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(54) SURFACE ENGAGEMENT SENSING FOR A SURFACE CLEANING APPARATUS

(57) A surface cleaning apparatus includes an air pathway having a suction inlet. A motor is configured to generate airflow through the air pathway. One or more operating parameters of the motor may vary when the suction inlet is engaged or disengaged with a surface. A power level of the motor may be controlled based, at least on part, on changes in one or more operating parameters of the motor.

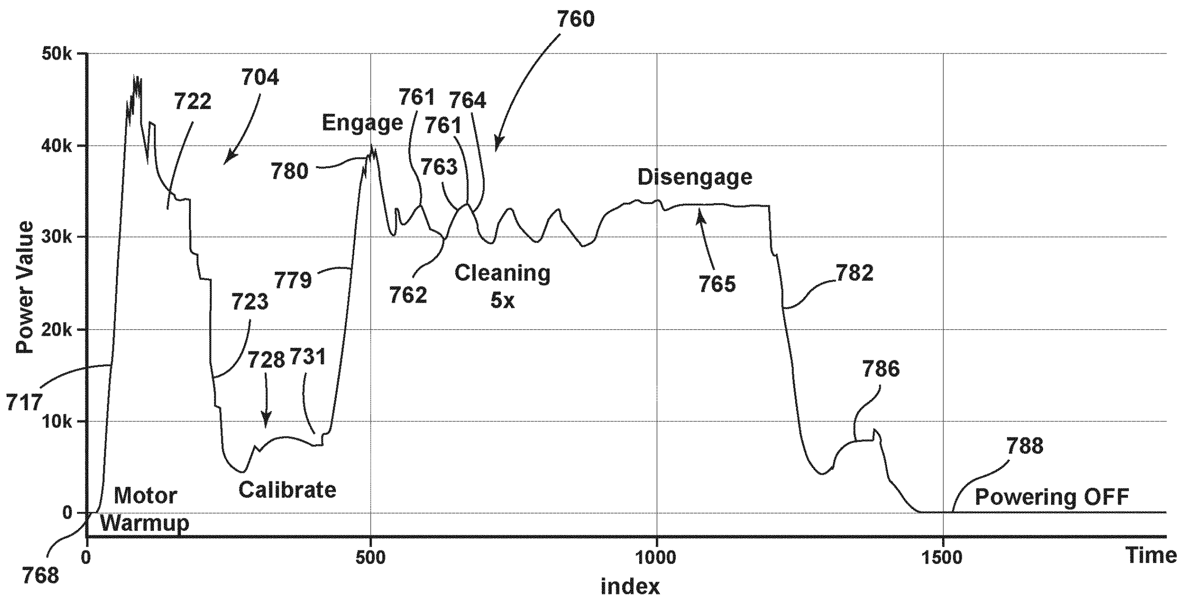


FIG. 15

EP 4 548 829 A2

Description

TECHNICAL FIELD

[0001] The subject disclosure pertains to a surface cleaning apparatus, and, more particularly, a surface cleaning apparatus with a power saving operation.

BACKGROUND

[0002] Cleaning apparatuses that utilize suction to clean a surface require a significant amount of power consumption. During use, a suction orifice is typically moved into and out of contact with the surface. During use, when the suction orifice is moved out of contact with the surface, unnecessary power consumption is continued. The unnecessary power consumption wastes power resources and, as many modern cleaning apparatuses are powered by batteries, require larger batteries with a shorter than necessary battery life.

BRIEF SUMMARY

[0003] An aspect of the present disclosure involves detecting when a suction inlet (e.g. a nozzle) of a cleaning device is engaged and/or disengaged from a surface that is being cleaned by the suction inlet. The cleaning device may optionally include a battery powered electric motor to create suction, and power to the electric motor may be reduced (e.g. relative to a baseline power) when the suction nozzle is disengaged from a surface being cleaned. Reducing power to the electric motor when the suction nozzle is disengaged reduces power being drawn from the battery while the suction nozzle is disengaged from a surface being cleaned. The electric power supplied to the motor while the suction inlet is engaged with a surface may be increased relative to the power supply to the electric motor when the suction inlet is disengaged from a surface. Thus, in contrast to existing controls that may unnecessarily increase power to a motor when a suction inlet is disengaged from a surface, the present disclosure may reduce power consumption when the suction inlet is disengaged from a surface to thereby increase energy efficiency. If the device is battery powered, the reduction in power consumption may also extend battery life.

[0004] A cleaning apparatus or device according to one or more aspects of the present disclosure may include a controller that is configured to detect or determine when a suction inlet of the device is engaged and/or disengaged from a surface being cleaned. The determination may utilize one or more operating parameters such as engine revolutions per minute (RPM), electrical power used by the motor, electric current of the motor, changes in power of the motor and/or changes in electrical current of the motor, rates of change in motor power, motor RPM, motor electrical current, and/or other power metrics or operating parameters. Detection of engagement and/or disengagement of the suction inlet may involve detecting changes in one or more operating parameters of an electric motor. The operating parameters of the motor may have first expected ranges of one or more operating parameters when the suction inlet is engaged with a surface, and second expected ranges of the one or more operating parameters when the suction inlet is disengaged from a surface being cleaned. The controller may be configured to determine that the suction inlet is engaged if one or more of the operating parameters are within the first ranges, and the controller may be configured to determine that the suction inlet is disengaged if one or more of the operating parameters are within the second ranges. The controller may also be configured to utilize changes and/or rates of change in the operating parameters as the suction inlet is brought into engagement with a surface and/or brought out of an engagement with a surface to detect or determine engagement and/or disengagement of the suction inlet from a surface. Detection of engagement and/or disengagement may optionally include utilizing a time criteria or delay such as a debounce whereby changes in one or more parameters of the motor must satisfy predefined criteria over a predefined period of time to satisfy predefined criteria indicative of a change from an engaged state to a disengaged state and/or vice-versa.

[0005] According to one aspect of the present disclosure, a surface cleaning apparatus includes a housing including a debris holding container. The surface cleaning apparatus further includes a suction nozzle having a suction inlet, an air pathway at least partially defined by the debris holding container and the suction inlet, and a motor in operable communication with a fan within the air pathway. The motor selectively generates an airflow through the air pathway and includes a cleaning engaged state at a first power usage performance and a cleaning disengaged state at a second power usage performance that is different than the first power usage performance. A power source provides a power level to the motor, and a control system is in operable communication with the motor. The control system is configured to, upon activation of the motor, detect a baseline shift of a power metric from the first power usage performance to the second power usage performance. The control system is further configured to generate a reduction signal to the power source to reduce the power level provided to the motor in a power restricted mode.

[0006] According to another aspect of the present disclosure, a surface cleaning apparatus includes a housing including a debris holding container. The surface cleaning apparatus further includes a suction nozzle having a suction inlet, an air pathway at least partially defined by the debris holding container and the suction inlet, and a motor in operable communication with a fan within the air pathway. The motor selectively generates an airflow through the air pathway and includes a cleaning engaged state at a first power usage performance and a cleaning disengaged state at a second power usage performance that is different than the first power usage performance. A power source provides a power level to the motor, and a control system is in operable communication with the motor. The control system is configured to, upon activation of the motor, detect a baseline shift of a current draw from the motor as a result of switching from the first power usage performance to the second power usage performance. The control system is further configured to generate a reduction signal to the power source to reduce the power level provided to the motor in a power restricted mode.

[0007] According to yet another aspect of the present disclosure, a surface cleaning apparatus includes a housing including a debris holding container. The surface cleaning apparatus further includes a suction nozzle having a suction inlet, an air pathway at least partially defined by the debris holding container and the suction inlet, and a motor in operable communication with a fan within the air pathway. The motor selectively generates an airflow through the air pathway and includes a cleaning engaged state at a first power usage performance and a cleaning disengaged state at a second power usage performance that is different than the first power usage performance. A power source provides a power level to the motor, and a control system is in operable communication with the motor. The control system is configured to, upon activation of the motor, detect a baseline shift of a revolutions-per-minute (RPMs) of the motor as a result of switching from the first power usage performance to the second power usage performance. The control system is further configured to generate a reduction signal to the power source to reduce the power level provided to the motor in a power restricted mode.

[0008] A cleaning apparatus, according to an aspect of the present invention, includes a battery, and a motor that is operatively connected to the battery. The cleaning apparatus further includes an air conduit having a suction inlet, and an impeller and fluid communication with the air conduit and operably connected to the motor, whereby the motor can be actuated to cause the impeller to create suction at the suction inlet. The cleaning apparatus further includes a controller that is configured to cause the motor to operate in first and second modes, wherein the second mode provides increased suction at the suction inlet relative to the first mode when the inlet is engaging a surface. The controller is also configured to cause the motor to switch from the first mode to the second mode, based at least in part, on first engagement criteria. The controller is further configured to cause the motor to switch from the second mode to the first mode, based at least in part, on second engagement criteria. The first and second engagement criteria comprise changes in electrical power used by the motor, wherein the changes in electrical power are associated with engagement of the suction inlet with a surface, whereby the controller causes the motor to switch from the first mode to the second mode if the suction inlet is brought into engagement with a surface, and causes the motor to switch from the second mode to the first mode if the suction inlet is disengaged from a surface.

[0009] Another aspect of the present disclosure is an apparatus for cleaning surfaces. The apparatus includes an air passageway having a suction inlet that is configured to engage a surface to clean the surface. An impeller is in fluid communication with the air passageway, and a motor is operably connected to the impeller, whereby the motor causes air to flow in the air passageway to create suction at the suction inlet. The apparatus includes a controller that is configured to cause the apparatus to selectively operate in a first mode or a second mode, wherein suction at the suction inlet is increased in the second mode relative to suction at the suction inlet in the first mode. The controller is configured to change from the first mode to the second mode and/or from the second mode to the first mode based, at least in part, on power change criteria. The power change criteria comprises a rate of change of electrical power of the motor.

[0010] These and other features, advantages, and objects of the present disclosure will be further understood and appreciated by those skilled in the art by reference to the following specification, claims, and appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] In the drawings:

FIG. 1 is a schematic view of a surface cleaning apparatus, according to an aspect of the present disclosure;
FIG. 2 is an enlarged view of a surface cleaning apparatus in a cleaning engaged state, according to an aspect of the present disclosure;
FIG. 3 is an enlarged view of a surface cleaning apparatus in a cleaning engaged state, according to an aspect of the present disclosure;
FIG. 4 is a graphical representation of a baseline shift in a current draw to a motor, according to an aspect of the present disclosure;
FIG. 5 is a graphical representation of a baseline shift in revolutions-per-minute (RPMs) of a motor, according to an aspect of the present disclosure;
FIG. 6 is a graphical representation of a gradual baseline change of a power metric between wet and dry cleaning surfaces, according to an aspect of the present disclosure;
FIG. 7 is a schematic view of a control system in a surface cleaning apparatus, according to an aspect of the present

disclosure;
FIG. 8 is a flow chart illustrating a method of controlling a power saving operation in a surface cleaning apparatus, according to an aspect of the present disclosure;
FIG. 9 is a perspective view of a surface cleaning apparatus configured as a portable deep cleaner device, according to an aspect of the present disclosure;
FIG. 10 is a perspective view of a surface cleaning apparatus configured as an upright vacuum cleaner device, according to an aspect of the present disclosure;
FIG. 11 is a schematic view of a surface cleaning apparatus according to an aspect of the present disclosure;
FIG. 12 is an enlarged view of a suction inlet of a surface cleaning apparatus in an engaged state;
FIG. 13 is an enlarged view of a suction inlet of a surface cleaning apparatus in a disengaged state;
FIG. 14 is a flow chart showing operation of a surface cleaning device according to an aspect of the present disclosure;
FIG. 15 is a graph showing an example of motor power value during warmup, calibration, engagement, disengagement, and powering off;
FIG. 16 is a first portion of a flow chart according to an aspect of the present disclosure;
FIG. 17 is a second portion of the flow chart of FIG. 16;
FIG. 18 is a third portion of the flow chart of FIGS. 16 and 17;
FIG. 19 is a chart showing calibration following a cold start of the motor;
FIG. 20 is a chart showing detection of engagement;
FIG. 21 is a chart showing detection of disengagement;
FIG. 22 is a graph showing High Power Mode (HPM) change in power (ΔP) signals;
FIG. 23 is a graph showing Low Power Mode (LPM) change in power (ΔP) signals;
FIG. 24 is a perspective view of a surface cleaning apparatus configured as a portable deep cleaner device, according to an aspect of the present disclosure; and
FIG. 25 is a perspective view of a surface cleaning apparatus configured as an upright vacuum cleaner device, according to an aspect of the present disclosure.

[0012] The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles described herein.

DETAILED DESCRIPTION

[0013] The present illustrated embodiments reside primarily in combinations of method steps and apparatus components related to a surface cleaning apparatus with a power saving operation. Accordingly, the apparatus components and method steps have been represented, where appropriate, by conventional symbols in the drawings, showing only those specific details that are pertinent to understanding the embodiments of the present disclosure so as not to obscure the disclosure with details that will be readily apparent to those of ordinary skill in the art having the benefit of the description herein. Further, like numerals in the description and drawings represent like elements.

[0014] For purposes of description herein, the terms "upper," "lower," "right," "left," "rear," "front," "vertical," "horizontal," and derivatives thereof, shall relate to the disclosure as oriented in FIG. 1. Unless stated otherwise, the term "front" shall refer to a surface closest to an intended viewer, and the term "rear" shall refer to a surface furthest from the intended viewer. However, it is to be understood that the disclosure may assume various alternative orientations, except where expressly specified to the contrary. It is also to be understood that the specific structures and processes illustrated in the attached drawings, and described in the following specification are simply exemplary embodiments of the concepts defined in the appended claims. Hence, specific dimensions and other physical characteristics relating to the embodiments disclosed herein are not to be considered as limiting, unless the claims expressly state otherwise.

[0015] The terms "including," "comprises," "comprising," or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises a list of elements does not include only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus. An element preceded by "comprises a ... " does not, without more constraints, preclude the existence of additional identical elements in the process, method, article, or apparatus that comprises the element.

[0016] The present disclosure generally involves detecting when a suction inlet (e.g. a nozzle) of a cleaning device is engaged and/or disengaged from a surface being cleaned by the suction inlet. The cleaning device may optionally include a battery powered electric motor to create suction, and power to the electric motor may be reduced (e.g. relative to a baseline power) when the suction nozzle is disengaged from a surface being cleaned. Reducing power to the electric motor when the suction nozzle is disengaged reduces power being drawn from the battery while the suction nozzle is disengaged from a surface being cleaned. The electric power supplied to the motor while the suction inlet is engaged with a surface may be increased relative to the power supply to the electric motor when the suction inlet is disengaged from a surface. Thus, in contrast to existing controls that may unnecessarily increase power to a motor when a suction inlet is disengaged from a surface, the present disclosure may reduce power consumption when the suction inlet is disengaged from a surface to thereby increase energy efficiency. If the device is battery powered, the reduction in power consumption may also extend battery life.

[0017] A cleaning apparatus or device according to one or more aspects of the present disclosure may include a controller that is configured to detect or determine when a suction inlet of the device is engaged and/or disengaged from a surface being cleaned. The determination may utilize one or more operating parameters such as engine revolutions per minute (RPM), electrical power used by the motor, electric current of the motor, changes in power of the motor and/or changes in electrical current of the motor, rates of change in motor power, rates of change in motor RPM, rates of change in motor electrical current, and/or other power metrics or operating parameters. Detection of engagement and/or disengagement of the suction inlet may involve detecting changes in one or more operating parameters of an electric motor. The operating parameters of the motor may have first expected ranges of one or more operating parameters when the suction inlet is engaged with a surface, and second expected ranges of the one or more operating parameters when the suction inlet is disengaged from a surface being cleaned. The controller may be configured to determine that the suction inlet is engaged if one or more of the operating parameters are within the first ranges, and the controller may be configured to determine that the suction inlet is disengaged if the parameters that are within the second ranges. The controller may also be configured to utilize changes and/or rates of change in the operating parameters as the suction inlet is brought into engagement with a surface and/or brought out of an engagement with a surface to detect or determine engagement and/or disengagement of the suction inlet from a surface. Detection of engagement and/or disengagement may optionally include utilizing a time criteria or delay such as a debounce whereby changes in one or more parameters of the motor must satisfy predefined criteria over a predefined period of time to satisfy predefined criteria indicative of a change from an engaged state to a disengaged state and/or vice-versa. For example, in use, movement of a suction inlet over a surface that is being cleaned may result in at least some variation in electrical power, electrical current, and/or other operating parameters of the electric motor even though the suction inlet may be nominally engaged with a surface. Also, in use, the suction inlet may be moved across a surface in a cleaning stroke, and the suction inlet may then be moved in a direction that is generally opposite to a direction during a cleaning while the suction inlet is spaced apart from the surface, followed by another cleaning stroke while the suction inlet is engaged with a surface being cleaned. Thus, a user may repeatedly engage and disengage a surface being cleaned while the user is cleaning a surface. An aspect of the present disclosure is a time delay or debounce feature that may be utilized by the controller to ensure that short fluctuations in operating parameters of the motor do not result in an incorrect determination that the user is not actively using the device to clean a surface, thereby ensuring that the proper suction is maintained while the device is in use even if there is momentary disengagement of a suction inlet from a surface while the device is in use. Accordingly, it will be understood that the engagement and/or disengagement criteria utilized by the controller to cause the motor to operate at increased and decreased power levels may contemplate at least some periods of disengagement of the suction inlet while the device is in use.

[0018] With reference to FIGS. 1-3, reference numeral 10 generally designates a surface cleaning apparatus according to an aspect of the present disclosure. It will be understood that the following description of surface cleaning apparatus 10 may also apply to the surface cleaning apparatus 610 described in more detail below in connection with FIGS. 11-23. Thus, the features of the cleaning apparatuses 10 and 610 may be utilized in any combination in cleaning devices according to the present disclosure unless expressly stated to the contrary herein. The surface cleaning apparatus 10 includes a housing 12 including a debris holding container 14. The surface cleaning apparatus 10 further includes a suction nozzle 15 having a suction inlet 16. An air pathway 18 is at least partially defined by the debris holding container 14, the suction nozzle 15, and the suction inlet 16. A motor 20 is in operable communication with a fan 22 within the air pathway 18. The motor 20 selectively generates an airflow 24 through the air pathway 18 and includes a cleaning engaged state (FIG. 2) at a first power usage performance (first operating parameters profile) and a cleaning disengaged state (FIG. 3) at a second power usage performance (operating parameter profile) that is different than the first power usage performance or profile. Thus, the first power profile generally corresponds to an engaged state, and the second power profile generally corresponds to a disengaged state. One or more operating parameters or metrics (e.g. motor RPM, motor electrical current, motor electrical power, changes in motor electrical power or current, etc.) may be measured to determine if the suction inlet 16 is engaged or disengaged with a surface, and changes or rates of change in one or more of the operating parameters may be utilized to detect changes from an engaged state or condition to a disengaged state or condition, and vice-versa.

[0019] A power source 26 provides a power level to the motor 20, and a controller such as control system 200 is in operable communication with the motor 20. The control system 200 may be configured to, upon activation of the motor 20, detect a baseline shift of a power metric or parameter from the first power usage performance (first power profile) to the second power usage performance (second power profile). For example, the power metric or parameter may comprise motor RPM and/or motor electrical current and/or the motor electrical power, and a first power metric or parameter (e.g. a first RPM and first electrical current) may define a first power profile indicating that the suction inlet 16 is engaged with a surface, and a second power metric or parameter (e.g. a second RPM and a second electrical current) may define a second power profile indicating that the suction 16 is disengaged from a surface. Thus, the power metric or parameter can be measured, and the control system 200 may utilize the measured parameters to determine if the inlet 16 is engaged or disengaged. Changes and/or rates of change in the motor operating parameter may also be utilized to determine or detect a transition from an engaged state to a disengaged state and/or vice-versa. The control system 200 is further configured to generate a reduction signal to the power source 26 to reduce the power level provided to the motor 20 in a power restricted mode.

[0020] With reference now to FIG. 1, the surface cleaning apparatus 10 removes debris or other content from a cleaning surface 28 and routes the debris or other content through the air pathway 18 to the debris holding container 14. The surface cleaning apparatus 10 includes a user interface 30 that provides two or more power settings (e.g., off and on). In some embodiments, the surface cleaning apparatus 10 may include high or low power settings accessible via the user interface 30 based on user preference and/or characteristics of the cleaning surface 28. The user interface 30 may be located on the housing 12 and/or the nozzle 15. The surface cleaning apparatus 10 may include a battery 32 that, at least partially, functions as the power source 26. The battery 32 may be charged by an AC current from an electrical outlet to a charging module 34, which may or may not be located directly on the battery 32. However, it should be appreciated that, in some embodiments, the household AC current at least partially functions as the power source 26 in addition or alternatively to the battery 32. At least one sensor 36 may be located proximate the motor 20 that is configured to monitor the power metric. The control system 200 may adjust the power level provided to the motor 20 by software components (e.g., software), hardware components (e.g., a power regulating module 37), or a combination thereof. In some embodiments, a flexible suction hose 38 extends from the housing 12 to the suction nozzle 15 and at least partially defines the air pathway 18. The flexible suction hose 38 may be configured to connect a variety of different accessory tools that can be selected based on characteristics of the cleaning surface 28 (e.g., carpet, tile, wood) and the debris or other content (e.g., dirt, hair, liquid) that needs to be removed. It should be appreciated for purposes of this disclosure, that when an accessory tool is connected to the flexible suction hose 38, the nozzle 15 and the suction inlet 16 may be defined by the accessory tool as illustrated. It should be also appreciated that in other constructions the nozzle 15 may be defined by the housing 12 (e.g., in a handheld vacuum cleaner or upright vacuum cleaner).

[0021] With continued reference to FIG. 1, the surface cleaning apparatus 10 may include a fluid delivery and recovery system 42. The fluid delivery and recovery system 42 may include a supply tank 44 containing a cleaning fluid 45. A fluid delivery line 46 extends from the supply tank 44 to a fluid outlet port 48. A pump 50 is operably coupled to the supply tank 44 and/or the fluid delivery line 46. The user interface 30 may therefore include one or more options for operating the pump 50 and delivering the cleaning fluid 45 to the cleaning surface 28. In operation, the cleaning fluid 45 delivered to the cleaning surface 28 may subsequently be removed and routed (e.g., through the air pathway 18) to the debris holding container 14. A valve 52 may be located between the supply tank 44 and the pump 50 or between the fluid outlet port 48 and the pump 50 for selectively opening and closing the fluid delivery line 46. In some embodiments, the fluid delivery line 46 may extend along the flexible suction hose 38, such that the cleaning fluid 45 is delivered proximate the suction nozzle 15.

[0022] With reference now to FIGS. 2 and 3, during operation, the suction inlet 16 is often moved into and out of contact with the cleaning surface 28 during a cleaning process. For example, a user often must lift the suction nozzle 15 and, as a result, the suction inlet 16 out of contact with the cleaning surface 28 when cleaning around various household appliances, furniture, or moving between cleaning tasks. In this manner, when the suction inlet 16 is in contact with the cleaning surface 28 (FIG. 2), the motor 20 is in the cleaning engaged state and the first power usage performance. As noted above, the first power usage performance (first power profile) may comprise one or more operating parameters of the motor including one or more of electrical power or current or changes in electrical power or current and/or RPM of the motor 20 when suction inlet 16 engages a surface being cleaned. However, when the suction inlet 16 is out of contact with the cleaning surface 28 (FIG. 3), the motor 20 is in the cleaning disengaged state and the second power usage performance. The second power usage performance (second power profile) may comprise electrical power or current or changes in electrical power or current and/or RPM of the motor 20 when suction inlet 16 is disengaged from a surface being cleaned. The control system 200 may further be configured to detect the baseline shift of the power metric from the second power usage performance to the first power usage performance. In response, the control system 200 may generate an increased signal to the power source 26 to increase the power level provided to the motor 20 in a power unrestricted mode. Because differences between the first power usage performance and the second power usage performance are identifiable by the control system 200, whether or not the suction inlet 16 is in contact with the cleaning surface 28 can also be identified. By identifying when the suction inlet 16 is not in contact with the cleaning surface 28, power consumption can be reduced via the power restricted mode. As discussed in more detail below, identifying when suction inlet 16 is in and/or out of contact with cleaning surface 28 may include identifying a change and/or a rate of change in one or more of the operating parameters of the electrical motor (e.g. RPM, electrical power and/or electrical current) indicative of a change or transition from an engaged state to a disengaged state and vice-versa.

