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(54) **SYSTEMS AND METHODS FOR PROVIDING NETWORK CONNECTIVITY AND REMOTE MONITORING, OPTIMIZATION, AND CONTROL OF POOL/SPA EQUIPMENT**

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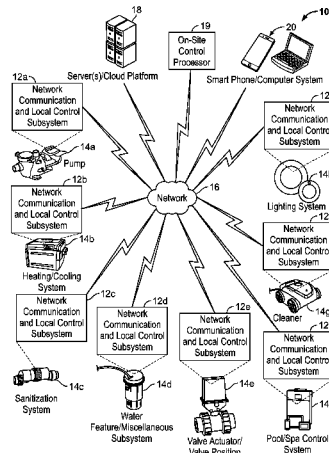
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(57) **ABSTRACT**

Systems and methods for providing network connectivity and remote monitoring, optimization, and control of pool/spa equipment are provided. "Internet-of-Things" (IoT) functionality is provided for pool and spa equipment in a flexible and cost-effective manner. Network connectivity and remote monitoring/control of pool and spa equipment is provided by various components such as a network communication and local control subsystem installed in pool/spa equipment, and other components. Also disclosed are vari-

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ous control processes (“pool logic”) which can be embodied as software code installed in any of the various embodiments of the present disclosure.

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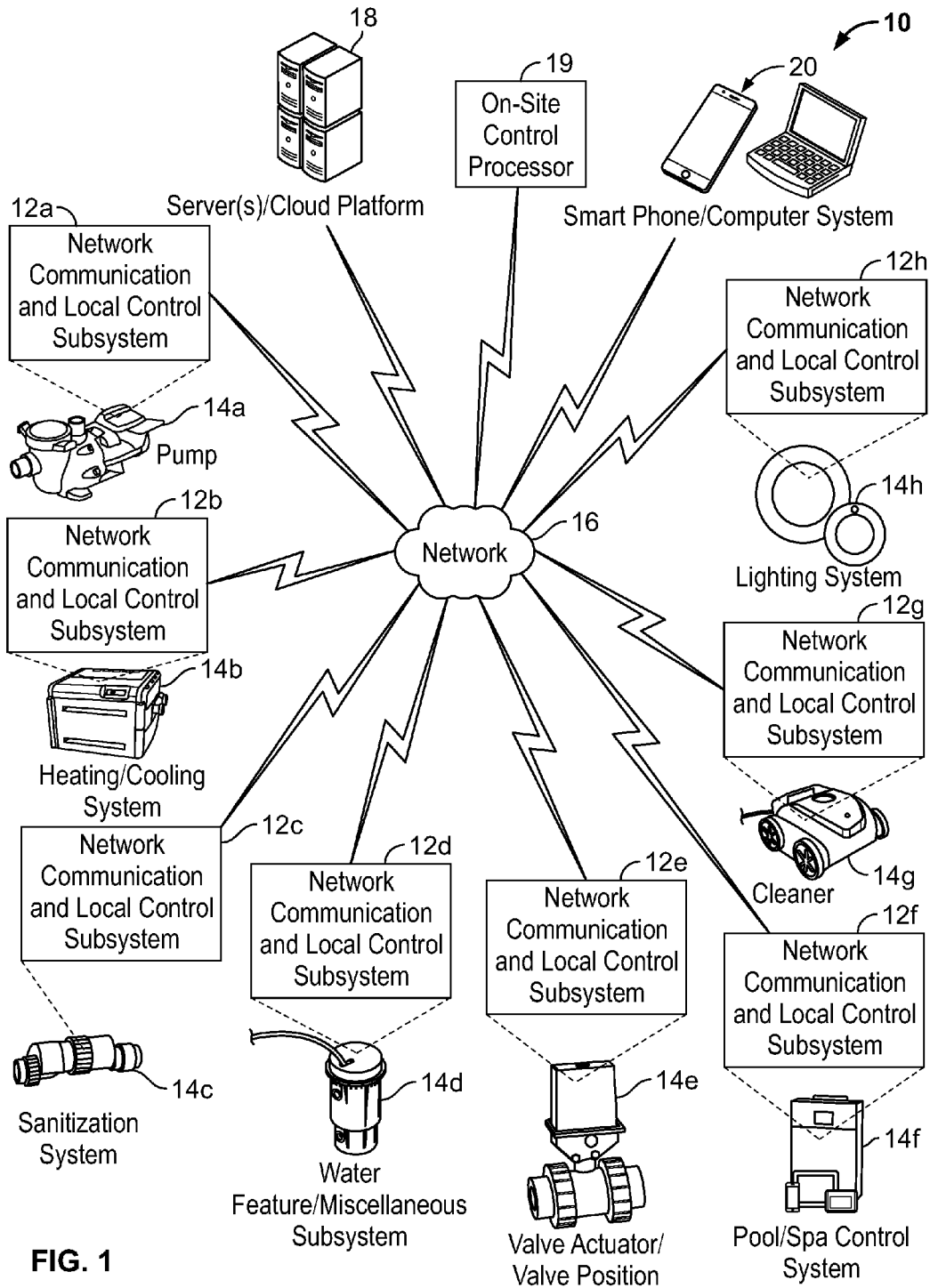
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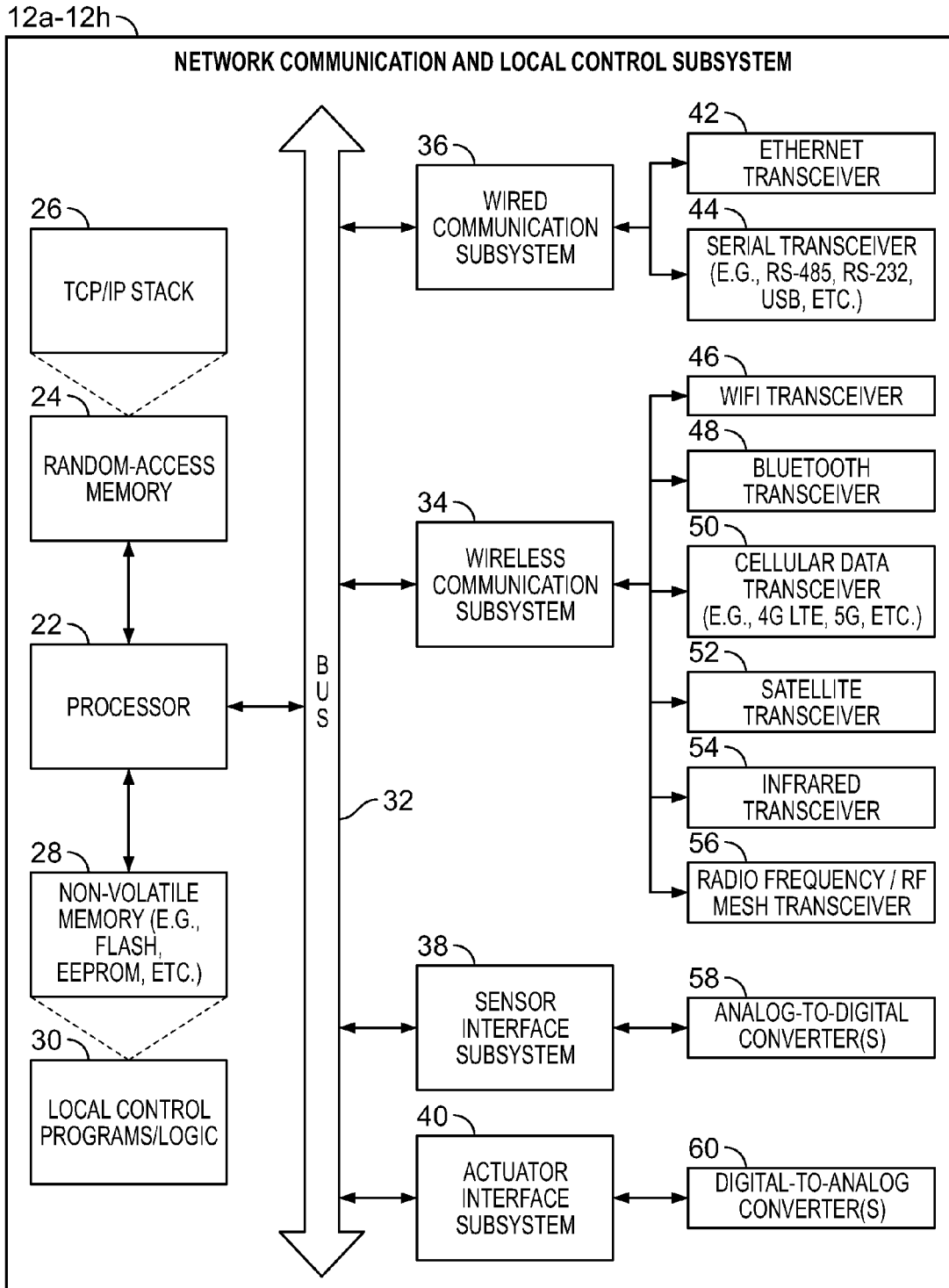


FIG. 2

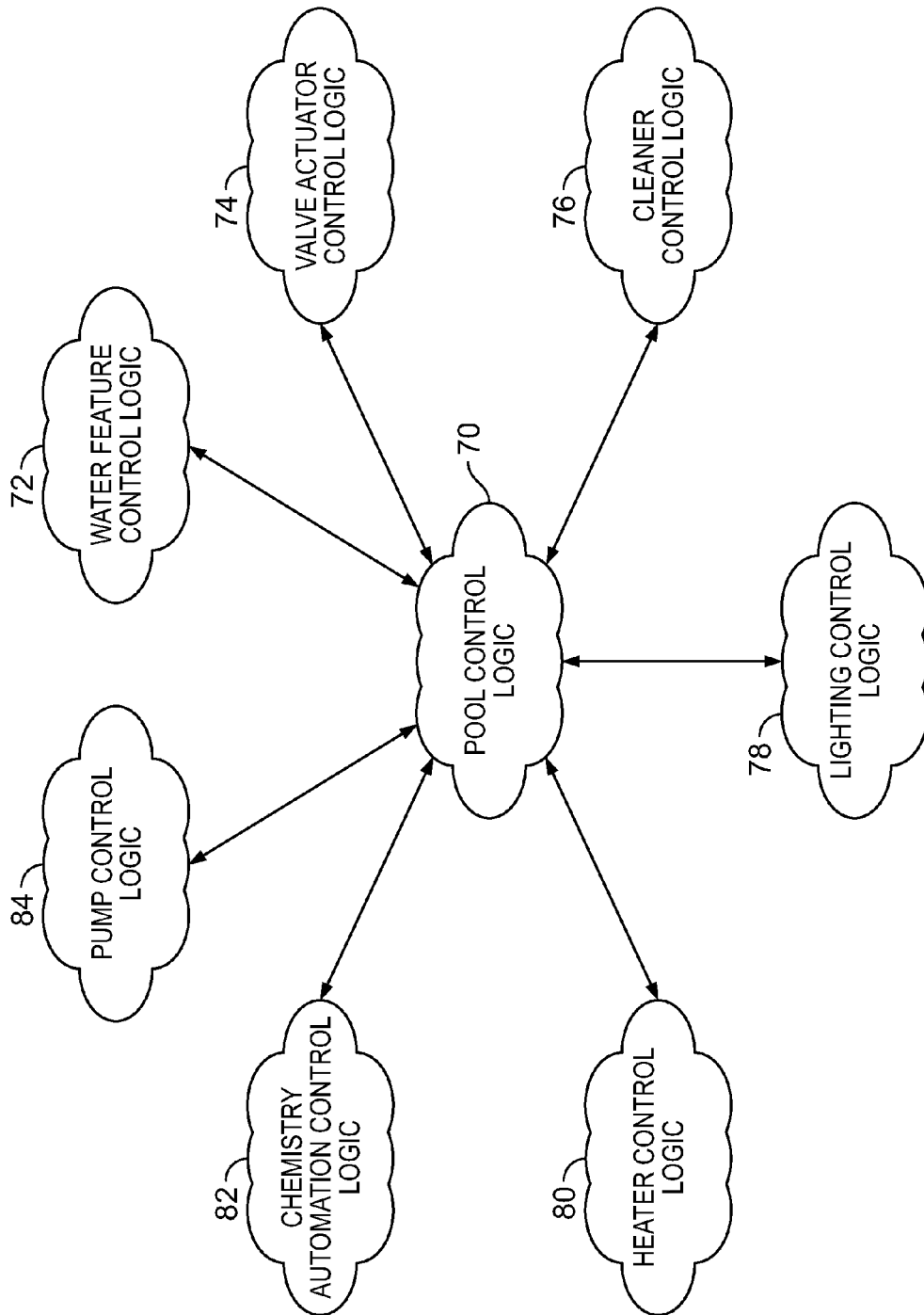


FIG. 3

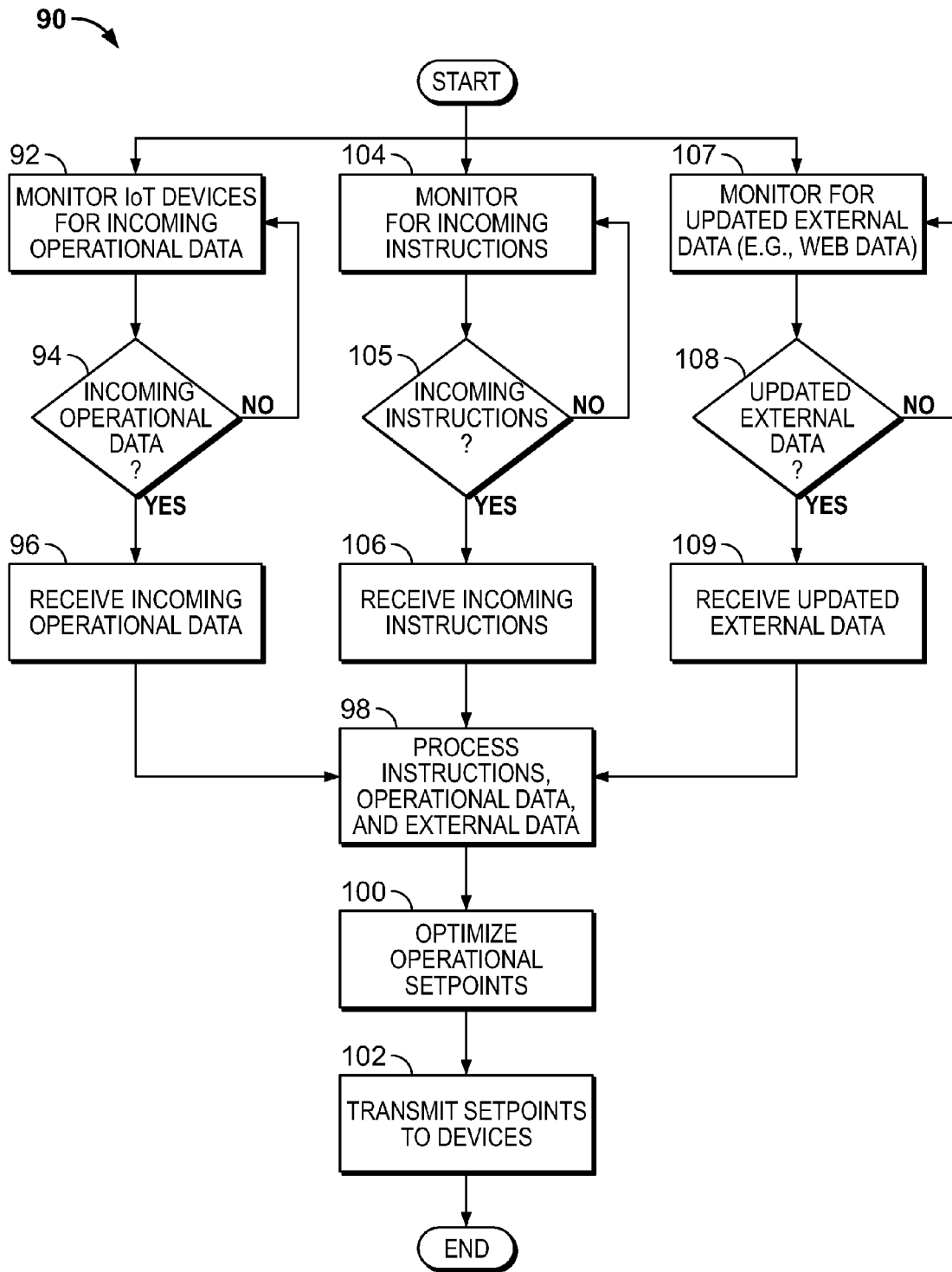


FIG. 4

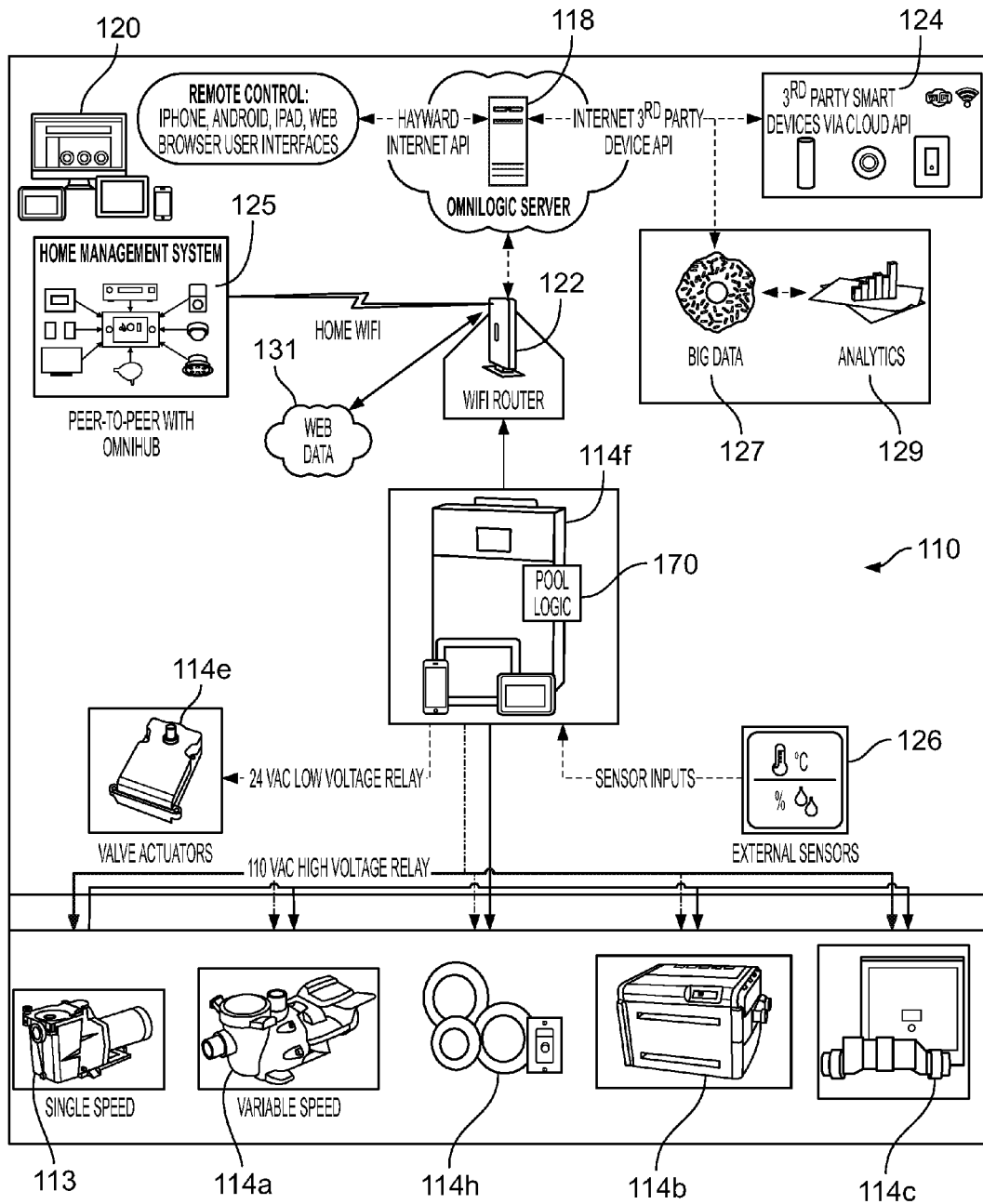


FIG. 5

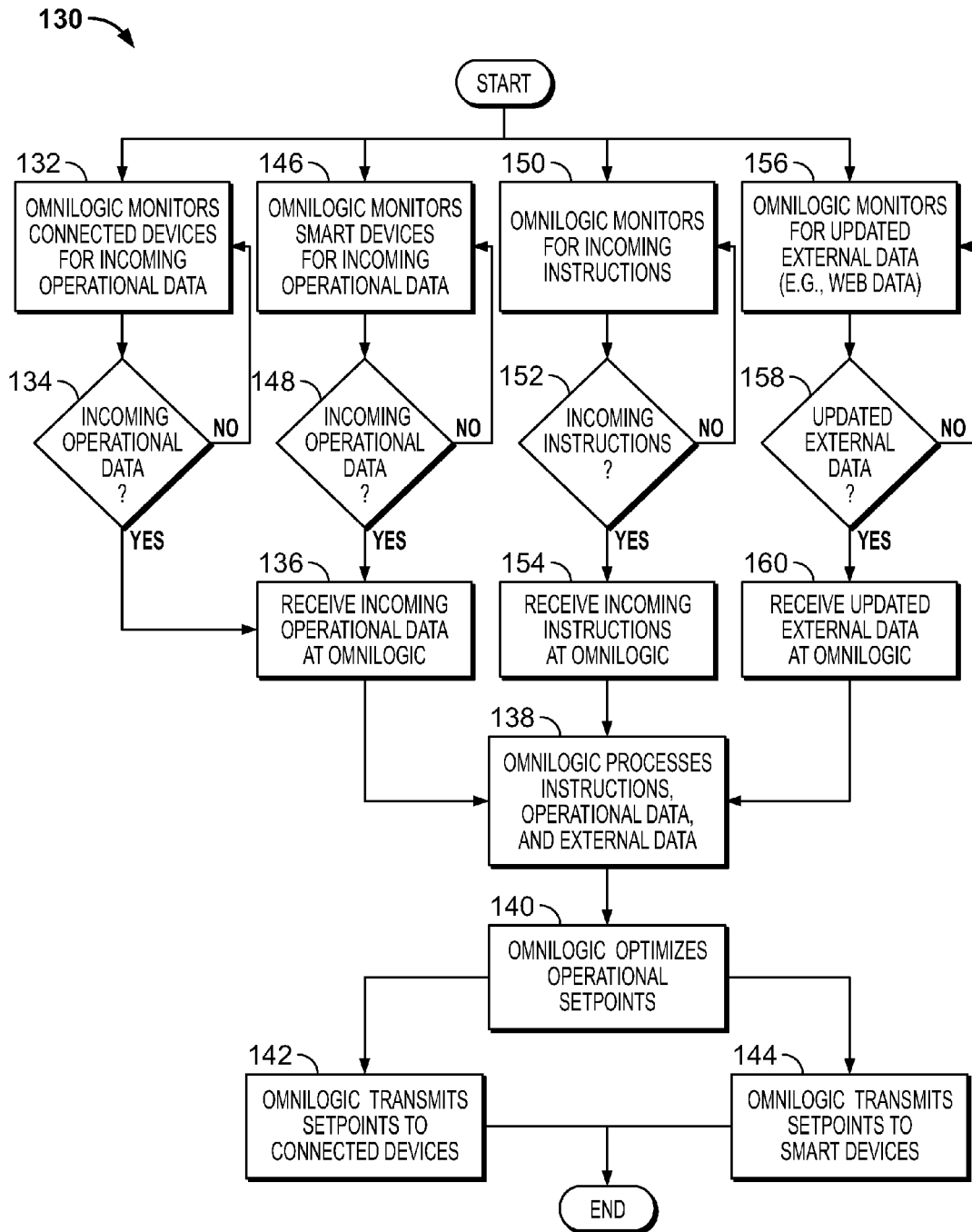
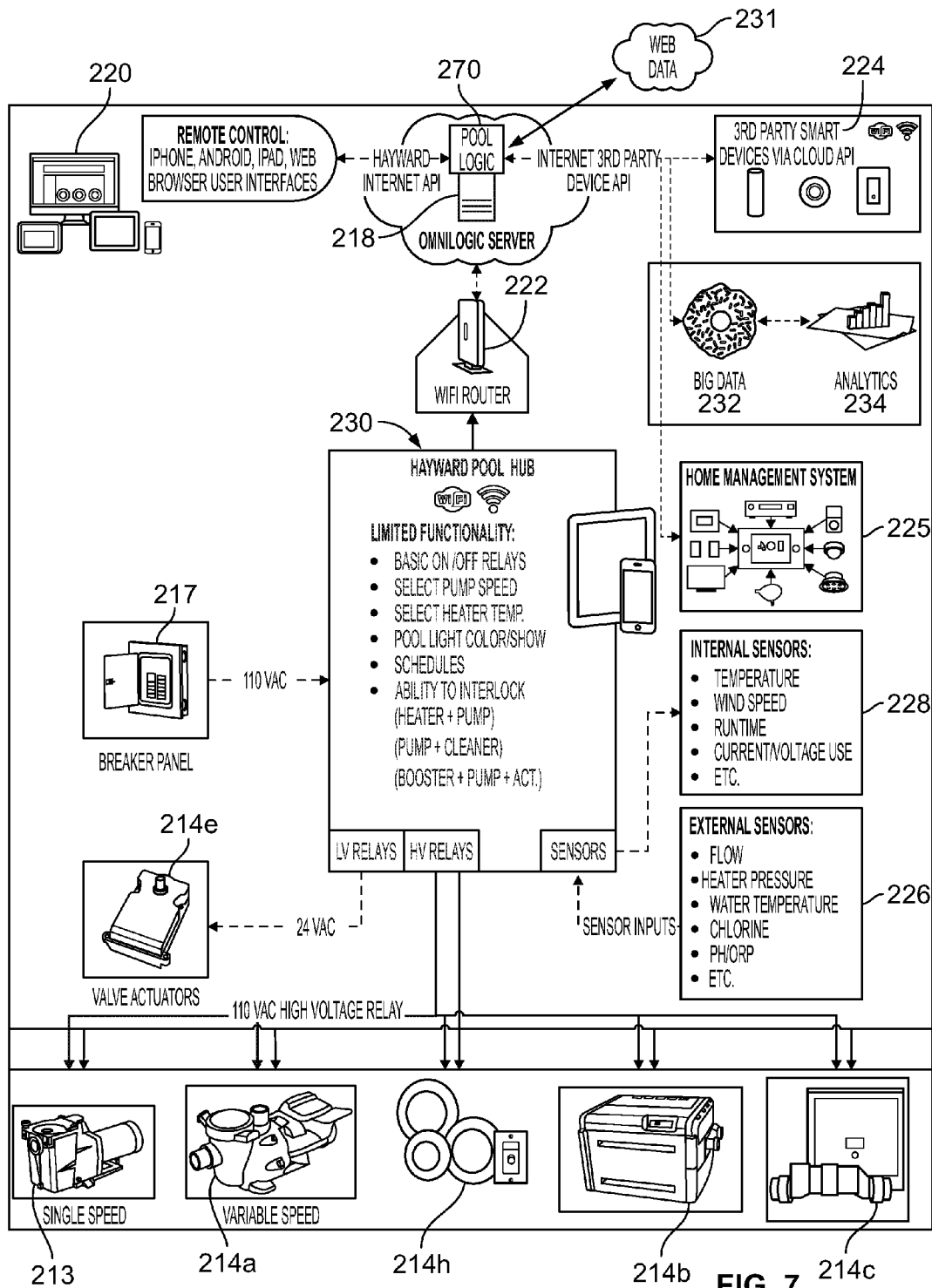


