many applications, this can further assist in the cleaning efficiency of mobile floor cleaner 10.

FIGS. 8 and 9 illustrate another alternative embodiment in which multiple solution generators 54 are secured to cover 24 at a location that is in front of scrubbing brush 26 (in the direction of movement illustrated by arrow 16). In this embodiment, conduit 44 and control line 62 may each branch into each of the solution generators 54 for independent or collective operation.

The number, sizes, and arrangements of the multiple solution generators 54 in this embodiment may also vary depending on the particular cleaning requirements. Preferably, the multiple solution generators 54 in this embodiment produce a sufficient quantity of the generated cleaning solution to function with the size of scrubbing brush 26. As can be appreciated, due to the increased number of solution generators 54 in this embodiment, they each may also be smaller in size than the single, axially-located solution generator shown in FIGS. 1-5. Examples of suitable numbers of solution generators 54 in this embodiment range from one to ten, or from two to eight, or from four to six.

As shown in FIG. 9, the multiple solution generators 54 are arranged on cover 24 of cleaning head 22 in an arc row in front of scrubbing brush 26 (in the movement direction of arrow 16). Alternatively, the multiple solution generators 54 may be arranged in any suitable manner, such as in a linear row, a staggered row, and the like.

FIGS. 10 and 11 illustrate another embodiment, which may utilized in addition to the embodiments shown in FIGS. 1-9 (as well as in FIG. 12) or alternatively to the shown embodiments. As shown in FIG. 10, scrubbing brush 26 may also include multiple tracks, blocks, or other sub-units 122 that are supported by backing portion 94, but are capable of vibrating relative to backing portion 94. In particular, each sub-unit 122 is molded with or otherwise retains a group of bristles 100, and is engaged with one or more transducing elements 124 (e.g., as shown in FIG. 11).

The number and dimensions of sub-units 122 may be selected to optimize the placement of bristles 100. Each sub-unit 122 is preferably sized such that the associated transducing element(s) 124 are capable of generating sufficient vibrations. While illustrated as rectangular tracks, each sub-unit 122 may have any suitable geometric shape (e.g., square, round, etc.) and size, and sub-units 122 of different shapes and sizes may be used together to increase the covered surface area of scrubbing brush 26. Additional bristles 100 may also be molded or otherwise secured to backing portion 94 between the sub-units 122 to increase the brushing capabilities while rotating.

Each transducing element 124 may receive electrical power from contacts 106 and 108, as discussed above, and is configured to vibrate at a high frequency, such as at an ultrasonic frequency, for example (e.g., from about 20 kilohertz to about 400 kilohertz). This can assist in removing contaminants from surface 18 with or without rotation. Accordingly, in some embodiments, the high-frequency vibrations are used in combination with the rotation of scrubbing brush 26 (via motor 30). Alternatively, the high-frequency vibrations may be used in lieu of the rotation of scrubbing brush 26, such as for use on delicate or fragile surfaces 18, for example.

In either case, one or more solution generators 54 may also be used to generate the cleaning solution, as discussed above. However, in some optional and alternative embodiments, solution generator 54 may be omitted, and the scrubbing brush 26 with transducing elements 124 may be used with conventional cleaning solutions. In further embodiments, the scrubbing brush 26 with transducing elements 124 may be used in combination with one or more electrolysis cells 58 or other nanobubble generators (i.e., transducer units
are omitted). This arrangement allows the scrubbing brush 26 with transducing elements 124 to be used with a cleaning solution having entrained nanobubbles. As such, the high-frequency vibrations of this embodiment may be used with or without brush rotation, with or without solution generator(s) 54, and/or with or without electrolysis cells 58 (or other nanobubble generators). These alternative combinations increase the versatility of mobile floor cleaner 10.

FIG. 12 illustrates an embodiment that is similar to that shown in FIGS. 8 and 9. However, in this embodiment, one or more solution generators 54 may be separate from cleaning head 22, and located in front of scrubbing brush 26 (in the direction of movement illustrated by arrow 16). For example, a line or row of multiple solution generators 54 may be positioned in front of scrubbing brush 26, similar to that shown in FIG. 9, but separate from cleaning head 22. Furthermore, the line or row of multiple solution generators 54 may be a linear row, an arced row (as illustrated in FIG. 9), a staggered row, and the like. Examples of suitable numbers of solution generators 54 in this embodiment range from one to ten, or from two to eight, or from four to six. One of the benefits of this design is the ability to retrofit solution generators 54 into existing mobile floor cleaners.

FIG. 13 illustrates an embodiment that is similar to that shown in FIG. 12, where cleaning head 22 is replaced with cleaning head 122, which includes one or more soil transfer rollers or extractor brushes 124 for cleaning soft floors. In this embodiment, recovery system 64 may also include an additional vacuum extractor tool (not shown) directed at rollers 124.