[0023] With continued reference to FIGS. 2 and 3, in embodiments where the battery 32 functions as the power source 26, the power saving operation described herein can result in extended battery life and/or smaller battery storage capacity requirements. The power restricted mode may include a significant reduction of the power level provided by the power source 26. In some embodiments, the power restricted mode may completely shut-off the power level provided by the power source 26, such that the motor 20 does not receive any power or receives a negligible amount of power. In some embodiments, the power restricted mode may reduce the power level provided by the power source 26, such that the motor 20 continues to run with less power. The power restricted mode may require 70% or less power than the power unrestricted mode, for example, 60% or less, 50% or less, 40% or less, 30% or less, 20% or less, or 10% or less.

[0024] With reference now to FIGS. 2-5, in the cleaning engaged state and the first power usage performance, the motor 20 operates at a greater revolutions-per-minute (RPMs) and requires less current draw (e.g., AC current or DC current) than in the cleaning disengaged state and the second power usage performance. As such, one or both of the RPMs and current draw of the motor 20 can be monitored as the power metric. In some embodiments, the one or more sensors 36 may include at least one of a series shunt resistor (e.g., for measuring the RPMs) or a current sense amplifier (e.g., for measuring current draw). During operation, the power metric is at a baseline that is relatively stable when the motor 20 remains in one of the disengaged and engaged states (i.e., when the suction inlet 16 remains in or out of contact with the cleaning surface). However, when the suction inlet 16 is moved into or out of contact with the cleaning surface 28, the motor 20 changes between the cleaning engaged state or the cleaning disengaged state. Respectively, the power metric experiences the baseline shift. The baseline shift of the power metric is a rapid change (e.g., increase or decrease) of the baseline of the power metric within a predetermined threshold. In some embodiments, the predetermined threshold may be an increase or decrease of over 5% of the baseline, for example, over 10%, over 15%, over 20%, over 25%, over 30%. The baseline of the power metric may be monitored (e.g., by the control system 200) for the baseline shift to limit power consumption in the disengaged state by generating the reduction signal to the power source 26. In this manner, power consumption can be reduced when the surface cleaning apparatus 10 is operating in the power restricted mode. As a result, the power restricted mode can reduce overall power consumption of the surface cleaning apparatus 10 during the cleaning process. In some embodiments, the baseline of the power metric is determined by averaging a plurality of measurements over a time period rather than a single measurement from the one or more sensors 36.

[0025] With continued reference to FIGS. 2-5, the monitoring of the power metric (i.e., via the one or more sensors 36) may occur repeatedly by detecting one or both of the RPMs and current draw over short periods of time for baseline shifts that are rapid. More particularly, in certain scenarios, the baseline of the power metric may drift as battery 32 becomes depleted. The baseline drift may result in the power metric gradually becoming higher or lower depending on the control system 200 architecture. In this manner, detecting baseline shifts that are rapid minimizes any variations of the baseline that occur as a result of the drift. A baseline shift that is rapid may be defined as a baseline shift occurring over a period of time that may be 0.1 second or less, between 0.1 second and 1 second, 0.5 second or less, between 0.5 second and 2 seconds, less than 1 second, at least 1 second, less than 2 seconds, less than 15 seconds, less than 30 seconds, or between 1 second and 5 seconds.

[0026] In some embodiments, the control system 200 is further configured to generate the reduction signal after a first delay period. The delay period may comprise a debounce that requires predefined operating conditions to continue for a period of time prior to determining that a change of state from engaged to disengaged and vice-versa has occurred. In this manner, the motor 20 remains in the power unrestricted mode for a short period of time after the suction inlet 16 is removed from contact with the cleaning surface 28. The delay period may be particularly useful for further preservation of power resources and operational convenience in situations where the suction inlet 16 is removed from contact with the cleaning surface 28 for a short period of time (i.e., when a scrubbing action is needed or a quick repositioning of the suction inlet 16). More particularly, the delay period prevents additional power resources that may be required to power-up the motor 20 and the inconvenience of a user having to wait for the motor 20 to power-up into the power unrestricted mode from the power restricted mode.

[0027] The delay period may be 0.5 seconds or less, at least 0.5 seconds, less than 1 second, at least 1 second, less than 2 seconds, less than 5 seconds, or between 0.5 seconds and 2 seconds. In some embodiments, the power restricted mode may include a first power restriction mode with a reduction to the power level and a second power restriction mode with a complete shut-off to the power level. In such embodiments, the control system 200 may generate a first reduction signal (e.g., after a first delay period) to reduce the power level and, after a second delay period, generate a second reduction signal to completely shut-off the power level. The first delay period may be shorter in time than the second delay period. For example, the first delay period may be 0.5 seconds or less, at least 0.5 seconds, less than 1 second, at least 1 second, less than 2 seconds, less than 5 seconds, or between 0.5 seconds and 2 seconds, and the second delay period may be over twice as long (e.g., at least four times as long) as the first delay period. It should be appreciated that the second reduction signal would not be generated in situations where the baseline shift is detected before the second delay period has expired.

[0028] With reference now to FIGS. 4 and 5, the control system 200 is configured to determine the baseline (e.g., by averaging several measurements) of the power metric continually regardless of the state or power mode of the motor 20. The baseline may be obtained by measurements of the current draw (FIG. 4), the RPMs (FIG. 5), or both the current draw and RPMs. In this manner, the first power usage performance and the second power usage performance can be identified in both the power restricted mode and the power unrestricted mode by rapid changes in the baseline of the power metric (e.g., within the predetermined threshold). For example, when the motor 20 is operating in the power restricted mode in the second power usage performance, the baseline of the power restricted mode in the second power usage performance is determined. Once the suction inlet 16 is brought into contact with the cleaning surface 28, the baseline of the power restricted mode in the second power usage performance will rapidly change to a baseline of the power restricted mode in the first power usage performance and be identified by the control system 200 as the baseline shift. Once identified, the control system 200 is configured to generate the increase signal so that the motor 20 is operating in the first power usage performance in the power unrestricted mode. The baseline of the power unrestricted mode in the first power usage performance can then be determined. While continuing use, once the suction inlet 16 is moved out of contact from the cleaning surface 28, the baseline of the power unrestricted mode in the first power usage performance will rapidly change to a baseline of the power unrestricted mode in the second power usage performance and be identified by the control system 200 as the baseline shift. Once identified, the control system 200 is configured to generate the reduction signal so that the motor 20 is operating in the second power usage performance in the power restricted mode. In this manner, over the course of operation, the motor 20 may perpetually switch between the power restricted mode (i.e., in the cleaning disengaged state) and the power unrestricted mode (i.e., in the cleaning engaged state).

[0029] With continued reference to FIGS. 4 and 5, the control system 200 may be configured to initially operate the motor 20 in the power restricted mode or the power unrestricted mode. Regardless of which mode the motor 20 is initially operated in, the control system 200 can still detect the baseline shift and initiate the power saving operation described herein. For example, in a scenario where the motor 20 initially operates in the power restricted mode and the suction inlet 16 is already in contact with the cleaning surface 28 when the motor 20 is activated, the power saving operation described herein is self-correcting. More particularly, the motor 20 may continue to operate in the power restricted mode and, when the suction inlet 16 is moved out of contact with the cleaning surface 28, the RPMs are decreased and the current draw is increased. The decrease of the RPMs and/or the increase of the current draw is associated with the second power usage performance and, therefore, the motor 20 will continue to operate in the power restricted mode. However, when the suction inlet 16 is moved back into contact with the cleaning surface 28, the RPMs are increased and the current draw is decreased. The increase of the RPMs and/or the decrease of the current draw is associated with the first power usage performance and the control system 200 will generate the increase signal to the power source 26 in order to increase the power level provided to the motor 20 in a power unrestricted mode. Similar self-correcting steps may be initiated in a scenario where the motor 20 initially operates in the power unrestricted mode and the suction inlet 16 is not in contact with the cleaning surface 28 when the motor 20 is activated.

[0030] With continued reference to FIGS. 4 and 5, it should be appreciated that regardless of different operational scenarios including the number of available power settings, characteristics of the cleaning surface 28, or accessory tools, the principle operation of the power saving operation described herein can still be implemented. More particularly, the surface cleaning apparatus 10 operating in any combination of the above-described scenarios will exhibit the relatively stable baseline of the power metric until a switch between the engaged and disengaged states when the baseline shift can be detected. In some embodiments, the control system 200 may be configured to identify various accessory tools. More particularly, the control system 200 may include pre-saved predictive behavior models that include baseline behavior of the power metric in one or both of the first power usage performance and the second power usage performance that can be compared to the baseline of the power metric during use. Once an accessory is identified, the control system 200 may be configured to change operational settings, provide additional settings on the user interface 30, and/or the like.

[0031] With reference back to FIGS. 1-3, in addition to the power saving operations, the control system 200 may be configured to perform additional functionalities in response to detecting and characterizing changes in the baseline of the power metric. For example, the control system 200 may be configured to detect a semi-gradual change in the baseline of the power metric in the first power usage performance over a threshold period of time and extrapolate a dryness level of a surface being cleaned. For example, when the cleaning surface 28 is wet, such as after the application of the cleaning liquid or a spill, the control system 200 may be configured to detect the semi-gradual change in the baseline of the power metric to extrapolate the dryness level.

[0032] With reference now to FIG. 6, when the suction inlet 16 is in contact with a cleaning surface 28 that is wet, there is a significant amount of suction between the suction inlet 16 and the cleaning surface 28, which results in an even greater revolutions-per-minute (RPMs) and even less current draw than in the first and second power usage performances associated with a cleaning surface 28 that is dry. In this manner, the control system 200 may be configured to extrapolate the dryness level of the cleaning surface 28 by monitoring the semi-gradual change in the baseline of the power metric over a threshold period of time. In some embodiments, the semi-gradual change in the baseline of the power metric may be profiled and compared to a pre-saved predictive behavior model of wet and dry power metric behavior. In other embodiments, the control system 200 may be configured to extrapolate the dryness level of the surface 28 being cleaned by detecting that a change in the baseline of the power metric is above a threshold quantity. More particularly, there may be a predictive range of RPMs or current draw that indicates that the cleaning surface 28 is dry when the suction inlet 16 is in contact with the cleaning surface 28. In still other embodiments, the control system 200 may be configured to extrapolate the dryness level of the surface 28 being cleaned by detecting that a change in the baseline of the power metric is above the threshold quantity and over the threshold period of time. More particularly, the first power metric performance may be profiled over the threshold period of time for a change the power metric that is above the threshold quantity. In this manner, rapid baseline shifts and the drift of the baseline as a result of a depleted battery can be accounted for and discarded. For example, the threshold period of time may be greater (i.e., more gradual) than the rapid changes associated with the engaged and disengaged states and less (i.e., more sudden) than the drift associated with the battery 32 being depleted. The control system 200 may further be configured to generate a notification signal to a user conveying that a surface 28 is wet, dry, or semi-dry. For example, the notification signal may be an illumination for a light source (not shown) and/or other types of communication processes (e.g., audible or graphics on the user interface 30).

[0033] With reference to FIG. 7, the control system 200 of the suction cleaning apparatus 10 may include at least one electronic control unit (ECU) 202. The at least one ECU 202 may be located in housing 12. The at least one ECU 202 may include a processor 204 and a memory 206. The processor 204 may include any suitable processor 204. Additionally, or alternatively, each ECU 202 may include any suitable number of processors, in addition to or other than the processor 204. The memory 206 may comprise a single disk or a plurality of disks (e.g., hard drives) and includes a storage management module that manages one or more partitions within the memory 206. In some embodiments, memory 206 may include flash memory, semiconductor (solid state) memory, or the like. The memory 206 may include Random Access Memory (RAM), Read-Only Memory (ROM), Electrically Erasable Programmable Read-Only Memory (EEPROM), or a combination thereof. The memory 206 may include instructions that, when executed by the processor 204, cause the processor 204 to, at least, perform the functions associated with the components of the suction cleaning apparatus 10. The motor 20, the power supply 26, responses to inputs from the user interface 30, the one or more sensors 36, and the fluid delivery and recovery system 42 may, therefore, be controlled by the control system 200. The memory 206 may, therefore, include a monitoring module 208, engagement profile dictionary 210, a drying profile dictionary 212, and a filtering module 214.

[0034] With continued reference to FIG. 7, the monitoring module 208 may include pre-saved information relating to changes in the baseline of the power metric over the predetermined threshold and within the period of time (i.e., rapid changes) that are compared to measurements received by the one or more sensors 36. When the measurements received by the one or more sensors 36 meet the criteria of the baseline shift that is rapid, the monitoring module 208 may include instructions to switch between the power restricted and unrestricted modes. The measurements may be saved (e.g., temporarily) and profiled with instructions for performing functions (e.g., with the processor 204) related to averaging the baseline of the power metric, extrapolating a dryness level of a surface being cleaned, power metric drift as a result of the battery 32 being depleted, and accessory tool identification.

[0035] The engagement profile dictionary 210 may include one or more pre-saved predictive behavior models of the baseline of the power metric between the first and second power usage performances and accessory tool behavior. In some embodiments, the engagement profile dictionary 210 may compare profiled measurements from the monitoring module 208 with the pre-saved predictive behavior models. In some embodiments, the pre-saved predictive behavior models may include a predictive baseline of the power metric in one or more of the first and second power usage performances that can be compared to the measured behavior of baseline of the power metric to determine if the motor 20 is in the first or second power usage performance. In this manner, the control system 200 may generate the reduction or increase signal as a result of comparing the measured profile with one of the pre-saved predictive behavior models rather than as a result of the baseline shift. In some embodiments, the engagement profile dictionary 210 may include pre-saved predictive behavior models of varying air path restrictions (e.g., of the baseline) that correspond to different accessory tools that can be compared to the measured behavior of baseline of the power metric to determine if an accessory tool is attached and identify the accessory tool. In response to detecting and identifying an accessory tool, the engagement profile dictionary may include instructions to change operational settings, provide additional settings on the user interface 30, and/or the like.

[0036] The drying profile dictionary 212 may include one or more pre-saved predictive behavior models of the power metric between wet and dry conditions. The drying profile dictionary 212 may compare profiled measurements from the monitoring module 208 with the pre-saved predictive behavior models. In some embodiments, the drying profile dictionary 212 may further or alternatively include threshold information, such as the threshold quantity of change in the power metric between wet and dry conditions over the threshold period of time. The drying profile dictionary 212 may further include instructions to generate a notification signal to a user conveying that a surface 28 is wet, dry, or semi-dry.

[0037] In some embodiments, the filtering module 214 may (e.g., prior to utilizing modules 208-212) receive detection signals of the baseline or baseline shift (e.g., from the one or more sensors 36) and filter out various noises prior to comparison with the engagement profile dictionary 210 and/or the drying profile dictionary 212. More particularly, the filtering module 214 may include instructions to implement one (e.g., a single pole high pass filter) or more (e.g., a multiple pole high pass filter) high pass filter operations that permits high frequencies (e.g., frequency above a threshold) of the detection signal to pass therethrough. For example, frequencies below 0.25 Hz may be filtered out by the high pass filter operation. In some embodiments, the one or more high pass filter operations may include a plurality of high pass filter operations that are stacked or copied with the same or gradually decreasing or increasing threshold frequency for sharper attenuation above the threshold.

[0038] The filtering module 214 may include instructions to implement a moving average operation on the detection signal that takes an average of a plurality of detection signals passed through the one or more high pass filter operations to develop a simple moving average and cancel out irregularities. For example, the plurality of detection signals may be 10 or more detection signals, 15 or more detection signals, 20 or more detection signals, or 30 or more detection signals. The filtering module 214 may include instructions to implement one (e.g., a single pole low pass filter) or more (e.g., a multiple pole low pass filter) low pass filter operations that permit low frequencies (e.g., frequency below a threshold) of the detection signal to pass therethrough. For example, frequencies above 3 Hz may be filtered out by the high pass filter operation. In some embodiments, the one or more low pass filter operations may include a plurality of low pass filter operations that are stacked or copied with the same or gradually decreasing or increasing threshold frequency for sharper attenuation below the threshold.

[0039] The filtering module 214 may include instructions to implement a debounce operation on the filtered detection signal that samples the plurality of filtered detection signals and/or moving averages (e.g., 5 or more) for consistency within the threshold to further remove samples or groups of samples that are not consistent as a result of irregularities or noise. After the detection signal has been filtered, the control system 200 may monitor the filtered detection signal for baseline shifts, compare it to the engagement profile dictionary 210, and/or compare it to the drying profile dictionary 212 (e.g., pre-saved predictive behavior models or thresholds associated with the engagement profile dictionary 210 and/or the drying profile dictionary 212). In some embodiments, the filtered detection signal comparison may be utilized to determine if the surface cleaning apparatus 10 is in the cleaning engaged or disengaged states (based on pre-saved predictive behavior models of the power metric). In this manner, switching between reduced and unrestricted power levels may be accomplished with the filtered detection signal comparison rather than a detection of the baseline shift.

[0040] It should be appreciated that the control system 200 may have a variety of other configurations that implement the power saving operation. For example, in some embodiments, the control system 200 may include a logic-based configuration or other processing-based configurations for performing the functions described herein.

[0041] With reference now to FIG. 8, a method 300 of controlling a power saving operation in a surface cleaning apparatus, such as the cleaning apparatus 10 of FIGS. 1-3 is illustrated. The surface cleaning apparatus 10 may include a housing 12 including a debris holding container 14. The surface cleaning apparatus 10 further includes a suction nozzle 15 having a suction inlet 16, an air pathway 18 at least partially defined by the debris holding container 14 and the suction nozzle 15 having the suction inlet 16, and a motor 20 in operable communication with a fan 22 within the air pathway 18. The motor 20 selectively generates an airflow 24 through the air pathway 18 and includes a cleaning engaged state (FIG. 2) at a first power usage performance and a cleaning disengaged state (FIG. 3) at a second power usage performance that is different than the first power usage performance. A power source 26 provides a power level to the motor 20, and a control system 200 is in operable communication with the motor 20. The method 300 saves power resources (e.g., extends battery life) when the surface cleaning apparatus 10 is in the cleaning disengaged state and the suction inlet 16 is not in contact with a cleaning surface 28.

[0042] The method 300 includes, at step 302, upon activation of the motor, detecting a baseline shift of a power metric from the first power usage performance associated with the suction inlet being in contact with the cleaning surface 28 to the second power usage performance associated with the suction inlet 16 being out of contact with the cleaning surface 28. For example, a control system 200 may be in communication with a sensor 36 that measures the power metric to detect the baseline shift. More particularly, the sensor 36 may include at least one of a series shunt resistor (e.g., for measuring the RPMs) or a current sense amplifier (e.g., for measuring current draw). In this manner, one or more of the RPMs and current draw may be used as the power metric.

[0043] The method 300 further includes, at step 304, generating a reduction signal to the power source 26 to reduce the power level provided to the motor in a power restricted mode. More particularly, the control system 200 may be in communication with and transmit the reduction signal to the power source 26. In the power restricted mode, less energy resources are depleted when the suction inlet 16 is out of contact with the cleaning surface 28.

[0044] Step 304 may include, at step 306, postponing the generation or transmission of the reduction signal to the power source 26 until after a delay period. For example, the control system 200 may be in communication with and transmit the reduction signal to the power source 26 (e.g., a power regulation module) after the delay period.

[0045] The method 300 further includes, at step 308, detecting a baseline shift of the power metric from the second power usage performance to the first power usage performance. For example, a control system 200 may be in communication with the sensor 36 that measures the power metric to detect the baseline shift.

[0046] The method 300 further includes, at step 310, generating an increase signal to the power source 26 to increase the power level provided to the motor 20 in a power unrestricted mode. More particularly, the control system 200 may be in communication with and transmit the increase signal to the power source 26 (e.g., a power regulation module).

[0047] Step 310 may include, at step 312, postponing the generation or transmission of the increase signal to the power source 26 until after a delay period. For example, the control system 200 may be in communication with and transmit the increase signal to the power source 26 (e.g., a power regulation module) after the delay period.

[0048] The method 300 further includes, at step 314, detecting a baseline shift of the power metric from the first power usage performance to the second power usage performance. For example, a control system 200 may be in communication with a sensor 36 that measures the power metric to detect the baseline shift. More particularly, the sensor 36 may include at least one of a series shunt resistor (e.g., for measuring the RPMs) or a current sense amplifier (e.g., for measuring current draw). In this manner, one or more of the RPMs and current draw may be used as the power metric. After step 314, the method 300 may continue (e.g., cycle back) to step 304.

[0049] With reference now to FIGS. 9 and 10, it should be appreciated that certain features of surface cleaning apparatus 10 are exemplary in nature. As such, it will be understood that the features, functions, and methods described herein may be used in conjunction with a variety of surface cleaner configurations. For example, the disclosure may be implemented in conjunction with traditional vacuum cleaners, handheld vacuum cleaners, cleaners with liquid distribution, dry cleaners, and any logically relevant type of vacuum-based cleaning system. With reference now to FIG. 9, the surface cleaning apparatus 10 is configured as a portable deep cleaner device 400. The portable deep cleaner device 400 may have a variety of uses including the general cleaning of surfaces 28, but also offer additional components and functionalities that are particularly suitable for stain removal of surfaces 28, like a carpet, by introducing fluids, heat, and/or other cleaning agents to the surface 28 during cleaning. The portable deep cleaner device 400 may include a base 402 (e.g., a flat base) defined by the housing 12 that sits on the cleaning surface 28. A handle 404 may be connected to the housing 12 (e.g., opposite the base) for lifting and moving the portable deep cleaner device 400 between locations during the cleaning process. It should further be appreciated that the suction cleaning apparatus 10 may include a variety of different components, functionalities, and materials, such as the device shown in U.S. Patent No. 9,474,424. With reference now to FIG. 10, the suction cleaning apparatus 10 may be configured as an upright vacuum cleaner device 500. The upright vacuum cleaner device 500 may have a variety of uses including the general cleaning of surfaces 28, but also offer additional components and functionalities that are particularly suitable for larger areas than, for example, portable deep cleaner devices. The upright vacuum cleaner device 500 may also include components that facilitate the introduction of fluids, heat, and/or other cleaning agents to the surface 28 during cleaning. The upright vacuum cleaner device 500 may include a handle 502 that extends from the housing 12 opposite a suction nozzle 15. The suction nozzle 15 may be defined by a base assembly 504 and may further include the flexible suction hose 38 or a ridged cylinder (not shown) for connection to various accessory tools. One or more wheels 506 are rotatably connected to the housing 12 to facilitate movement of the suction cleaning apparatus 10 around the cleaning surface 28. It should further be appreciated that the suction cleaning apparatus 10 may include a variety of different components, functionalities, and materials, such as the device shown in U.S. Patent No. 10,188,252.

[0050] With further reference to FIGS. 11-13, a surface cleaning apparatus 610, according to another aspect of the present disclosure, includes a housing 612 and a debris holding container 614. The surface cleaning apparatus 610 further includes a suction nozzle 615 having a suction inlet 616. An air pathway 618 may be at least partially defined by the debris holding container 614, the suction nozzle 615, and the suction inlet 616. A motor 620 is operably connected to an impeller such as a fan 622 whereby the motor 620 can be actuated to selectively generate airflow 624 through the air pathway 618 to create a suction at suction inlet 616. A power source 626 provides power (e.g. electrical power) to the motor 620, and a control system 800 is in operable communication with the motor 620. It will be understood that the present disclosure is not limited to a specific configuration of motor 620, fan 622, and air pathway 618.