FIG. 6



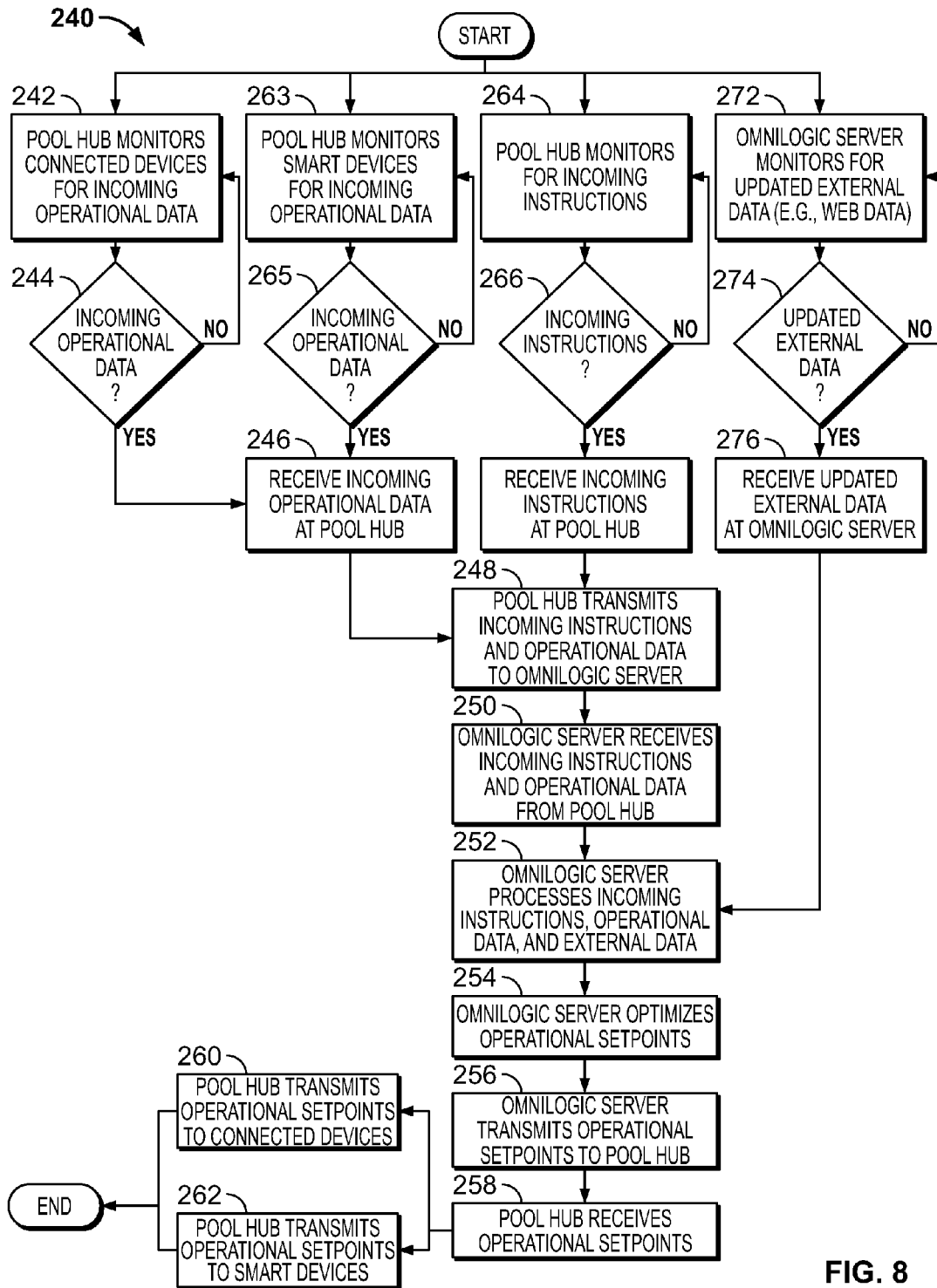


FIG. 8

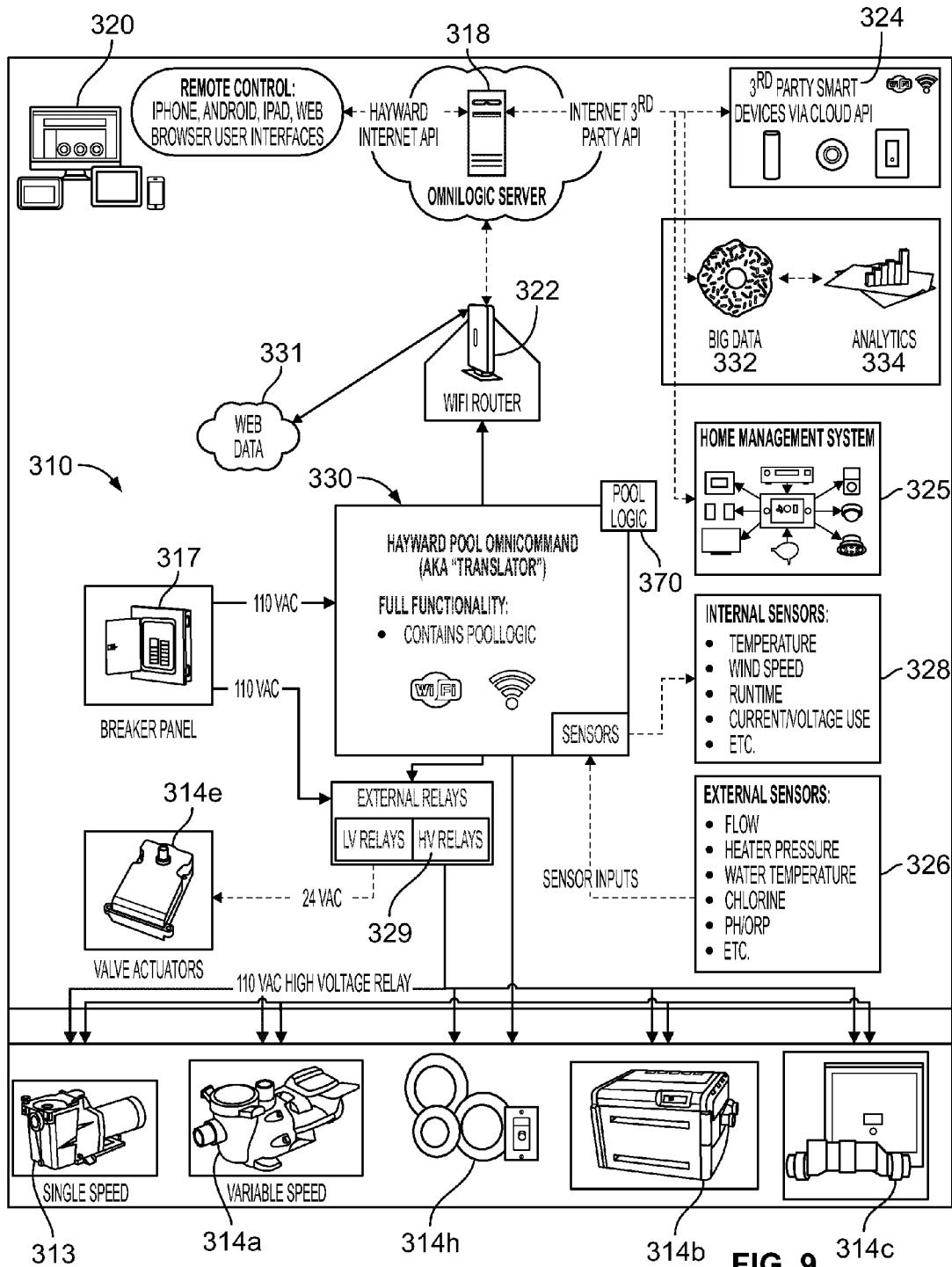


FIG. 9

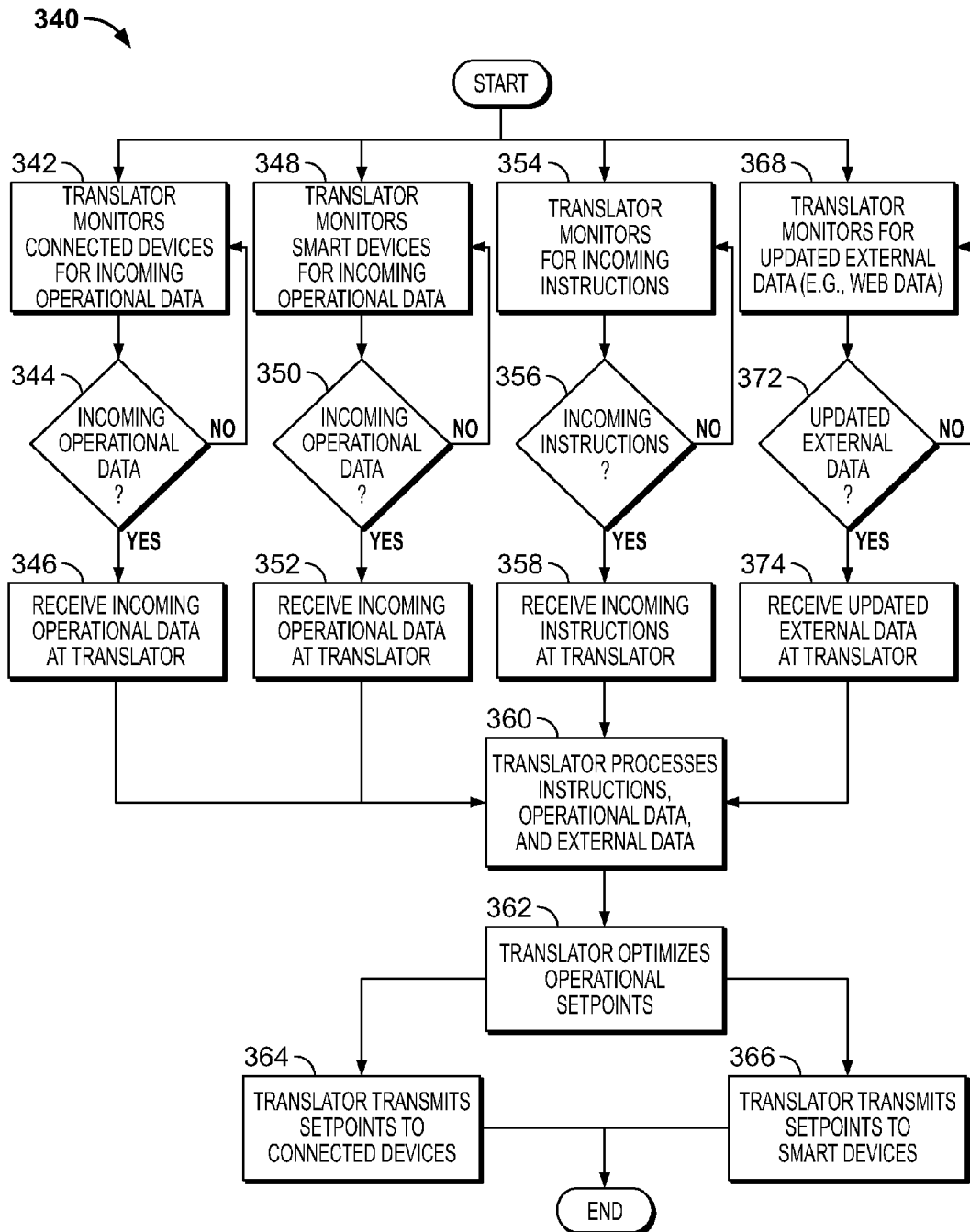
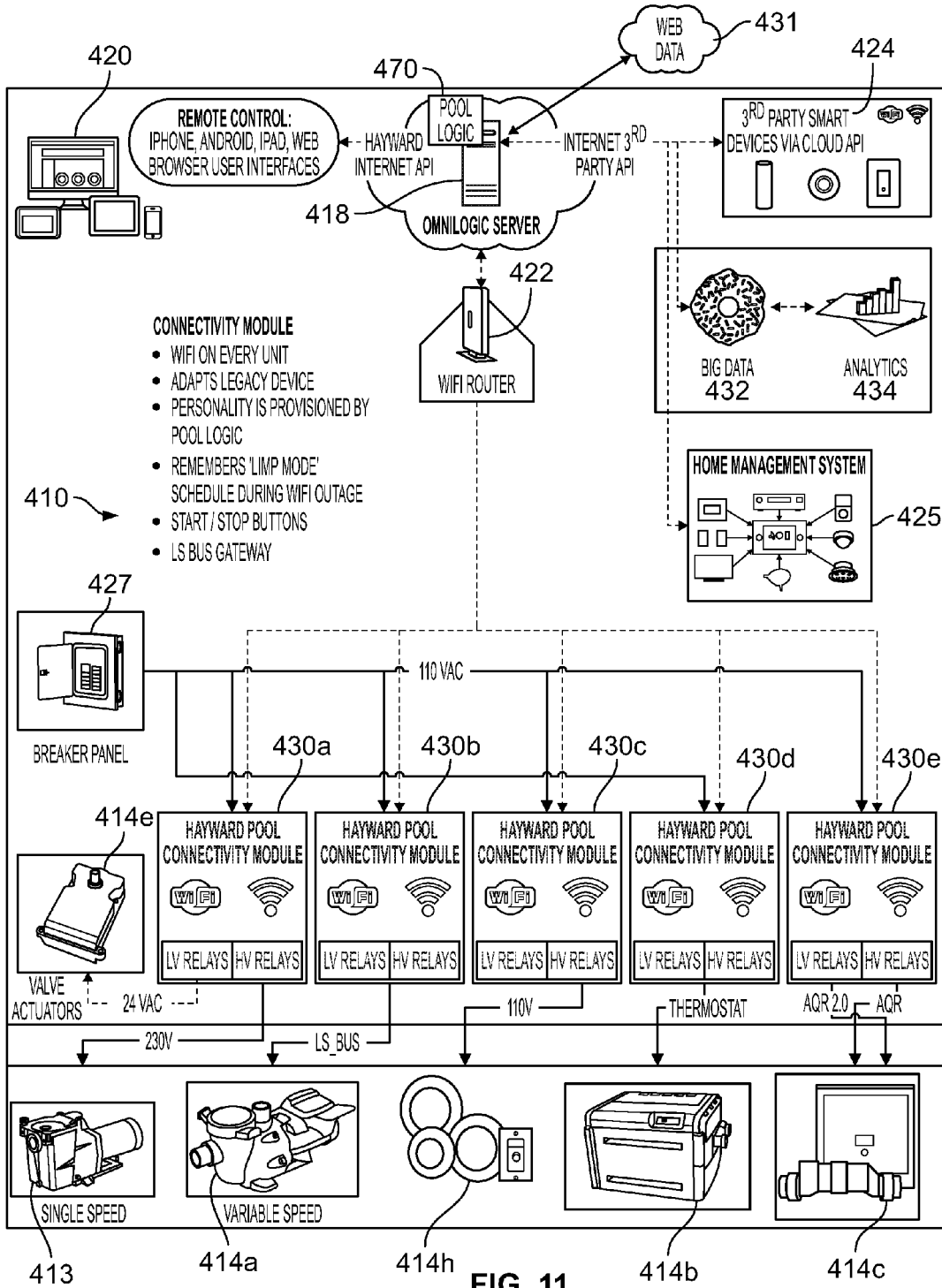


FIG. 10



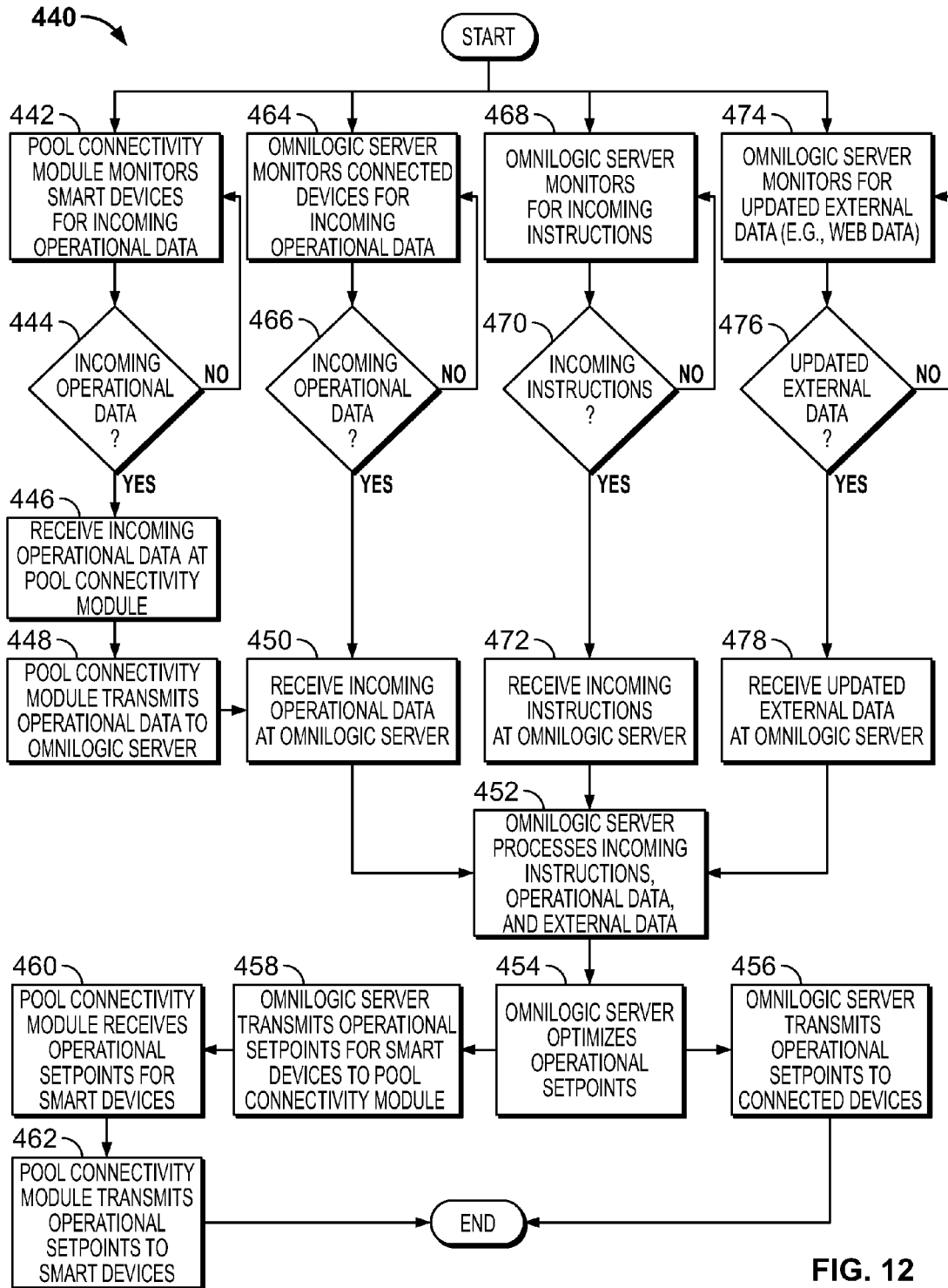
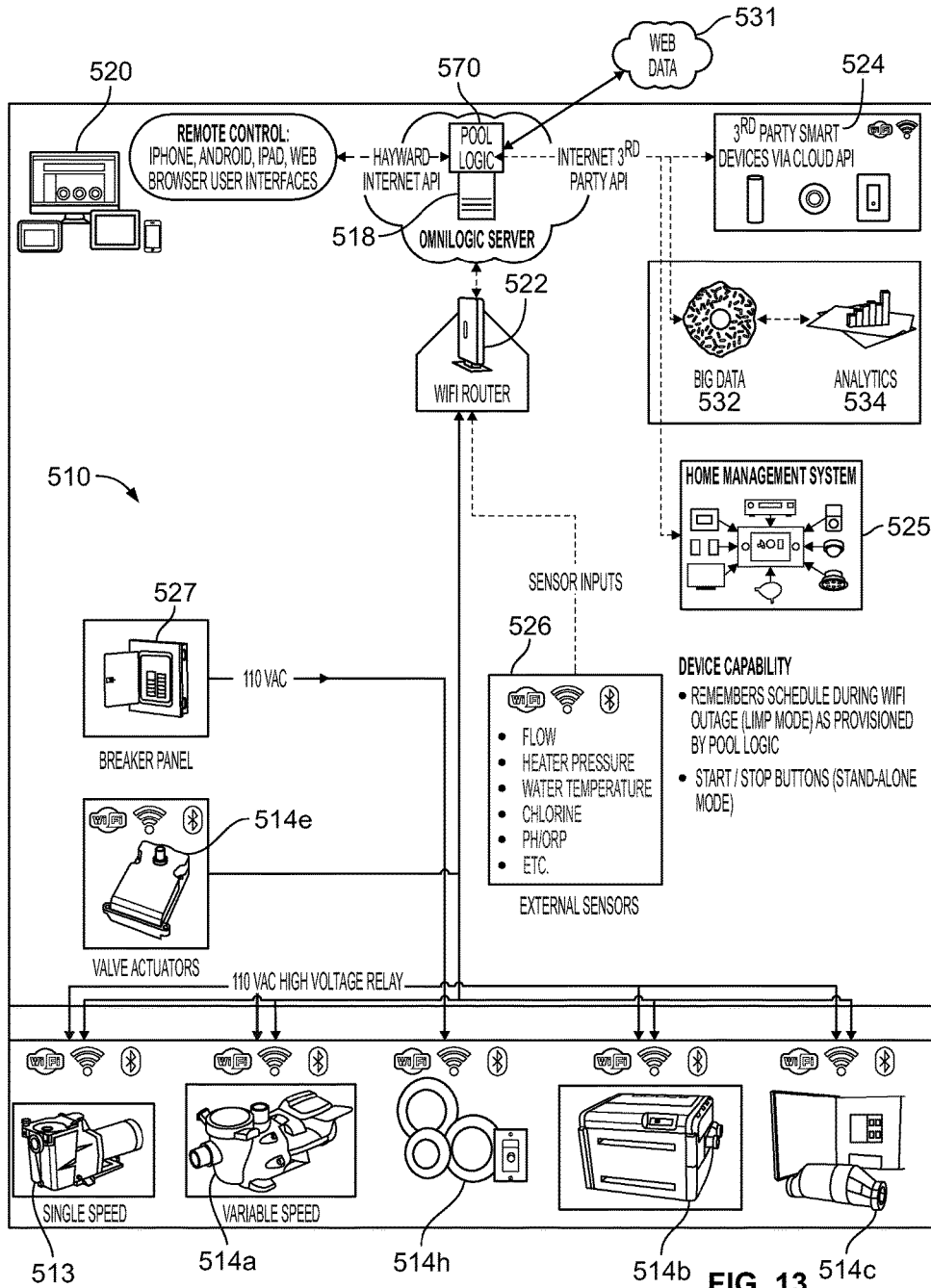