The rotation of rollers 124 (via motor 30) in the directions indicated by the arrows results in portions of the rollers 124 being wetted with the generated cleaning solution, extracted by rollers 124, and wiped or brushed against surface 18. For example, as rollers 124 rotate, they engage the soft floor (e.g., carpet fibers) and cause soil to be transferred from the carpet fibers to rollers 124. Rollers 124 are further rotated and may optionally be sprayed again by a separate nozzle (not shown). Subsequently, the surfaces of rollers 124 may be vacuum extracted to remove the soiled cleaning liquid from the rollers 124, which is conveyed into recovery tank 74.

As can be seen, the line or row of solution generators 54 in front of cleaning head 122 may function in the same manner as discussed above for the embodiment shown in FIG. 12. This also allows existing mobile floor cleaners having cleaning head 122 to be retrofitted to incorporate solution generators 54.

FIGS. 14 and 15 depict another embodiment that incorporates a cleaning head 126 as disclosed in U.S. Publication No. 2011/0219555, and which is modified to incorporate an elongated solution generator. As shown in FIG. 14, cleaning head 126 is configured to dispense the generated cleaning solution to surface 18 from within the interior of the cleaning head 126. Cleaning head 126 includes a cylindrical member 128 that is configured to engage surface 18 and rotate about a central axis that is parallel to the surface 18 being cleaned, during the performance of the cleaning operation on surface 18.

In one embodiment, the rotation of cylindrical member 128 is not driven by a motor, such as motor 30. This non-motorized rotation of cylindrical member 128 means that, unlike conventional floor cleaning heads, no motor is directly coupled to cylindrical member 128 through a mechanical linkage of the cleaner, such as a drive belt or gear train, through which the rotation of cylindrical member 128 about its axis can be driven. Rather, the rotation of cylindrical member 128 is driven solely by engagement of cylindrical member 128 with surface 18 as mobile floor cleaner 10 travels across surface 18.

As further shown in FIG. 15, conduit 44 may connect to a transducing dispenser tube 130 within the cylindrical member 128, which may include one or more apertures or slots distributed along the length of tube 130 to allow for substantially even dispensing of the feed liquid 42 to the interior cavity of the cylindrical member 128. As such, conduit 44 delivers a flow of feed liquid 42 into the interior cavity of the tube 130.

In the shown embodiment, dispenser tube 130 may include one or more acoustic transducers (not shown) along its length or at its end locations to generate acoustic waves (e.g., ultrasonic waves) in the feed liquid 42 dispensed into the interior cavity of the cylindrical member 128. In other words, dispenser tube 130 may function as a transducing unit in a similar manner to transducing unit 54 discussed above.

As further shown, cylindrical member 128 also includes a tubular electrolysis cell 132, which may function in the same manner as disclosed in U.S. Publication No. 2011/0219555. Electrolysis cell 132 is correspondingly located within a porous and rigid inner cylindrical wall 134, and a porous and compressible outer cylindrical wall 136, as also disclosed in U.S. Publication No. 2011/0219555.

In particular, the compressibility of the outer cylindrical wall 136 can agitate the surface 18 using the generated cleaning solution without sliding contact with surface 18. This occurs as outer cylindrical wall 136 is first compressed against surface 18 and then decompressed as cylindrical member 128 rolls over surface 18. The compression of outer cylindrical wall 136 causes an initial increase in pressure within its apertures. This pressure is released when outer cylindrical wall 136 decompresses and expands as cylindrical member 128 continues to rotate. This compression and decompression operation moves the generated cleaning solution proximate to the apertures, which encourage the release of dirt on surface 18 for later collection by recovery system 64.

In this embodiment, the generated cleaning solution typically forms a small pool in front of the rotating cylindrical member 128 due to the compression of outer cylindrical wall 136. While not wishing to be bound by theory, it is believed that the pooling provides a suitable path for conducting the acoustic waves (e.g., ultrasonic waves) from the transducer(s) to the surface 18 being cleaned, through the dispensed cleaning solution. This is accordingly believed to provide suitable contact for the generated cleaning solution to attract to and/or dislodge the contaminants (e.g., dirt) on surface 18 prior to being drawn back by the apertures in outer cylindrical wall 136. Thus, the cleaning solution generated by the combination of acoustic energy (e.g., ultrasonic waves) and nanobubble generation is also suitable for use with the compressible and rotatable cylindrical member 128.