[0051] As discussed in more detail below, control system 800 may be configured to detect one or more of an engaged state (FIG. 12) of suction inlet 616, a disengaged state (FIG. 13) of suction inlet 616, and transitions (engagement and disengagement) between the engaged and disengaged states, and automatically shift motor 620 between a HIGH power ("Power Boost") mode and a LOW power mode based, at least in part, on predefined criteria that takes into account changes in power used by motor 620 due to engagement and/or disengagement with a surface 628 that is being cleaned. Control system 800 may be configured to automatically switch motor 620 from a LOW power mode to a HIGH power mode based on first engagement criteria, and to shift motor 620 from a HIGH power mode to a LOW power mode based, at least in part, on second engagement criteria. The first and second engagement criteria may comprise rates of change in electrical power (ΔP) used by motor 620. For example, the first engagement criteria may comprise a first rate of change in power (derivative of power), and the second engagement criteria may comprise a second change in power (derivative of power) used by the motor 620.

[0052] With reference to FIG. 11, the surface cleaning apparatus 610 is configured to remove debris or other content from a cleaning surface 628 and routes the debris or other content through the air pathway 618 to the debris holding container 614. The surface cleaning apparatus 610 includes a user interface 630 that provides two or more power settings (e.g. OFF and ON). The user interface 630 may be located on the housing 612 and/or the nozzle 615. The surface cleaning apparatus 610 may optionally include HIGH power ("Power Boost") and/or LOW power settings that are accessible via the user interface 630 whereby a user can select HIGH or LOW power mode. As discussed in more detail below, the HIGH and/or LOW power settings of user interface 630 may, optionally, override automatic switching between HIGH and LOW power modes that could otherwise occur due to engagement and/or disengagement of suction inlet 616 with a surface. User interface 630 may optionally include an "AUTOMATIC Power" input feature or setting whereby a user can choose to allow controller 800 to automatically switch between HIGH and LOW power modes based, at least in part, on predefined engagement and/or disengagement criteria.

[0053] The surface cleaning apparatus 610 may include a battery 632 that, at least partially, functions as the power source 626. The battery 632 may be configured to be recharged utilizing AC current from an electrical outlet to a charging module 634, which may or may not be located directly on the battery 632. However, the present disclosure is not limited to battery powered operation, and household AC current may (optionally) at least partially function as the power source 626 in addition or alternatively to the battery 632.

[0054] The surface cleaning apparatus 610 may include at least one sensor 636 may be located proximate the motor 620 that is configured to monitor (measure) power (P) used by motor 620. For example, sensor 636 may measure electrical current (I) and voltage (V) whereby power (P) can be determined utilizing an equation of the form P = V * I. The control system 800 may adjust the power level provided to the motor 620 utilizing software components (e.g. software), hardware components (e.g. a power regulating module 637), or a combination thereof. It will be understood that control system 800 may comprise virtually any suitable arrangement of hardware and/or software, and the present disclosure is not limited to a specific configuration of hardware and/or software.

[0055] The surface cleaning apparatus 610 may optionally include a flexible suction hose 638 that extends from the housing 612 to the suction nozzle 615 and at least partially defines the air pathway 618. The flexible suction hose 638 may be configured to connect a variety of different accessory tools that can be selected based on characteristics of the cleaning surface 628 (e.g. carpet, tile, wood), the debris or other content (e.g. dirt, hair, liquid) that needs to be removed and/or user preference. It should be appreciated for purposes of this disclosure, that when an accessory tool is connected to the flexible suction hose 638, the nozzle 615 and the suction inlet 616 may be defined by the accessory tool as illustrated. It should be also appreciated that in other constructions that the nozzle 615 and suction inlet 616 may be defined, at least in part, by the housing 612 (e.g. in a handheld vacuum cleaner or upright vacuum cleaner), or other suitable arrangement.

[0056] With continued reference to FIG. 11, the surface cleaning apparatus 610 may optionally include a fluid delivery and recovery system 642. The fluid delivery and recovery system 642 may include a supply tank 644 containing a cleaning fluid 645. A fluid delivery line 646 extends from the supply tank 644 to a fluid outlet port 648. A pump 650 is operably coupled to the supply tank 644 and/or the fluid delivery line 646. The user interface 630 may therefore include one or more options for operating the pump 650 and delivering the cleaning fluid 645 to the cleaning surface 628. In operation, the cleaning fluid 645 that has been delivered to the cleaning surface 628 may subsequently be removed and routed (e.g. through the air pathway 618) to the debris holding container 614. A valve 652 may be located between the supply tank 644 and the pump 650 or between the fluid outlet port 648 and the pump 650 for selectively opening and closing the fluid delivery line 646. The fluid delivery line 646 may optionally extend along the flexible suction hose 638, such that the cleaning fluid 645 is delivered proximate the suction nozzle 615.

[0057] With reference to FIGS. 12 and 13, during operation, the suction inlet 616 may be moved into and out of contact (engagement) with the cleaning surface 628 during cleaning. For example, a user may lift the suction nozzle 615 and, as a result, the suction inlet 616 may be out of contact with the cleaning surface 628. As noted above, control system 800 may be configured to cause motor 620 to operate in a HIGH power mode when an engaged state (FIG. 12) is detected and/or when a transition from a disengaged state to an engaged state is detected. Control system 800 may also be configured to cause motor 620 to operate in a LOW power mode when a disengaged state (FIG. 13) is detected and/or when a transition from an engaged state to a disengaged state is detected. In general, the HIGH and LOW power modes may provide generally constant power to motor 620, wherein increased power (P) is supplied to motor 620 in HIGH power mode relative to the LOW power mode. When in HIGH and/or LOW power mode, control system 800 may utilize open or closed loop control to maintain a generally constant power (P). Alternatively, controller 800 may be configured to maintain a constant motor RPM in the HIGH and LOW power modes utilizing open and closed loop control. As discussed in more detail below, the power (P) may vary or fluctuate somewhat in HIGH and/or LOW power modes as suction inlet 616 engages and/or disengages a surface. Control system 800 may be configured to utilize rates of change in power (e.g. the derivate of power with respect to time) to determine if suction inlet 616 is engaged and/or disengaged and/or transitioning between engaged and disengaged states, to automatically switch between the HIGH and LOW power modes. The rate of change in power may be generally referred to herein as ΔP.

[0058] With further reference to FIG. 14, a control system 800 may be configured to utilize process 100 to control motor 620. FIG. 14 is a high level overview of the process 100 described in more detail below in connection with FIGS. 15-17. Control system 800 may comprise a motor driver (e.g. power regulating module 637) that drives motor 620 to selected states using hardware and/or software. After START 702, at 704 motor 620 is operated in HIGH and LOW power modes and calibration is conducted while suction inlet 616 is disengaged to measure electrical current (I) and/or power (P) whereby baseline (expected) current (I) and/or power (P) of motor 620 in HIGH and/or LOW disengaged modes/states can be determined. Example of changes in power during operation are also shown in FIG. 15. After calibration, at 606 the system operates in a LOW power mode and monitors for surface engagement, which may comprise a first power change criteria. The first power change criteria may comprise a power level having a rate of change that is above or below predefined first threshold rates of change and/or during use. As shown at step 708, if the first power change criteria is not detected/satisfied, the process returns to step 706. However, if the first power change criteria is detected/satisfied at 708, the system operates in a HIGH power mode as shown at 710, and the system monitors for surface disengagement (e.g. second power change criteria). The second power change criteria may comprise a power level having a rate of change that is above or below predefined second threshold rates of change. As shown at 712, if the second power change criteria is not detected/satisfied, the system continues to operate in the HIGH power mode and monitors for disengagement (step 710). If the second power change criteria is detected/satisfied at 712, the process returns to 706, and the system operates in LOW power mode and monitors for the first power change criteria. Process 700 ends when a user selects OFF on the user interface 630.

[0059] As discussed above, in connection with FIG. 11, control system 800 may comprise a motor driver. The motor driver may be configured to utilize Pulse Width Modulation (PWM) (e.g. on a GPIO line) that drives voltage (V) through a switch, to cause motor 620 to operate within a range of speeds from off to full speed. As discussed in more detail below, ramping profiles can be utilized (e.g. in software) to adjust motor transition between speeds.

[0060] In general, the load on motor 620 in open air is constant if the duty of the voltage (V) provided to the motor 620 by the motor driver remains constant, and air flow remains constant, the amount of work the motor needs to do is constant, which means that the output current (I) is also constant.

[0061] Similarly, if the air path (e.g. air pathway 618) remains entirely blocked/occluded (e.g. suction inlet 16 is entirely engaged/sealed with a surface), the current (I) supplied to motor 620 by the motor driver will likewise remain substantially constant. Thus, the electrical current (I) (and/or power P) supplied to motor 620 by the motor driver may be an approximation for airpath occlusion, which may be an approximation for engagement of suction inlet 616 with a surface 628, which, in turn, may be an approximation for a user's active usage of surface cleaning apparatus 610.

[0062] Battery 632 (FIG. 11) may comprise a rechargeable battery that permits surface cleaning apparatus 610 to be used without being plugged in. In general, the voltage available to operate motor 620 may vary (e.g., decrease) as battery 632 drains. In order to compensate for reduced voltage (V) from battery 632, controller 800 may be configured (e.g. utilizing software) to provide voltage compensation to compensate for the loss of voltage over time by adjusting the duty cycle to the motor 622 to provide consistent suction power (e.g. motor RPM) over the life of the battery charge cycle (e.g. full to empty). By adjusting the duty cycle of voltage supplied to motor 620, the same effective motor power can be maintained as battery voltage decreases. However, as the battery voltage decreases, the electrical current being drawn by motor 620 increases if constant power is maintained.

[0063] Examples of engaged and disengaged voltage (V) and electrical current (I) in HIGH and LOW modes are shown in Table 1.

Table 1: Voltage to current Mapping Table

Voltage	High_E	High_D	Low_E	Low_D
28.0	800	1000	300	500
27.5	820	1020	320	520
27.0	840	1040	340	540

[0064] In Table 1, High_E designates High Power mode Engaged (e.g. suction inlet 616 is fully engaged with a surface 628). Similarly, High_D designates High Power mode Disengaged, Low_E designates Low Power mode Engaged, and Low_D designates Low Power mode Disengaged. As shown in Table 1, as the voltage (V) decreases (e.g. due to battery discharge), the electrical current (I) may be increased as a result of the voltage compensation utilized by control system 800 to maintain suction as the battery voltage drops. Table 1 represents measured (test) results for one device. However, it will be understood that Table 1 is merely an example of one possible arrangement, and the current (I) and voltage (V) may be different for different apparatuses and operating conditions.

[0065] In general, a simple control of motor 620 according to an aspect of the present disclosure, may utilize a voltage-to-current mapping table (e.g. similar to Table 1), and motor voltage and current levels may be periodically sampled. At a given voltage level and motor state (HIGH or LOW power mode) for the table, the system may compare whether the last measured current is closer to an engaged state or a disengaged state. If the last measured current is closer to disengaged and the motor 620 is currently in HIGH power mode, the system may transition to a LOW power mode. If the last measured electrical current is closer to engaged current levels (e.g. Table 1), the system can transition to a HIGH power mode. It will be understood that electrical currents (I) of Table 1 may be multiplied by the voltage (V) to provide power (P) rather than current (I). In general, Table 1 is an example of expected or baseline current (I) or power (P) for HIGH and LOW power modes when suction inlet 616 is engaged or disengaged.

[0066] Automatic mode switching between HIGH and LOW power modes may be undesirable if the system causes the cleaning apparatus 610 to operate in a mode that the user did not anticipate or desire.

[0067] Some potential "failures" that could occur include:

- **Scenario A:** The user is actively cleaning and the device (cleaning apparatus 610) is in a HIGH power mode. The device incorrectly determines it is no longer being actively used and switches to a LOW power mode.
- **Scenario B:** The user is not actively cleaning and the device is in a LOW power mode. The device incorrectly

determines it is being actively used and switches to a HIGH power mode.

- **Scenario C:** The user is not actively cleaning and the device is in a LOW power mode. The user attempts to clean and yet the device does not detect this and stays in LOW power mode.
- **Scenario D:** The user has completed cleaning with the device in HIGH power mode. The device has not detected that cleaning is no longer active and remains in HIGH power mode.
- **Scenario E:** Switching of modes is significantly delayed from user action.
- **Scenario F:** Mode switching behavior is erratic and does not appear to be related to any user behavior.

[0068] Noise may also create issues. For example, due to random noise in electrical current, a simple algorithm that is based solely on voltage and current (e.g. Table 1) may fail in scenarios A, B, and F. Noise may be addressed, at least to some extent, via smoothing by building up a running moving average, albeit at the expense of causing slight lag in the detection.

[0069] Response time may also be a consideration if a simple algorithm is utilized. The surface cleaning apparatus 610 may already have some lag due to the physics of the system. For example, experimental data shows that electric current samples (measurements) are delayed from the actual engagement of suction inlet 616 with a surface 628 by a time that may be in the range of 10 to 20 ms. In general, surface cleaning apparatus 610 is preferably configured to change from LOW power mode to HIGH power mode and vice versa with a lag of no more than a predefined limit (e.g. 500 ms, 600 ms, 700 ms, 800 ms, 900 ms, or 1,000 ms). It will be understood, however, these those are merely examples, and the changes in power mode could be less than 500 ms or greater than 1,000 ms, and the present disclosure is not limited to a specific transition time limit.

[0070] Also, automatic mode changes based solely on electrical current (or power) may not fully account for how users clean with a tool (e.g. suction nozzle 615). Users may clean with a tool by making multiple cleaning passes over a surface, picking up the tool between passes. With the algorithm, this may result in many detections of engagements and disengagements within a short span of time, which might look to the user to be scenarios A or F. Also, users may not fully occlude the airpath using the tool while cleaning. Instead there may be a range of occlusion that occurs as the angles of the tool change while the user is cleaning. This means that a single value at peak engagement might never be reached, leading to failures such as scenario C.

[0071] Furthermore, a single voltage-to-current (or power) mapping table (e.g. Table 1) may not fully account for production variations from one product to another, variations resulting from motor usage (life span), and variations due to changes in the air pathway 618. For example, longer-lived changes in air path 618 due to clogs or holes developing in the air pathway may render a fixed table of voltage to current (or power) mapping inaccurate. Still further, various cleaning surfaces 628 (e.g. carpet versus hard surface) may provide more or less occlusion with regards to the suction inlet 616 such that fixed (predefined) voltage-to-current mapping may not be accurate.

[0072] Nevertheless, the magnitude of the electrical current (and power) being drawn by motor 620 will tend to vary rapidly as the suction inlet 616 is engaged or disengaged with a cleaning surface 628. Because power (P) is the product of current (I) and voltage (V), the power (P) supplied to motor 620 also tends to vary significantly as suction inlet 616 engages and disengages a cleaning surface 628. Thus, detecting engagement and disengagement of suction inlet 616 with a cleaning surface 628 may be based, at least in part, on rates of change of power (ΔP) (i.e. the derivative of power with respect to time) of motor 620, wherein the power (P) may be the product of voltage (V) and electrical current (I). As noted above, control system 800 may be configured to provide voltage compensation whereby electrical current (I) to motor 620 is increased as the voltage (V) of battery 632 drops to thereby provide constant power (P) as the voltage (V) changes (drops). Thus, detecting engagement and disengagement utilizing changes in power (ΔP) (rather than electrical current only) reduces or eliminates false detection of engagement and disengagement that could otherwise result from voltage compensation-based changes in electrical current.

[0073] A more detailed flow chart of the process 700 discussed above in connection with FIG. 14 is shown in FIGS. 16-18. Steps 718, 720, 722, 724, 726, and 728 of FIG. 16 generally correspond to the calibration step 704 of FIG. 14. As shown in FIG. 16, after START 702, motor 620 is turned ON at 716. This may be accomplished utilizing user interface 630 (FIG. 11). User interface 630 may include an LED or other device to communicate with a user. For example, user interface 630 may include an LED that blinks ON and OFF to signal to a user not to clean while apparatus 610 is performing calibration 704 immediately following start 702.

[0074] After the motor is turned ON at step 716, controller 800 runs the motor 620 in HIGH power mode (after a ramp up) and waits for motor 620 to warm up. Following motor warm up, at step 720 controller 800 measures voltage (V) and electric current (I) in the HIGH power mode while the suction inlet 616 is disengaged from a surface (e.g. FIG. 13). It will be understood that the "measured" voltage may comprise the voltage of a signal from the motor driver to motor 620. As noted above, user interface 630 may include a blinking LED or other feature that communicates to a user not to engage a cleaning surface during calibration to ensure that inlet 616 remains disengaged.

[0075] A Baseline HIGH Disengaged Power Level is then determined at step 722 utilizing the measured voltage (V) and current (I). The High Disengaged Power Level criteria may be determined utilizing an equation of the form $P = V * I$. The criteria may be based on averages of voltage and current over a short period of time.

[0076] At step 724, controller 800 switches motor 620 to LOW power mode utilizing a ramp down function. At step 726 the controller 800 measures voltage (V) and electric current (I) while the motor 620 is in LOW power mode and the suction inlet 616 is disengaged from a surface. At step 728 the controller 800 determines a Baseline LOW Disengaged Power (or current) Level using the voltage (V) and current (I) while motor 620 is in the LOW power mode and suction inlet 616 is disengaged. Controller 800 may utilize average power and/or current over a short period of time during calibration to determine baseline values. As discussed in more detail below, the Baseline HIGH Disengaged Power Level and Baseline LOW Disengaged Power Level (and/or the electrical currents associated with the HIGH and LOW Disengaged Power Levels) may be utilized in connection with rates of change of power to "double check" (confirm) engagement and/or disengagement of suction inlet 616 with a cleaning surface 628.

[0077] Referring again to FIG. 16, after the Baseline LOW Disengaged Power (or current) Level is determined at step 728, controller 800 operates in a LOW power (Power Boost Ready) mode as shown at step 730. While in the LOW power mode (step 730), controller 800 repeatedly measures the electric current (I) and voltage (V) at short time intervals (ΔT) while motor 620 is in the LOW power mode. ΔT may be 10 ms or other suitable time interval. As shown at steps 732 and 734, controller 800 determines the measured power (P) at each time interval, and calculates a derivative of power (ΔP) at each time interval. At step 736, each new derivative of power (ΔP) is added to a circular buffer, and the oldest ΔP value is deleted from the circular buffer. A moving average of the derivative of power (ΔP) is then calculated at step 737 using the ΔP values stored in the circular buffer. The circular buffer may store any suitable number of ΔT values. A circular buffer storing 50 individual ΔP values has been found to be suitable in some cases. Controller 800 may be configured to avoid use of floating point math operations to reduce the processing and/or memory demands of controller 800. For example, the values of current (I), voltage (V) and power (P) may be multiplied by 100 or 1,000. For example, the calculation for power may be shifted up (multiplied) to account for precision to avoid floating point math in determining average ΔP values. Thus, the power value (e.g. FIG. 15) may comprise power (P) multiplied by a large number (100 or 1,000).

[0078] Also, the moving average of the derivative of power (ΔP) determined at step 737 may be bound on the low and/or high end for ease of data analysis. Thus, if the calculated ΔP falls below a lower boundary, controller 800 replaces the calculated ΔP with the low boundary value. Similarly, if the calculated ΔP value exceeds the high boundary, controller 800 replaces the calculated ΔP with the high boundary value.

[0079] At step 738, controller 800 determines if the moving average of ΔP satisfies predefined threshold ΔP-based criteria for surface engagement. The criteria utilized at step 738 may comprise a first predefined criteria, and controller 800 may shift the motor from the LOW power mode to the HIGH power mode if the first predefined criteria is satisfied. The first predefined criteria may comprise a derivative of power (ΔP) that is greater than, or less than, predefined threshold values. Thus, the first predefined criteria may be satisfied if average ΔP exceeds an upper (positive) threshold value or if average ΔP is below a lower (negative) threshold value. For example, if the criteria comprises a threshold value of 600, the criteria will be satisfied (signifying engagement) if the moving average ΔP is 601 or greater, or -601 or less. The threshold ΔP value (criteria) may (optionally) be determined empirically. For example, a surface cleaning apparatus 610 may be used in various tests, and the threshold ΔP value (criteria) may be adjusted to reduce or eliminate incorrect determinations that suction inlet is (or is not) engaged with a surface. Also, it will be understood that the threshold ΔP criteria does not necessarily need to comprise positive and negative numbers of the same magnitude. For example, the threshold ΔP criteria could comprise -550 and +650. Still further, a single (e.g. positive) ΔP threshold criteria could be used, and the absolute value of the moving average of ΔP could be utilized. Also, the magnitude of the ΔP threshold criteria number may vary, and may be larger if the "raw" numbers are multiplied by a larger number (e.g. 1,000) to reduce or eliminate floating point math operations.

[0080] Referring again to FIG. 16, if the moving average of ΔP does not satisfy the first predefined criteria at 738, the process returns to step 730 and the power (P) for the next time interval is calculated, the circular buffer is updated with the new ΔP, and the moving average of ΔP is again calculated.

[0081] If the moving average of ΔP does satisfy the first predefined criteria at step 738, the process continues to steps 740 and 742, and a debounce is implemented. The debounce utilized at steps 740 and 742 may vary as required for a particular application. In general, a short debounce time may be utilized to detect engagement at steps 740 and 742 whereby the apparatus 10 shifts to HIGH power mode from LOW power mode shortly after a user brings the suction inlet 616 into engagement with a cleaning surface 628. It will be understood that a debounce is not necessarily required, and controller 800 may be configured to automatically change from LOW power mode to HIGH power mode when a moving average of ΔP satisfies the predefined criteria. The debounce window (time) utilized at steps 740 and 742 may comprise, for example, 0.05 seconds, 0.1 seconds, 0.5 seconds, 1.0 seconds, or more. The debounce time may be selected based on, for example, observation of various users on various surfaces. If the debounce time is very short (or zero), random motor noise or other power variations could result in a false engagement determination leading to one or both of scenarios B and F discussed above. In general, if scenario C is a lower priority than scenarios B and F, a debounce when motor 20 is in LOW power mode may be utilized at step 740.

[0082] With further reference to FIG. 17, at step 742 the controller 800 determines if the moving average of ΔP has continued to satisfy predefined criteria for surface engagement during the debounce time. The debounce delays determination that the first predefined criteria for a surface engagement has been satisfied to thereby reduce or eliminate false or incorrect determinations that engagement has occurred. If the first predefined criteria (ΔP) is not satisfied during the debounce time at step 742, the process returns to step 730 (FIG. 16), and the system operates in LOW power mode.

[0083] If the ΔP criteria is satisfied during debounce at step 742, the process continues to step 744. The ΔP-based criteria of steps 738 and 740 may, in some cases, result in an incorrect determination that suction inlet 616 is engaged, even though suction inlet 616 is not actually engaged. Step 744 utilizes Baseline Power (or current) criteria to double check an "engaged" determination at step 742.

[0084] At step 744, the controller 800 determines if the power P and/or electrical current (I) satisfies Baseline Low Disengaged Power (or current) criteria (e.g. during a debounce window). As noted above, the power (P) and electrical current (I) of motor 620 remain relatively constant if inlet 616 is continuously disengaged from a cleaning surface 628. However, the power (P) and electrical current (I) may also be constant if suction inlet 616 is continuously engaged with a surface (e.g. without movement). The power (P) and electrical current (I) of motor 620 may also be constant if a user brings suction inlet 616 into engagement with a cleaning surface 628 very slowly, or moves the suction inlet 616 away from a cleaning surface 628 very slowly. Still further, noise or random variations in power (P) may occur even if suction inlet 616 remains disengaged, resulting in an average ΔP that is above the threshold ΔP criteria. Step 744 may comprise comparing the measured power (P) or measured current (I) (e.g. during the debounce time) to an expected (baselined) power or electrical current for a LOW power disengaged state. The criteria may comprise a value that is within, for example, 5% of the Baseline LOW Power Disengaged Power (or electric current) measured at step 726. Thus, if the power (P) at step 744 is within, for example, 5% of the Baseline LOW Power Disengaged value, controller 800 determines that suction inlet 616 is disengaged (despite satisfying the threshold ΔP criteria for engagement at steps 738 and 742) and the debounce window (time) is cleared at 746, and the process returns to step 730. It will be understood that a 5% range about power or current values measured during calibration is merely an example of one possible baseline criteria.