FIG. 12



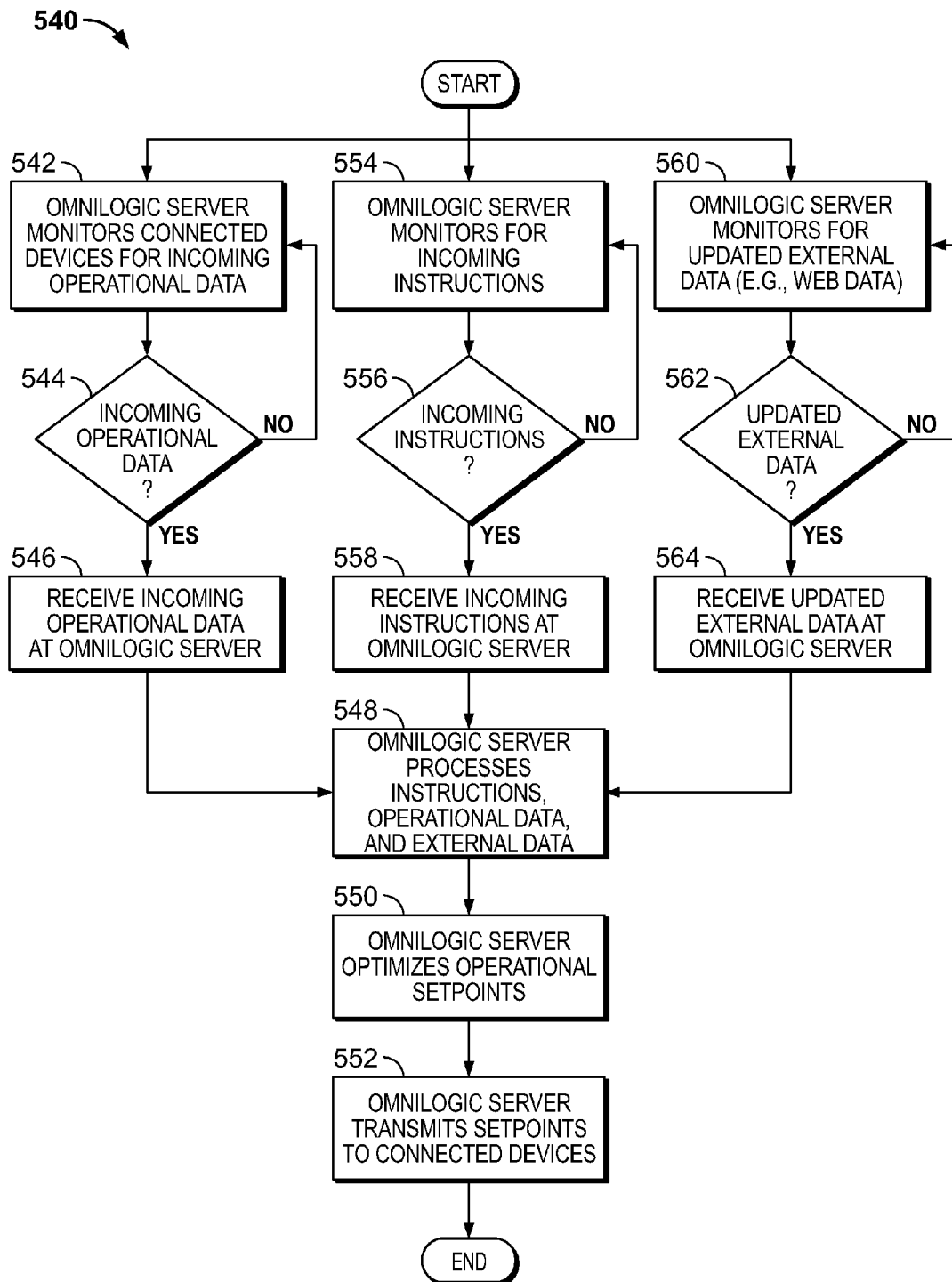


FIG. 14

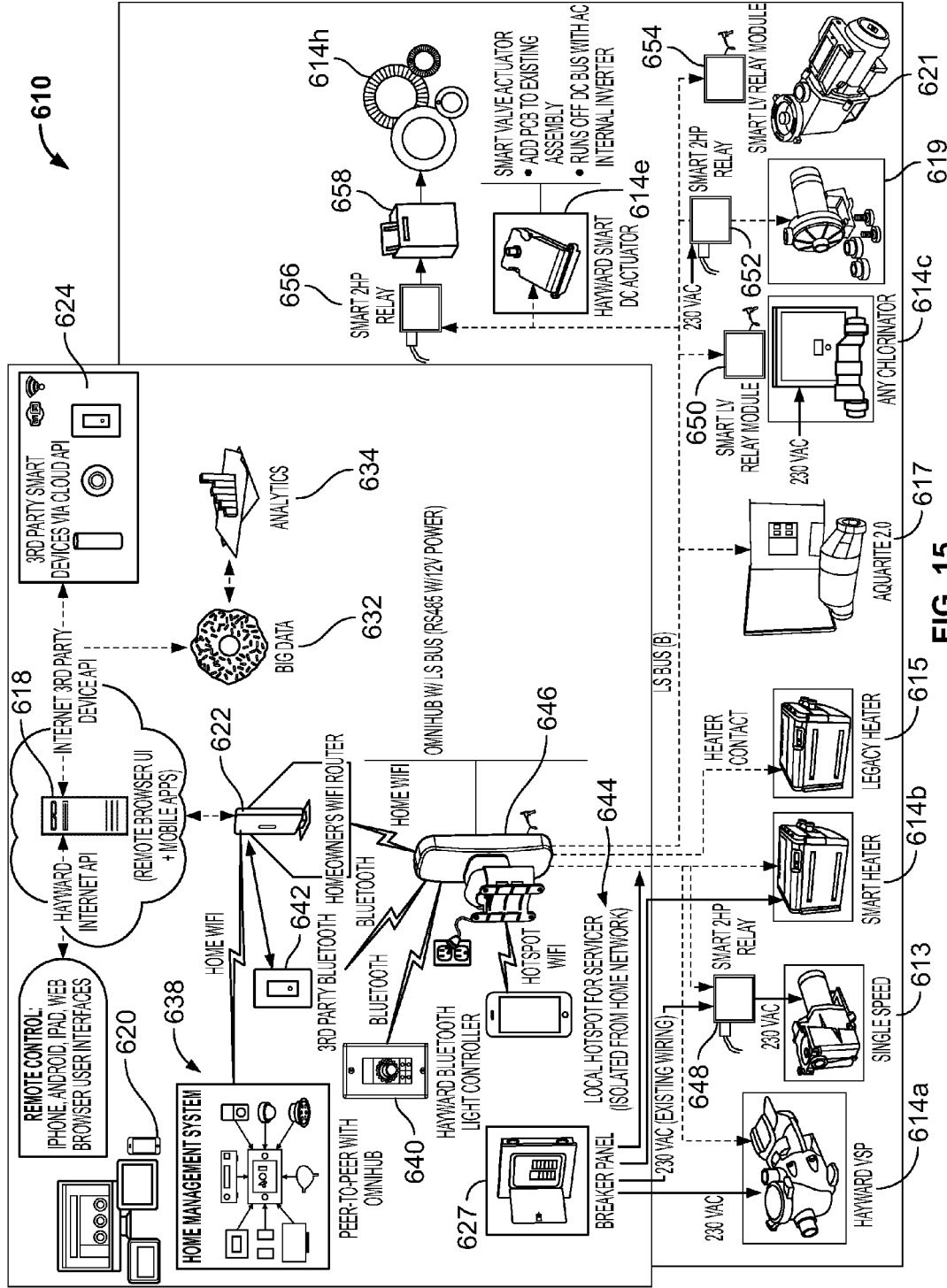


FIG. 15

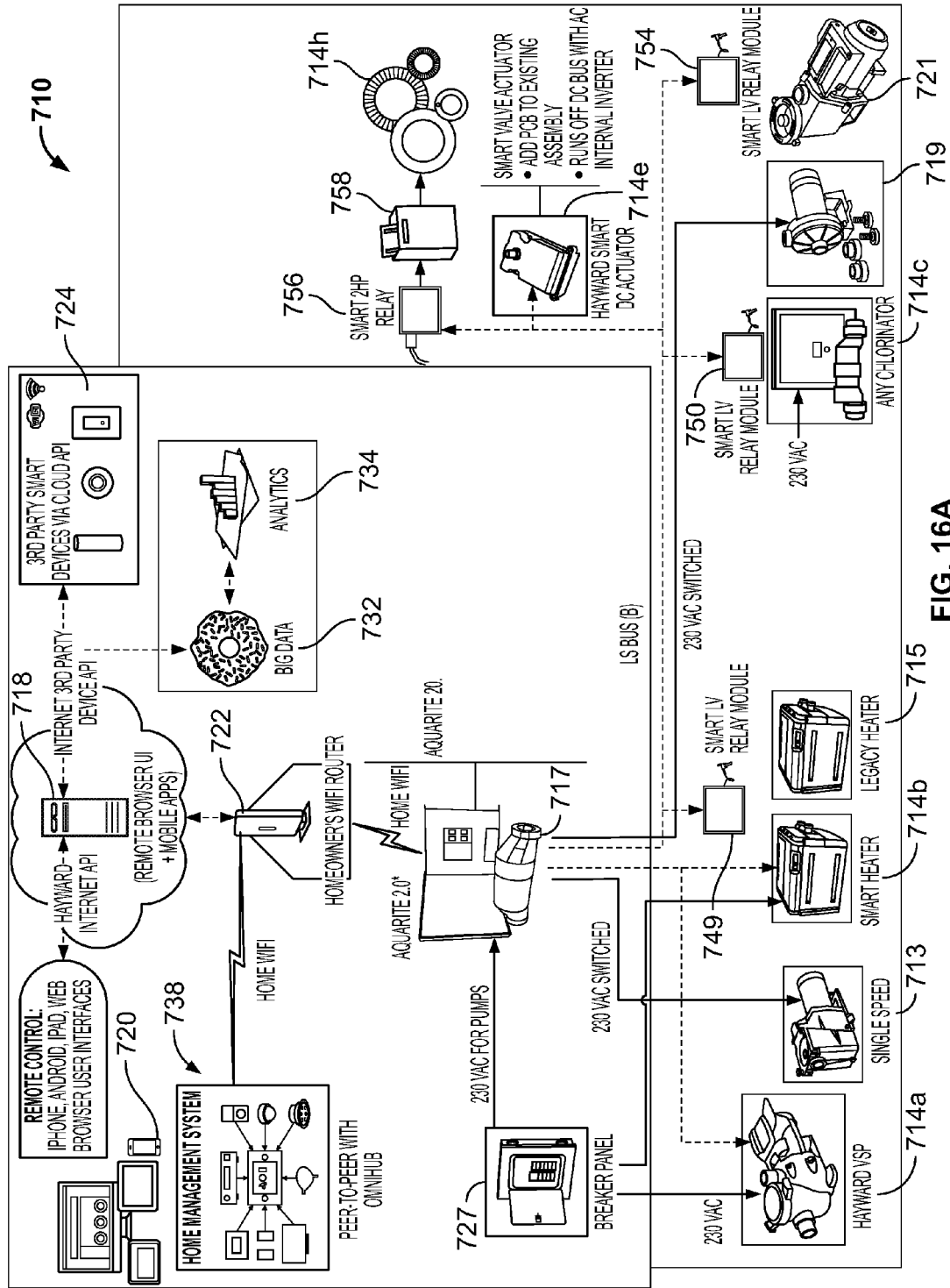


FIG. 16A

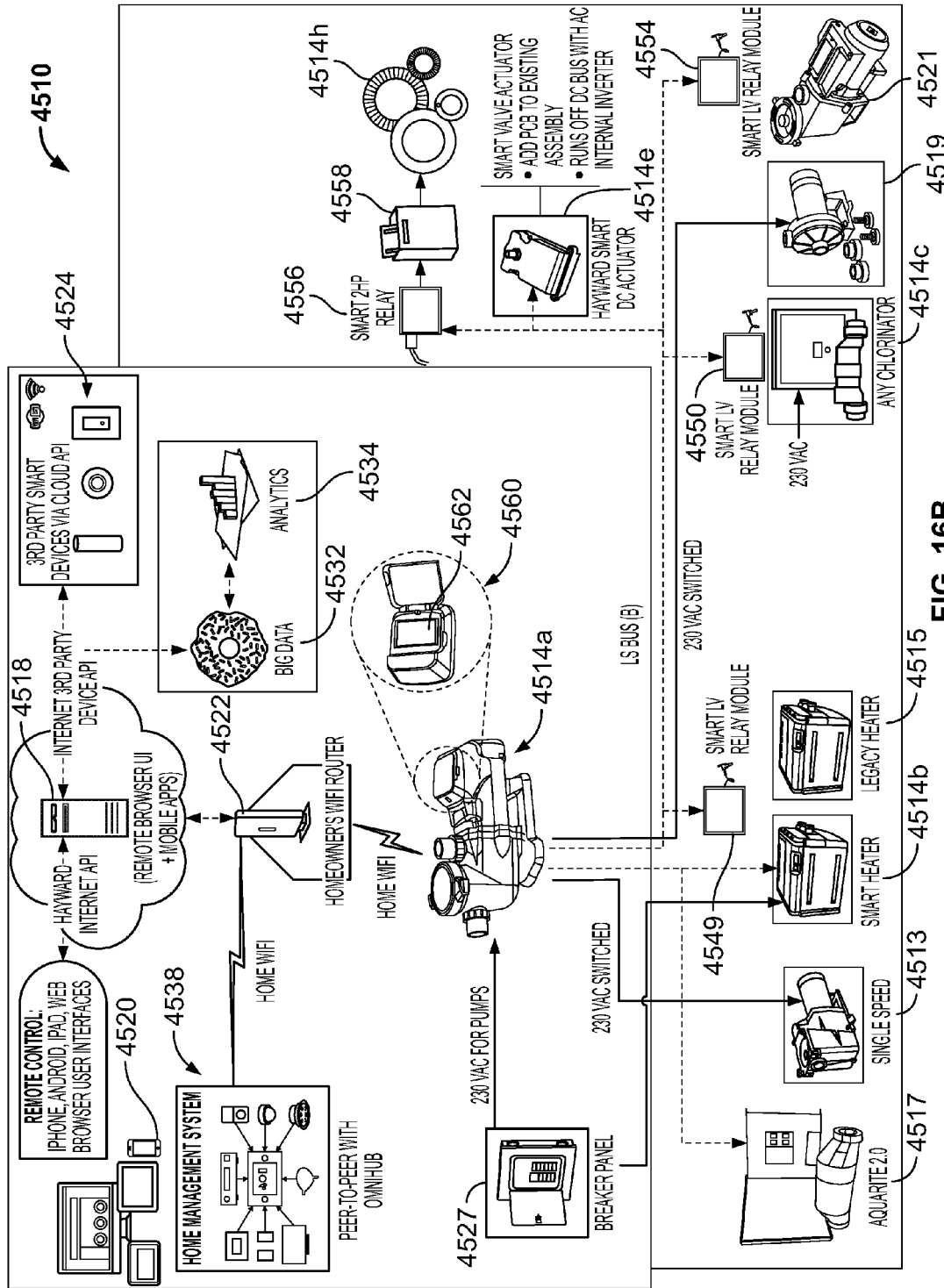


FIG. 16B

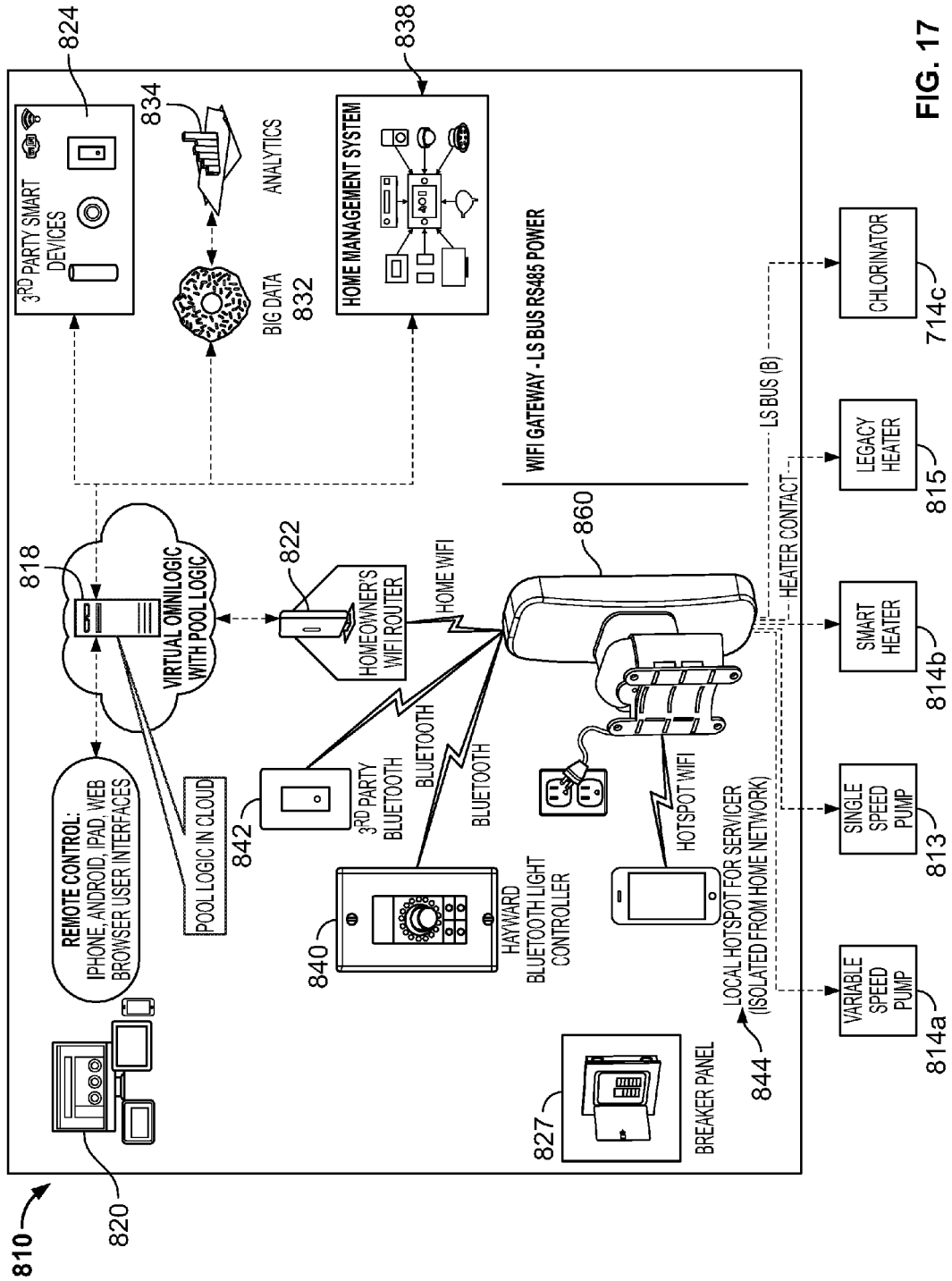


FIG. 17

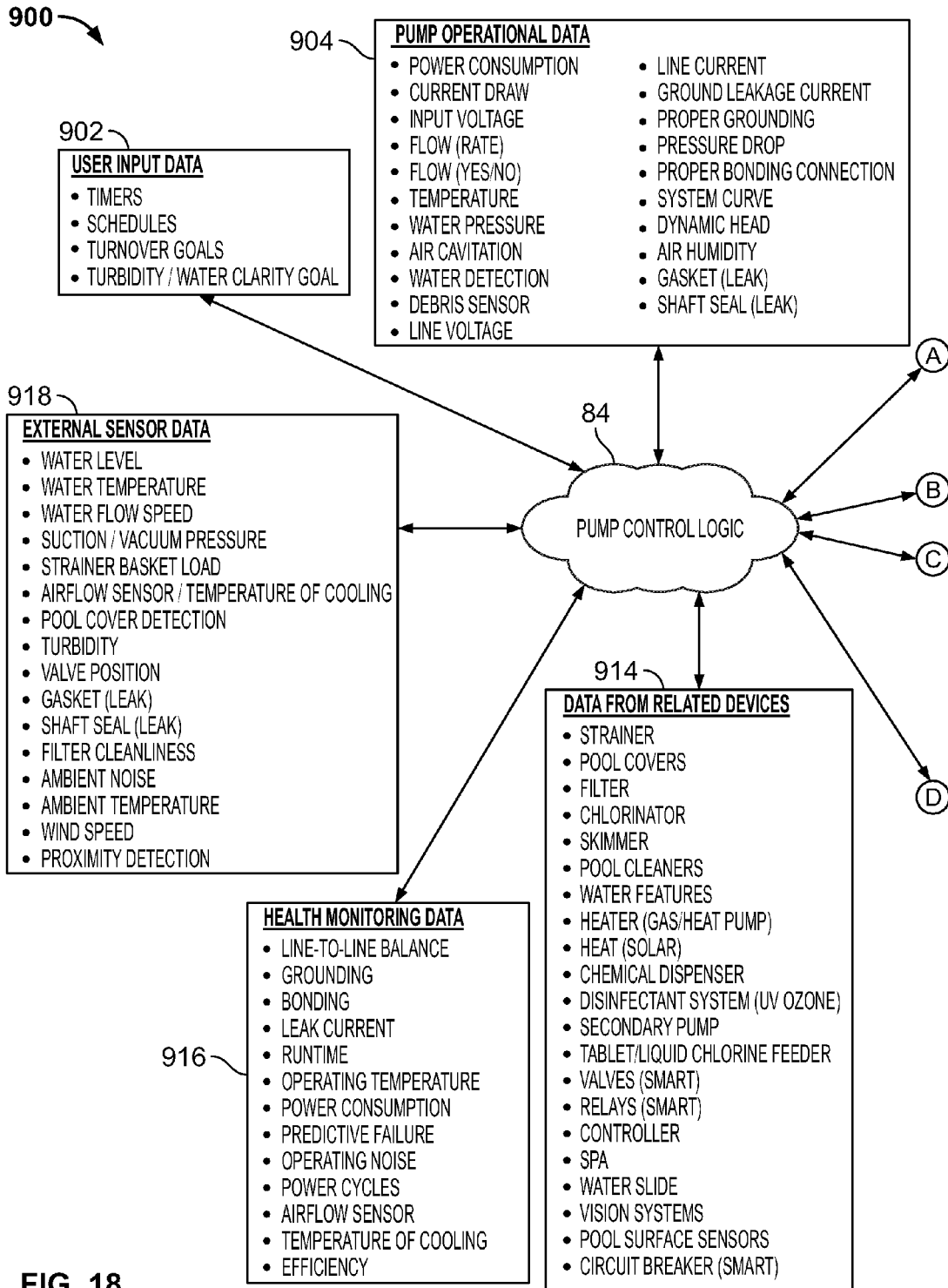


FIG. 18

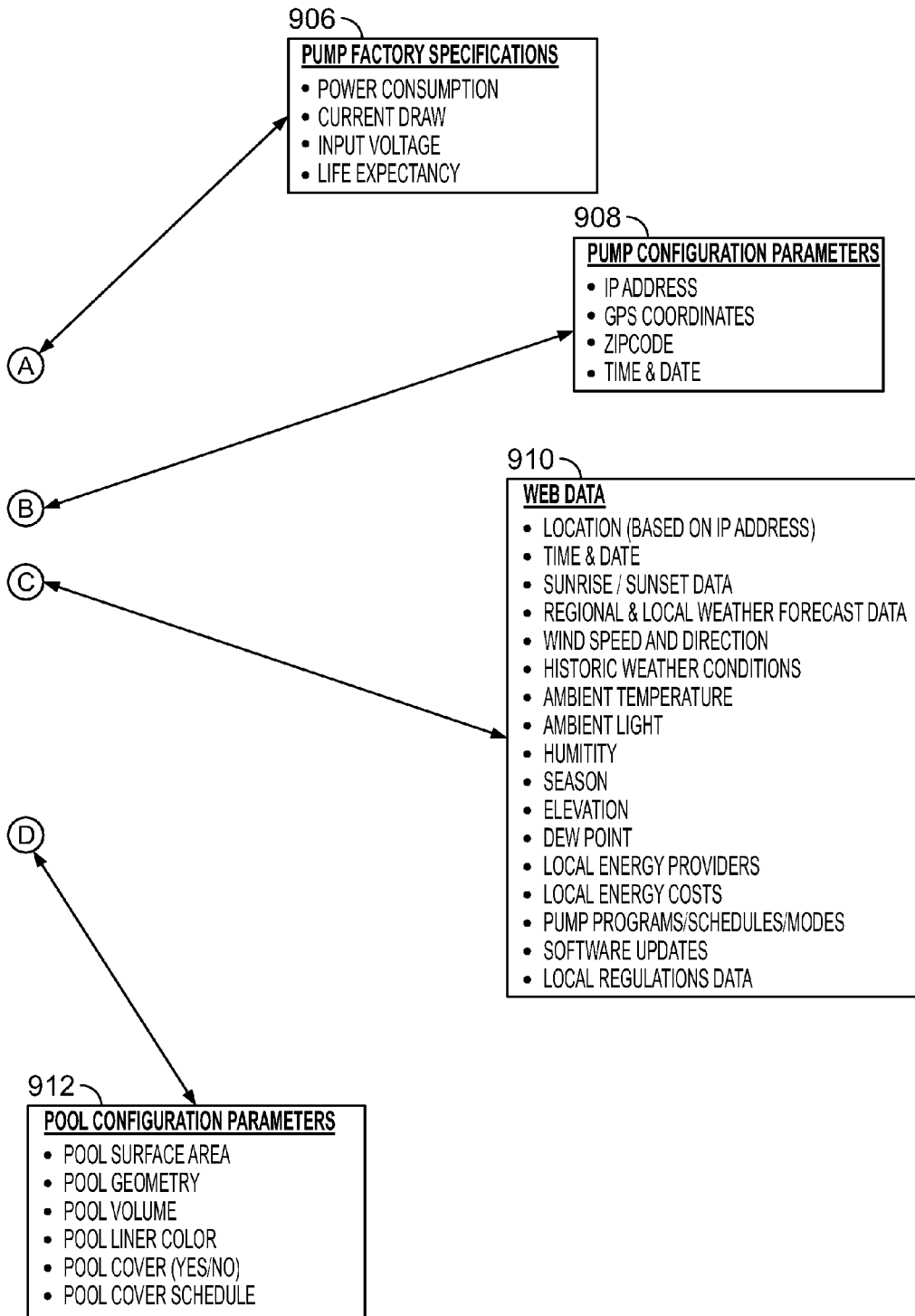


FIG. 18 (Cont.)