As can be appreciated from the above embodiments, the solution generator disclosed therein, which includes acoustic waves through a feed liquid (e.g., with an ultrasonic transducer), and generates nanobubbles in the liquid (e.g., with an electrolysis cell or other nanobubble generator), is suitable for use with a variety of different mobile floor cleaners. The resulting mobile floor cleaners are then capable of generating cleaning solutions from aqueous liquids (e.g.,
water that have good cleaning capabilities without additives such as detergents, while also consuming lower amounts of electrical power, for example. This correspondingly allows the mobile floor cleaners in some embodiments to incorporate smaller and/or fewer batteries with suitable operating durations.

While a solution generator according to the disclosure has generally been described in the foregoing as being implemented on a mobile floor cleaner, it should be recognized that other cleaning applications or application for cleaning are possible in accordance with the disclosure. As one example, the solution generator can be implemented on a cleaning wand or cleaning stick that can be grasped and manipulated by a human user. The user can control the cleaning stick to provide localized cleaning to a soiled region, for example, treating pernicious soils not readily released by mobile floor cleaner 10.

FIG. 16 illustrates an example cleaning stick 200 that is configured (e.g., sized and/or shaped) to be manipulated by a human user and that incorporates a solution generator 54. Cleaning stick 200 may have an elongated shaft 202 that includes a handle portion 204 and a cleaning head 206. The cleaning head 206 can carry a scrubbing brush, such as bristles, pads, or other fibers, that can be used to apply abrasive friction to a surface to be cleaned. In addition, cleaning head 206 can have one or more dispensing nozzles or orifices 208 through which cleaning fluid is dispensed on a surface to be cleaned. In operation, the user can grasp the handle portion 202 of cleaning stick 200 and control the stick to dispense cleaning fluid through dispensing orifice 208 onto a surface to be cleaned. After dispensing the cleaning fluid or while dispensing the cleaning fluid, the user can physically move the cleaning stick to engage the scrubbing brush carried on cleaning head 206 with the cleaning fluid dispensed on the surface to be cleaned. The combination of localized application of cleaning fluid with localized scrubbing action can help remove pernicious soils, allowing an operator to perform selective “spot” treatment where needed.

Solution generator 54 carried by cleaning stick 200 can be implemented using any of the solution generator configurations described herein. In one example, solution generator 54 includes a nanobubble generator and a transducer unit. The solution generator 54 receives liquid from a reservoir, generates nanobubbles in the liquid, and applies acoustic energy to the liquid. The nanobubble generator can be implemented as an electrolysis cell that generates the nanobubbles through electrolysis and/or a mechanical nanobubble generator that generates the nanobubbles without the application of electrical energy. The transducer unit can apply acoustic energy to the liquid upstream and/or downstream of the nanobubble generator. In another example, solution generator 54 includes either a nanobubble generator or a transducer unit but not both features. Other configurations of nanobubble generator are possible as described herein.

To control dispensing of cleaning liquid from cleaning stick 200, the stick can have user controls (e.g., switches, buttons, touchscreen interface, etc.). An operator can interact with the user controls to control solution generator 54, causing the solution generator to generate cleaning liquid that is then dispensed on a surface at which the operator physically points cleaning head 206. In one example, the user controls are positioned on handle 202 of cleaning stick 200.

In the example of FIG. 16, cleaning stick 200 is illustrated as being tethered to mobile floor cleaner 10, which may or may not carry one or more solution generators 54 as described above. Cleaning stick 200 can be tethered to mobile floor cleaner 10 via one or more lines 210 that provide power and/or fluid to the cleaning stick. For example, cleaning stick 200 may be tethered to mobile floor cleaner 10 by a power line having an electrical conductor and providing electricity from a battery carried by the mobile floor cleaner. Additionally or alternatively, cleaning stick 200 may be tethered to mobile floor cleaner 10 by a fluid line providing fluid communication between mobile floor cleaner 10 and solution generator 56 carried on the cleaning stick. In operation, liquid can flow from a fresh liquid supply reservoir carried on mobile floor cleaner 10, through fluid line 210, to solution generator 56 carried on cleaning stick 200. If cleaning stick 200 is configured with fluid removal means (e.g., suction), a separate waste liquid line can provide fluid communication between the fluid removal means and the waste liquid reservoir carried on mobile floor cleaner 10.

Configuring cleaning stick 200 as a tethered unit to mobile floor cleaner 10 can be useful so that power and/or fluid utilized by the stick during cleaning operation are carried by mobile floor cleaner 10. This can reduce the weight of cleaning stick 200, making the stick easier to use and more maneuverable by the operator. In addition, tethering cleaning stick 200 to mobile floor cleaner 10 can ensure that the stick stays in close proximity to the mobile floor cleaner. As the operator is performing a cleaning operation using mobile floor cleaner 10, the operator can readily access and use cleaning stick 200 to treat particularly pernicious soils. In some such configurations, mobile floor cleaner 10 includes a mounting or carrying structure configured to receive and hold cleaning stick 200 when the stick is not in use.