[0085] If the Baseline Low Power (or current) criteria is satisfied at step 744, the process continues to step 748, and controller 800 ramps up the electric motor 620 to the HIGH power mode.

[0086] At step 750, while the motor 620 operates in the HIGH power mode, controller 800 repeatedly measures the electrical current (I) and voltage (V), and calculates the power P at each time interval.

[0087] At step 752, the controller 800 calculates the derivative of power ΔP for each time interval, and stores the new ΔP value in the circular buffer, and deletes the oldest ΔP value from the circular buffer.

[0088] At step 754, the controller 800 determines if the moving average of the ΔP value stored in the circular buffer satisfies predefined criteria for surface disengagement. The predefined criteria utilized at step 754 may comprise a second (threshold) power change criteria (derivate of power) as discussed above in connection with step 712 (FIG. 14). The predefined criteria for a surface disengagement may comprise an average ΔP having a sufficiently small magnitude to signify that the suction inlet 616 is not in use and is not engaging a cleaning surface 628. Restated, if the average ΔP is greater than a predefined threshold, or less than a predefined negative threshold, controller 800 determines that suction inlet 616 is engaged, and the disengagement criteria is not detected/satisfied. For example, if the HIGH power thresholds are +1,000 and =1,000, controller 800 will, in this example, determine (at least initially) that suction inlet 16 is engaged if the average ΔP is greater than 1,000, and controller 800 will also determine (at least initially) that suction inlet 616 is engaged if the average ΔP is less than -1,000. The LOW power and HIGH power ΔP thresholds may be equal or they may not be equal. Typically, better results may be obtained if LOW power ΔP threshold is less than the HIGH power ΔP threshold. Thus, in the examples of steps 738 and 754, the LOW and HIGH ΔP threshold values are 600 and 1,000, respectively. These are merely examples, however, and the LOW and HIGH ΔP thresholds may be adjusted as required for a partial application.

[0089] An example of disengagement is shown in FIG. 15. After cleaning 760, a user may bring suction inlet 616 out of engagement with a cleaning surface resulting in a constant power P (and current) as shown at 765. Thus, when disengaged voltage V is constant, and the derivative (average ΔP) of power P is small indicating that suction inlet 616 is not engaged, but rather is disengaged. The threshold ΔP criteria for disengagement in LOW and HIGH power modes may be determined empirically, and may be large enough to avoid false "engaged" determinations due to random noise and fluctuations in power.

[0090] Referring again to FIG. 17, if the average ΔP does not satisfy the HIGH power ΔP threshold criteria at step 754, the process returns to step 750, and the controller 800 continues to repeatedly measure current (I), voltage (V), and calculate power (P).

[0091] If the predefined threshold High power ΔP criteria is satisfied at step 754, the process continues to step 756, and a debounce is applied to avoid a false determination that suction inlet 616 is disengaged. As shown in FIG. 15, during cleaning 660 the power P may vary significantly. The debounce delays determination of a disengaged state for a period of time (e.g. 1.0 second, 1.5 seconds, 2.0 seconds, etc.) to avoid an incorrect determination (based on short disengagements) that disengagement has occurred.

[0092] Referring again to FIG. 17, at step 758 the process determines if the average ΔP value satisfied the predetermined HIGH power ΔP threshold criteria for disengagement during the debounce time window. If the average ΔP values do not satisfy the disengagement criteria during the debounce (e.g. the engagement and disengagement were rapid), the process returns to step 750 and controller 800 continues to monitor for disengagement. However, if the predetermined HIGH power ΔP threshold criteria is satisfied at step 758, the process continues to step 766. At step 766, controller 800 determines if the power (P) and/or current (I) satisfy Baseline Disengaged Power and/or Current criteria. The Baseline Disengaged Power Criteria may comprise power (P) (or current (I)) that is within, for example, 5% of the Baseline HIGH Disengaged Power or current measured during calibration at step 720. As discussed above, if a user holds suction inlet 616 in engagement with a cleaning surface 628 for a period of time, the average ΔP value (step 758) may be small, leading to an incorrect initial determination at step 758 that the suction the inlet 616 is disengaged. Step 766 provides an additional power (or current) based criteria that must also be satisfied to determine that suction inlet 616 is disengaged. It will be understood that a 5% range about power or current values measured during calibration is merely an example of a possible baseline criteria. If the power (electrical current) criteria is not satisfied at step 766, the debounce window is cleared at 776, and the process returns to step 750 without switching to a LOW power mode.

[0093] If the power-based criteria for disengagement is satisfied at step 766, the process continues to step 768, and the controller 800 switches the motor from the HIGH power mode to the LOW power mode. Controller 800 is preferably configured to ramp the voltage to motor 620 from HIGH power mode to LOW power mode (and vice-versa) over a period of time to avoid abrupt changes in the power level to the motor 620. The controller 800 may be configured to "ignore" or otherwise not take into account changes in power level during the ramping from HIGH power to LOW power (and ramping from LOW to HIGH power) to avoid an incorrect determination that the changes in power due to ramping represent an engaged state.

[0094] Referring again to FIG. 18, at step 770 controller 800 measures voltage (V) and current (I) of the motor in LOW power mode, and then determines an updated Baseline LOW Disengaged Power (or current) level at step 772. Steps 770 and 772 provide an updated calibration of the Baseline LOW Disengaged Power (or current) Level during a short period of time following disengagement of suction inlet 616. This calibration may be conducted because users do not typically immediately engage a surface after disengagement whereby a LOW power disengaged condition can be assumed. If the power of apparatus 610 is turned OFF at step 774, the process ends at 778. If the power is not turned OFF, the process returns to step 730, and the electric current (I) and voltage (V) are measured at short time intervals to monitor for changes in power that meet the engagement criteria at step 738 as discussed above.

[0095] An example of power levels during use is shown in FIG. 15. After device 610 is turned ON at 768, the motor ramps to HIGH power at 717, and the Baseline HIGH Disengaged Power (or current) Level is then determined at 722. The controller 800 then causes the motor 20 to ramp down to LOW power mode at 723, and the controller 800 then determines the Baseline LOW Disengaged Power (or current) at 728.

[0096] Following calibration controller 800 initially causes the motor 620 to operate in LOW power mode. If the suction inlet 616 is then engaged with a surface, the power controller 800 detects engagement at 731, and controller 800 may rapidly ramp up power at 779 to a peak 780. In the example at FIG. 25, this is followed by a series of peaks and valleys 761 and 762, respectively, during use 760. The peaks 761 and valleys 762 may be caused by, for example, a user engaging a surface with suction inlet 616, followed by pulling the suction inlet 616 along the surface, followed by disengaging the suction inlet 616 from a surface as the suction inlet 616 is moved forward, followed by reengagement of suction inlet 616 with a cleaning surface. When the suction nozzle 616 is disengaged for a period of time 765, the power value remains relatively constant, thereby (at least initially) satisfying the threshold disengaged criteria. If the Baseline Power (or electrical current) criteria for disengagement is also satisfied (e.g. during time period 765), controller 800 ramps the power down at 782. In the example of FIG. 15, the device 610 operates in a LOW power mode while disengaged for a short period of time 786, and the apparatus 610 is then powered off at 788. The Baseline LOW Disengaged Power (or current) may be calculated at 786, and the value determined during initial calibration may be replaced if the updated value calculated at 786 is sufficiently different than the value calculated during initial calibration at 728.

[0097] FIG. 19 shows calibration 704 according to another aspect of the present disclosure. In this example, power is OFF during an initial period of time 715. The motor 620 is turned ON at 716, and the motor 620 ramps from LOW power mode to HIGH power mode as shown at 779. In the illustrated example, the ramp 779 is 1300 ms. It will be understood, however, that the ramp time may vary as required for a particular application. In the example of FIG. 19, the motor warmup is complete at 790 when the ramp up 779 is completed. However, motor 620 may continue to operate in the HIGH power mode for a period of time following the ramp 779 for motor warmup.

[0098] After the warmup is complete at 790, motor 620 is run for a period of time 792, and controller 800 measures the Baseline High Disengaged Power (or current) Level. The High Disengage Power Level may comprise an average power supplied to motor 620 over a period of time. In the illustrated example, the High Disengaged Power Level is determined utilizing a time period of 1,000 ms. However, the time period may vary as required for a particular application. The power level then ramps down at 793 between points 794 and 796. The ramp 793 may be, for example, 200 ms or other suitable period of time. Controller 800 then causes the motor 620 to operate in a LOW power mode 798 for a period of time (e.g. 1,000 ms), and the Baseline LOW Disengaged Power (or current) Level is measured. The controller 800 then transitions to a HIGH power mode (Power_Boost_Ready") at 799, and the controller 800 then repeatedly measures electric current (I) and voltage (V) at short time intervals 730 while in the LOW power mode.

[0099] The power level (vertical axis) in FIG. 19 corresponds to the power signal from the motor driver to motor 620. It will be understood that the power level may comprise relatively large numerical number if the power level is multiplied by, for example, 1,000 to reduce floating point math operations.

[0100] With reference to FIG. 20, following the calibration 704 (FIG. 19), the apparatus 610 may operate at a LOW disengaged power level 730 for a period of time while the electric current (I) and voltage (V) are repeatedly measured, and the derivative of power (ΔP) and average ΔP are calculated to determine if the threshold HIGH power engagement criteria has been satisfied. In the illustrated example, surface engagement begins at 802, and the power level is reduced at 804 until a detection floor is reached at 806. During engagement 760, if the ΔP and baseline criteria are satisfied during debounce (e.g. 50 ms), controller 800 detects engagement at 808, and controller 800 then ramps the voltage to the electric motor 620 as shown at 810. At 812, the motor 620 is in the HIGH power mode, and operation in HIGH power mode continues at 814. Controller 800 repeatedly measures the current (I) and voltage (V) during operation 814 to determine if the HIGH power mode disengaged criteria are satisfied.

[0101] With further reference to FIG. 21, apparatus 610 may operate in a HIGH power mode (Power_Boost_Engaged) during time 814. In this example, the user begins to disengage suction inlet 616 at 816. As the inlet is disengaged, the Power Level will increase as shown at 818 until a Disengagement Detection Floor is reached at 820. A debounce (e.g. 2,000 ms or other suitable time) is then implemented at 822. If the average ΔP and Baseline Power (or electric current) criteria for disengagement are satisfied at 824, controller 800 ramps the voltage to motor 620 down as shown at 826. In the example of FIG. 21, the ramp is 200 ms. However, virtually any suitable ramp time may be utilized. Controller 800 then causes the motor 620 to operate at the LOW disengaged power level for a period of time (e.g. 1,000 ms) as shown at 828, and controller 800 then updates (calibrates) the Baseline LOW Disengaged Power (or current) Level. After updating the Baseline LOW Disengaged Power Level, controller 800 operates a LOW power mode ("Power_Boost_Ready") at 830. It will be understood that FIGS. 19-21 are schematic, and the actual Power Levels (e.g. power signal to motor 620) may have fluctuations, curves, and other such irregularities that are not shown in FIGS. 19-21.

[0102] Examples of HIGH Powered Mode (HPM) signals developed during testing are shown in FIG. 22, and examples of LOW Powered Mode (LPM) signals are shown in FIG. 23. The signals of FIGS. 22 and 23 comprise average ΔP values calculated using a rolling window (e.g. a circular buffer of 50 ΔP values). In general, the Disengaged signals tend to be relatively small, whereas the Disengaging signals, Engaged signals, and Engaging signals tend to be significant. Thus, the magnitude of the signal (average ΔP) may provide an indication with regards to the engagement and disengagement of the suction inlet with a surface.

[0103] The disclosure herein may be further summarized in the following paragraphs and characterized by combinations of any and all of the various aspects described therein.

[0104] According to one aspect of the present disclosure, a surface cleaning apparatus includes a debris holding container. The surface cleaning apparatus further includes a suction inlet, an air pathway at least partially defined by the debris holding container and the suction inlet, and a motor configured to drive a fan to generate airflow through the air pathway. The motor defines a first power usage profile corresponding to a cleaning engaged state, and a second power usage profile corresponding to a cleaning disengaged state. The second power usage profile is not identical to the first power usage profile. An electrical power source is configured to provide electrical power to the motor. A controller is in operable communication with the motor. The controller is configured to detect a shift from the first power usage profile to the second power usage profile based, at least in part, on a change in at least one power metric, and reduce a level provided to the motor when a shift from the first power usage profile to the second power usage profile is detected.

[0105] According to another aspect, a control system may be further configured to detect a shift from the second power usage profile to the first power usage profile based, on at least in part, on a change in at least one power metric and increase power to the motor when a shift from the second power usage profile to the first power profile usage is detected.

[0106] According to yet another aspect, a control system may be further configured to increase power after a delay period if the controller determines that predefined debounce criteria are satisfied.

[0107] According to still yet another aspect, the delay period may comprise a first delay period and the controller is configured to turn off power to the motor after a second delay period that is greater than the first delay period.

[0108] According to another aspect, a power metric may include at least one operating parameter selected from the group consisting of electric current of the power, electric power of the motor, a rate of change of electric current of the motor, and a rate of change of electric power of the motor.

[0109] According to yet another aspect, a power metric may include at least a selected one of an RPM of the motor and an electric current draw of the motor.

[0110] According to another aspect, the controller may be configured to utilize a change of the power metric over a predefined time interval to determine if the suction inlet has moved into engagement with a surface and/or moved out of engagement with a surface.

[0111] According to another aspect of the present disclosure, a cleaning apparatus includes a battery and a motor that is operatively connected to the battery. The cleaning apparatus further includes an air conduit having a suction inlet, and an impeller and fluid communication with the air conduit and operably connected to the motor, whereby the motor can be actuated to cause the impeller to create suction at the suction inlet. The cleaning apparatus further includes a controller that is configured to cause the motor to operate in first and second modes, wherein the second mode provides increased suction at the suction inlet relative to the first mode when the inlet is engaging a surface. The controller is also configured to cause the motor to switch from the first mode to the second mode, based at least in part, on first engagement criteria. The controller is further configured to cause the motor to switch from the second mode to the first mode, based at least in part, on second engagement criteria. The first and second engagement criteria comprise changes in electrical power used by the motor, wherein the changes in electrical power are associated with engagement of the suction inlet with a surface, whereby the controller causes the motor to switch from the first mode to the second mode if the suction inlet is brought into engagement with a surface, and causes the motor to switch from the second mode to the first mode if the suction inlet is disengaged from a surface.

[0112] According to still yet another aspect, the controller may be configured to operate the motor at first and second power levels in the first and second modes, respectively. The second power level may be greater than the first power level.

[0113] According to another aspect, the first engagement criteria may comprise a rate of change in electrical power used by the motor that is greater than a predefined first threshold rate of change in electrical power of the motor. The controller may be configured to repeatedly determine electrical power of the motor when in the first and/or second modes based, at least in part, on the voltage and electrical current to the motor.

[0114] According to yet another aspect, when in the first mode, the controller may be configured to: 1) determine an average rate of change in electrical power used by the motor utilizing a plurality of individual rates of change in electrical power used by the motor over a period of time, and: 2) compare the average rate of change in electrical power used by the motor to the first threshold rate of change in electrical power used by the motor, and: 3) determine that the first engagement criteria is satisfied if the average rate of change in electrical power used by the motor is greater than or equal to the predefined first threshold rate of change in electrical power used by the motor.

[0115] According to another aspect, when in the first mode, the controller may be configured to: 1) determine the individual rates of change in electrical power used by the motor utilizing a difference in electrical power used by the motor over a period of time, and: 2) store the individual rates of change in electrical power used by the motor in a circular buffer, whereby a plurality of individual rates of change in electrical power used by the motor are stored in the circular buffer. The controller may also be configured to determine the average rate of change in electrical power used by the motor utilizing the plurality of individual rates of change in electrical power used by the motor stored in the buffer.

[0116] According to yet another aspect, the first mode may comprise a LOW power mode, and the second mode may comprise a HIGH power mode in which motor power is increased relative to the LOW power mode. The controller may be configured to implement a first debounce after initially determining that the first engagement criteria is satisfied to: 1) delay, by a first debounce time, switching the motor from the LOW power mode to the HIGH mode, and: 2) switch from the LOW power mode to the HIGH power mode after the first debounce time if the first engagement criteria is satisfied during the first debounce time.

[0117] According to still yet another aspect, the second engagement criteria may comprise a rate of change in electrical power used by the motor that is greater than a predefined second threshold rate of change in electrical power used by the motor. The predefined second threshold rate of change in electrical power used by the motor may be greater than the predefined first threshold rate of change in electrical power used by the motor.

[0118] According to another aspect, when in the second mode the controller may be configured to: 1) determine an average rate of change in electrical power used by the motor utilizing a plurality of individual rates of change in electrical power used by the motor over a period of time, 2) compare the average rate of change in electrical power used by the motor to the second threshold rate of change in electrical power used by the motor, and: 3) determine that the second engagement criteria is satisfied if the average rate of change in electrical power used by the motor is greater than or equal to the predefined second rate of change in electrical power used by the motor.

[0119] According to yet another aspect, when in the second mode the controller may be configured to: 1) determine the individual rates of change in electrical power used by the motor utilizing a difference in electrical power used by the motor over an increment of time, and: 2) store the individual rates of change in electrical power used by the motor in a circular buffer whereby a plurality of individual rates of change in electrical power used by the motor are stored in the circular buffer. The controller may be configured to determine the average rate of change in electrical power used by the motor utilizing the plurality of individual rates of change in electrical power used by the motor stored in the buffer.

[0120] According to still yet another aspect, the first mode may comprise a LOW power mode. The second mode may comprise a HIGH power mode in which motor power is increased relative to the LOW power mode. The controller may be configured to implement a second debounce after initially determining that the second engagement criteria is satisfied to: 1) delay, by a second debounce time, switching the motor from the HIGH power mode to the LOW power mode; and: 2) switch from the HIGH power mode to the LOW power mode after the second debounce time if the second engagement criteria is satisfied during the second debounce time.

[0121] According to another aspect, the second debounce time may be greater than the first debounce time.

[0122] According to yet another aspect, the controller may be configured to determine electrical current used by the motor and/or power used by the motor while the motor is in the LOW power mode and the suction inlet is disengaged from a surface to determine a baseline LOW disengaged power criteria comprising electrical current and/or power. The controller may be configured to determine electrical current used by the motor and/or electrical power used by the motor while the motor is in the HIGH power mode and the suction inlet is disengaged from a surface to determine a baseline HIGH disengaged power criteria comprising electrical current and/or power. The controller may be configured to switch from the LOW power mode to the HIGH power mode if: 1) the first engagement criteria is satisfied, and: 2) the baseline LOW disengaged power criteria is satisfied. The controller may be configured to switch from the HIGH power mode to the LOW power mode if: 1) the second engagement criteria is satisfied, and: 2) the baseline HIGH disengaged power criteria is satisfied.

[0123] According to still yet another aspect, the controller may be configured to determine the baseline LOW disengaged power criteria and/or baseline HIGH disengaged power criteria during initial calibration, whereby the controller is configured to: 1) initially operate the motor in HIGH power mode after the motor is turned ON, and: 2) determine the baseline HIGH disengaged power criteria while the motor is operating in HIGH power mode. The controller may be configured to: 1) initially operate the motor in LOW power mode after the motor is turned ON, and: 2) determine the baseline LOW disengaged power criteria while the motor is operating in LOW power mode.

[0124] According to another aspect, the controller may be configured to update the baseline LOW disengaged power criteria during use by measuring electrical current used by the motor and/or electrical power used by the motor while the motor is in the LOW power mode after changing from the HIGH power mode to the LOW power mode after the suction inlet is disengaged from a surface to determine an updated baseline LOW disengaged power criteria.

[0125] According to yet another aspect, the baseline LOW disengaged power criteria may comprise a range of electrical current about an electrical current measured while the motor is in LOW power mode and the suction inlet is disengaged from a surface. The baseline HIGH disengaged power criteria may comprise a range of electrical current about an electrical current measured while the motor is in HIGH power mode and the suction inlet is disengaged from a surface. The controller may be configured to continue operating in the HIGH power mode unless measured current is within the HIGH disengaged range of electrical current, even if the second engagement criteria is satisfied. The controller may be configured to continue operating in the LOW power mode unless measured current is outside of the LOW disengaged range of electrical current, even if the first engagement criteria is satisfied.

[0126] According to still yet another aspect, a user input feature may allow a user to input an override. The controller may be configured to continue operating the motor in HIGH power mode when the suction inlet is disengaged from a surface if an override has been input.

[0127] According to another aspect of the present disclosure, an air passageway has a suction inlet that is configured to engage a surface to clean the surface. An impeller may be in fluid communication with the air passageway. A motor may be operably connected to the impeller. The motor may cause air to flow in the air passageway to create suction at the suction inlet. A controller may be configured to cause the apparatus to selectively operate in a first mode or a second mode. Suction at the suction inlet may be increased in the second mode relative to suction at the suction inlet in the first mode. The controller may be configured to change from the first mode to the second mode and/or from the second mode to the first mode based, at least in part, on power change criteria. The power change criteria may comprise a rate of change of electrical power of the motor.

[0128] According to yet another aspect, the controller may be configured to switch from the second mode to the first mode if the rate of change of electrical power used by the motor is below a predefined threshold.

[0129] According to still yet another aspect, the controller may be configured to continue operating in the second mode if electrical current and/or power used by the motor is consistent with an electrical current and/or power that is expected, according to predefined criteria, when the suction inlet is engaging a surface in the second mode, even if the power change criteria is satisfied.

[0130] According to yet another aspect, the power change criteria may comprise first and second power change criteria. The first power change criteria may comprise a first threshold rate of change of electrical power used by the motor, and the second power change criteria may comprise a second threshold rate of change of electrical power used by the motor. The first threshold rate of change of electrical power used by the motor may be less than the second threshold rate of change of electrical power used by the motor. The controller may be configured to switch from the first mode to the second mode based, at least in part, on a comparison of a measured rate of change of electrical power used by the motor to the first threshold rate of change of electrical power used by the motor.

[0131] It will be understood by one having ordinary skill in the art that construction of the described disclosure and other components is not limited to any specific material. Other exemplary embodiments of the disclosure disclosed herein may be formed from a wide variety of materials, unless described otherwise herein.

[0132] For purposes of this disclosure, the term "coupled" (in all of its forms, couple, coupling, coupled, etc.) generally means the joining of two components (electrical or mechanical) directly or indirectly to one another. Such joining may be stationary in nature or movable in nature. Such joining may be achieved with the two components (electrical or mechanical) and any additional intermediate members being integrally formed as a single unitary body with one another or with the two components. Such joining may be permanent in nature or may be removable or releasable in nature unless otherwise stated.

[0133] It is also important to note that the construction and arrangement of the elements of the disclosure, as shown in the exemplary embodiments, is illustrative only. Although only a few embodiments of the present innovations have been described in detail in this disclosure, those skilled in the art who review this disclosure will readily appreciate that many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes, and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter recited. For example, elements shown as integrally formed may be constructed of multiple parts, or elements shown as multiple parts may be integrally formed, the operation of the interfaces may be reversed or otherwise varied, the length or width of the structures and/or members or connector or other elements of the system may be varied, the nature or number of adjustment positions provided between the elements may be varied. It should be noted that the elements and/or assemblies of the system may be constructed from any of a wide variety of materials that provide sufficient strength or durability, in any of a wide variety of colors, textures, and combinations. Accordingly, all such modifications are intended to be included within the scope of the present invention.