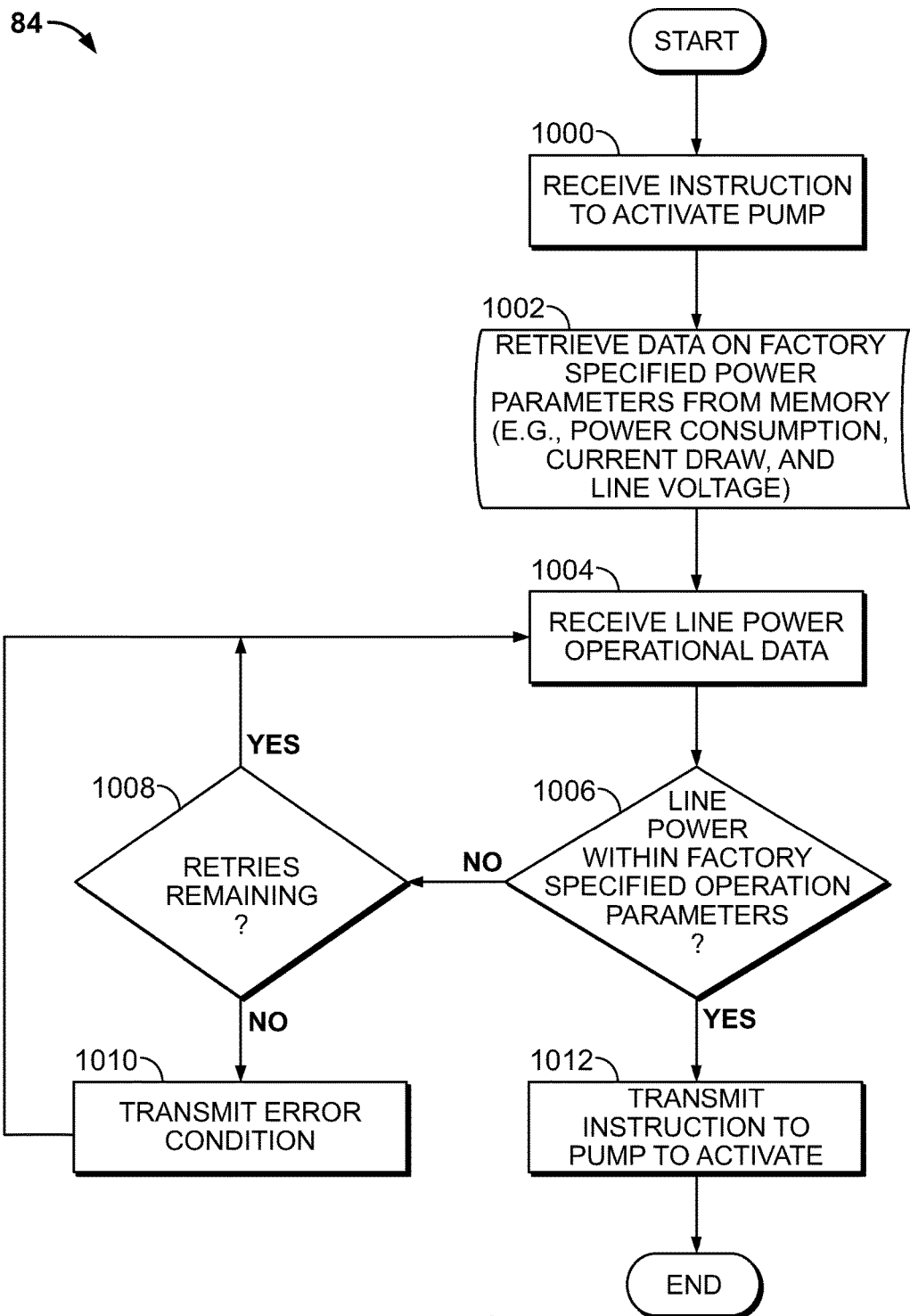


FIG. 19A

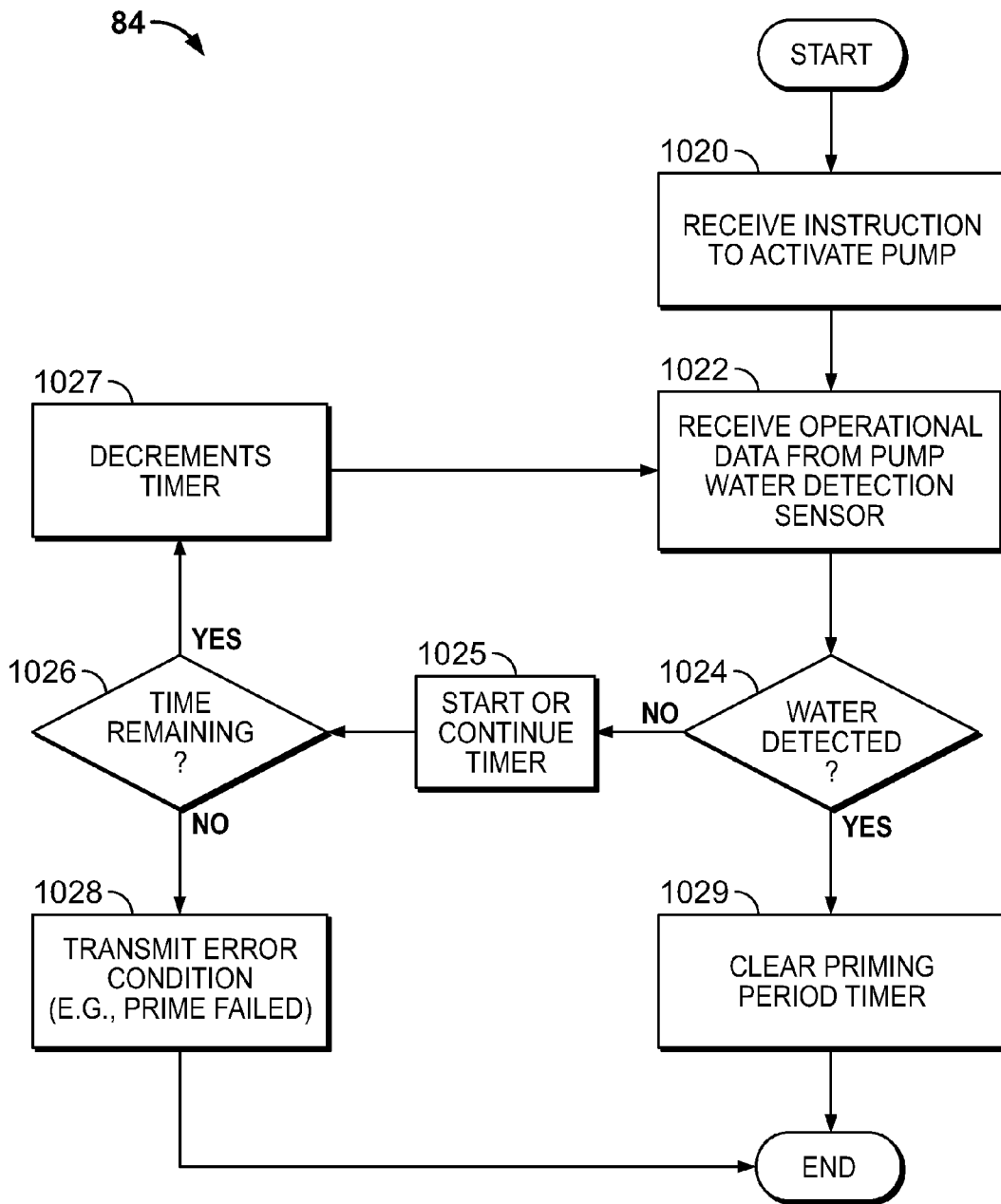


FIG. 19B

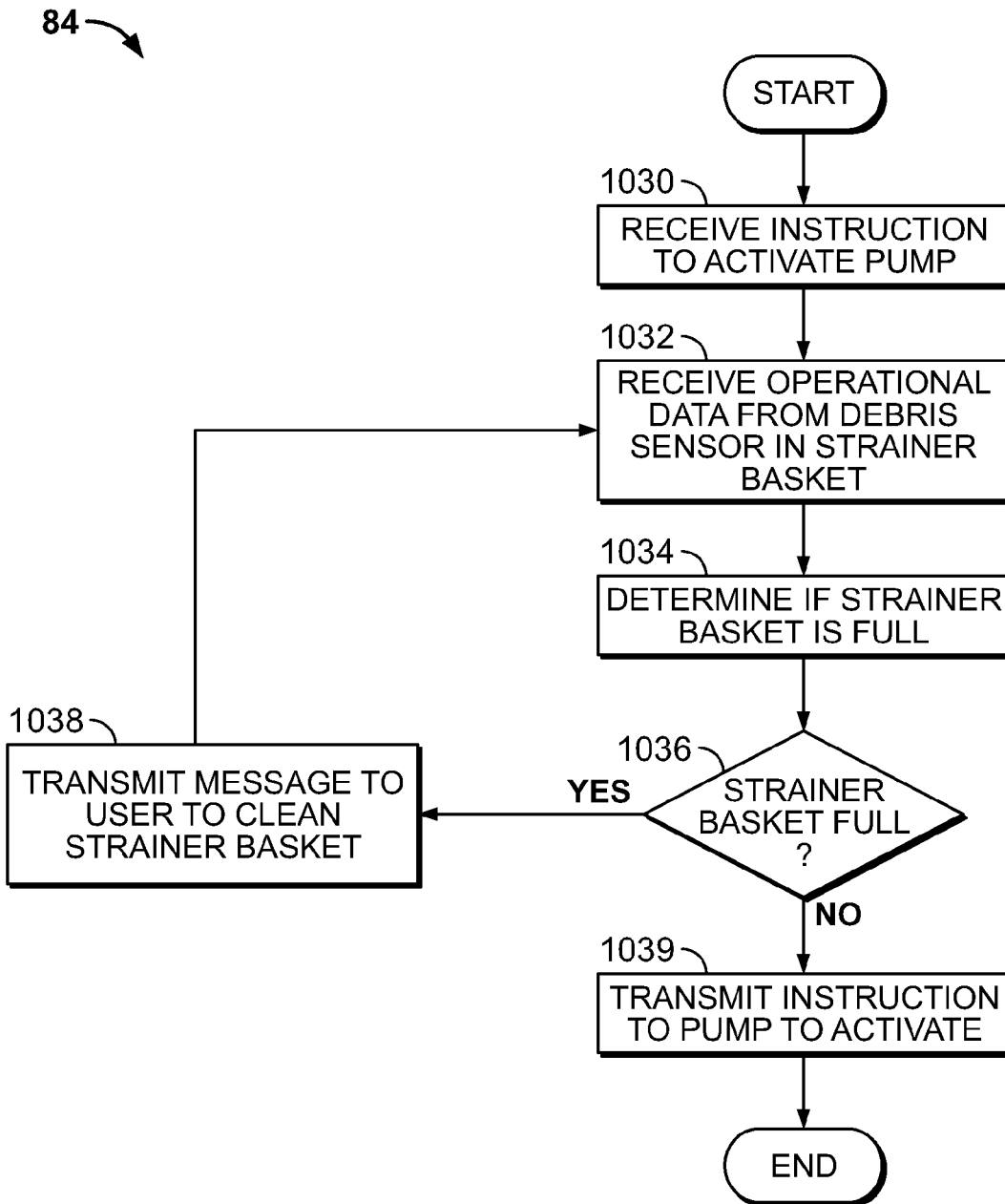


FIG. 19C

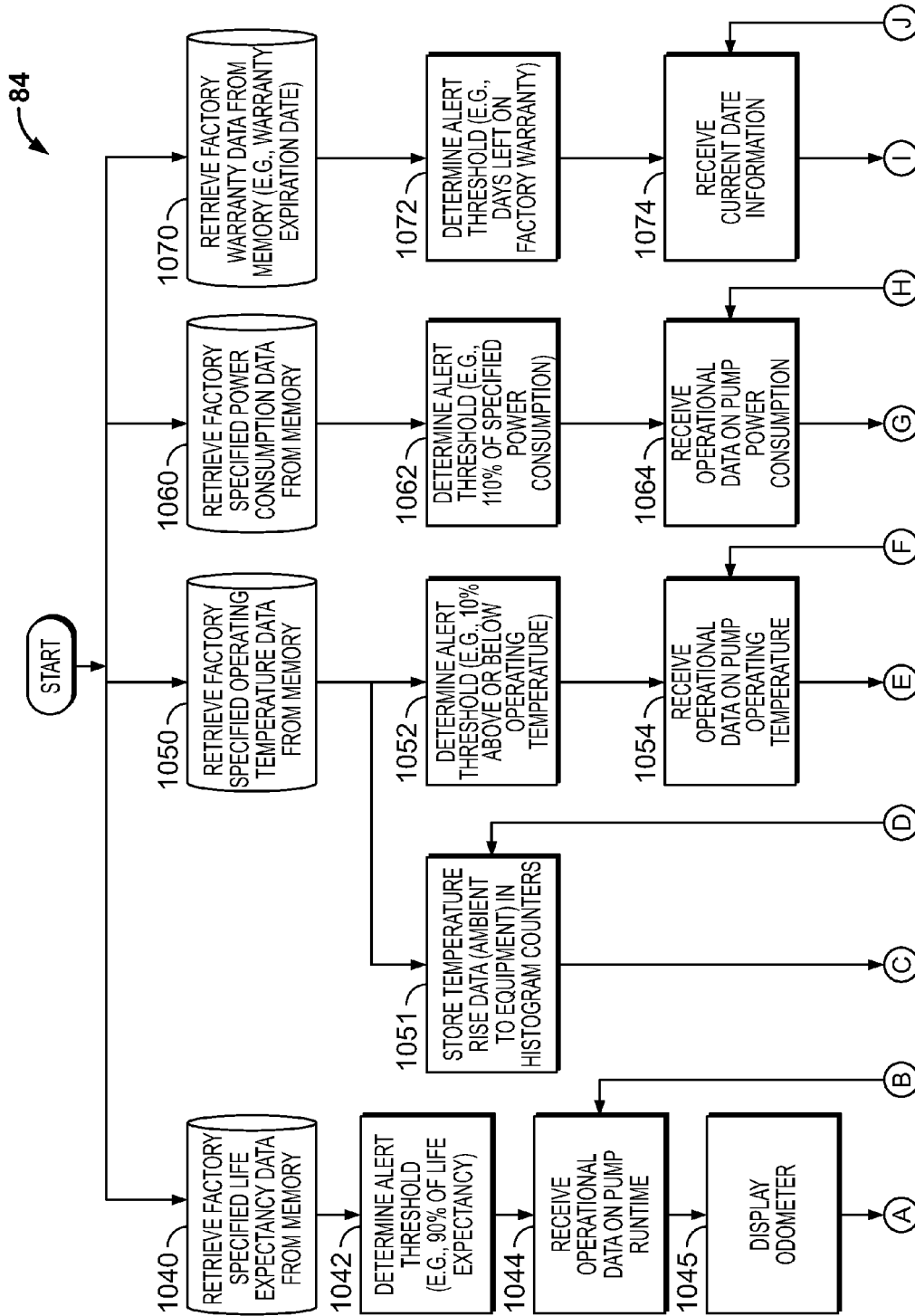


FIG. 19D

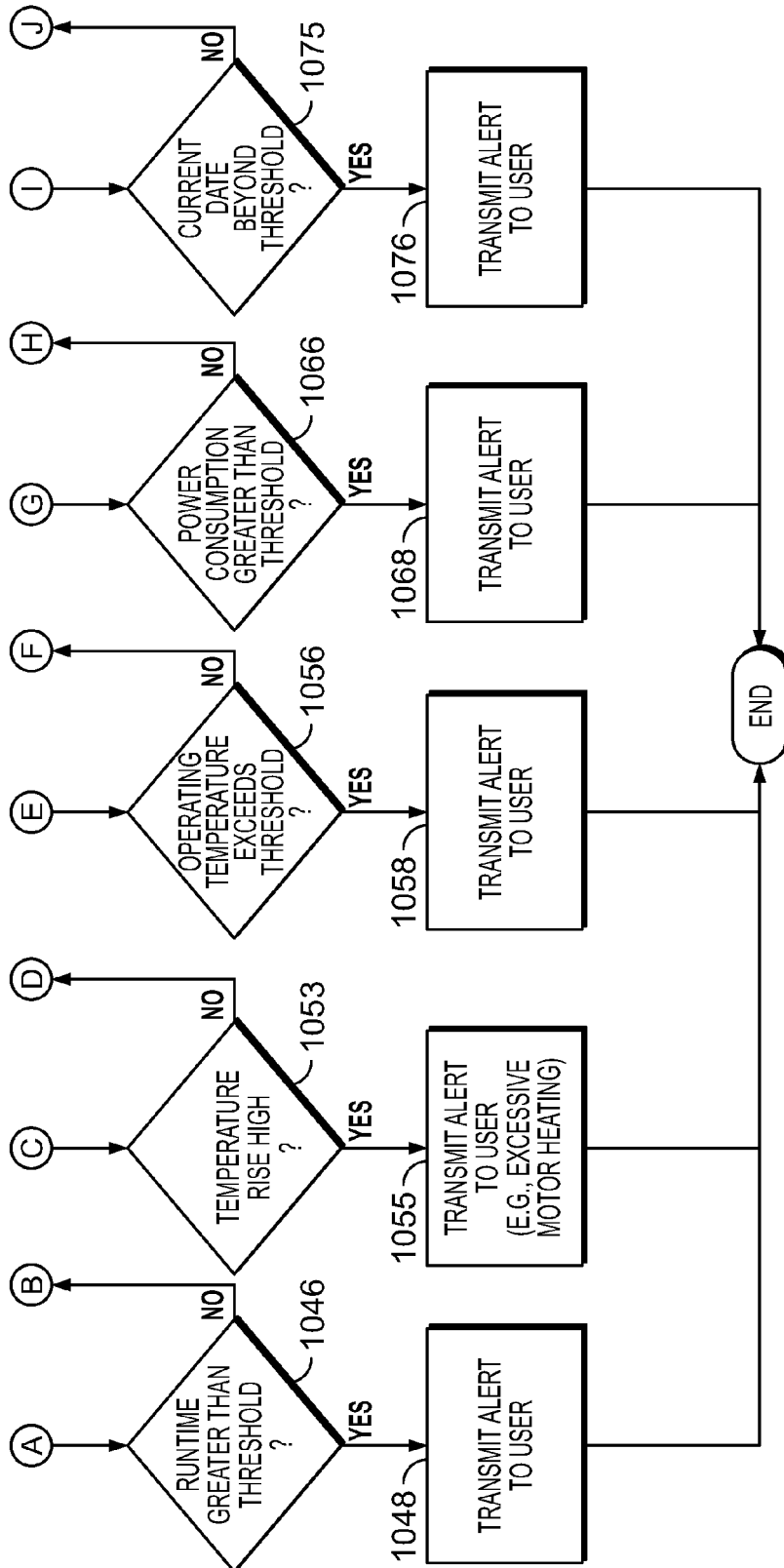


FIG. 19D (Cont.)