While tethering cleaning stick 200 to mobile floor cleaner 10 can be useful to access power and/or fluid storage on mobile floor cleaner 10, in other configurations, cleaning stick 200 is not tethered to the mobile floor cleaner. Rather, in these configurations, cleaning stick 200 can have self-contained fluid and/or power. For example, handle 202 of cleaning stick 200 can contain batteries for supplying power and/or a fluid reservoir for supplying liquid to solution generator 54. This can allow cleaning stick 200 to be readily portable to a wide range of locations.

Although the present disclosure has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the disclosure.

1. A mobile floor cleaner comprising:
   a moveable housing;
   a cleaning head operably supported by the moveable housing;
   a liquid source configured to provide a feed liquid;
   a conduit configured to relay the feed liquid from the liquid source;
   one or more solution generators configured to receive the feed liquid from the conduit, and to generate a cleaning solution from the feed liquid by application of acoustic energy and nanobubble generation; and
   control electronics configured to operate the one or more solution generators.

2. The mobile floor cleaner of claim 1, wherein at least one of the solution generators comprises:
   a transducing unit configured to apply the acoustic energy; and
at least one of an electrolysis cell configured to generate the nanobubbles by electrolysis and a mechanical nanobubble generator configured to generate the nanobubbles through shear forces.

3. The mobile floor cleaner of claim 2, wherein the acoustic energy comprises ultrasonic waves.

4. The mobile floor cleaner of claim 1, wherein the cleaning head comprises a disc-type scrubbing brush, and wherein the mobile floor cleaner further comprises a motor configured to operably rotate the scrubbing brush.

5. The mobile floor cleaner of claim 4, wherein the one or more solution generators are secured to the cleaning head.

6. The mobile floor cleaner of claim 5, wherein the cleaning head further comprises a cover for the scrubbing brush, and wherein the one or more solution generators comprise a plurality of solution generators secured to the cover of the cleaning head.

7. The mobile floor cleaner of claim 5, wherein the one or more solution generators are secured to the cleaning head as one or more radial rows.

8. The mobile floor cleaner of claim 1, wherein the one or more solution generators are arranged at a location that is in front of the cleaning head in a primary direction of movement of the mobile floor cleaner.

9. The mobile floor cleaner of claim 8, wherein the one or more solution generators comprise a plurality of the solution generators arranged in a row.

10. The mobile floor cleaner of claim 1, wherein the cleaning head comprises a rotatable cylindrical member having a compressible outer surface, and wherein the one or more solution generators are located inside of the rotatable cylindrical member.

11. A method for cleaning a surface, the method comprising:

- providing a mobile floor cleaner having a cleaning head and a solution generator;
- directing a flow of a feed liquid to the solution generator;
- generating a cleaning solution by applying acoustic energy to and generating nanobubbles in the feed liquid in the solution generator;
- dispensing the generated cleaning solution to the surface; and
- agitating the dispensed cleaning solution with the cleaning head.

12. The method of claim 11, wherein applying the acoustic energy is performed prior to generating the nanobubbles.

13. The method of claim 11, wherein generating the nanobubbles is performed prior to applying the acoustic energy.

14. The method of claim 11, wherein applying the acoustic energy to the feed liquid comprises inducing ultrasonic waves through the feed liquid.

15. The method of claim 11, wherein generating the nanobubbles in the feed liquid comprises conducting electrolysis on the feed liquid.

16. A mobile floor cleaner comprising:

- a moveable housing;
- a liquid source configured to provide a feed liquid;
- a conduit configured to relay the feed liquid from the liquid source;
- a scrubbing brush operably supported by the moveable housing, wherein the scrubbing brush comprises:
  - a backing portion;
  - one or more sub-units each configured to retain a set of bristles; and
  - one or more transducers supported by the backing portion and configured to vibrate the one or more sub-units and retained sets of bristles; and
- control electronics configured to operate the one or more transducers.

17. The mobile floor cleaner of claim 16, further comprising one or more solution generators configured to receive the feed liquid from the conduit, and to generate a cleaning solution from the feed liquid by application of acoustic energy and nanobubble generation.

18. The mobile floor cleaner of claim 16, further comprising a motor configured to rotate the scrubbing brush.

19. The mobile floor cleaner of claim 18, further comprising one or more solution generators configured to receive the feed liquid from the conduit, and to generate a cleaning solution from the feed liquid by application of acoustic energy and nanobubble generation.

20. The mobile floor cleaner of claim 16, wherein the one or more transducers are configured to vibrate the one or more sub-units and retained sets of bristles at an ultrasonic frequency.