[0134] It will be understood that any described processes or steps within described processes may be combined with other disclosed processes or steps to form structures within the scope of the present invention. The exemplary structures and processes disclosed herein are for illustrative purposes and are not to be construed as limiting.

Claims

1. A surface cleaning apparatus comprising:

    an air pathway having a suction inlet;
    a motor configured to drive an impeller to generate airflow through the air pathway, the motor defining a first power usage profile corresponding to a cleaning engaged state, and a second power usage profile corresponding to a cleaning disengaged state, wherein the second power usage profile is not identical to the first power usage profile;
    an electrical power source configured to provide electrical power to the motor; and
    a controller in operable communication with the motor, wherein the controller is configured to:

        detect a shift from the first power usage profile to the second power usage profile based, at least in part, on a change in at least one power metric; and
        reduce a power to the motor when a shift from the first power usage profile to the second power usage profile is detected.

2. The surface cleaning apparatus of claim 1, wherein:
    the controller is configured to:

    detect a shift from the second power usage profile to the first power usage profile based, on at least in part, on a change in at least one power metric; and
    increase power to the motor when a shift from the second power usage profile to the first power profile usage is detected.

3. The surface cleaning apparatus of claim 1 or claim 2, wherein:
    the control system is configured to increase power to the motor after a delay period if the controller determines that predefined debounce criteria are satisfied.

4. The surface cleaning apparatus of any one of claims 1-3, wherein:
    the power metric comprises at least one operating parameter selected from the group consisting of electric current of the motor, electric power of the motor, a rate of change of electric current of the motor, and a rate of change of electric power of the motor.

5. The surface cleaning apparatus of any one of claims 1-4, wherein:
    the controller is configured to:
    utilize a change of the power metric over a predefined time interval to determine if the suction inlet has moved into engagement with a surface and/or moved out of engagement with a surface.

6. A cleaning apparatus comprising:

a battery;
a motor that is operably connected to the battery;
an air conduit having a suction inlet;
an impeller in fluid communication with the air conduit and operably connected to the motor whereby the motor can be actuated to cause the impeller to create a suction at the suction inlet;
a controller that is configured to:

cause the motor to operate in first and second modes, wherein the second mode provides increased suction at the suction inlet relative to the first mode when the inlet is engaging a surface;
cause the motor to switch from the first mode to the second mode, based at least in part, on first engagement criteria;
cause the motor to switch from the second mode to the first mode, based at least in part, on second engagement criteria; and:
wherein the first and second engagement criteria comprise changes in electrical power used by the motor associated with engagement of the suction inlet with a surface, whereby the controller causes the motor to switch from the first mode to the second mode if the suction inlet is brought into engagement with a surface, and causes the motor to switch from the second mode to the first mode if the suction inlet is disengaged from a surface.

7. The cleaning apparatus of claim 6, wherein:
the first engagement criteria comprises a rate of change in electrical power used by the motor that is greater than a predefined first threshold rate of change in electrical power of the motor.

8. The cleaning apparatus of claim 6 or claim 7, wherein:
when in the first mode the controller is configured to: 1) determine an average rate of change in electrical power used by the motor utilizing a plurality of individual rates of change in electrical power used by the motor over a period of time, and: 2) compare the average rate of change in electrical power used by the motor to the first threshold rate of change in electrical power used by the motor, and: 3) determine that the first engagement criteria is satisfied if the average rate of change in electrical power used by the motor is greater than or equal to the predefined first threshold rate of change in electrical power used by the motor.

9. The cleaning apparatus of any one of claims 7-8, wherein:

when in the first mode the controller is configured to: 1) determine the individual rates of change in electrical power used by the motor utilizing a difference in electrical power used by the motor over an increment of time, and: 2) store the individual rates of change in electrical power used by the motor in a circular buffer whereby a plurality of individual rates of change in electrical power used by the motor are stored in the circular buffer; and
the controller is configured to determine the average rate of change in electrical power used by the motor utilizing the plurality of individual rates of change in electrical power used by the motor stored in the buffer.

10. The cleaning apparatus of any one of claims 6-9, wherein:

the first mode comprises a LOW power mode;
the second mode comprises a HIGH power mode in which motor power is increased relative to the LOW power mode;
the controller is configured to implement a first debounce after initially determining that the first engagement criteria is satisfied to: 1) delay, by a first debounce time, switching the motor from the LOW power mode to the HIGH mode, and: 2) switch from the LOW power mode to the HIGH power mode after the first debounce time if the first engagement criteria is satisfied during the first debounce time.

11. The cleaning apparatus of any one of claims 6-10, wherein:

the second engagement criteria comprises a rate of change in electrical power used by the motor that is greater than a predefined second threshold rate of change in electrical power used by the motor;
the predefined second threshold rate of change in electrical power used by the motor is greater than the predefined first threshold rate of change in electrical power used by the motor.

12. The cleaning apparatus of any one of claims 6-11, wherein:
when in the second mode the controller is configured to: 1) determine an average rate of change in electrical power used by the motor utilizing a plurality of individual rates of change in electrical power used by the motor over a period of time, 2) compare the average rate of change in electrical power used by the motor to the second threshold rate of change in electrical power used by the motor, and: 3) determine that the second engagement criteria is satisfied if the average rate of change in electrical power used by the motor is greater than or equal to the predefined second rate of change in electrical power used by the motor.

13. The cleaning apparatus of any one of claims 10-12, wherein:

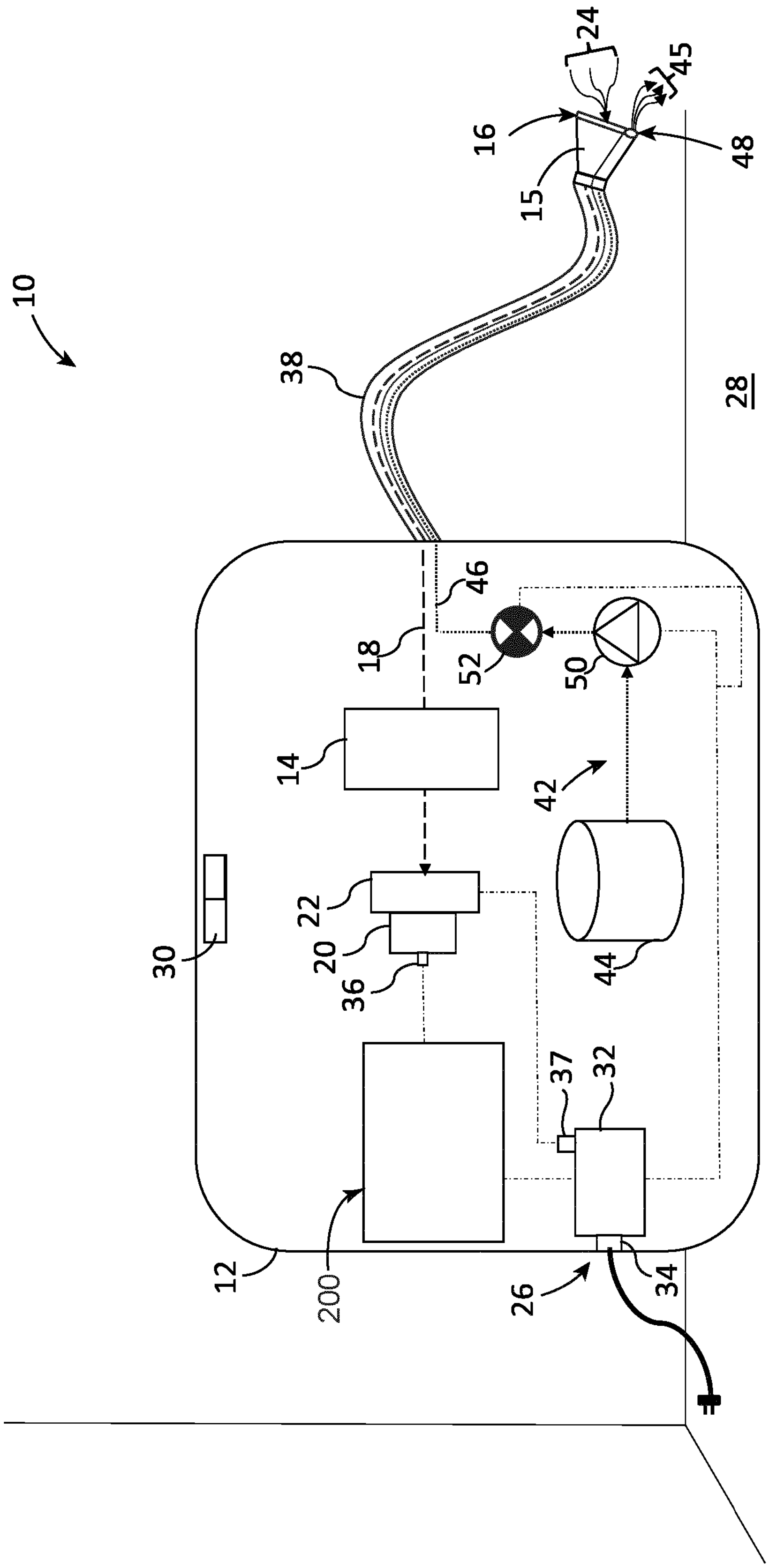
the first mode comprises a LOW power mode;
the second mode comprises a HIGH power mode in which motor power is increased relative to the LOW power mode;
the controller is configured to implement a second debounce after initially determining that the second engagement criteria is satisfied to: 1) delay, by a second debounce time, switching the motor from the HIGH power mode to the LOW power mode; and: 2) switch from the HIGH power mode to the LOW power mode after the second debounce time if the second engagement criteria is satisfied during the second debounce time.

14. The cleaning apparatus of claim 13, wherein:

the controller is configured to determine electrical current used by the motor and/or power used by the motor while the motor is in the LOW power mode and the suction inlet is disengaged from a surface to determine a baseline LOW disengaged power criteria comprising electrical current and/or power;
the controller is configured to determine electrical current used by the motor and/or electrical power used by the motor while the motor is in the HIGH power mode and the suction inlet is disengaged from a surface to determine a baseline HIGH disengaged power criteria comprising electrical current and/or power;
the controller is configured to switch from the LOW power mode to the HIGH power mode if: 1) the first engagement criteria is satisfied, and: 2) the baseline LOW disengaged power criteria is satisfied; and
the controller is configured to switch from the HIGH power mode to the LOW power mode if: 1) the second engagement criteria is satisfied, and: 2) the baseline HIGH disengaged power criteria is satisfied.

15. An apparatus for cleaning surfaces comprising:

an air passageway having a suction inlet that is configured to engage a surface to clean the surface;
an impeller in fluid communication with the air passageway;
a motor operably connected to the impeller, whereby the motor causes air to flow in the air passageway to create suction at the suction inlet;
a controller that is configured to cause the apparatus to selectively operate in a first mode or a second mode, wherein suction at the suction inlet is increased in the second mode relative to suction at the suction inlet in the first mode;
and wherein the controller is configured to change from the first mode to the second mode and/or from the second mode to the first mode based, at least in part, on power change criteria, wherein the power change criteria comprises a rate of change of electrical power of the motor.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45
46
48
50
52
200

FIG. 1

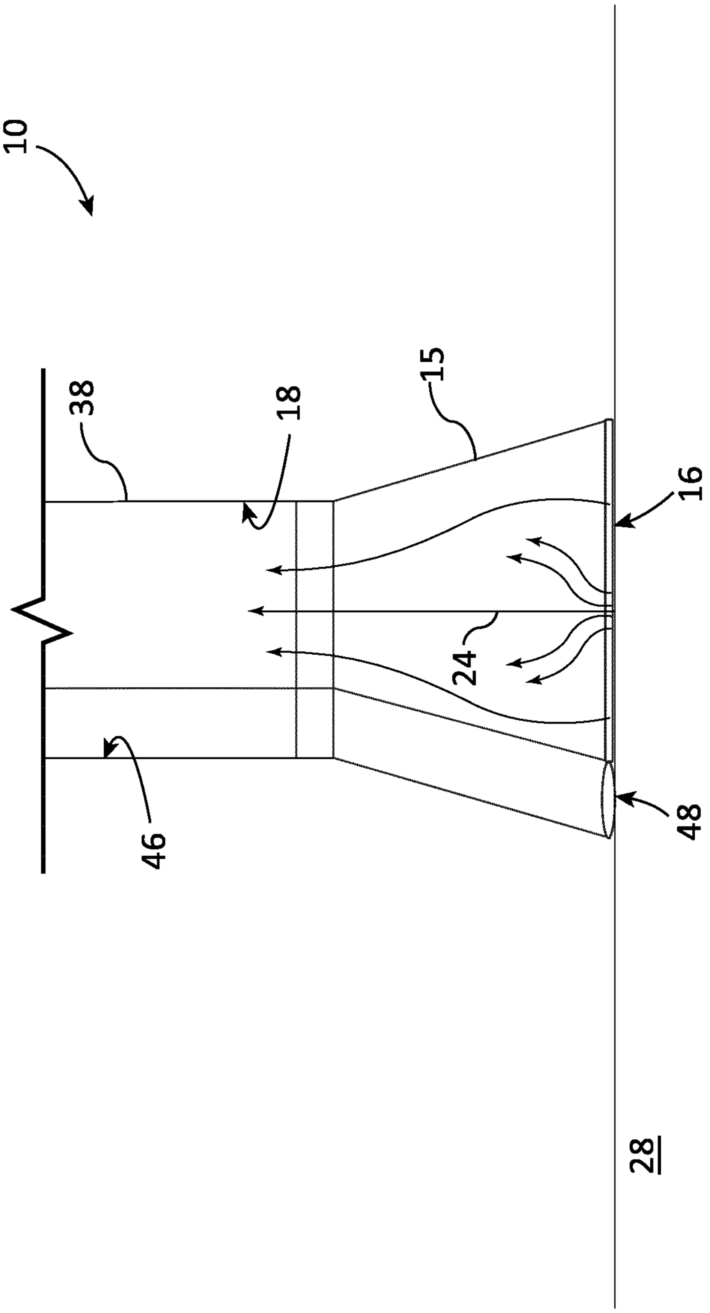


FIG. 2

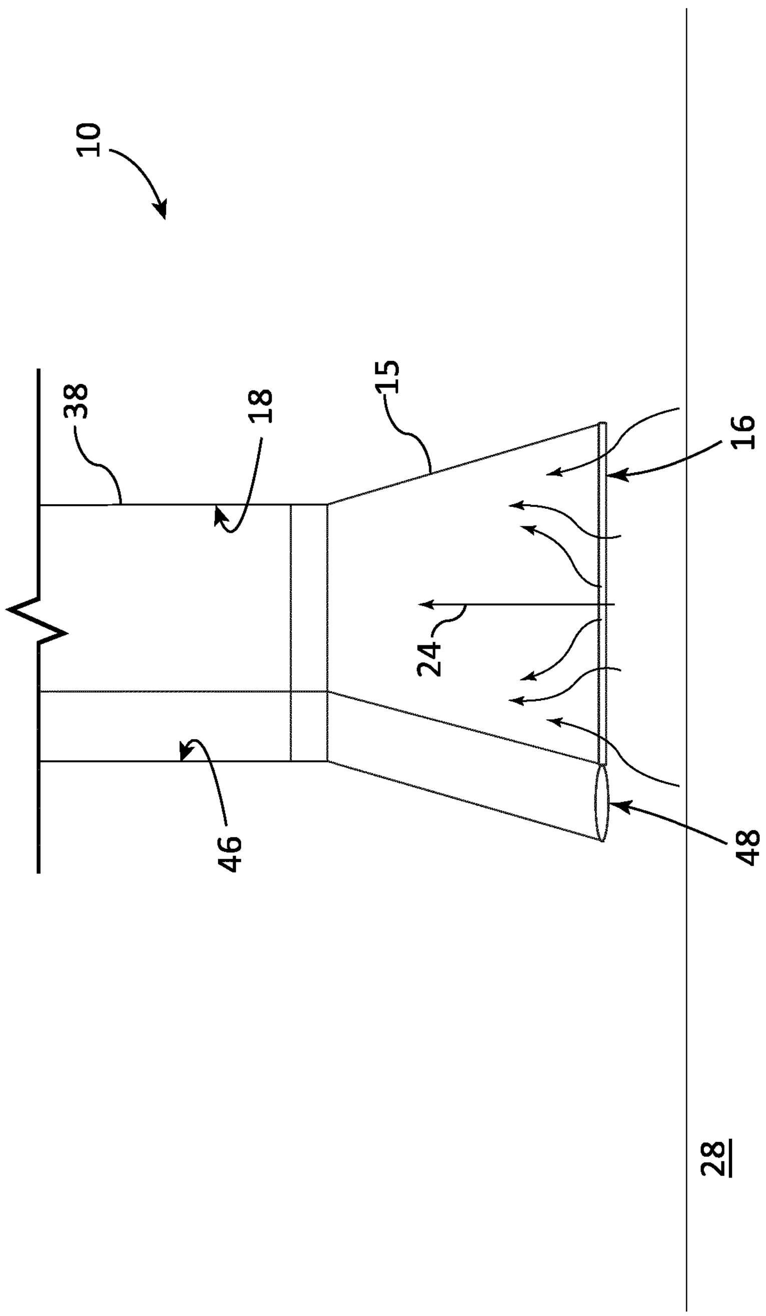


FIG. 3

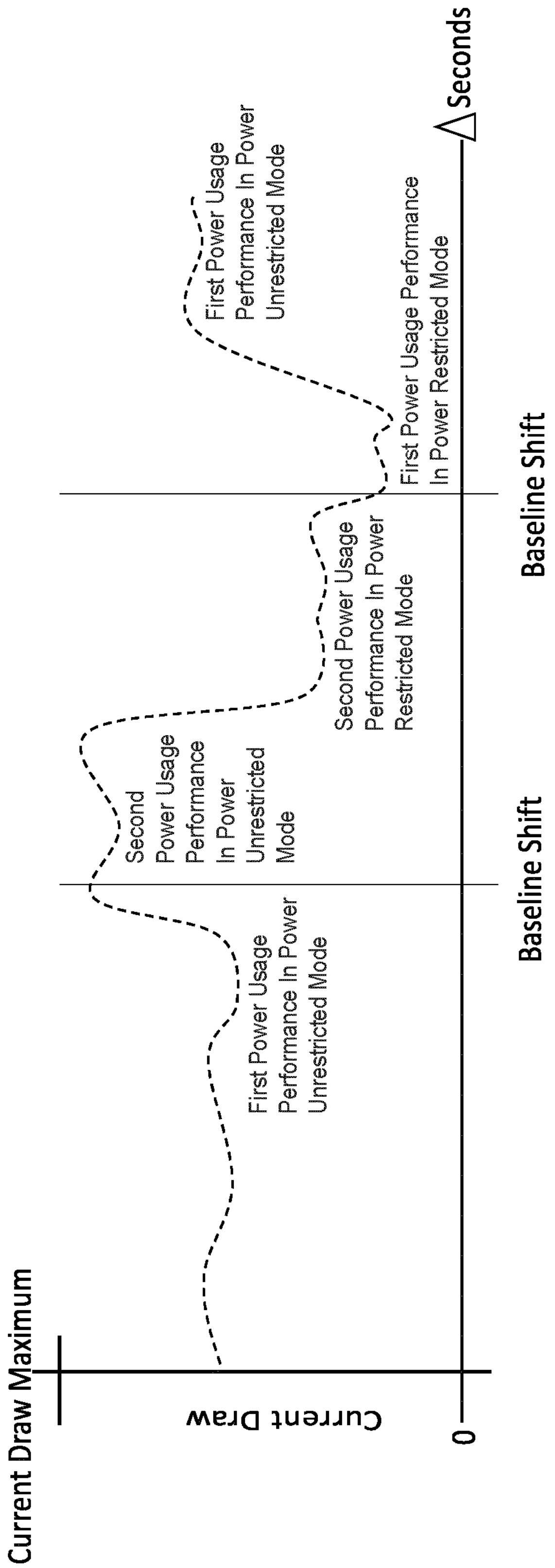

Current Draw Maximum
Current Draw
0
First Power Usage Performance In Power Unrestricted Mode
Baseline Shift
Second Power Usage Performance In Power Unrestricted Mode
Second Power Usage Performance In Power Restricted Mode
Baseline Shift
First Power Usage Performance In Power Restricted Mode
First Power Usage Performance In Power Unrestricted Mode
Seconds

FIG. 4

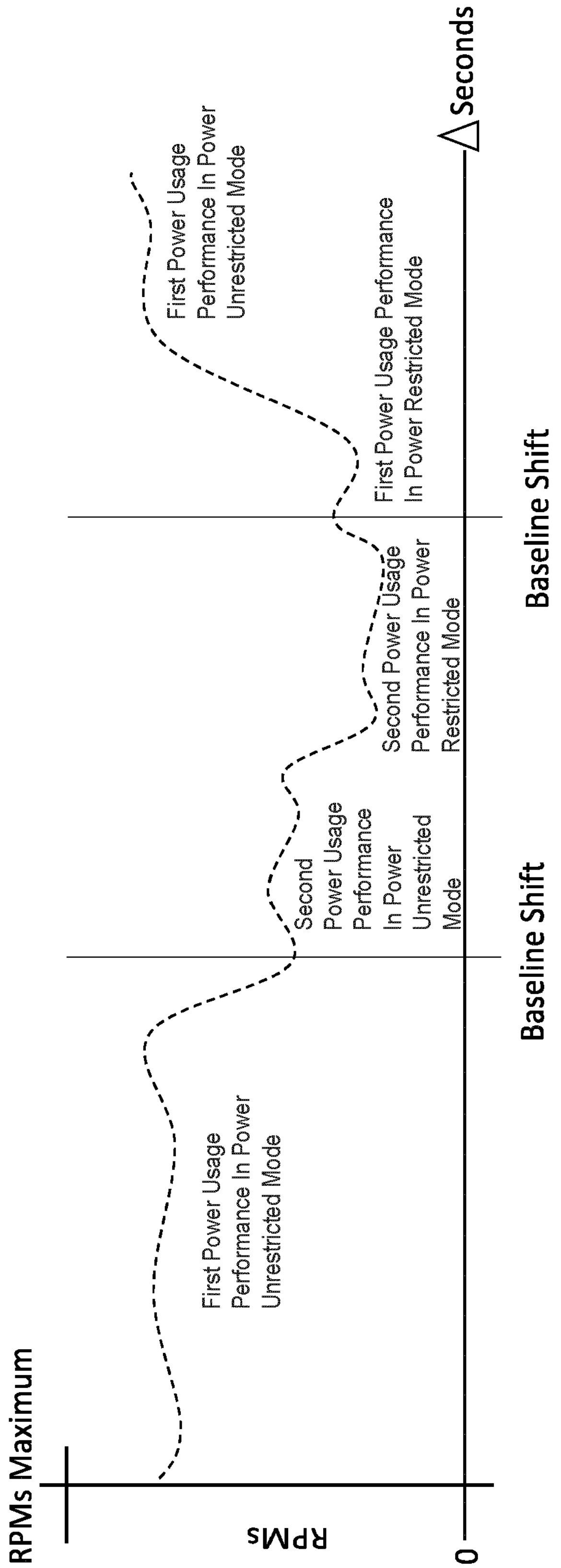

RPMs Maximum
RPMs
0
First Power Usage Performance In Power Unrestricted Mode
Second Power Usage Performance In Power Unrestricted Mode
Baseline Shift
Second Power Usage Performance In Power Restricted Mode
Baseline Shift
First Power Usage Performance In Power Restricted Mode
First Power Usage Performance In Power Unrestricted Mode
Seconds