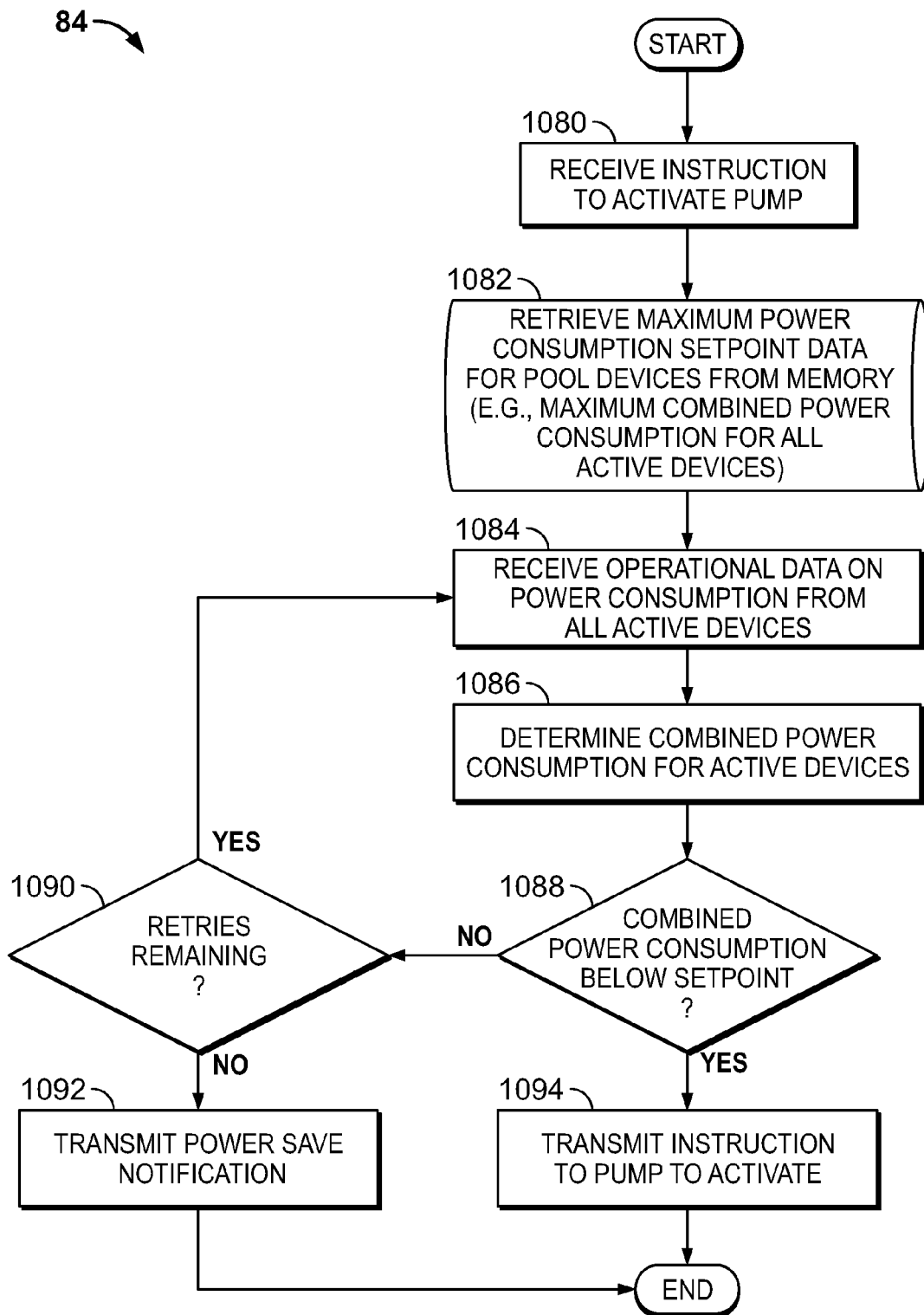


FIG. 19E

84 →

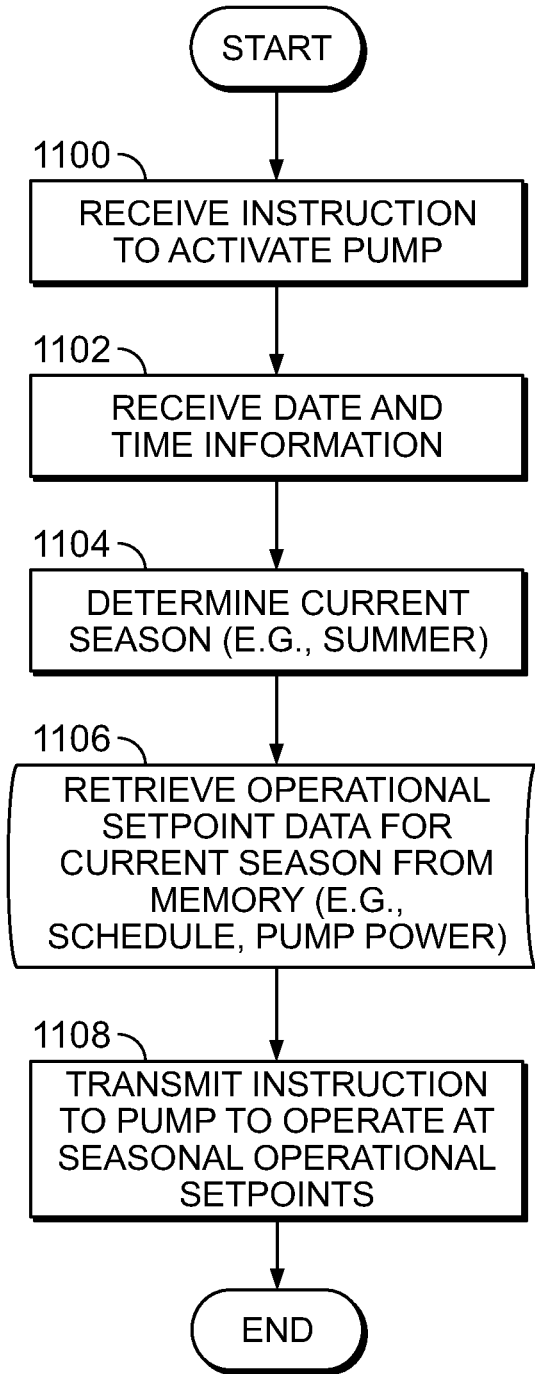


FIG. 19F

84 →

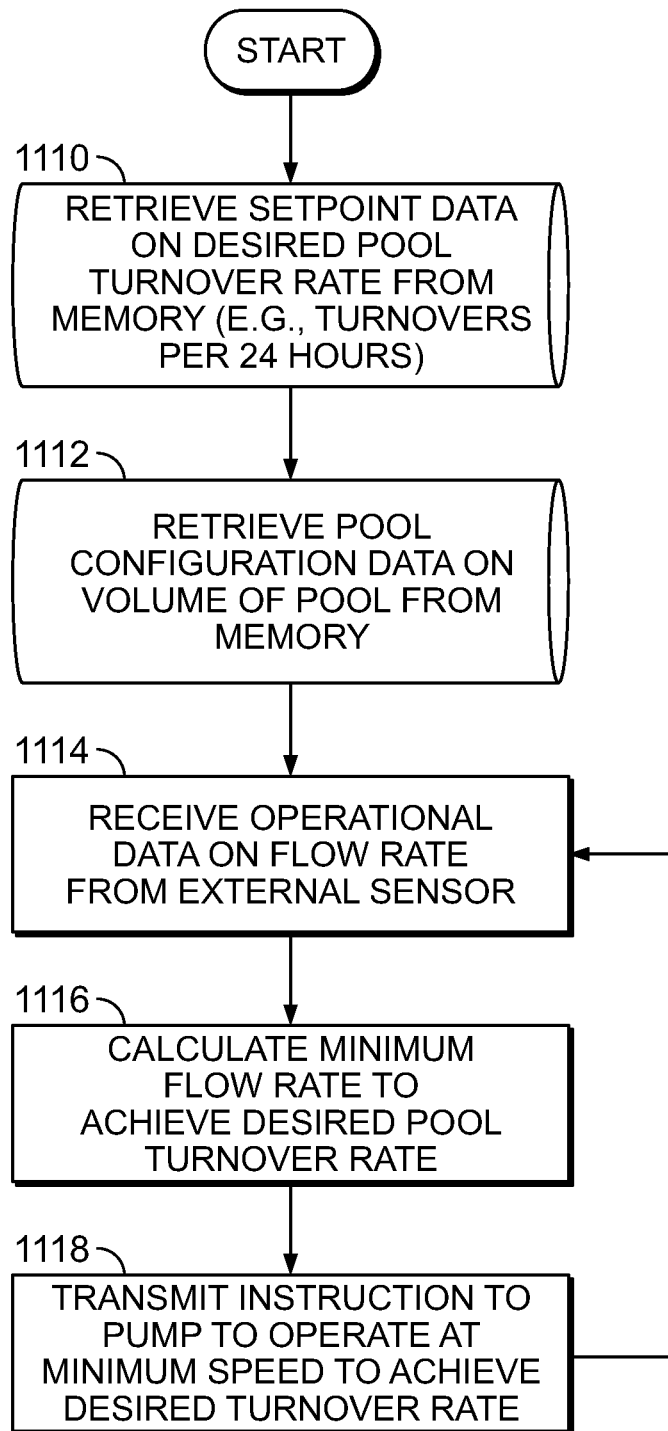


FIG. 19G

84

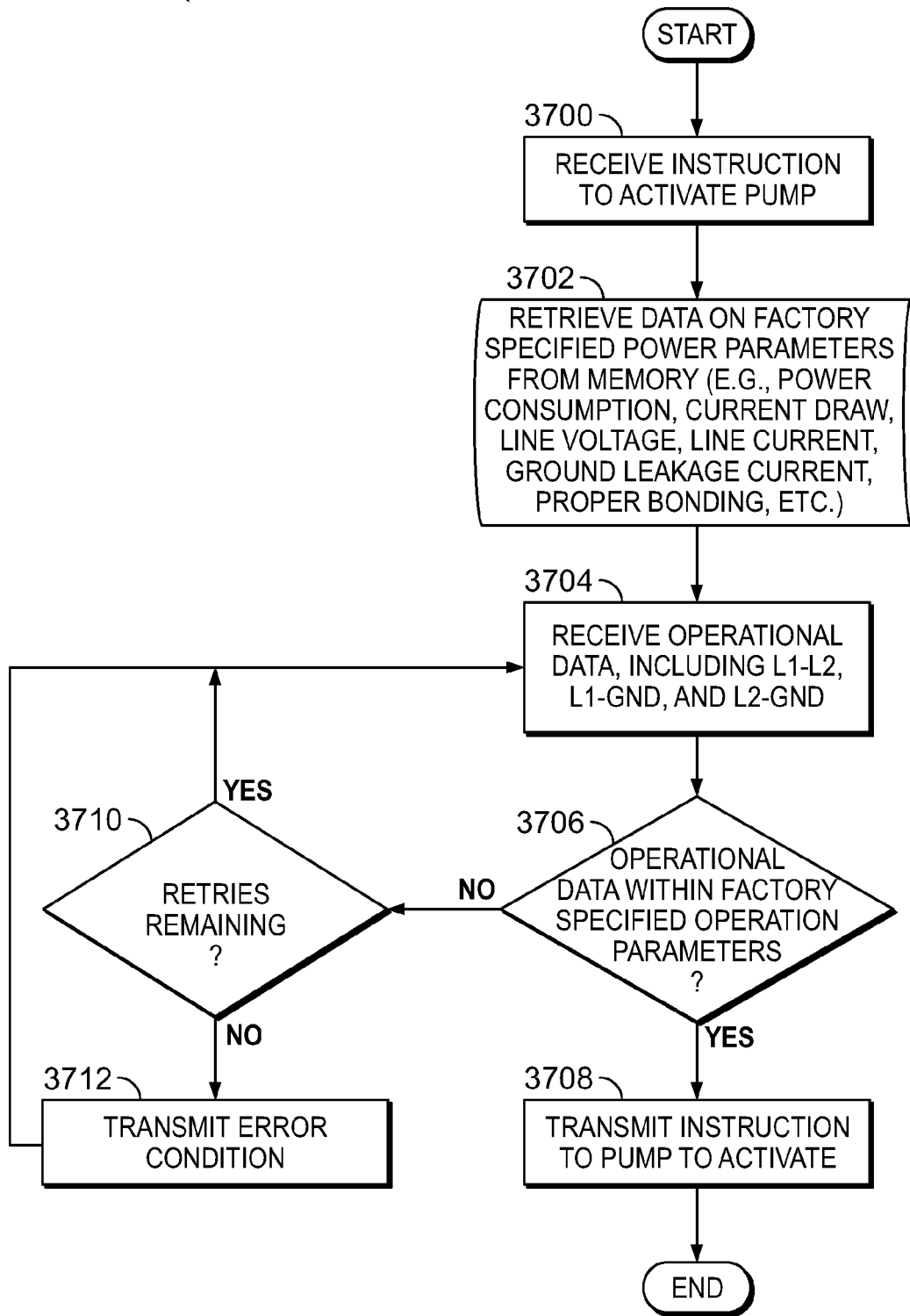


FIG. 19H

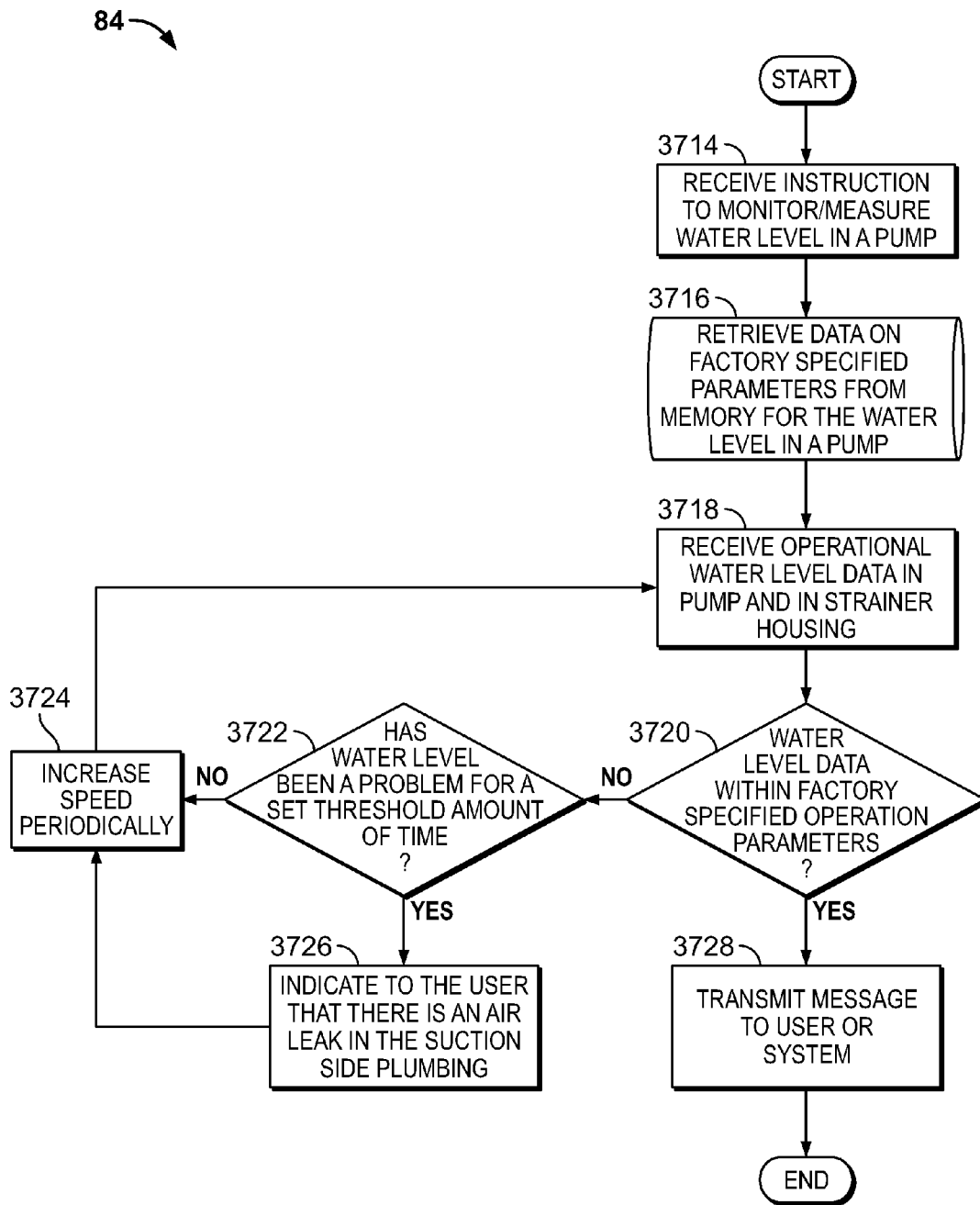


FIG. 19I

84

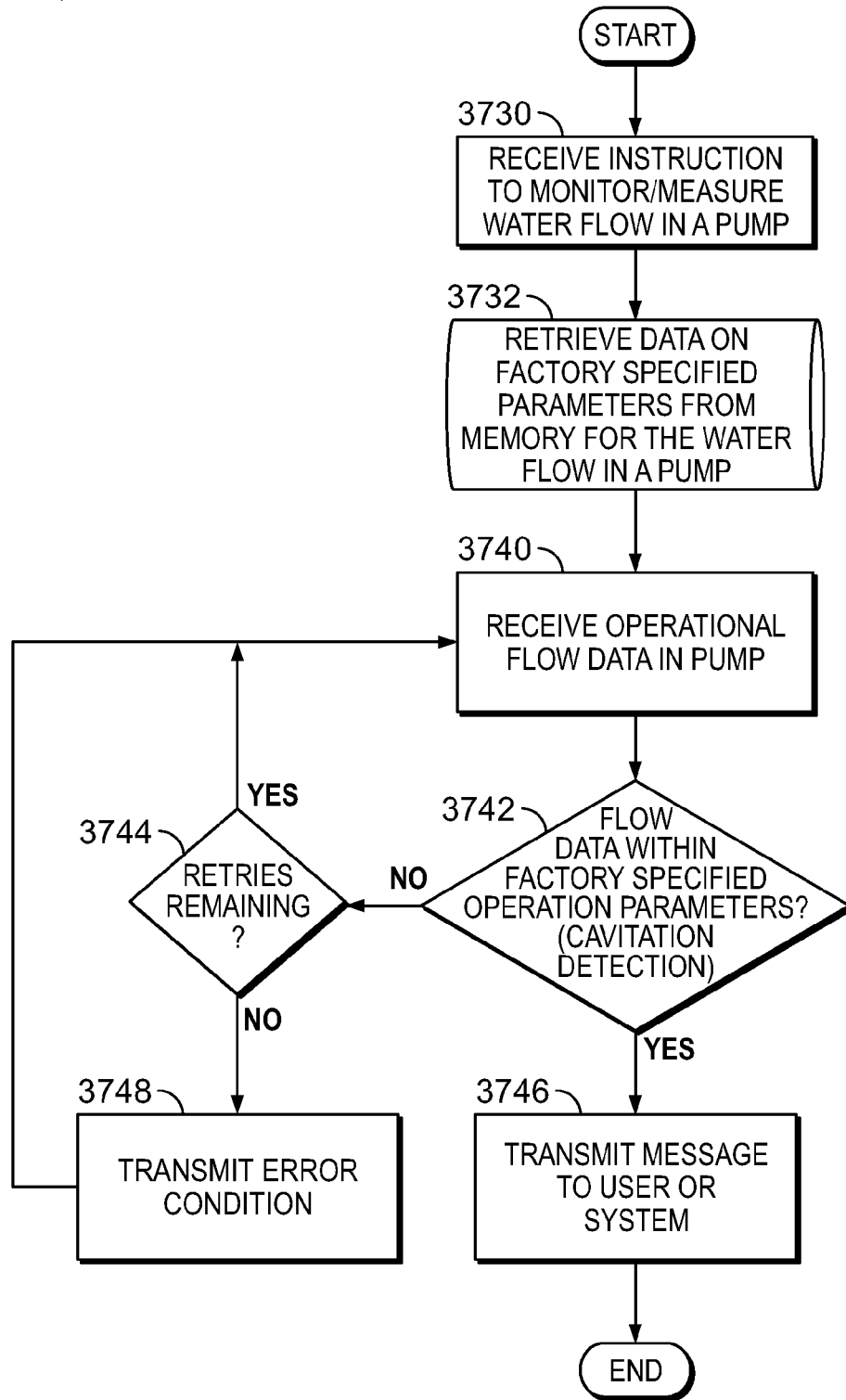


FIG. 19J

84 →

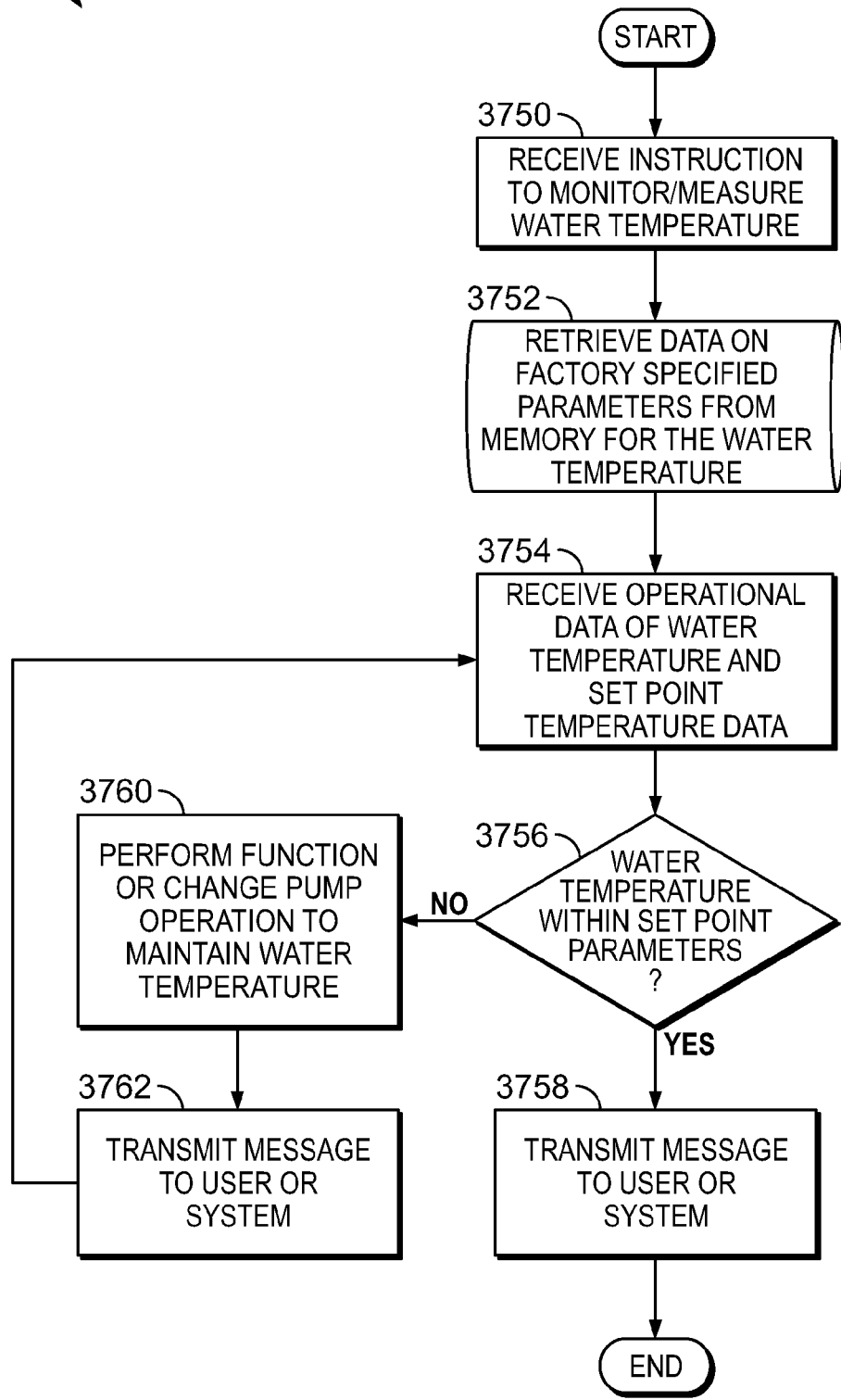


FIG. 19K

84

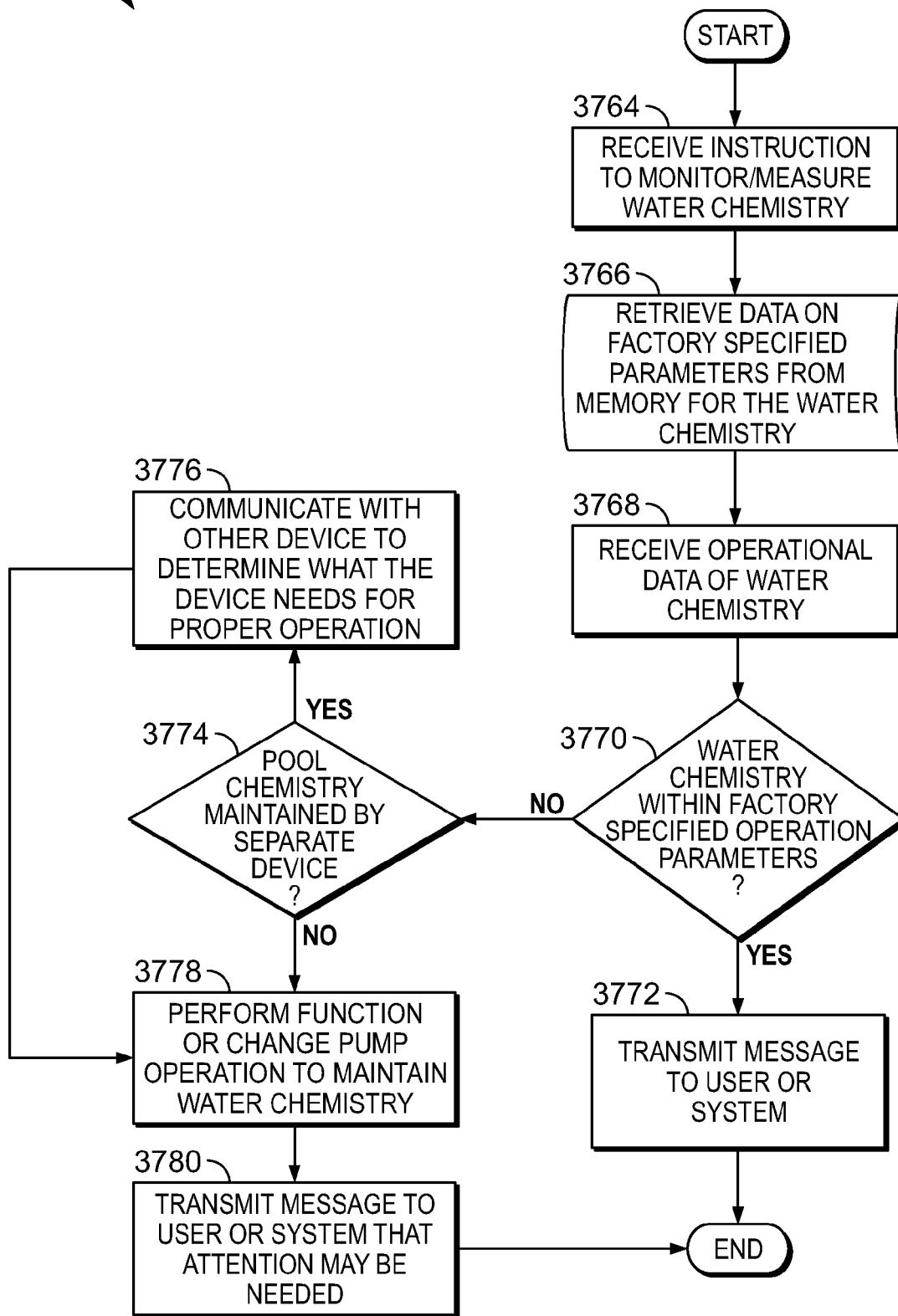


FIG. 19L