FIG. 5

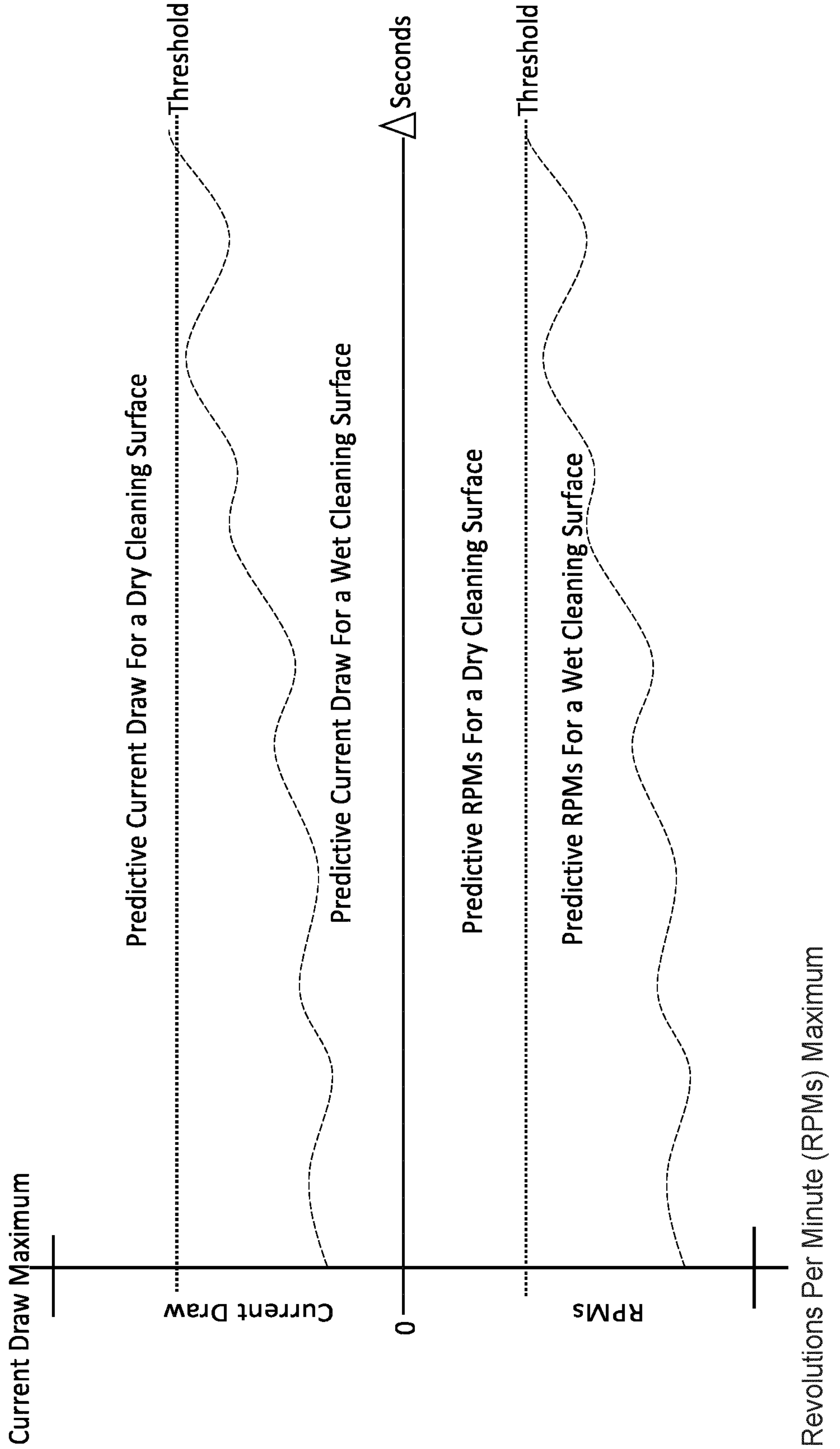

Current Draw Maximum
Current Draw
Threshold
Predictive Current Draw For a Dry Cleaning Surface
Predictive Current Draw For a Wet Cleaning Surface
0
Δ Seconds
Predictive RPMs For a Dry Cleaning Surface
Predictive RPMs For a Wet Cleaning Surface
Threshold
RPMs
Revolutions Per Minute (RPMs) Maximum

FIG. 6

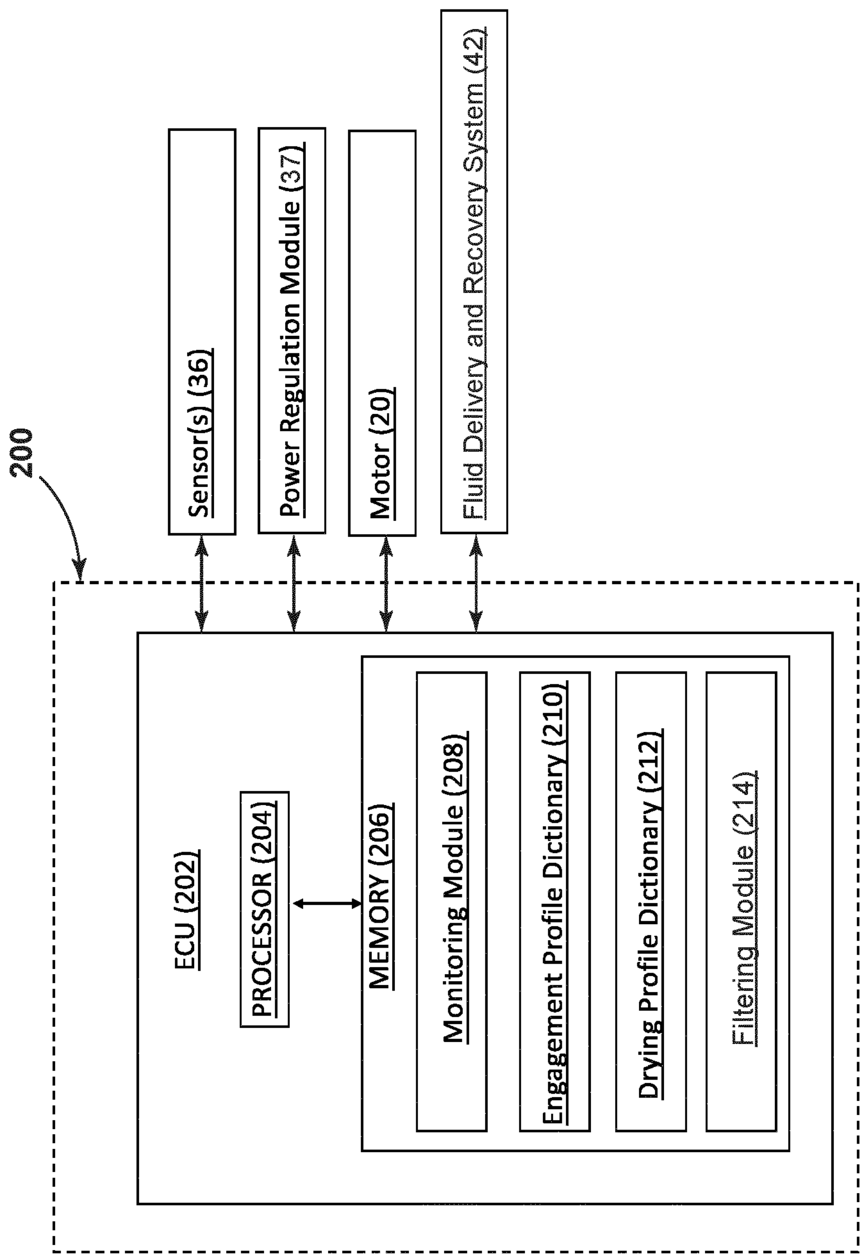

200
Sensor(s) (36)
Power Regulation Module (37)
Motor (20)
Fluid Delivery and Recovery System (42)
ECU (202)
PROCESSOR (204)
MEMORY (206)
Monitoring Module (208)
Engagement Profile Dictionary (210)
Drying Profile Dictionary (212)
Filtering Module (214)

FIG. 7

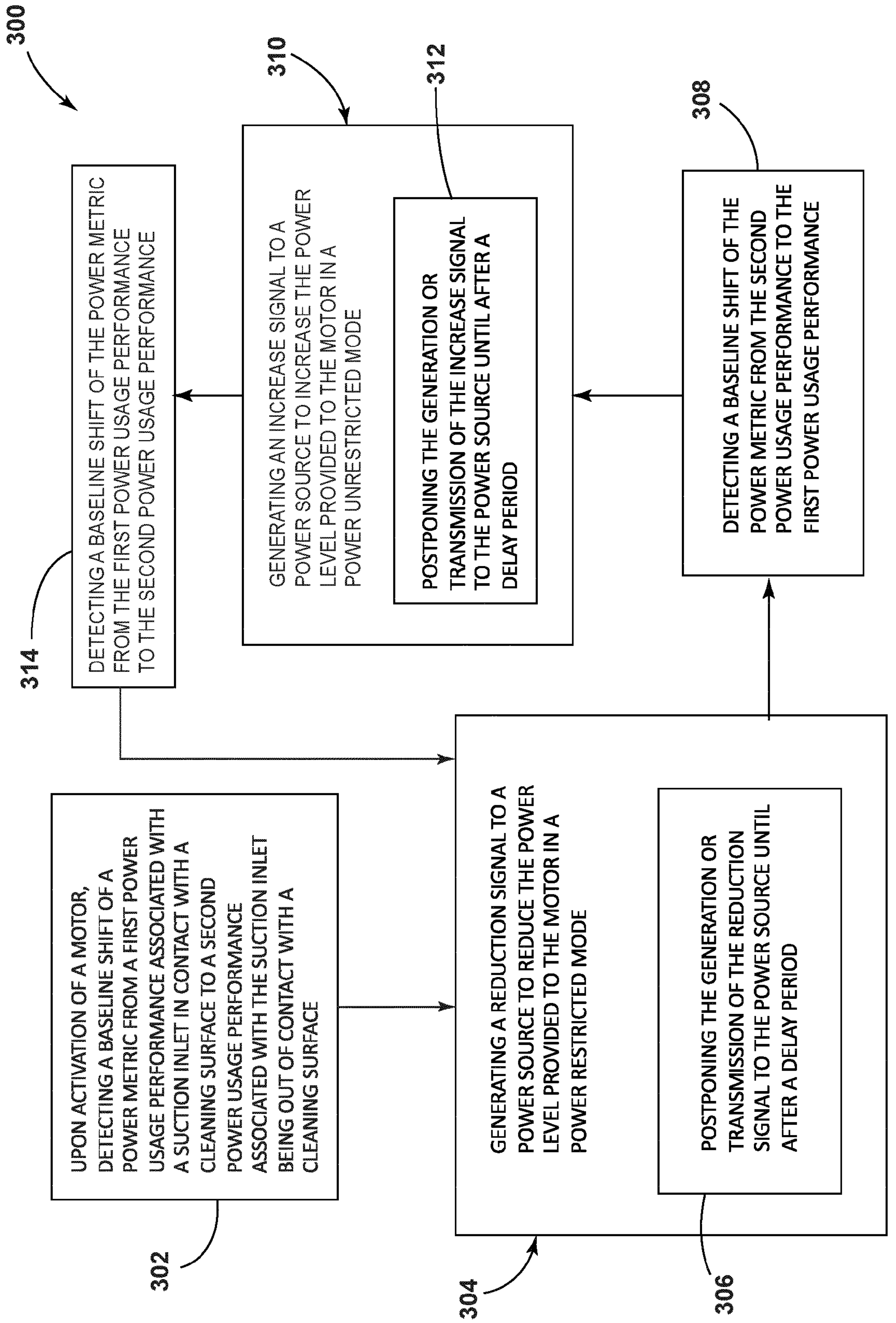

300
302
UPON ACTIVATION OF A MOTOR, DETECTING A BASELINE SHIFT OF A POWER METRIC FROM A FIRST POWER USAGE PERFORMANCE ASSOCIATED WITH A SUCTION INLET IN CONTACT WITH A CLEANING SURFACE TO A SECOND POWER USAGE PERFORMANCE ASSOCIATED WITH THE SUCTION INLET BEING OUT OF CONTACT WITH A CLEANING SURFACE
304
GENERATING A REDUCTION SIGNAL TO A POWER SOURCE TO REDUCE THE POWER LEVEL PROVIDED TO THE MOTOR IN A POWER RESTRICTED MODE
306
POSTPONING THE GENERATION OR TRANSMISSION OF THE REDUCTION SIGNAL TO THE POWER SOURCE UNTIL AFTER A DELAY PERIOD
308
DETECTING A BASELINE SHIFT OF THE POWER METRIC FROM THE SECOND POWER USAGE PERFORMANCE TO THE FIRST POWER USAGE PERFORMANCE
310
GENERATING AN INCREASE SIGNAL TO A POWER SOURCE TO INCREASE THE POWER LEVEL PROVIDED TO THE MOTOR IN A POWER UNRESTRICTED MODE
312
POSTPONING THE GENERATION OR TRANSMISSION OF THE INCREASE SIGNAL TO THE POWER SOURCE UNTIL AFTER A DELAY PERIOD
314
DETECTING A BASELINE SHIFT OF THE POWER METRIC FROM THE FIRST POWER USAGE PERFORMANCE TO THE SECOND POWER USAGE PERFORMANCE

FIG. 8

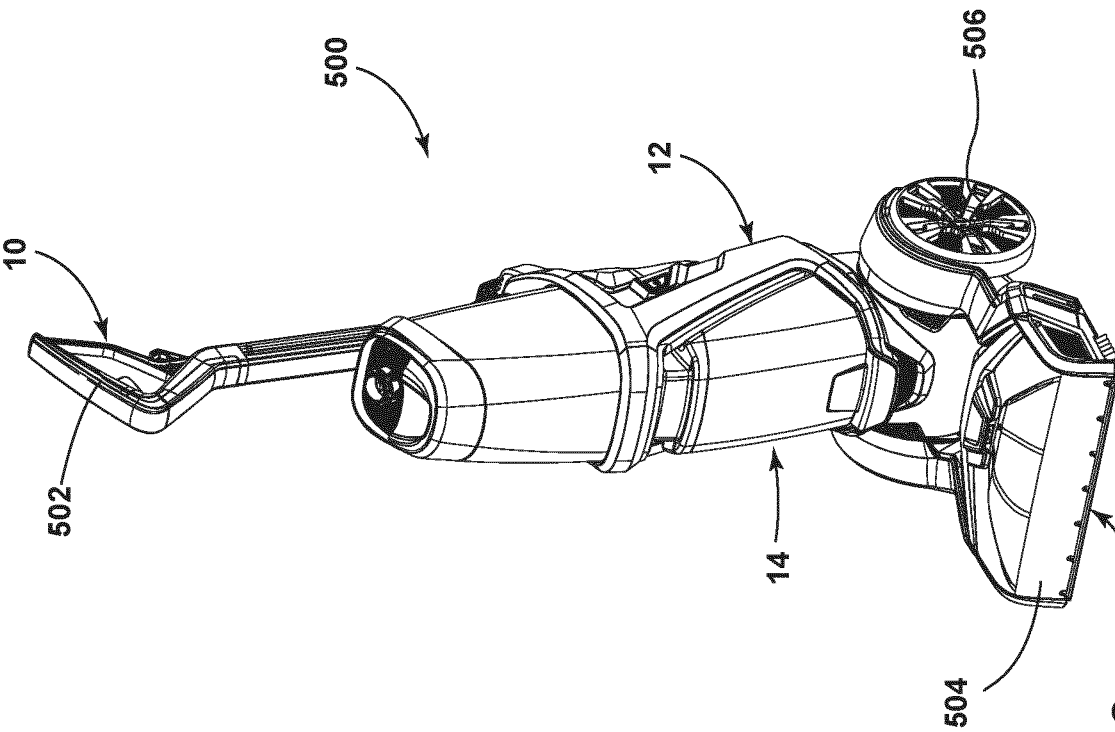


FIG. 10

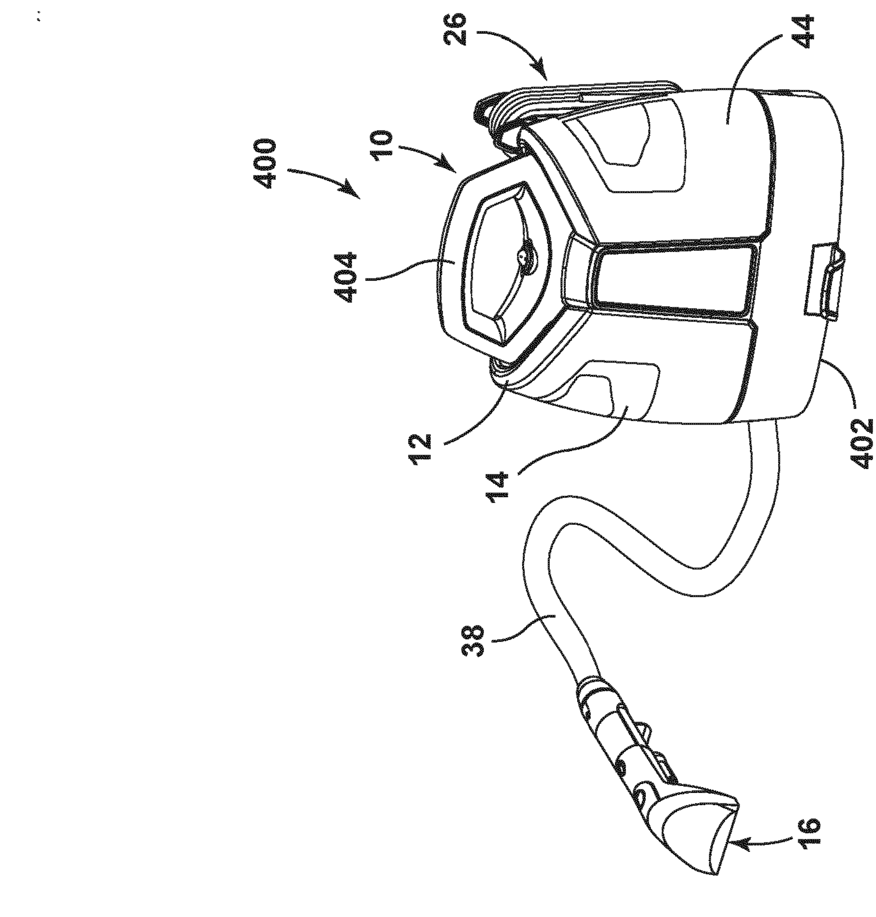


FIG. 9

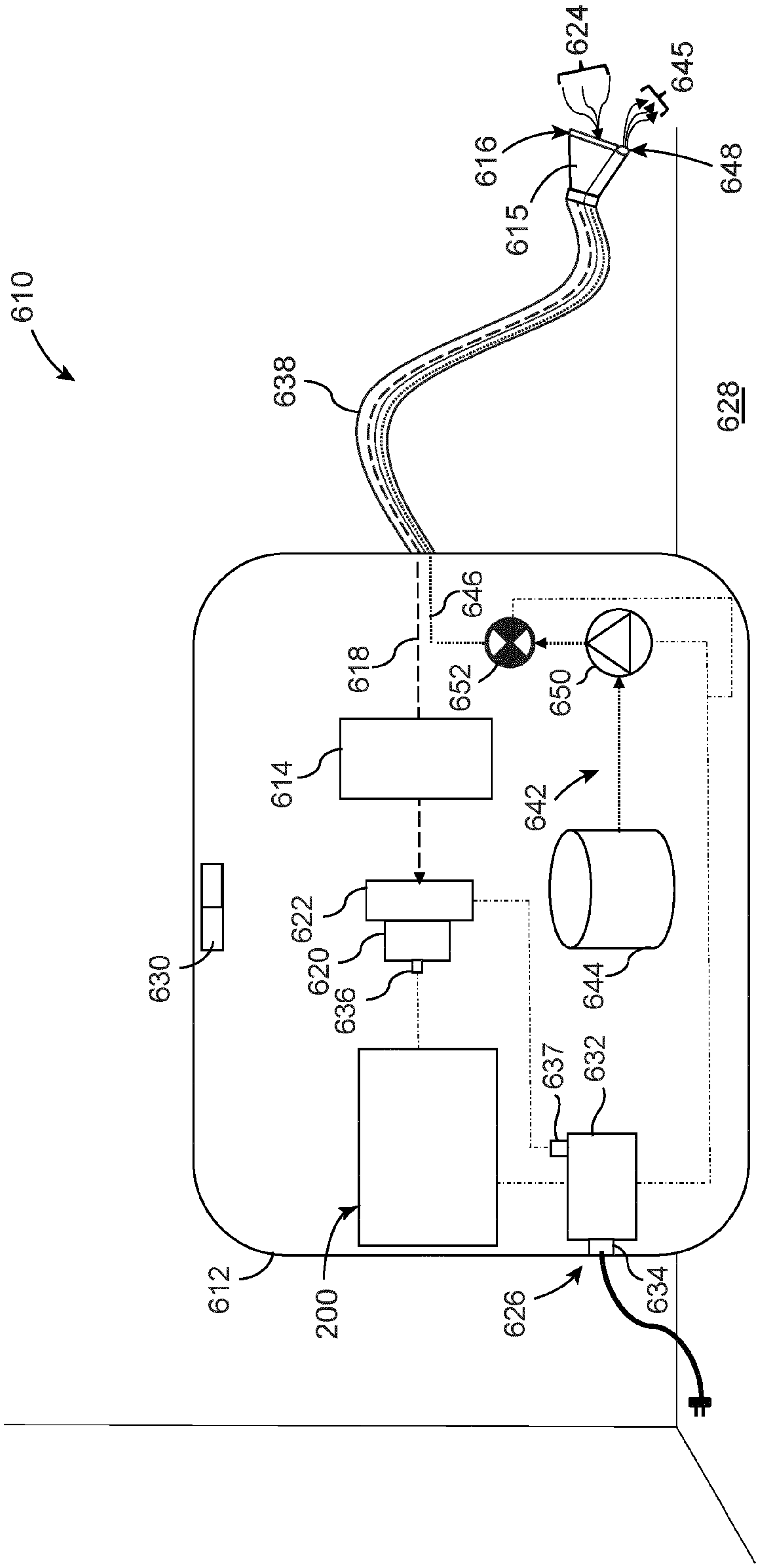

610
638
615
616
624
645
648
628
612
200
626
634
630
622
620
636
614
618
646
652
650
642
644
637
632

FIG. 11

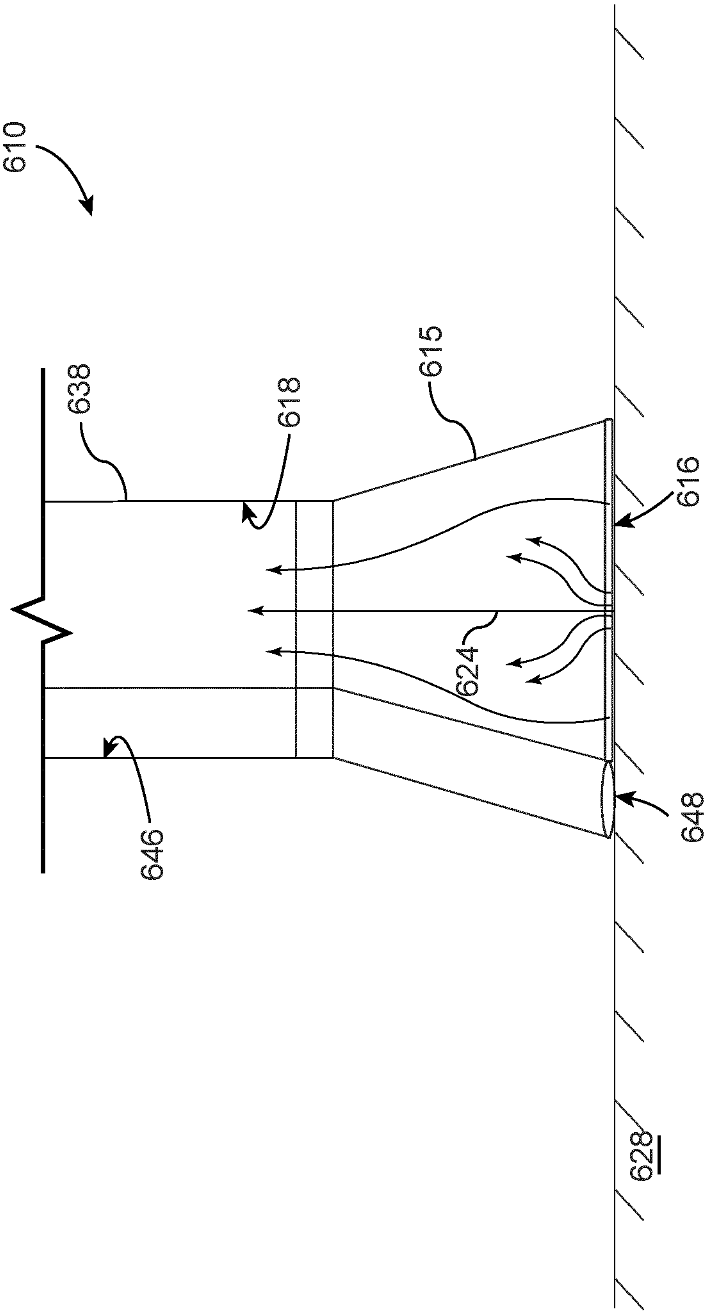


FIG. 12

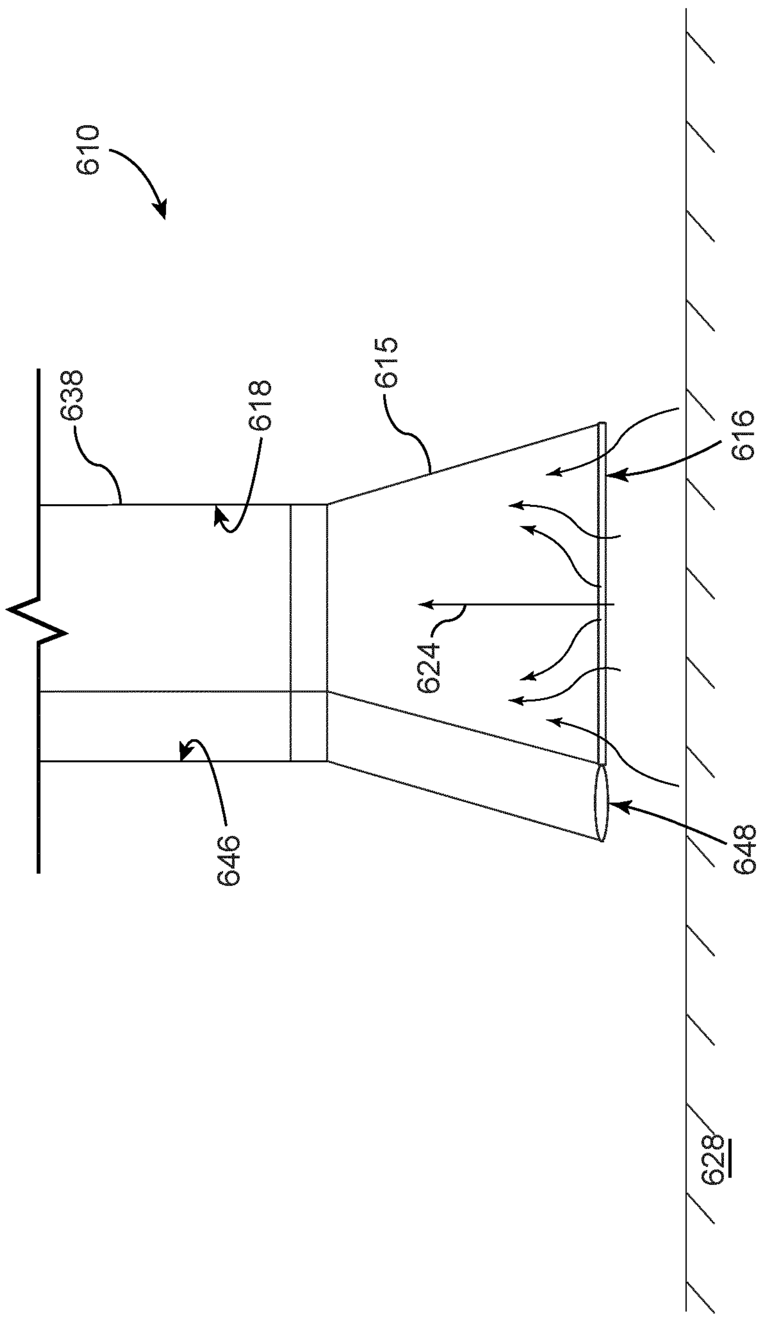


FIG. 13

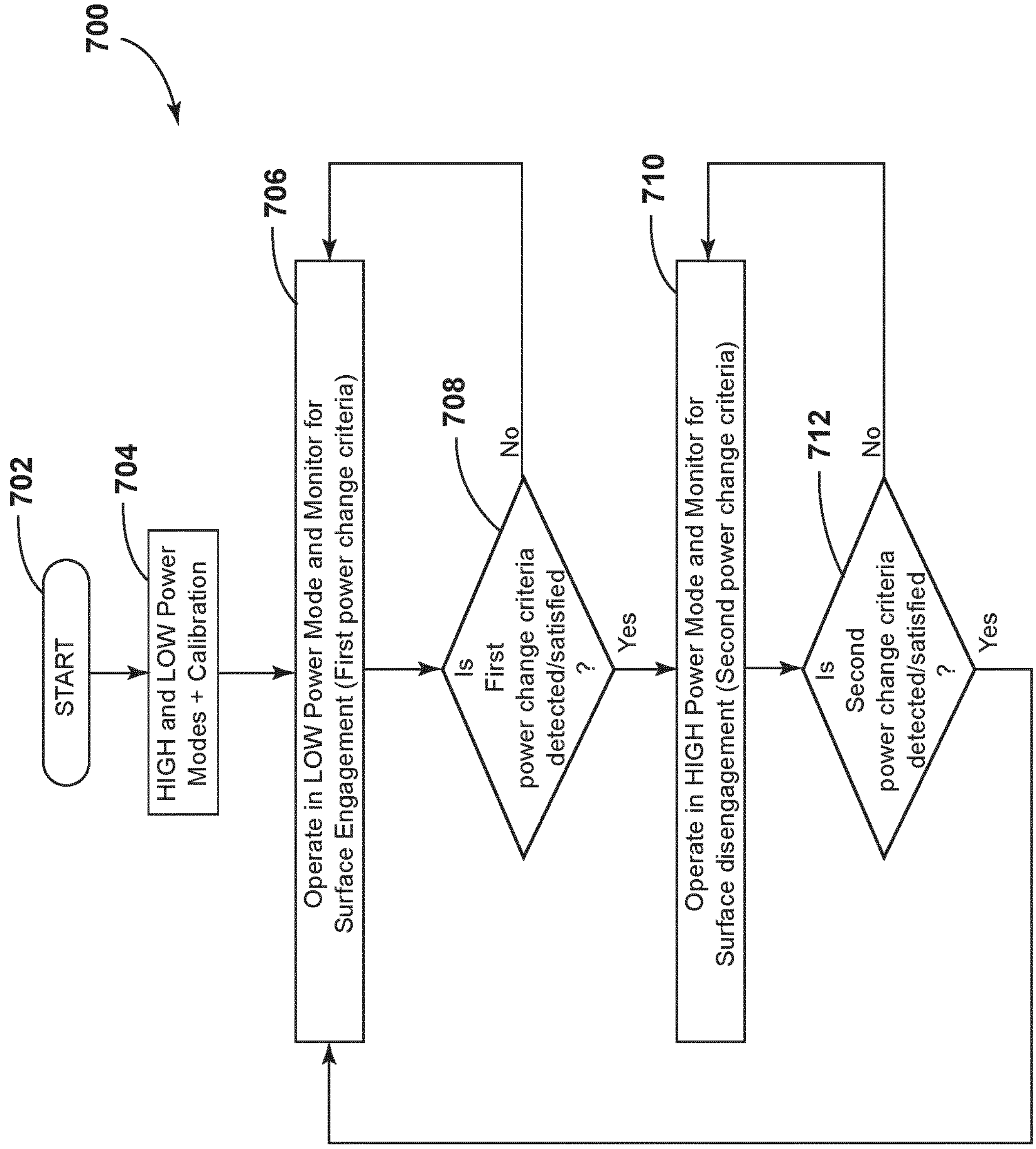

700
702
START
704
HIGH and LOW Power Modes + Calibration
706
Operate in LOW Power Mode and Monitor for Surface Engagement (First power change criteria)
708
Is First power change criteria detected/satisfied ?
No
Yes
710
Operate in HIGH Power Mode and Monitor for Surface disengagement (Second power change criteria)
712
Is Second power change criteria detected/satisfied ?
No
Yes

FIG. 14

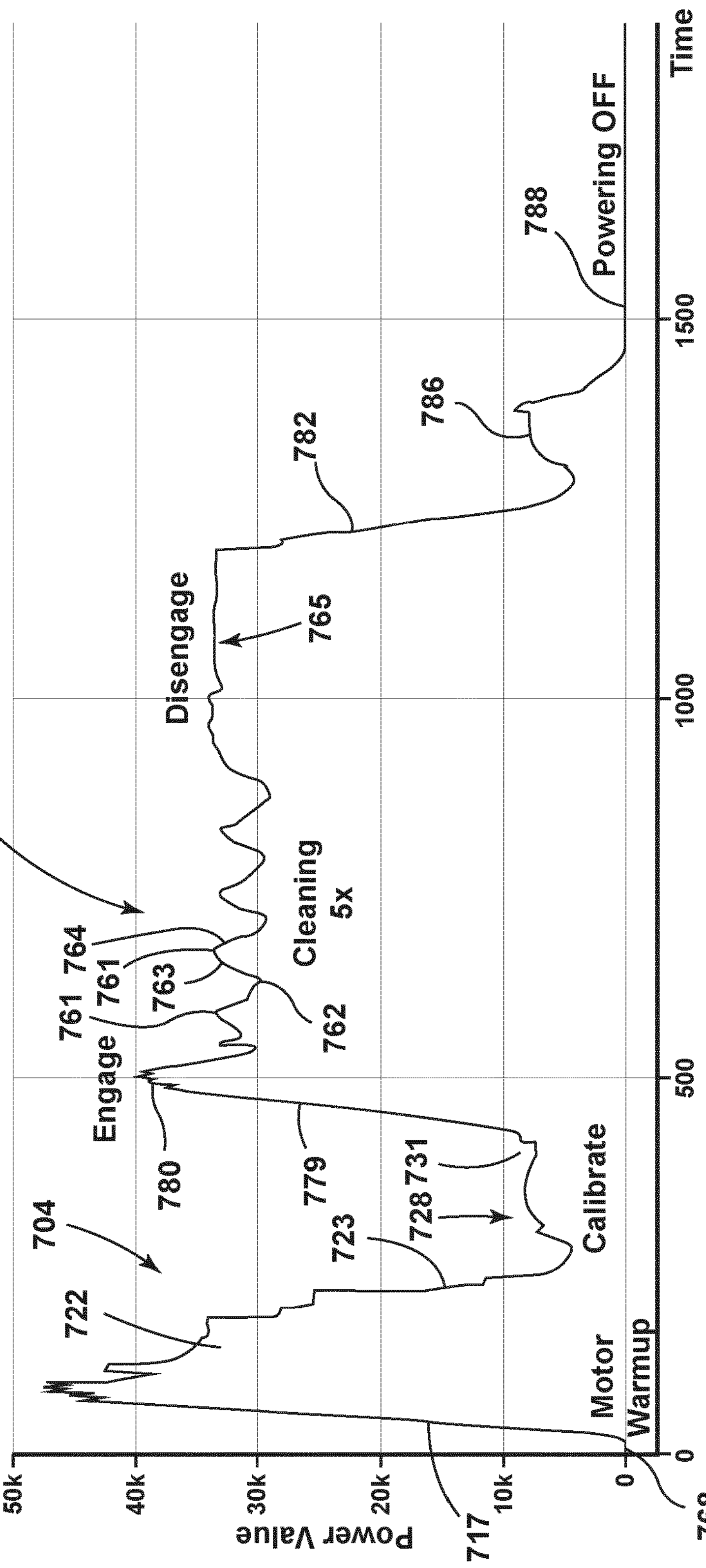

Power Value
50k
40k
30k
20k
10k
0
0
500
1000
1500
index
Time
Motor Warmup
Calibrate
Engage
Cleaning 5x
Disengage
Powering OFF
704
717
722
723
728
731
760
761
761
762
763
764
765
768
779
780
782
786
788

FIG. 15

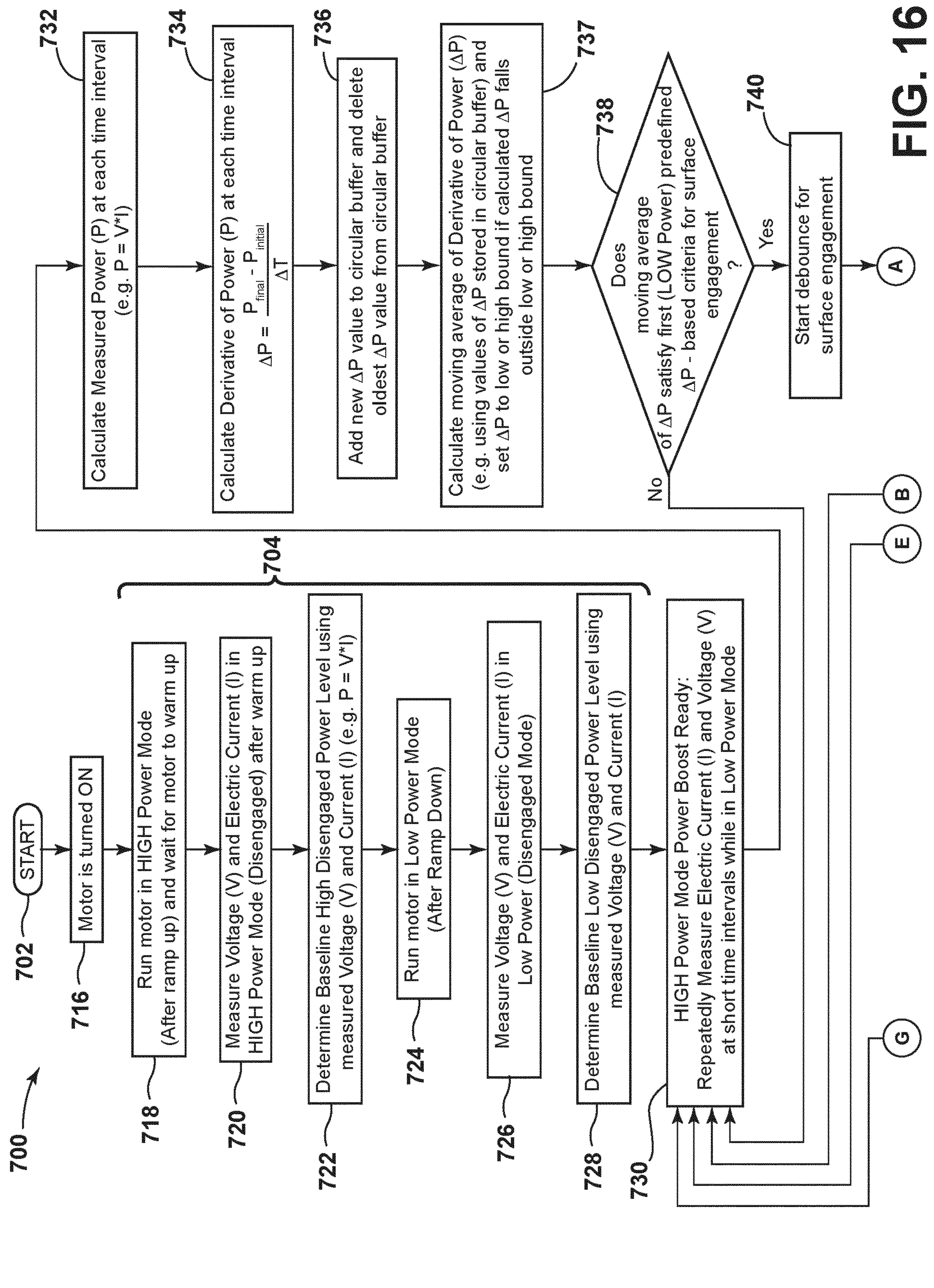

700
702
START
716
Motor is turned ON
718
Run motor in HIGH Power Mode (After ramp up) and wait for motor to warm up
720
Measure Voltage (V) and Electric Current (I) in HIGH Power Mode (Disengaged) after warm up
722
Determine Baseline High Disengaged Power Level using measured Voltage (V) and Current (I) (e.g. P = V*I)
724
Run motor in Low Power Mode (After Ramp Down)
726
Measure Voltage (V) and Electric Current (I) in Low Power (Disengaged Mode)
728
Determine Baseline Low Disengaged Power Level using measured Voltage (V) and Current (I)
704
730
HIGH Power Mode Power Boost Ready: Repeatedly Measure Electric Current (I) and Voltage (V) at short time intervals while in Low Power Mode
732
Calculate Measured Power (P) at each time interval (e.g. P = V*I)
734
Calculate Derivative of Power (P) at each time interval
ΔP = (P final - P initial) / ΔT
736
Add new ΔP value to circular buffer and delete oldest ΔP value from circular buffer
737
Calculate moving average of Derivative of Power (ΔP) (e.g. using values of ΔP stored in circular buffer) and set ΔP to low or high bound if calculated ΔP falls outside low or high bound
738
Does moving average of ΔP satisfy first (LOW Power) predefined ΔP - based criteria for surface engagement ?
No
Yes
740
Start debounce for surface engagement
A
B
E
G

FIG. 16

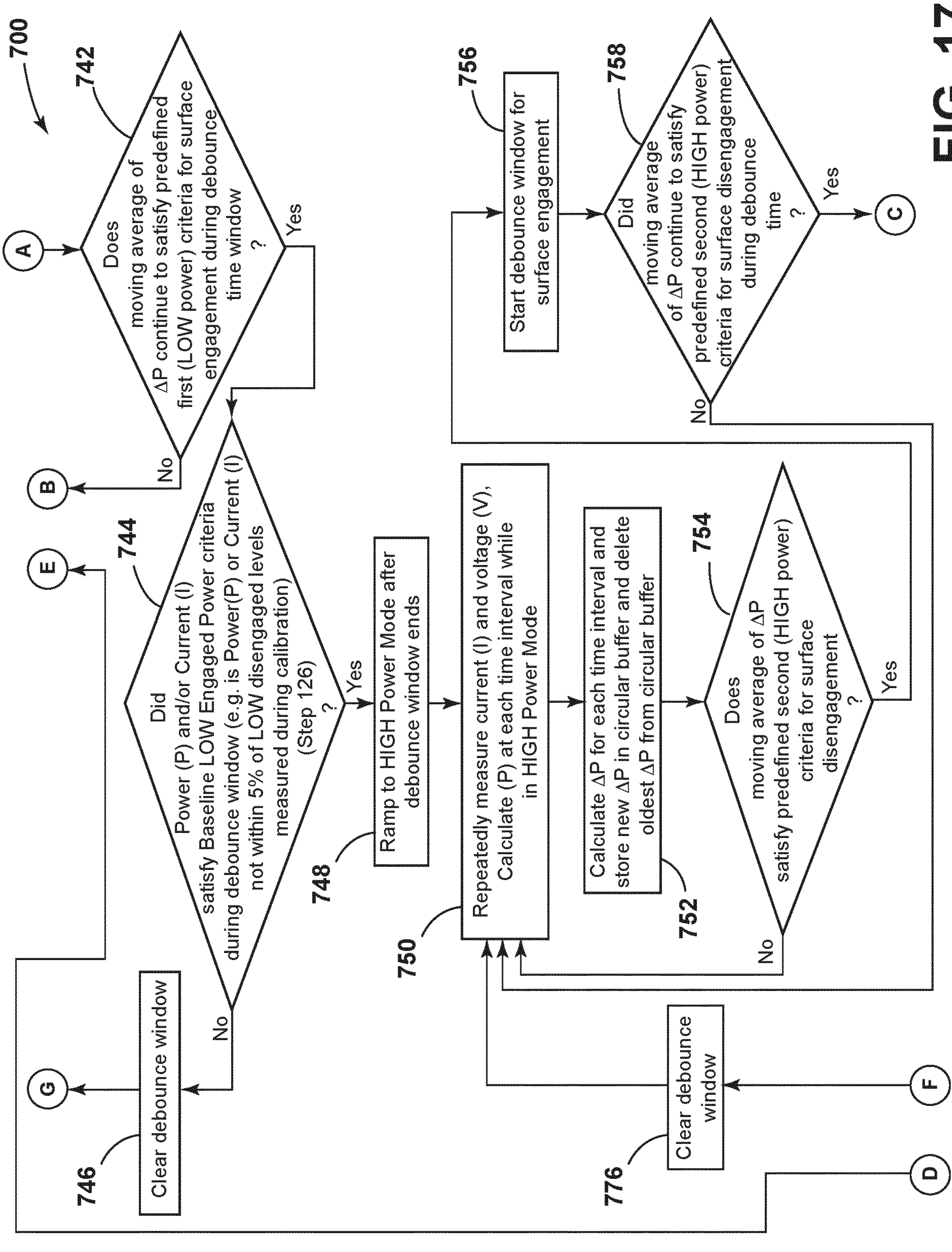

700
742
Does moving average of ΔP continue to satisfy predefined first (LOW power) criteria for surface engagement during debounce time window ?
A
B
Yes
No
744
Did Power (P) and/or Current (I) satisfy Baseline LOW Engaged Power criteria during debounce window (e.g. is Power(P) or Current (I) not within 5% of LOW disengaged levels measured during calibration) (Step 126) ?
E
G
746
Clear debounce window
748
Ramp to HIGH Power Mode after debounce window ends
750
Repeatedly measure current (I) and voltage (V), Calculate (P) at each time interval while in HIGH Power Mode
752
Calculate ΔP for each time interval and store new ΔP in circular buffer and delete oldest ΔP from circular buffer
754
Does moving average of ΔP satisfy predefined second (HIGH power) criteria for surface disengagement ?
756
Start debounce window for surface engagement
758
Did moving average of ΔP continue to satisfy predefined second (HIGH power) criteria for surface disengagement during debounce time ?
C
776
Clear debounce window
F
D