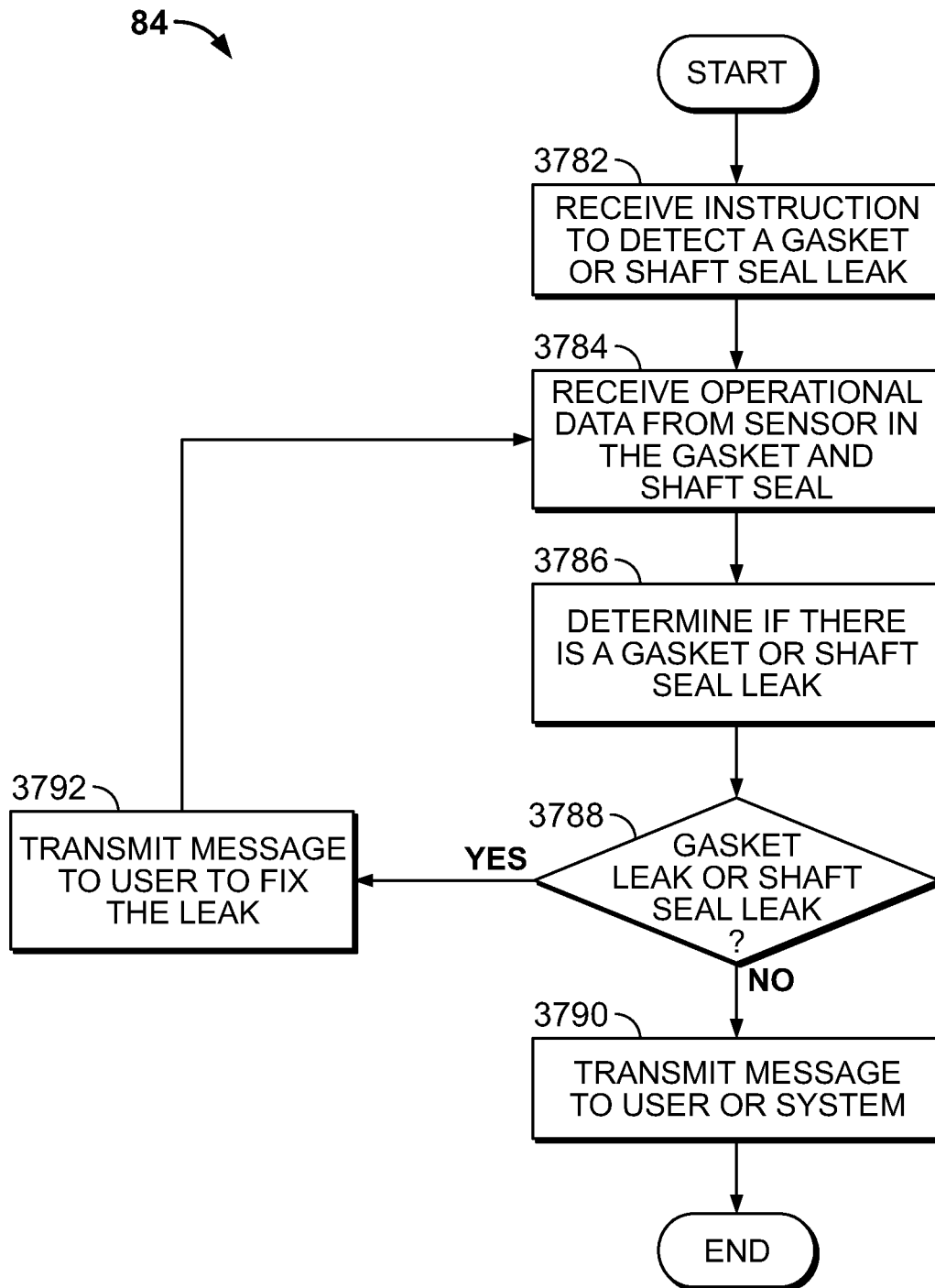


FIG. 19M

84 →

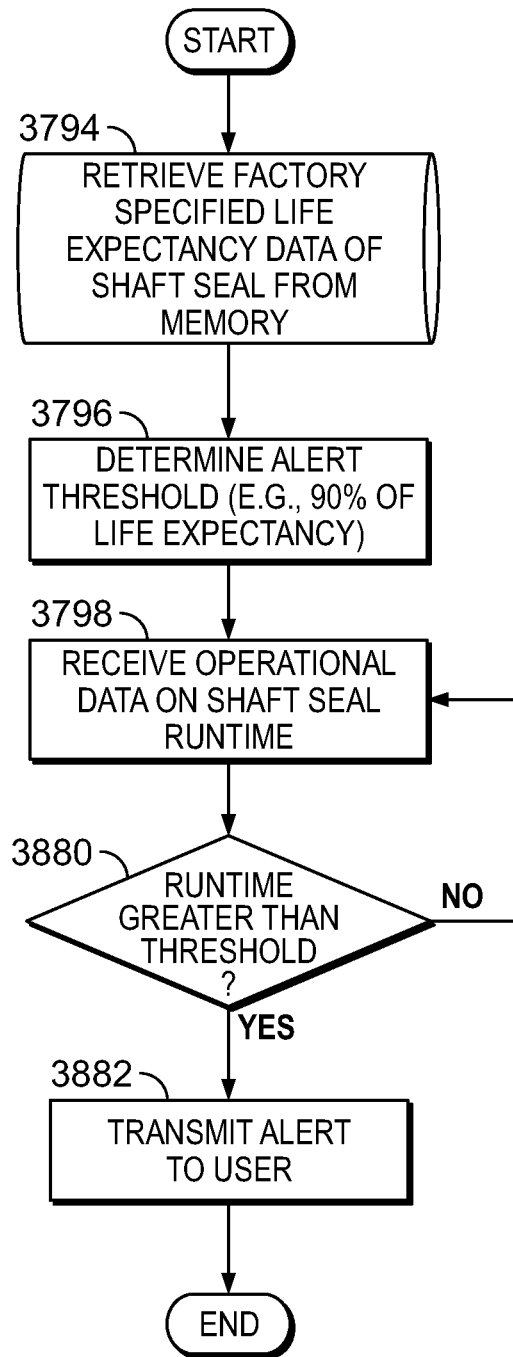


FIG. 19N

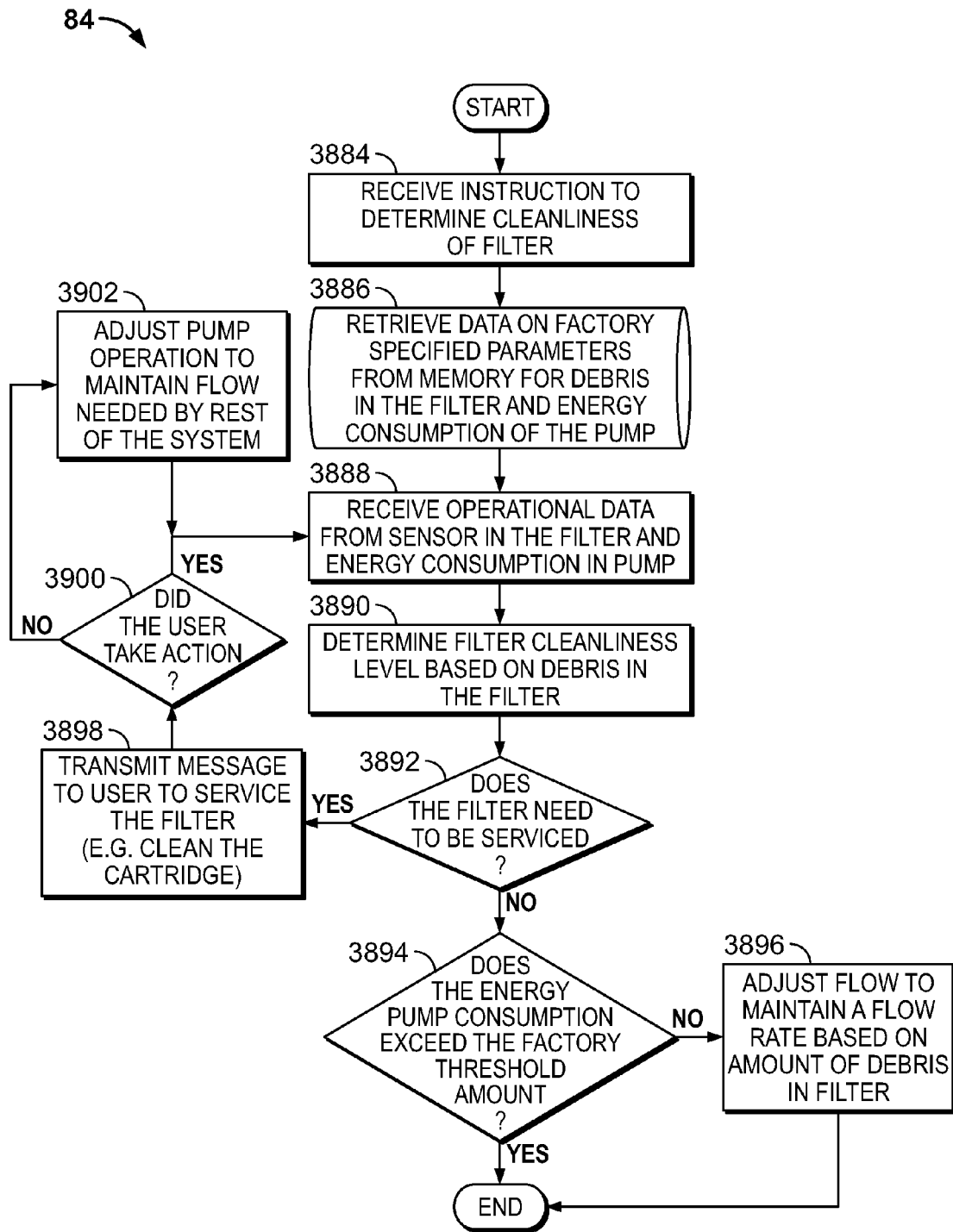


FIG. 190

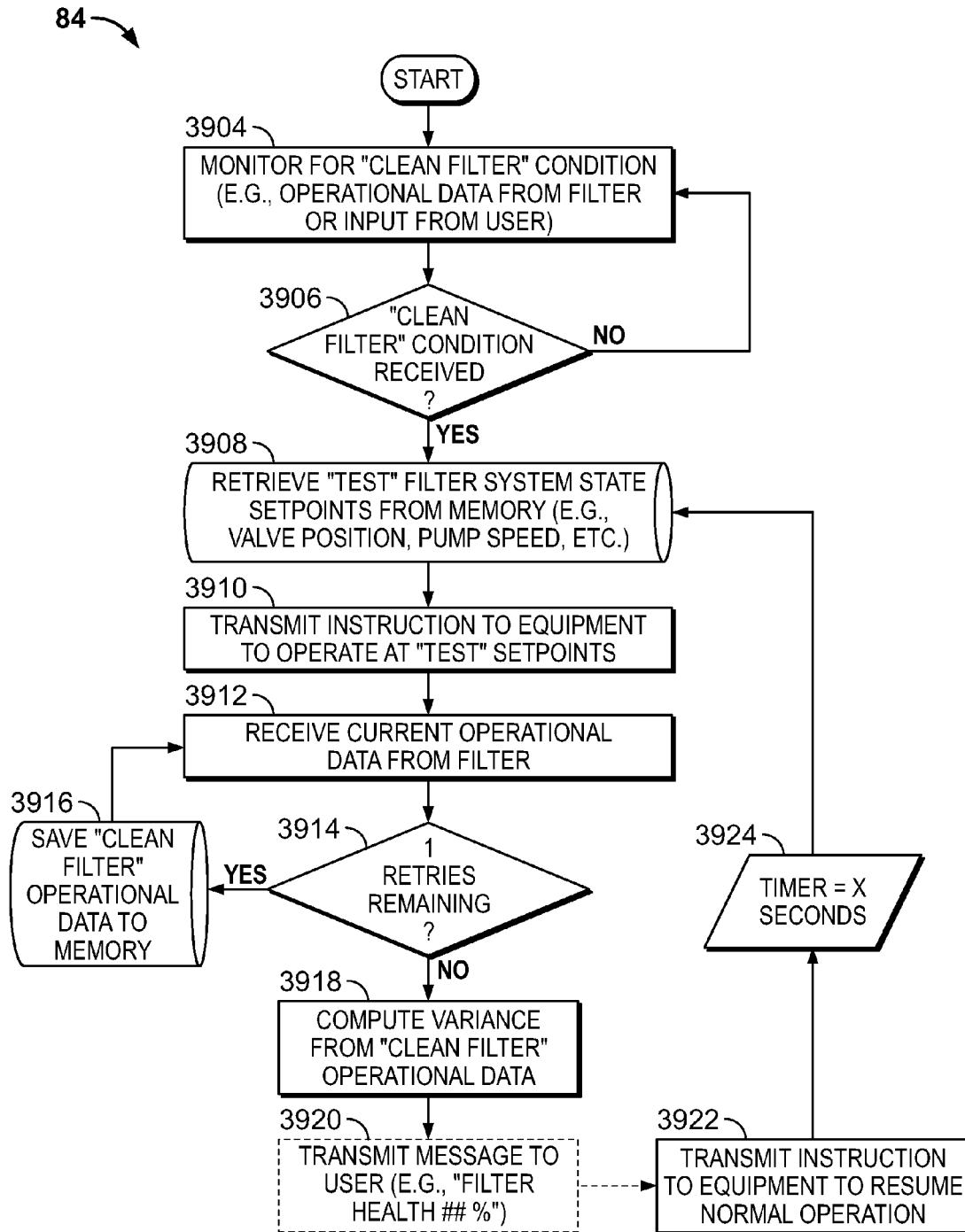


FIG. 19P

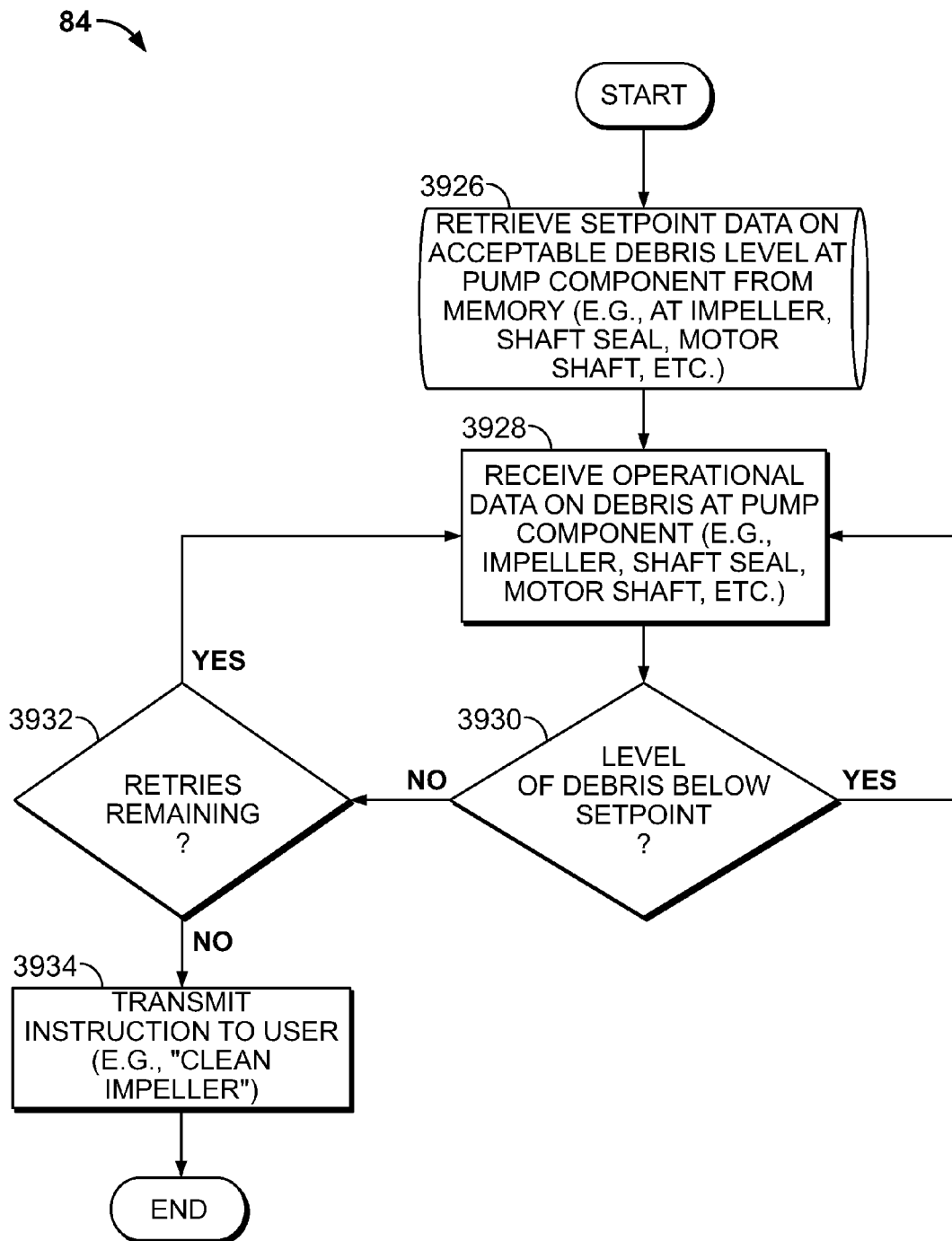


FIG. 19Q

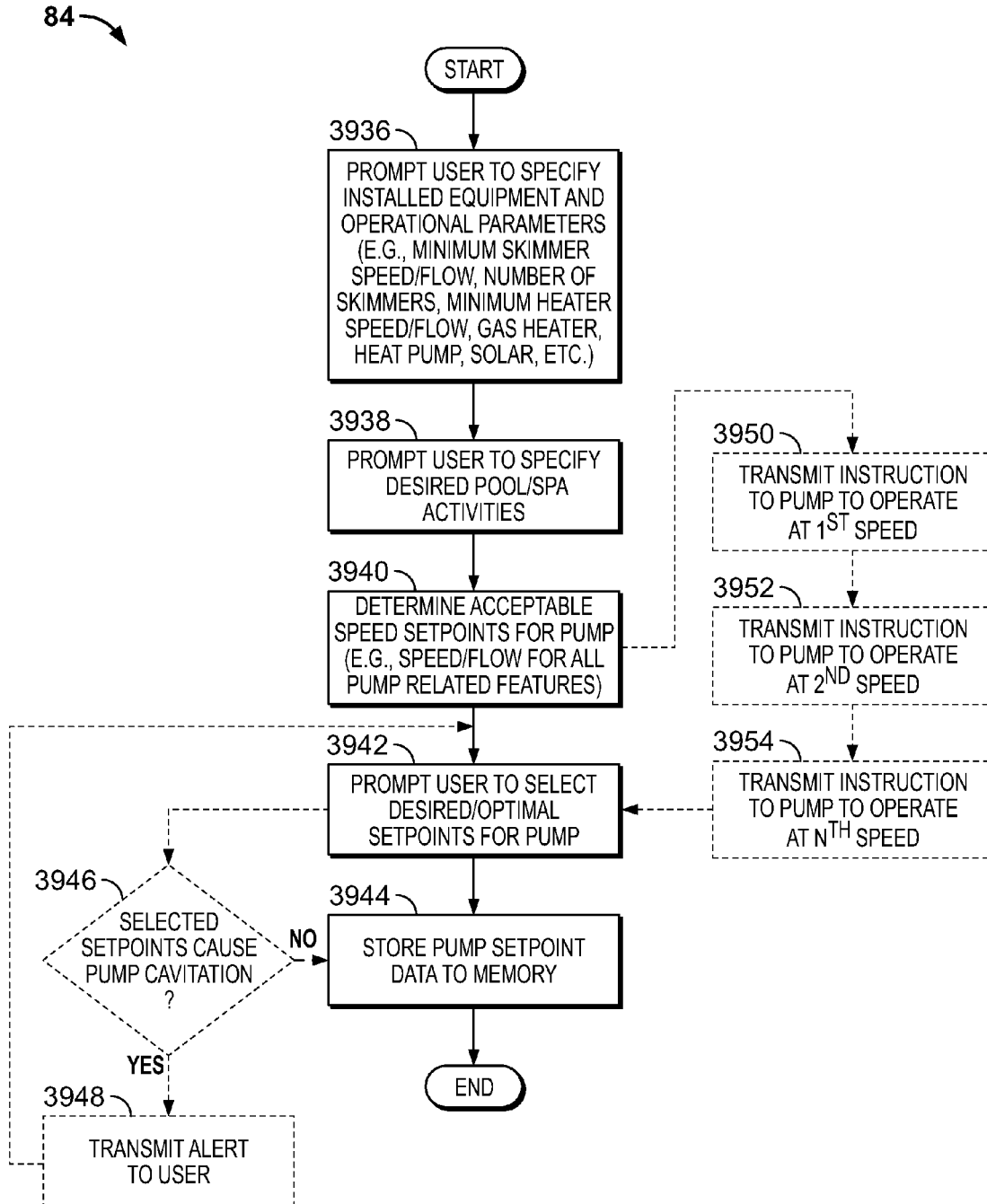


FIG. 19R

84 →

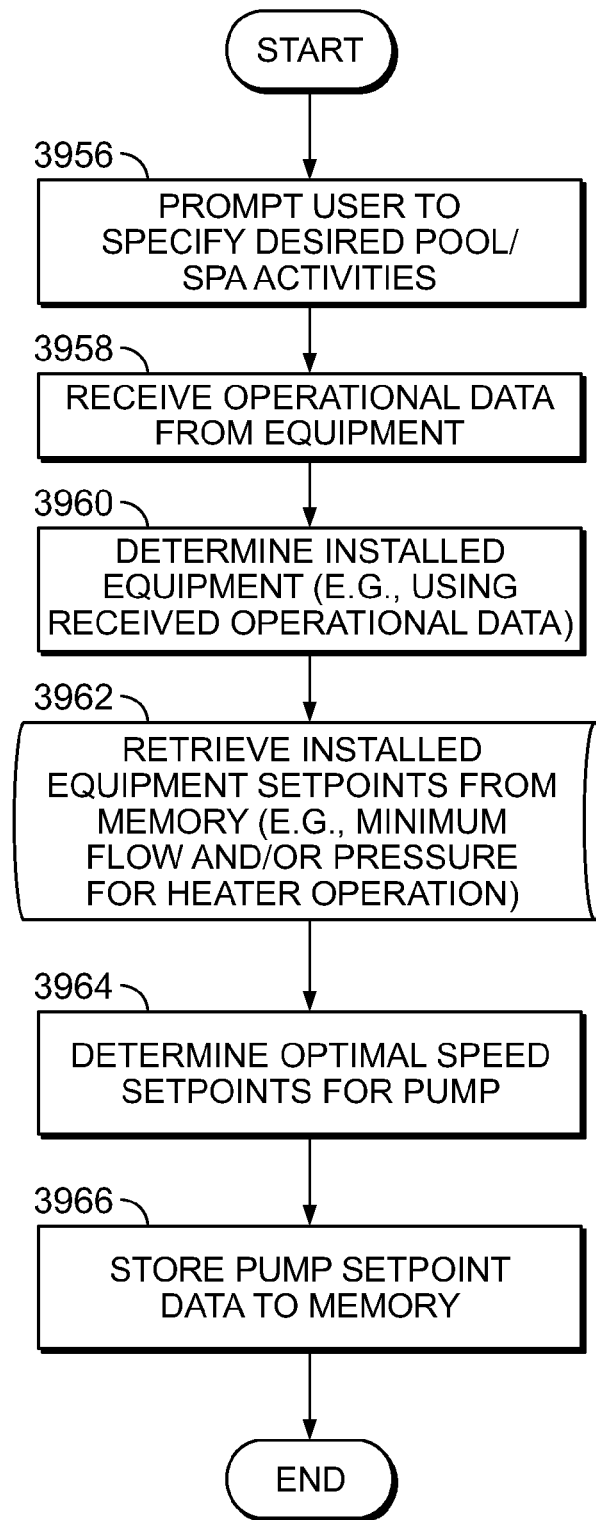


FIG. 19S

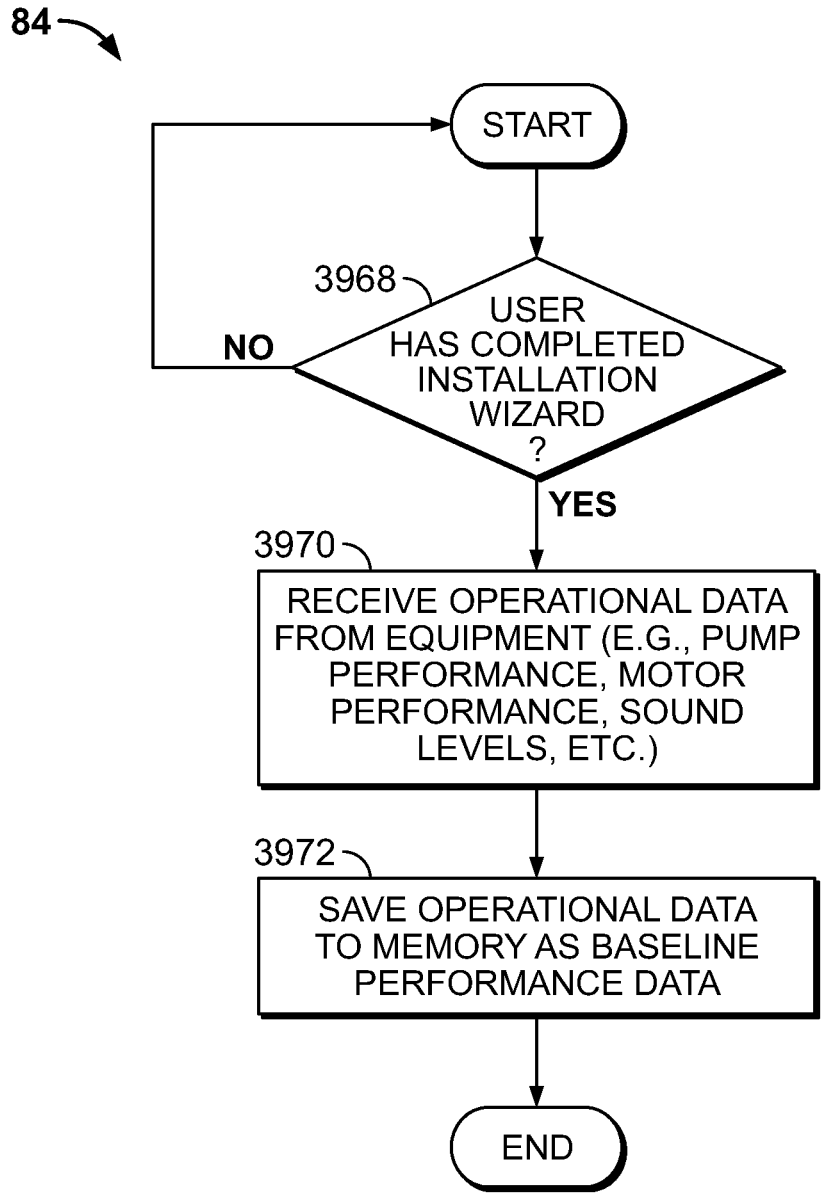
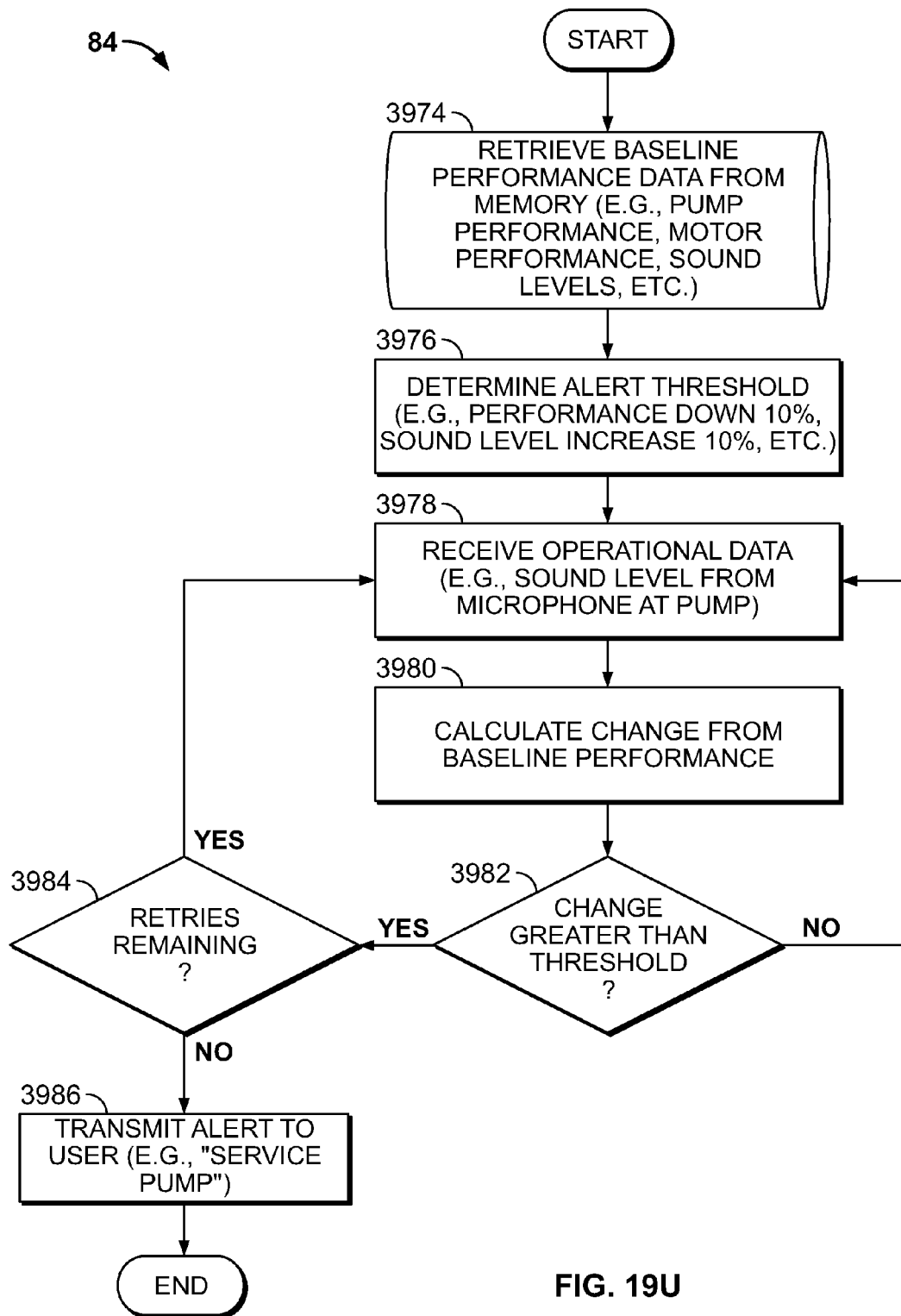


FIG. 19T



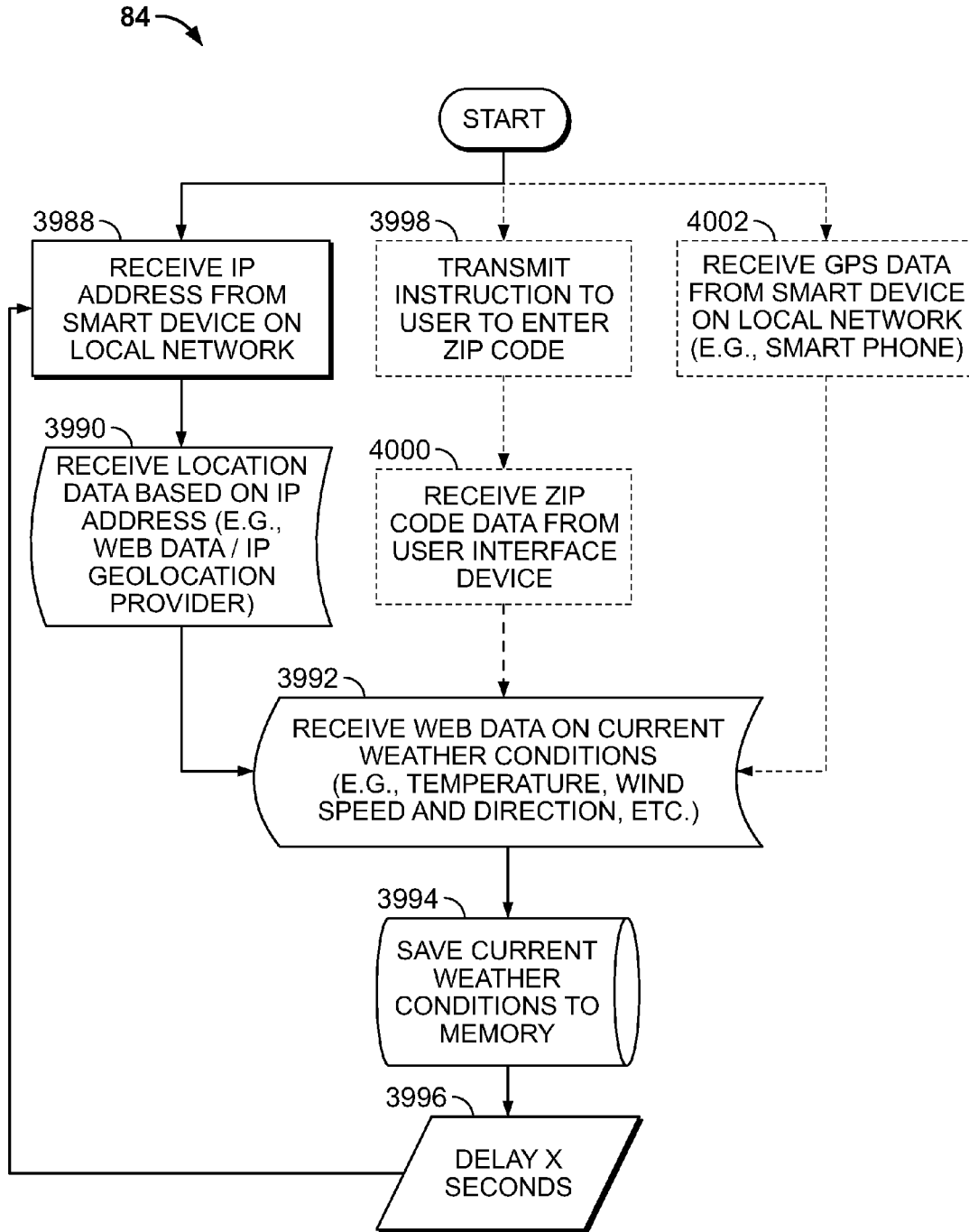


FIG. 19V

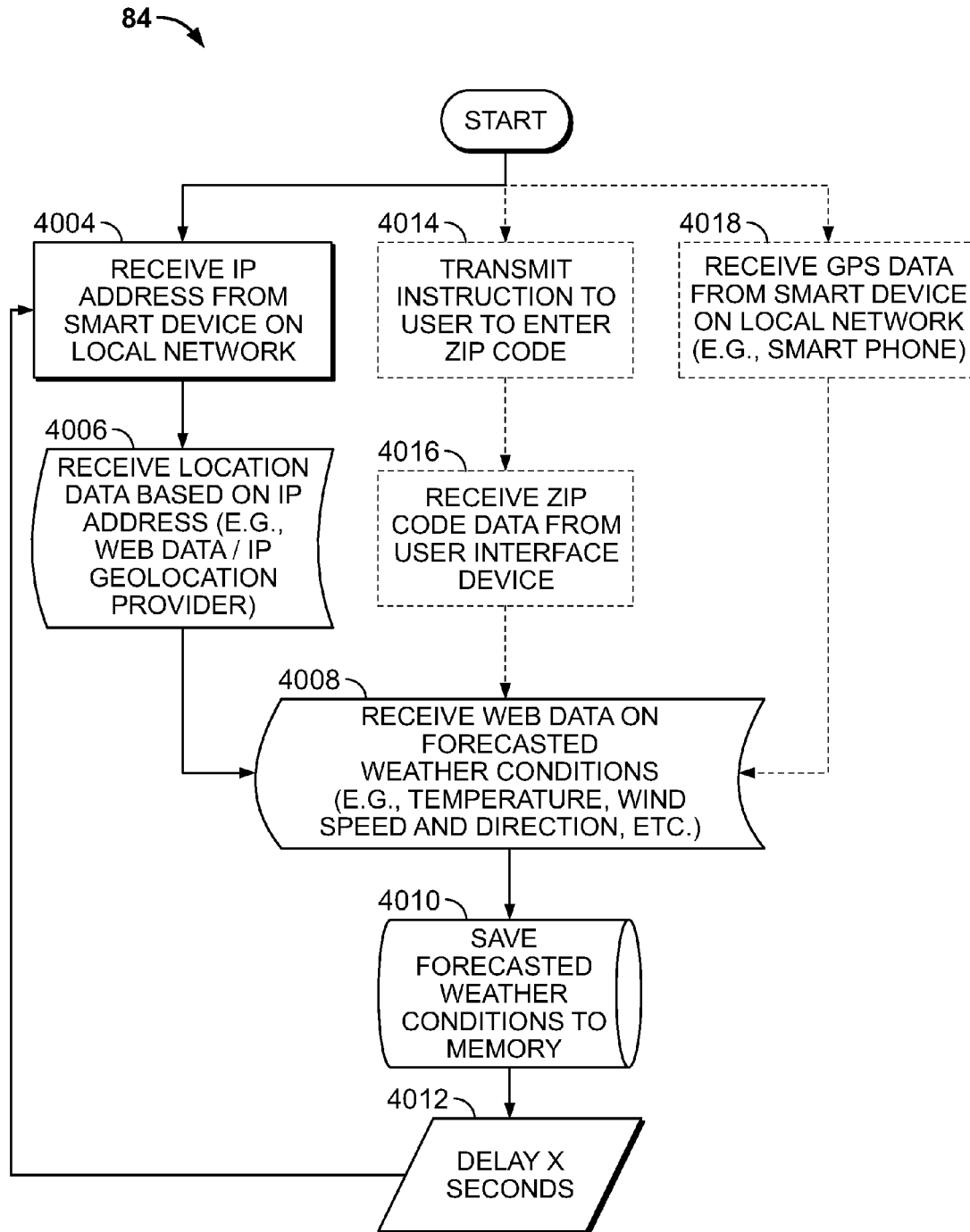


FIG. 19W

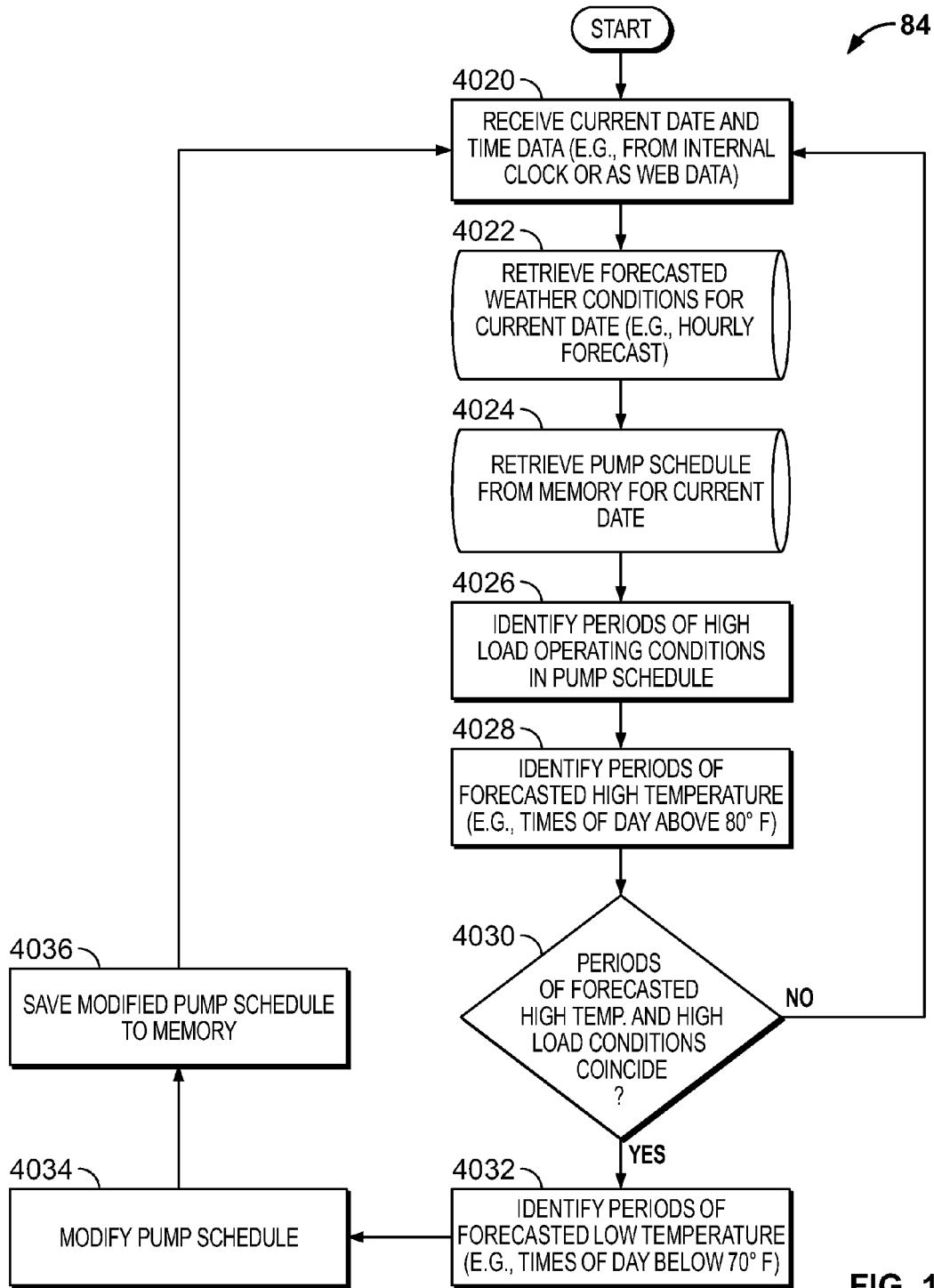


FIG. 19X

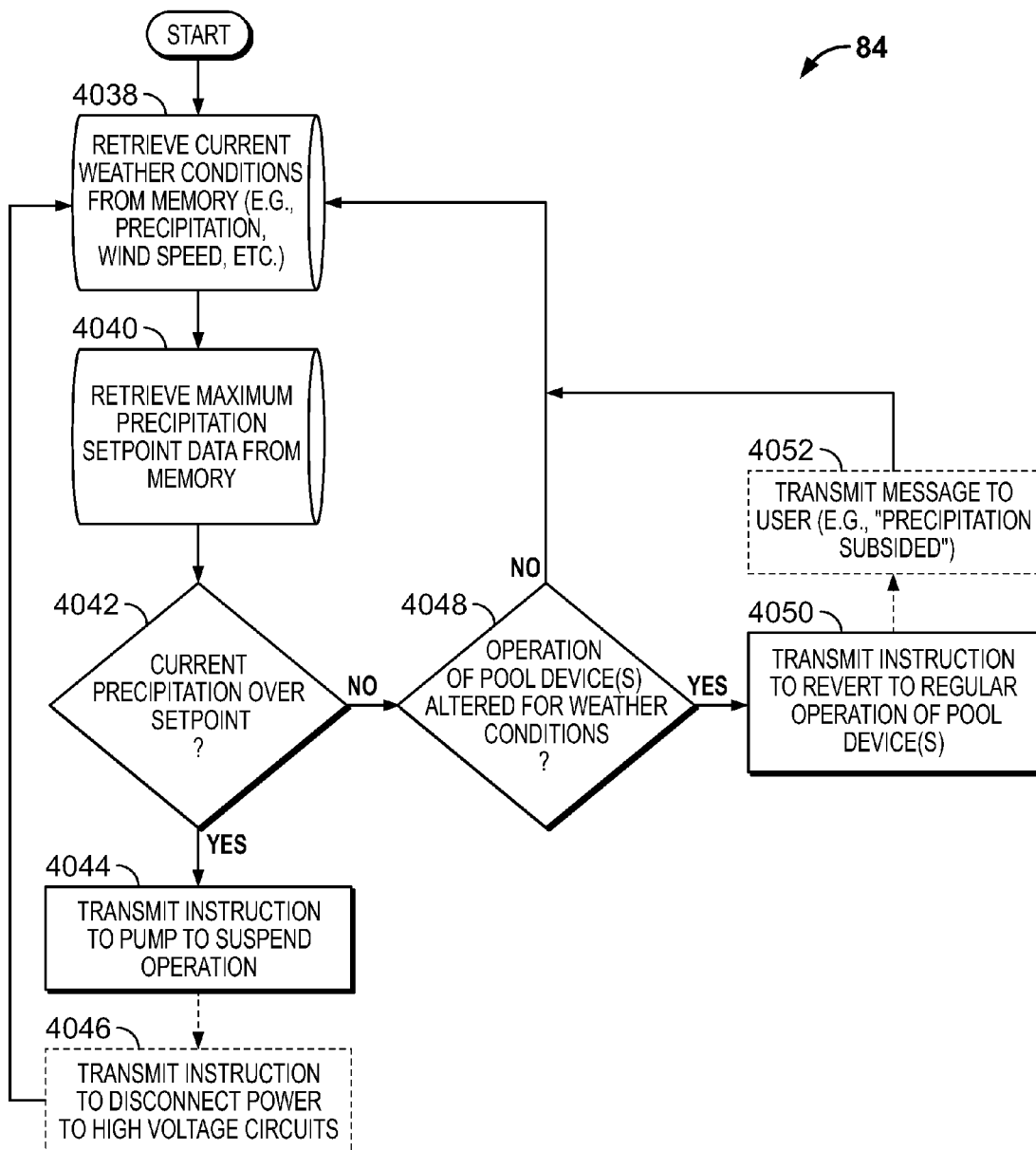


FIG. 19Y

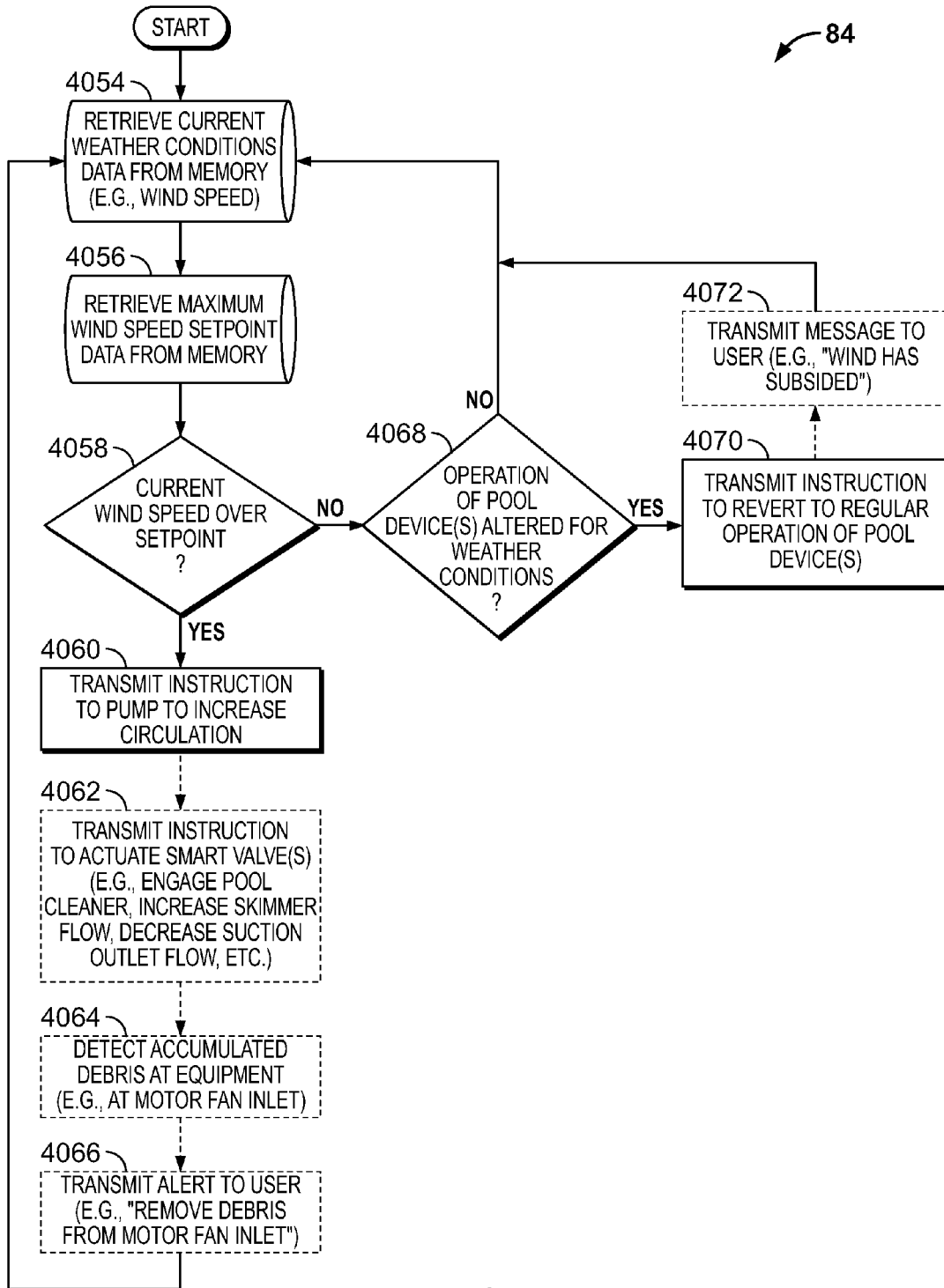


FIG. 19Z

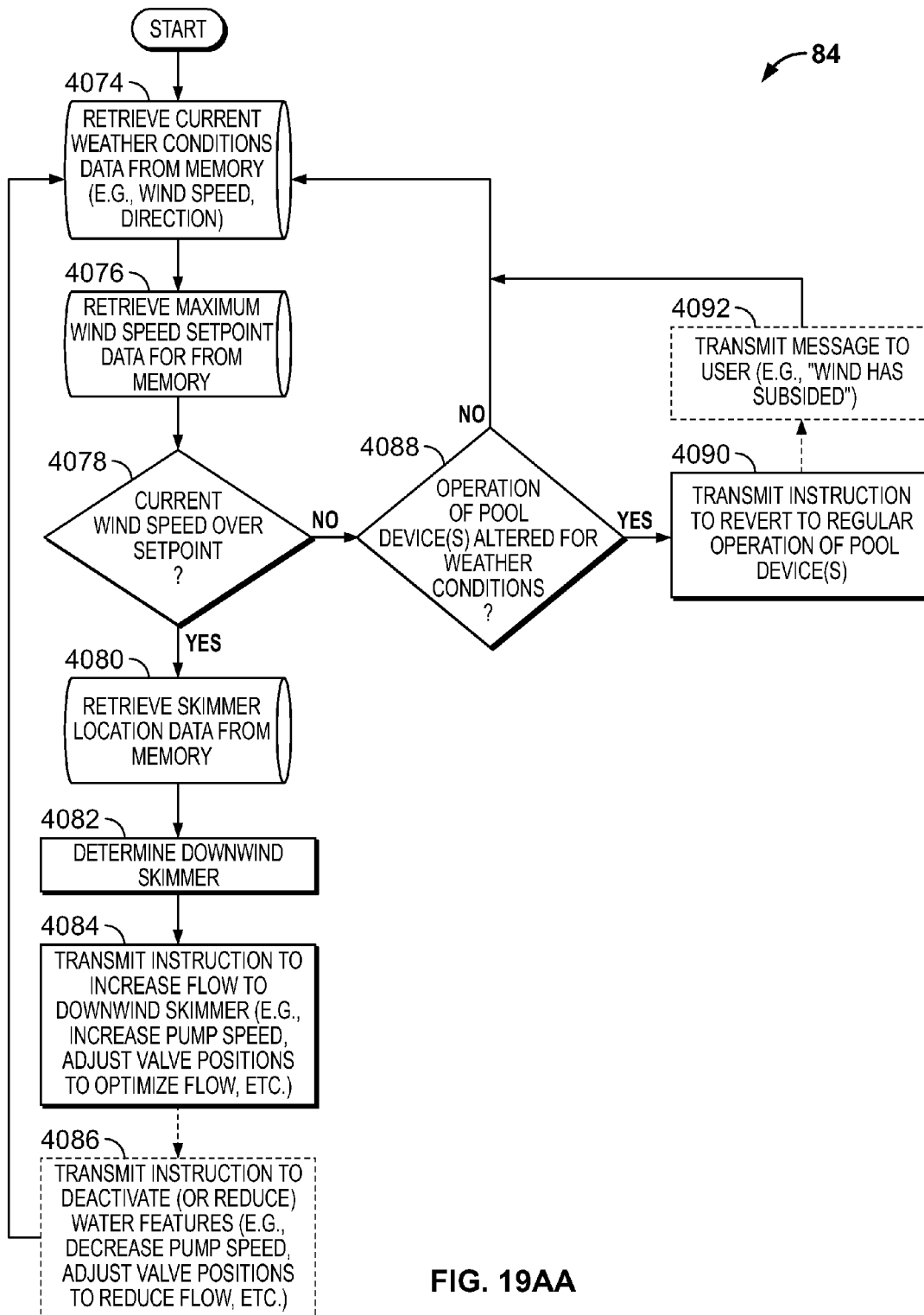


FIG. 19AA

84

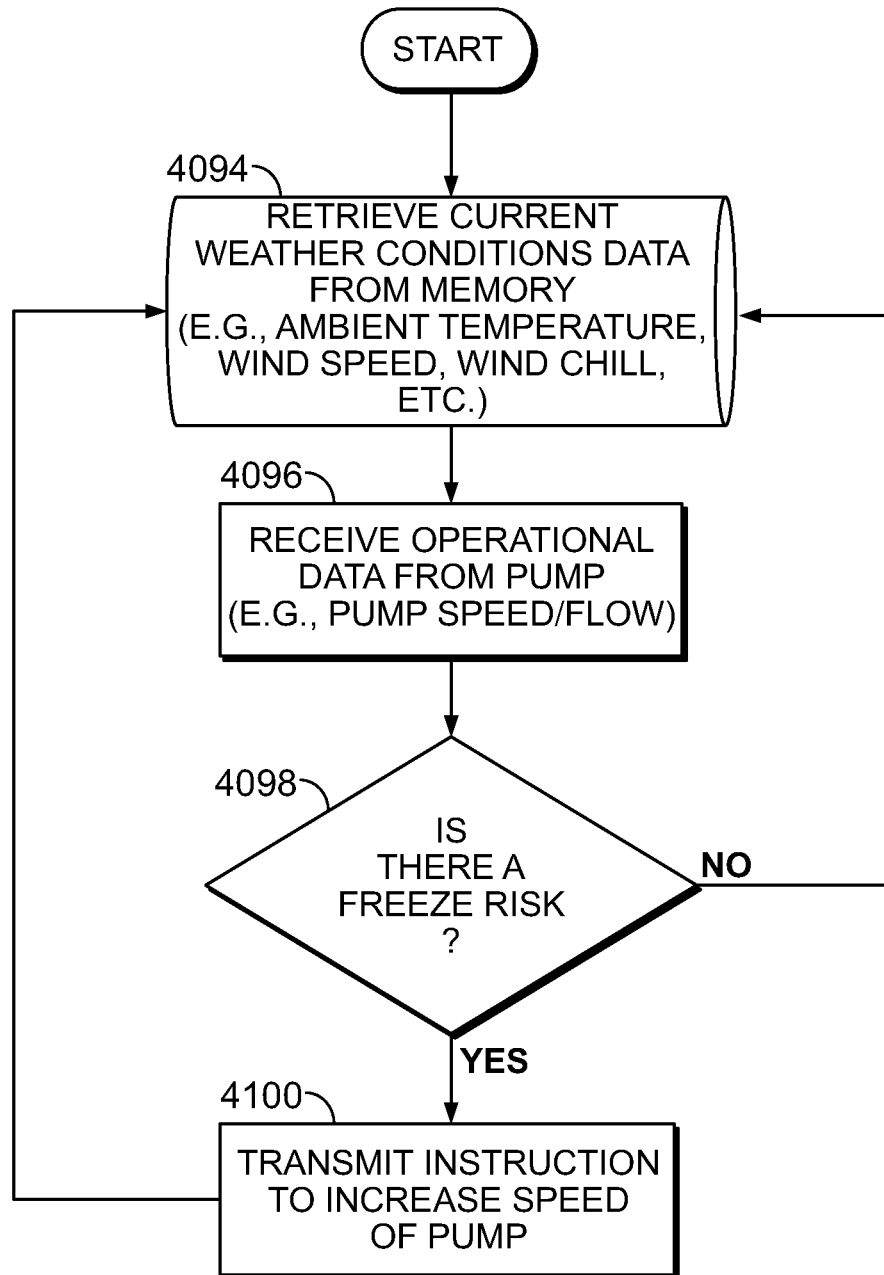


FIG. 19AB

84

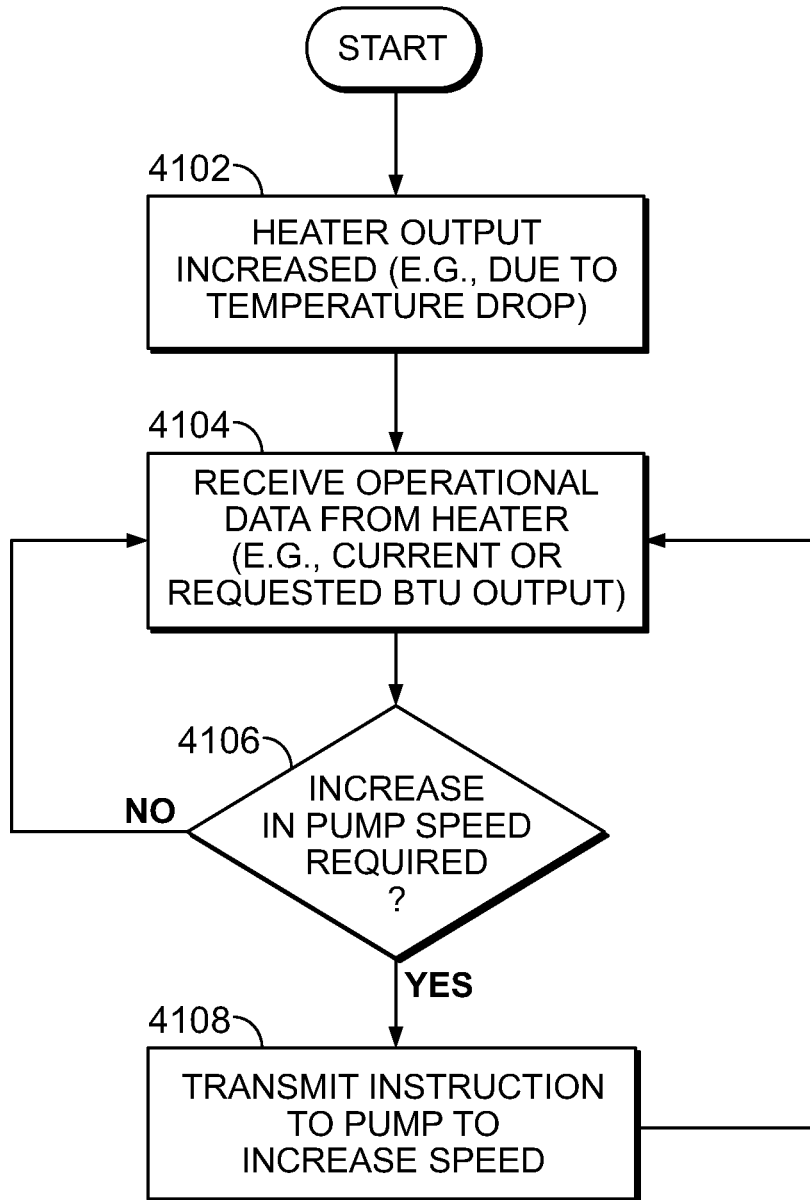


FIG. 19AC

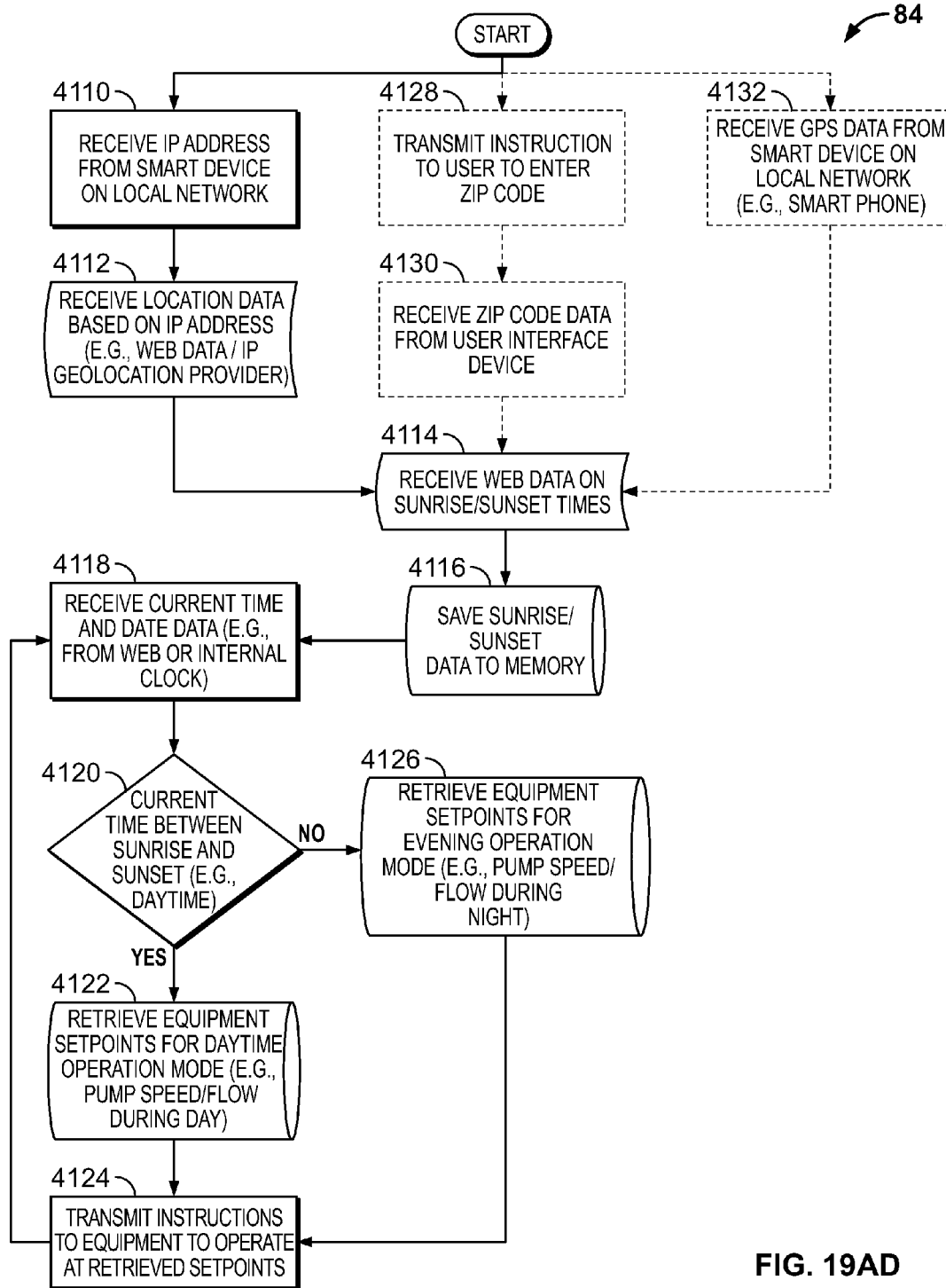


FIG. 19AD

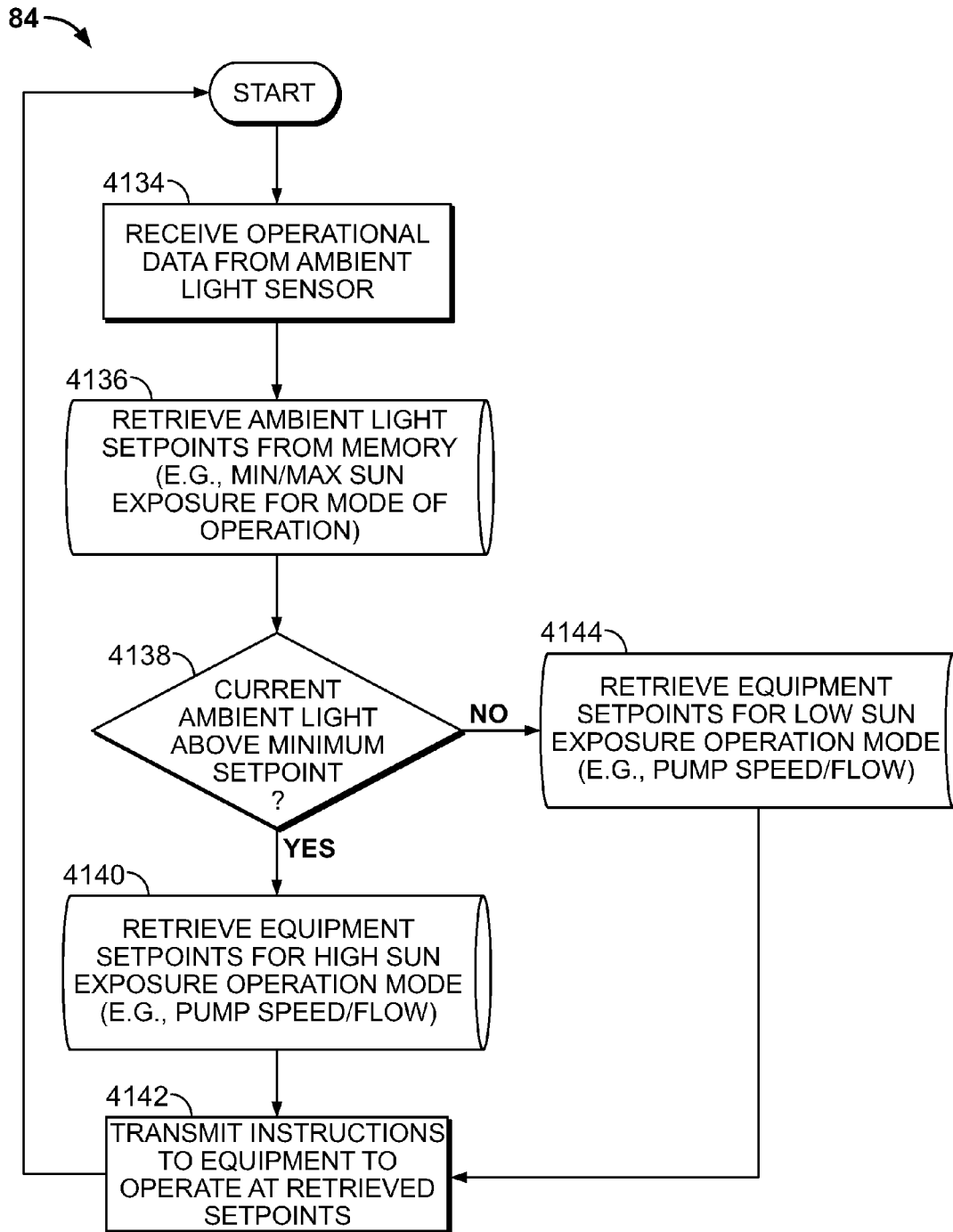