FIG. 17

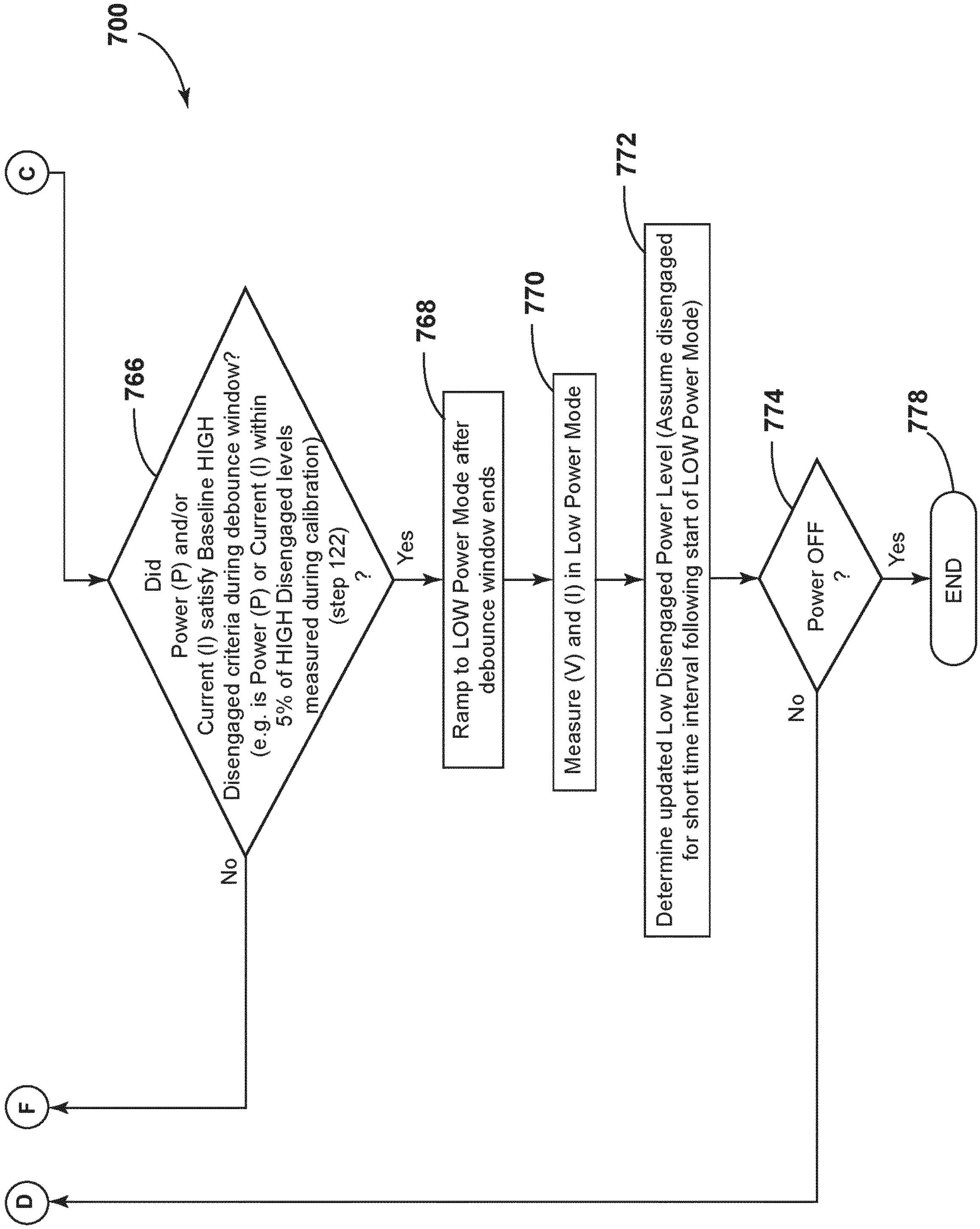

700
C
766
Did Power (P) and/or Current (I) satisfy Baseline HIGH Disengaged criteria during debounce window? (e.g. is Power (P) or Current (I) within 5% of HIGH Disengaged levels measured during calibration) (step 122) ?
Yes
No
768
Ramp to LOW Power Mode after debounce window ends
770
Measure (V) and (I) in Low Power Mode
772
Determine updated Low Disengaged Power Level (Assume disengaged for short time interval following start of LOW Power Mode)
774
Power OFF ?
Yes
No
778
END
F
D

FIG. 18

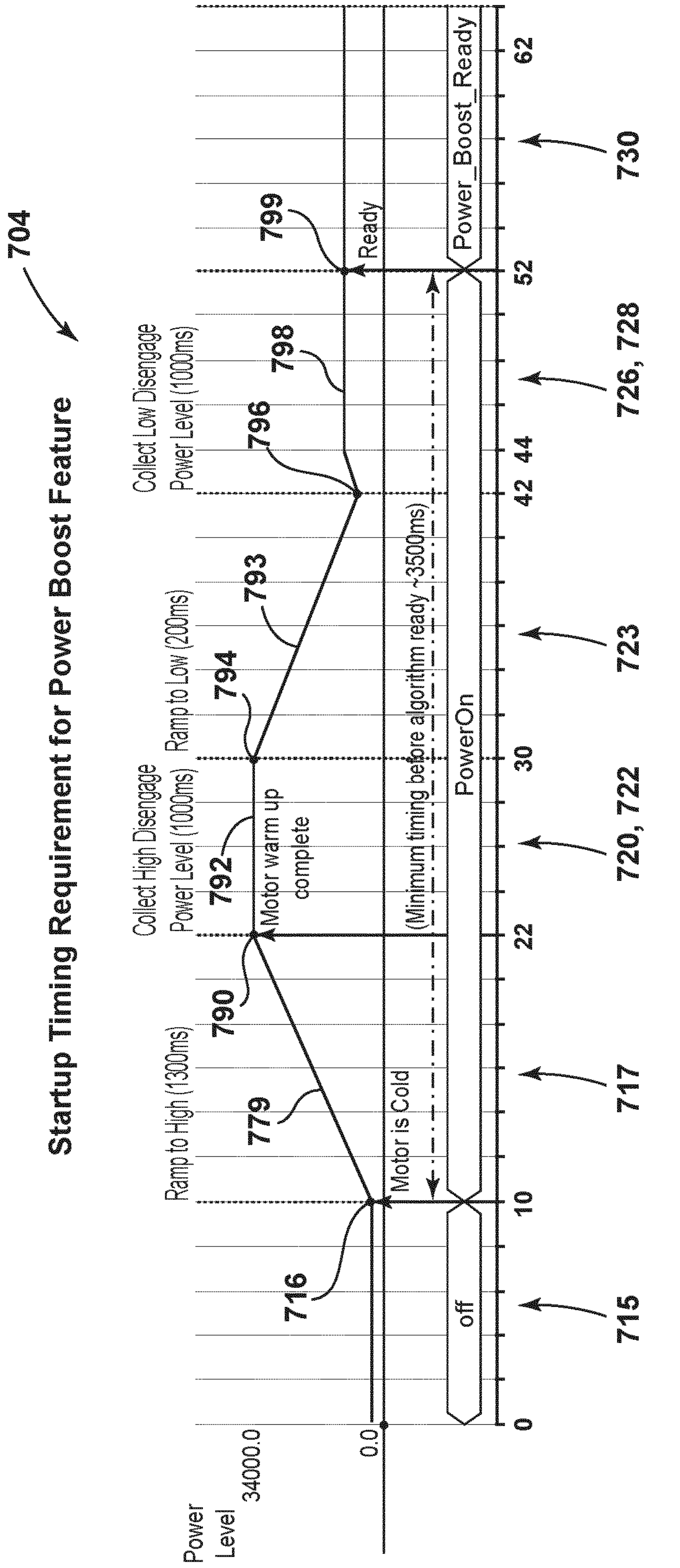

704
Startup Timing Requirement for Power Boost Feature
Power Level
34000.0
0.0
Ramp to High (1300ms)
Collect High Disengage Power Level (1000ms)
Ramp to Low (200ms)
Collect Low Disengage Power Level (1000ms)
716
779
790
792
794
793
796
798
799
Motor is Cold
Motor warm up complete
Ready
(Minimum timing before algorithm ready ~3500ms)
off
PowerOn
Power_Boost_Ready
0
10
22
30
42 44
52
62
715
717
720, 722
723
726, 728
730

FIG. 19

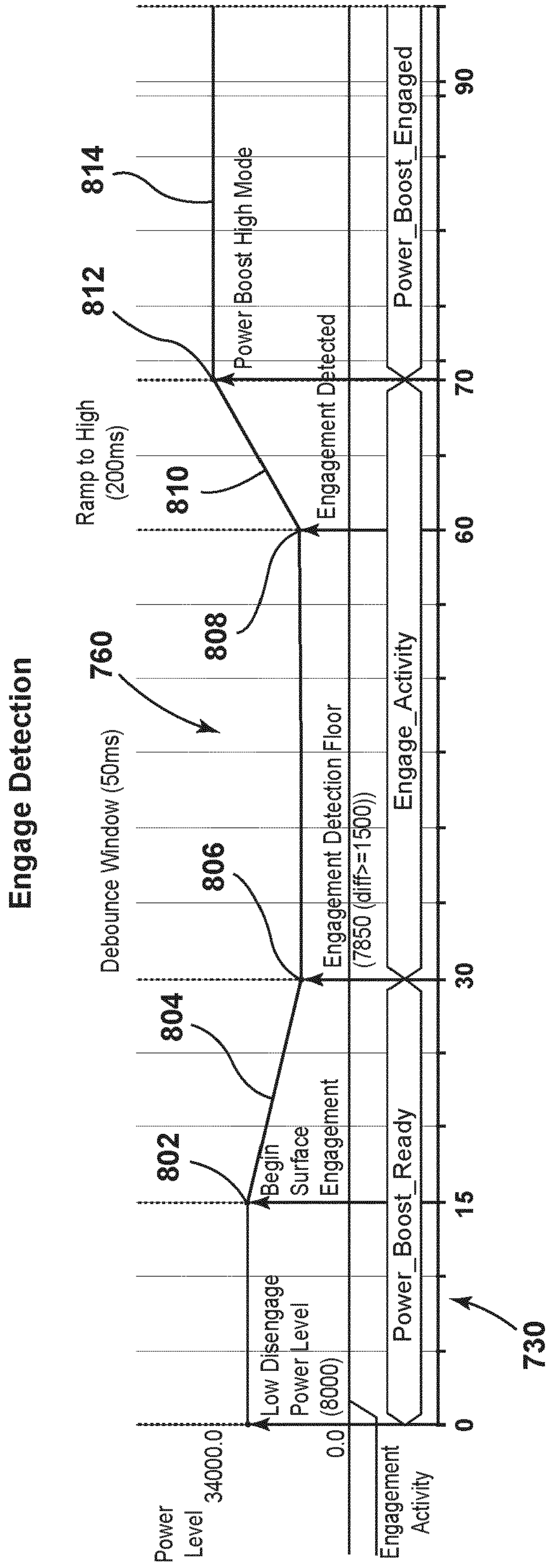

Engage Detection
Power Level
34000.0
0.0
Engagement Activity
Low Disengage Power Level (8000)
Begin Surface Engagement
Engagement Detection Floor
(7850 (diff>=1500))
Engagement Detected
Power Boost High Mode
Debounce Window (50ms)
Ramp to High (200ms)
Power_Boost_Ready
Engage_Activity
Power_Boost_Engaged
0
15
30
60
70
90
802
804
806
808
810
812
814
760
730

FIG. 20

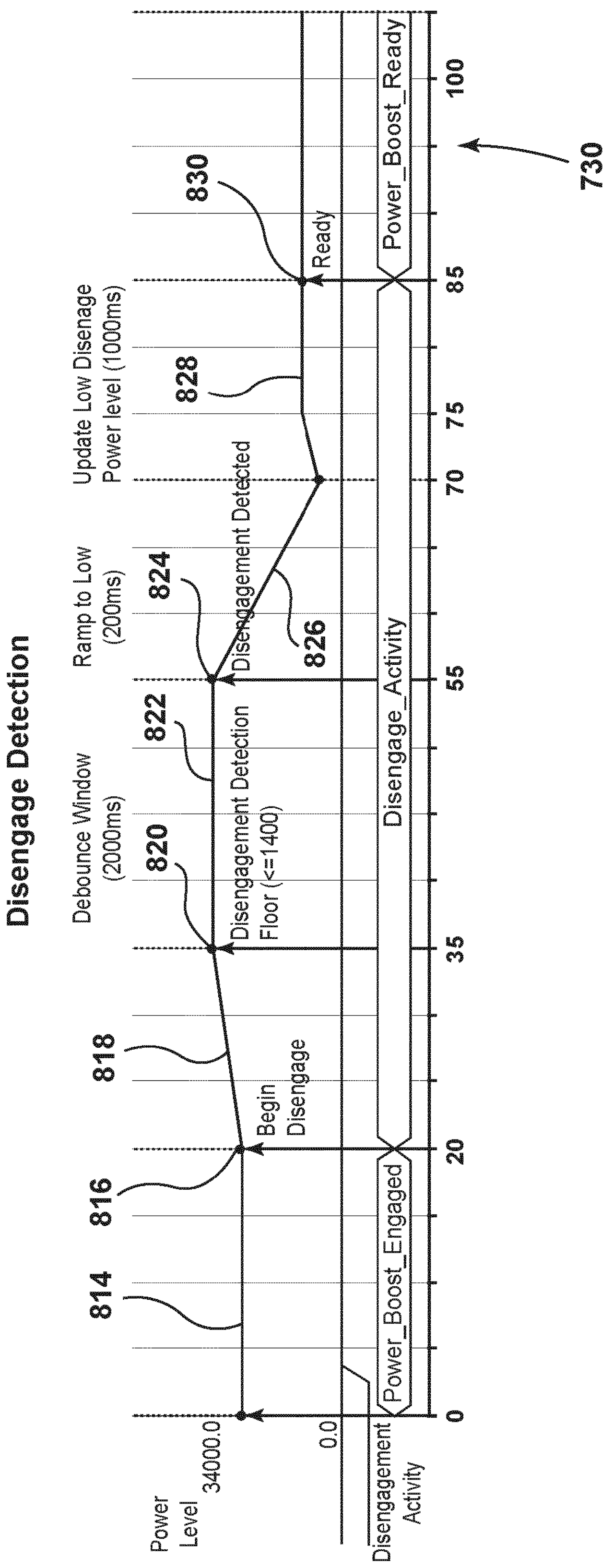
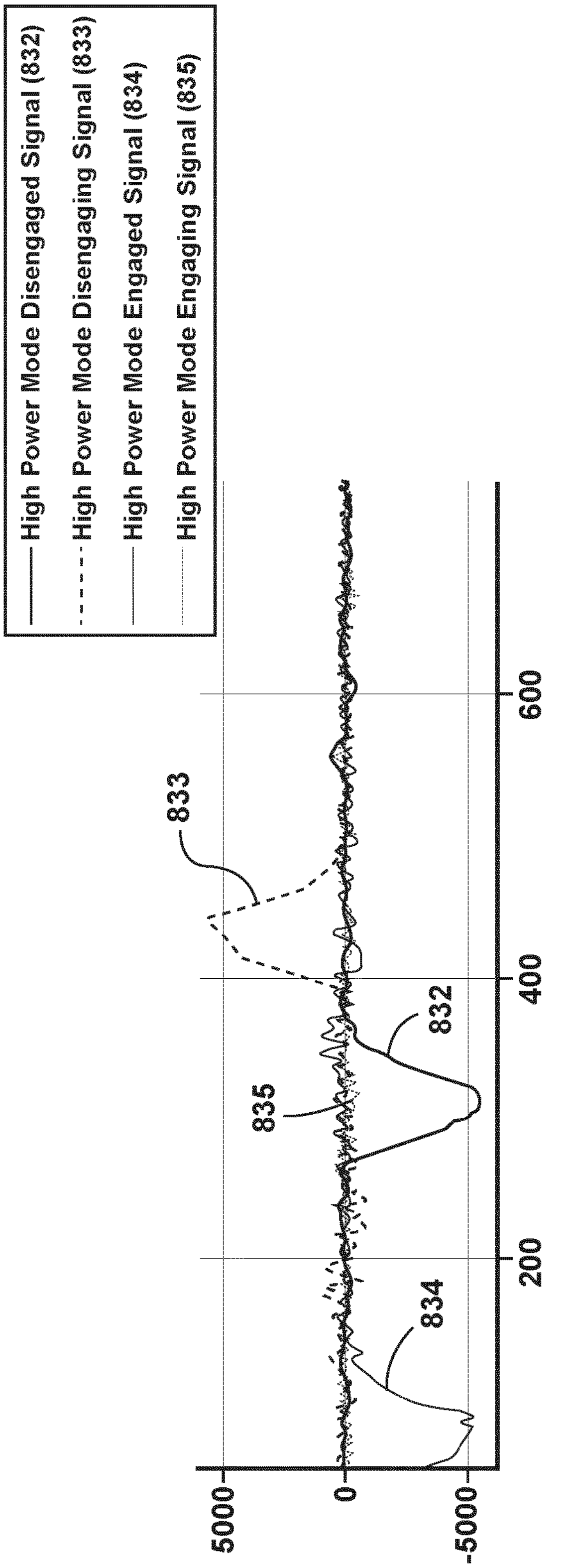
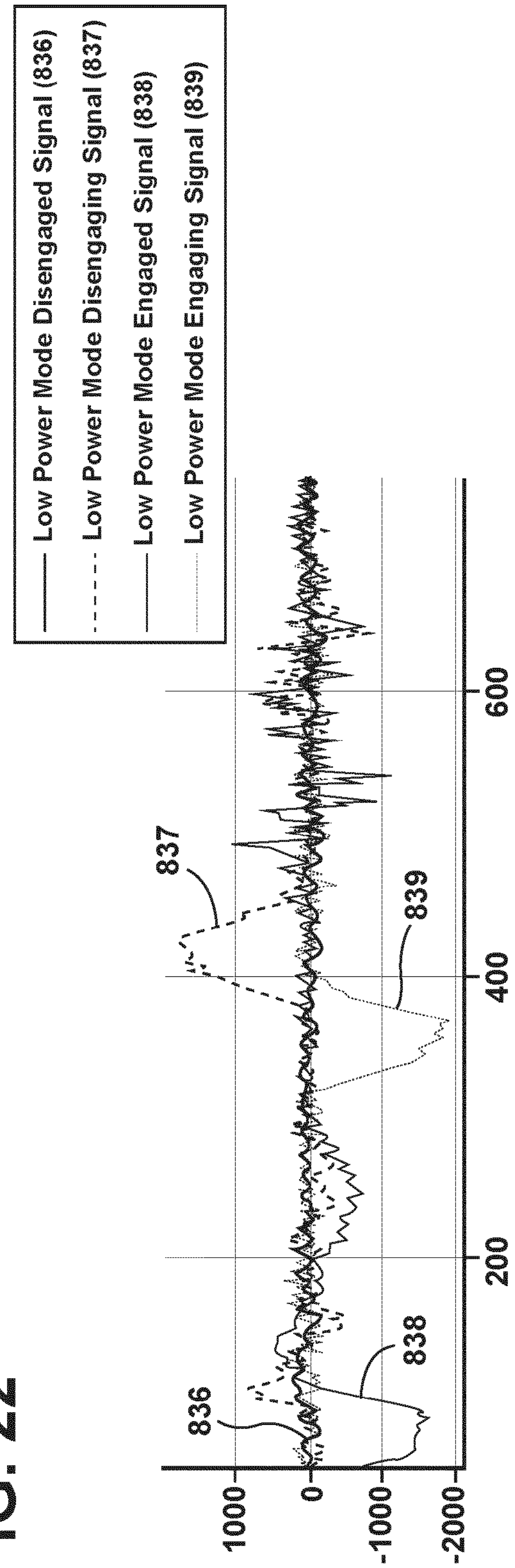

Disengage Detection
Debounce Window (2000ms)
Ramp to Low (200ms)
Update Low Disenage Power level (1000ms)
Power Level
34000.0
0.0
Disengagement Activity
814
816
818
820
822
824
826
828
830
Begin Disengage
Disengagement Detection Floor (<=1400)
Disengagement Detected
Ready
Power_Boost_Engaged
Disengage_Activity
Power_Boost_Ready
0
20
35
55
70
75
85
100
730

FIG. 21



High Power Mode Disengaged Signal (832)
High Power Mode Disengaging Signal (833)
High Power Mode Engaged Signal (834)
High Power Mode Engaging Signal (835)
833
835
832
834
5000
0
-5000
200
400
600

FIG. 22



Low Power Mode Disengaged Signal (836)
Low Power Mode Disengaging Signal (837)
Low Power Mode Engaged Signal (838)
Low Power Mode Engaging Signal (839)
837
839
836
838
1000
0
-1000
-2000
200
400
600

FIG. 23

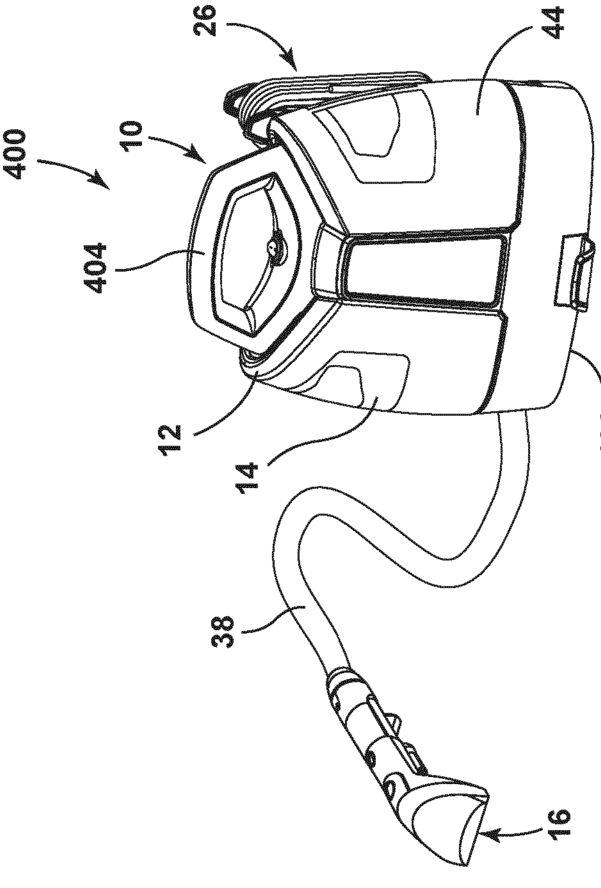


FIG. 24

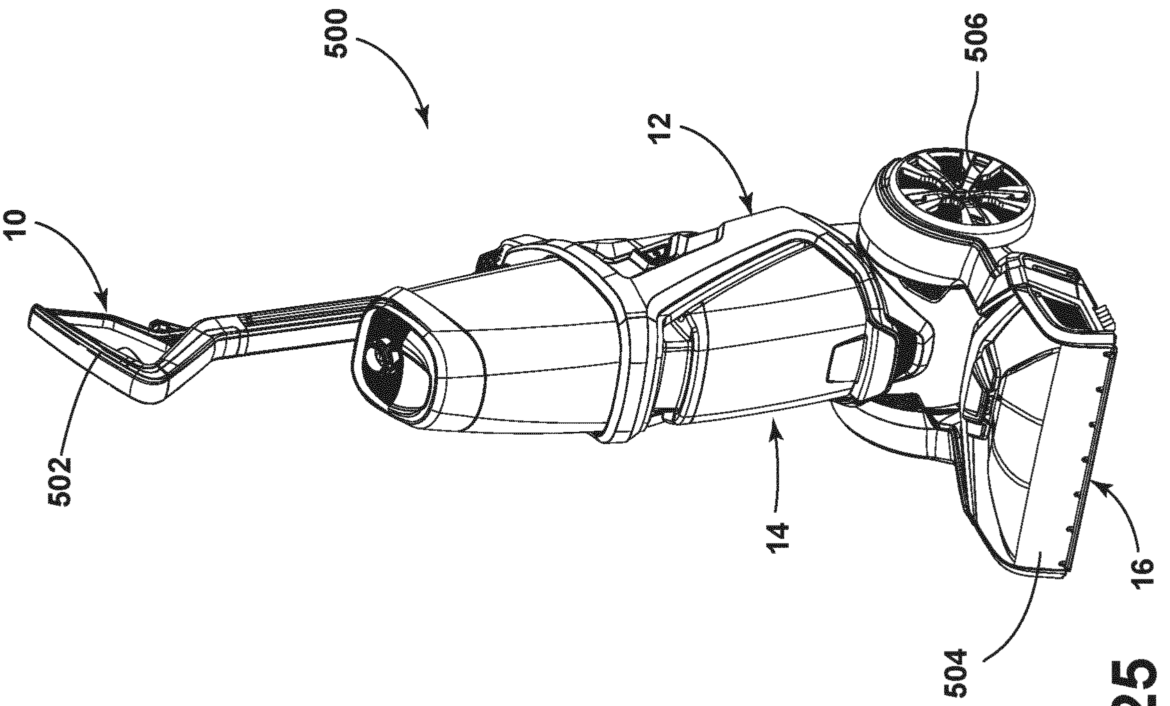


FIG. 25

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 9474424 B **[0049]**
- US 10188252 B **[0049]**