FIG. 19AE

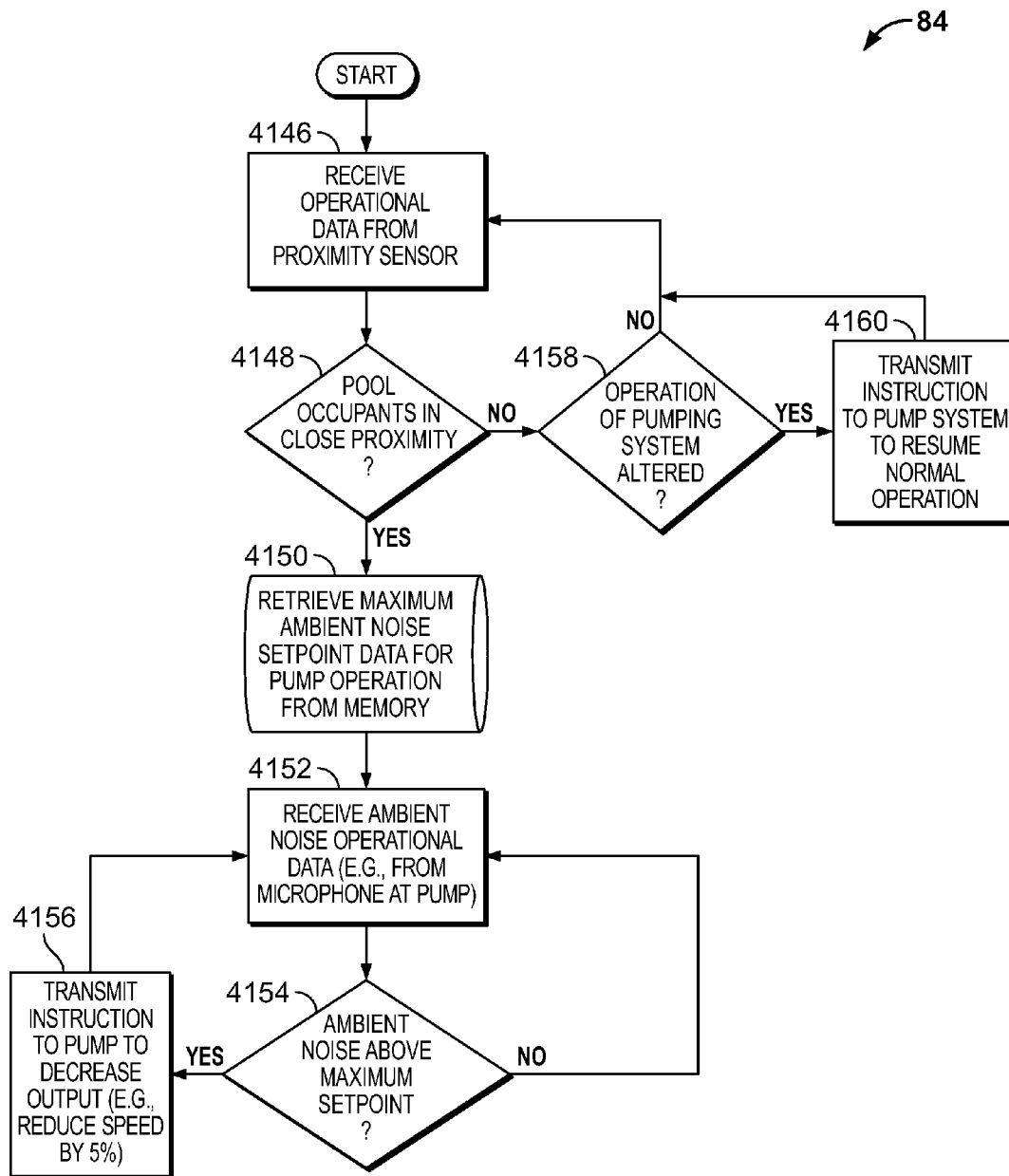


FIG. 19AF

84

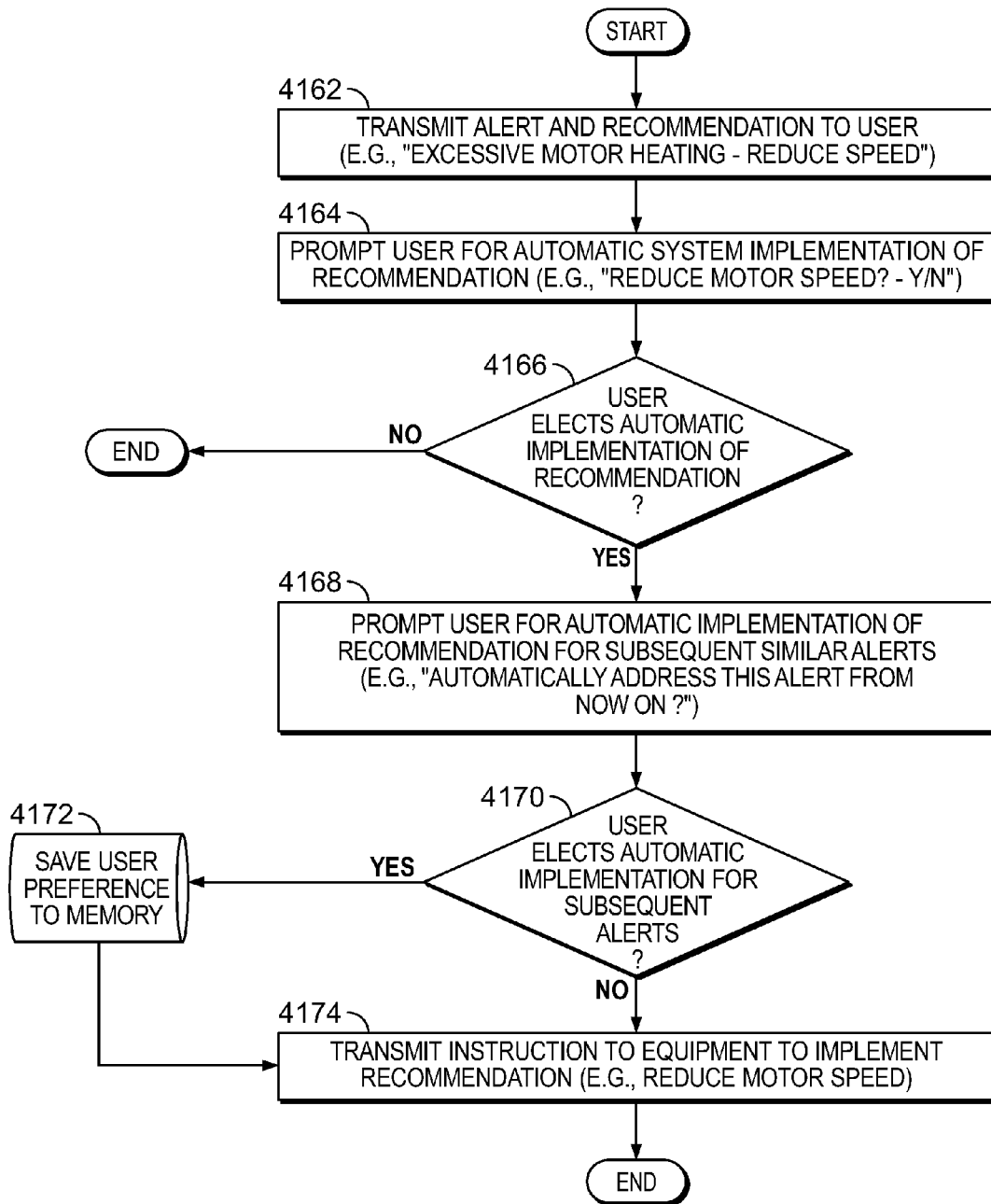


FIG. 19AG

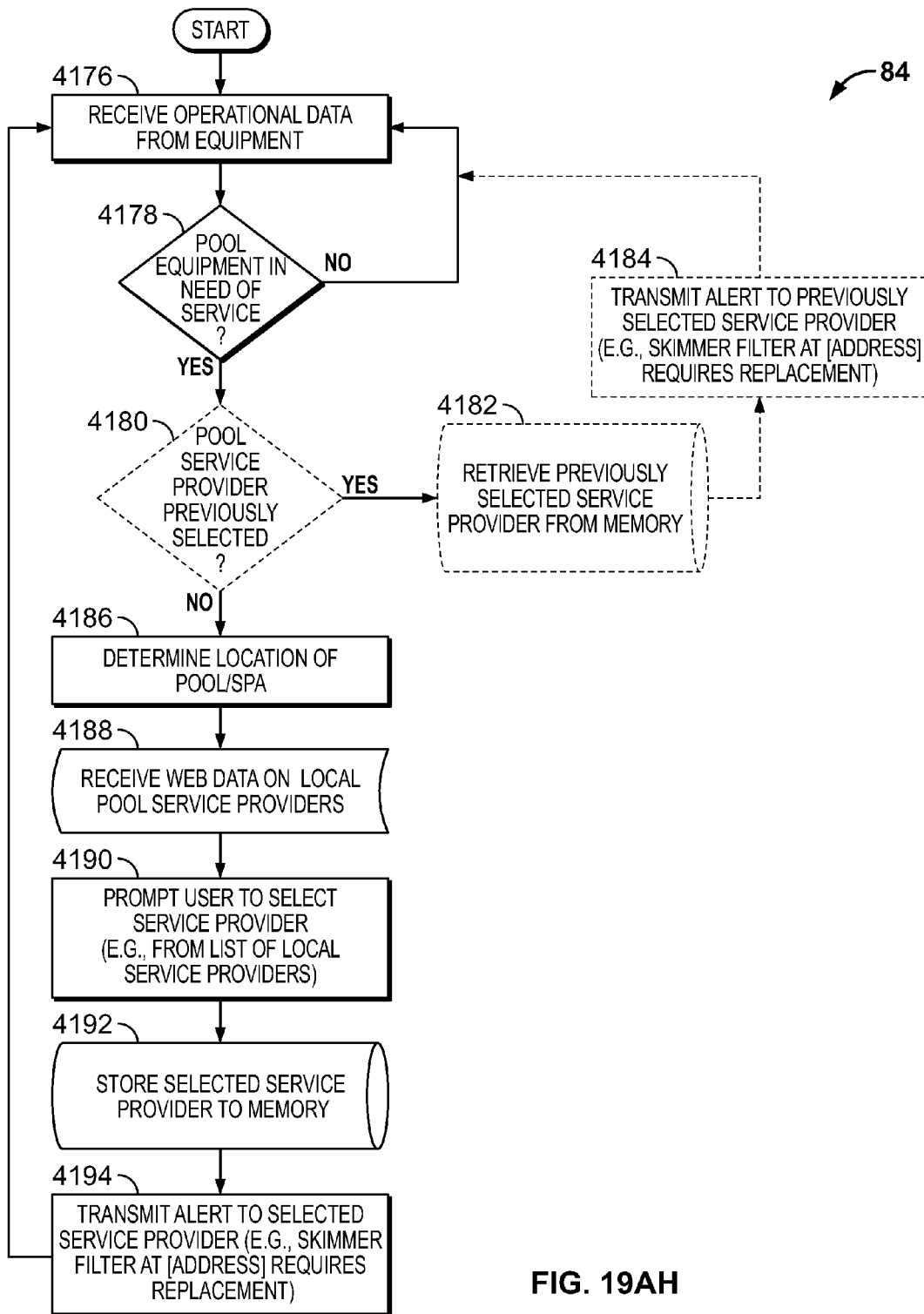


FIG. 19AH

84 →

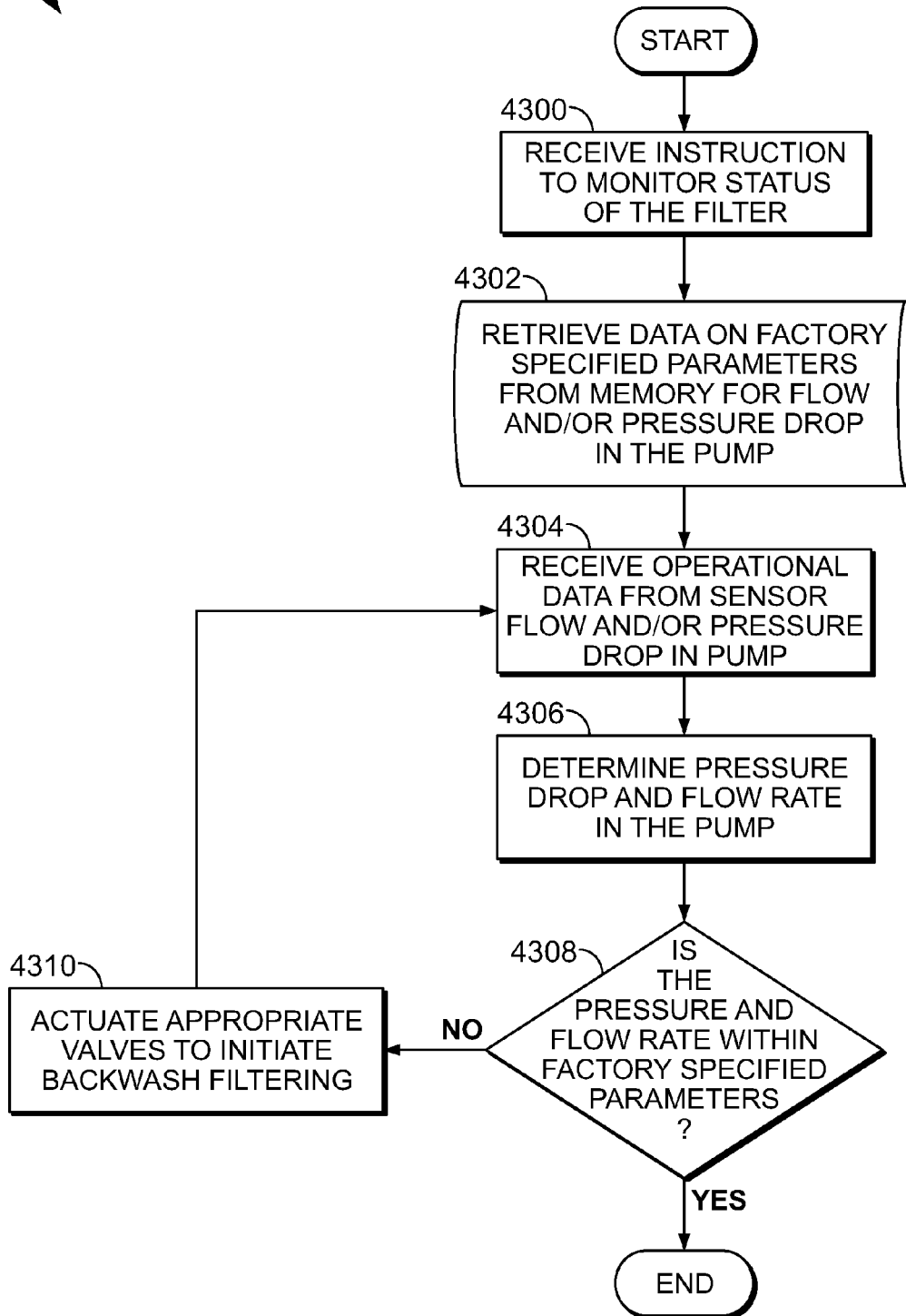


FIG. 19AI

84 →

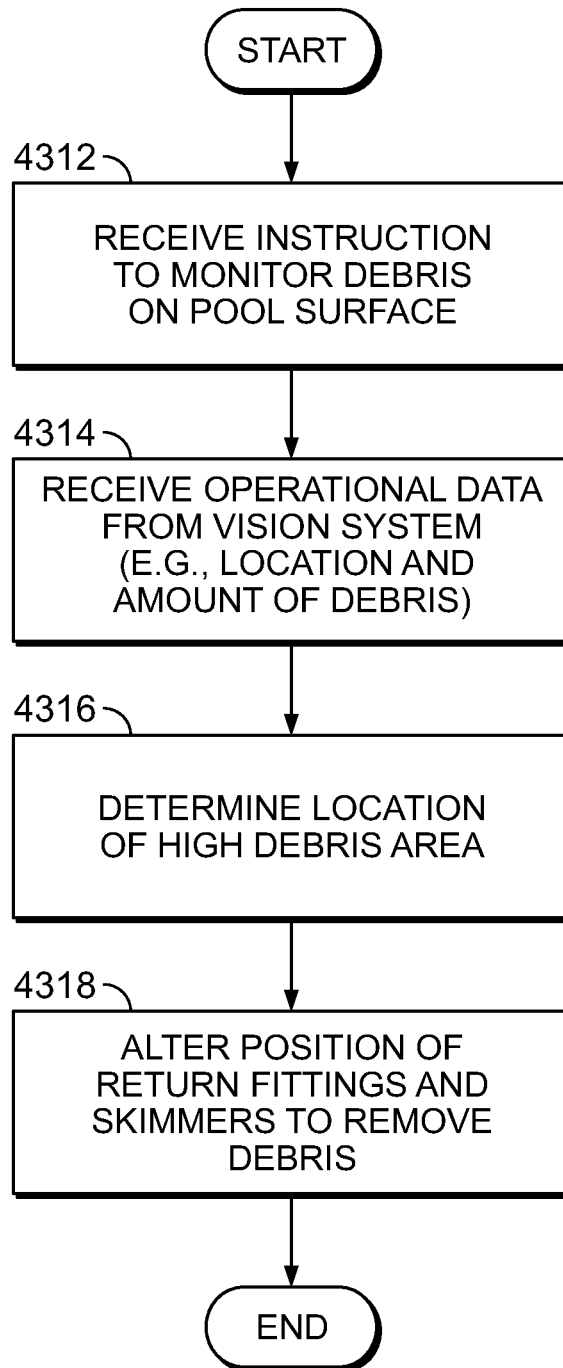


FIG. 19AJ

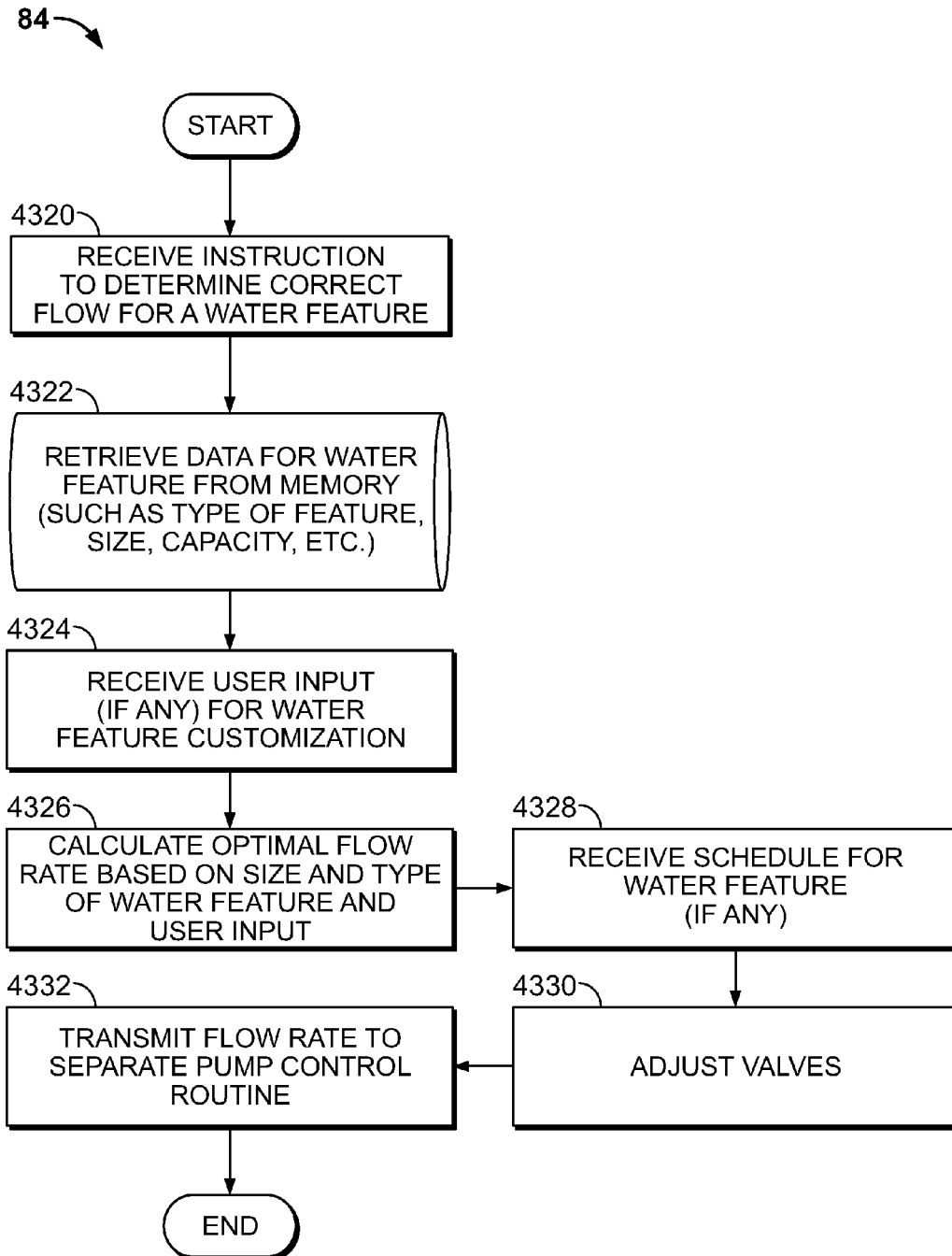


FIG. 19AK

84 ↗

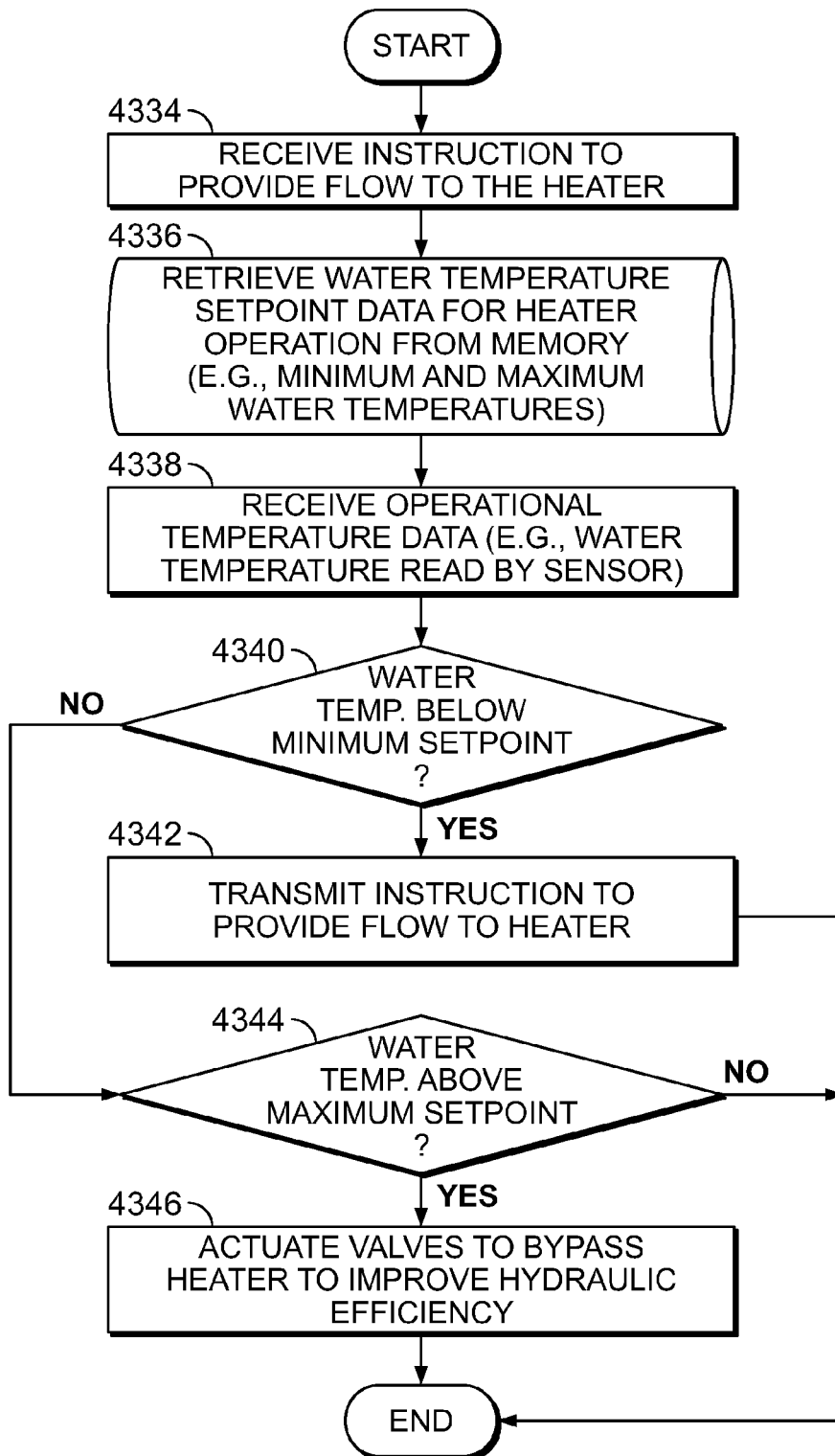


FIG. 19AL

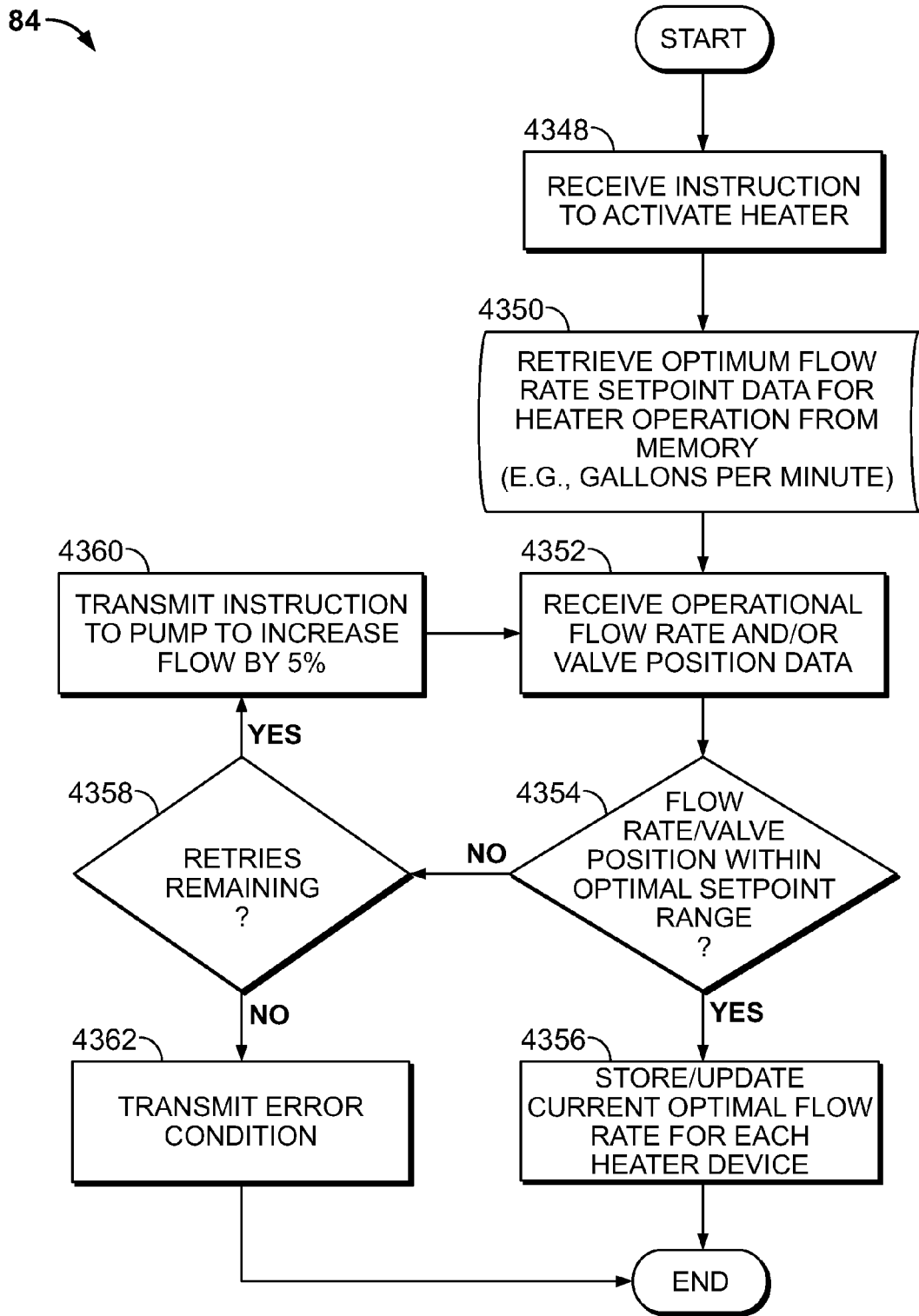


FIG. 19AM

84

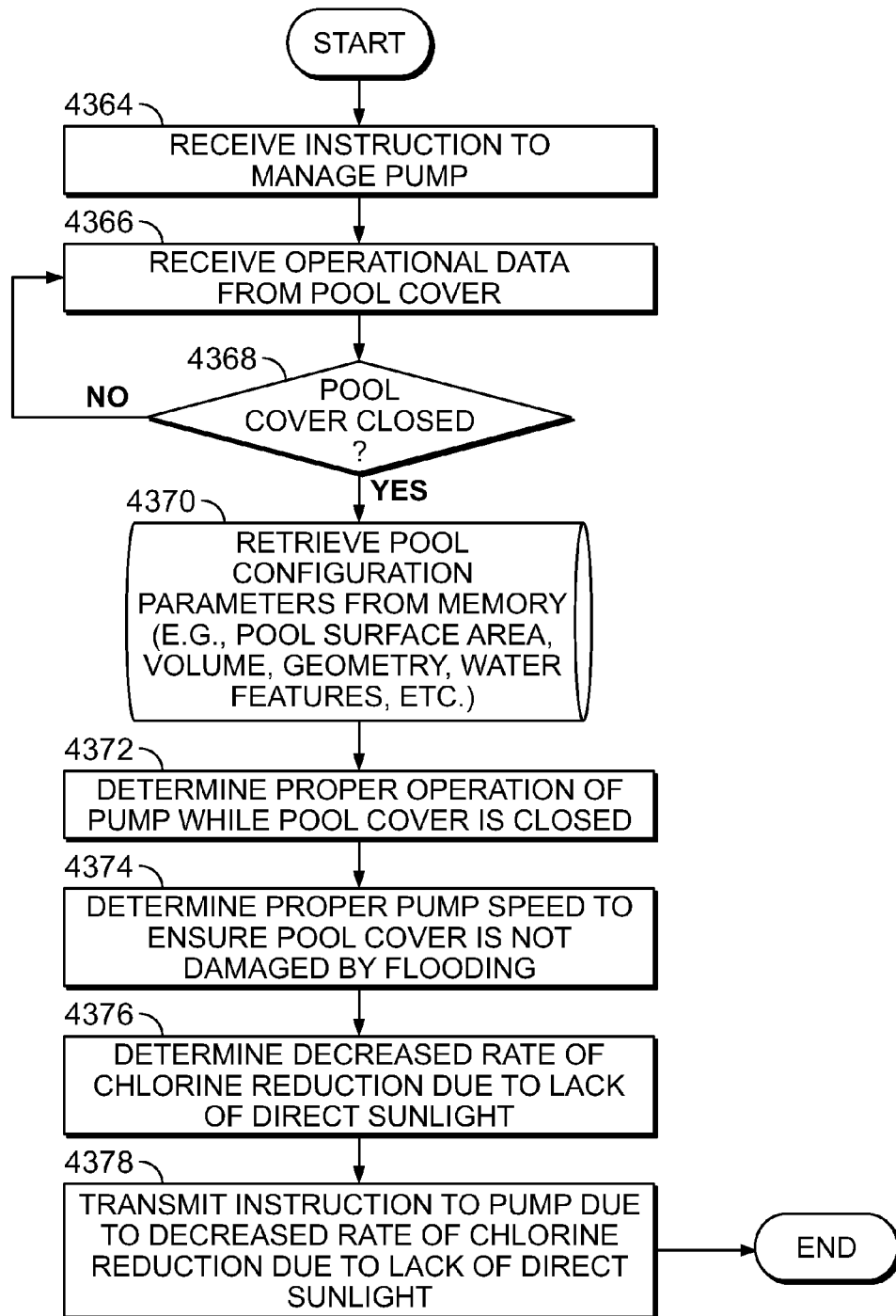


FIG. 19AN

84

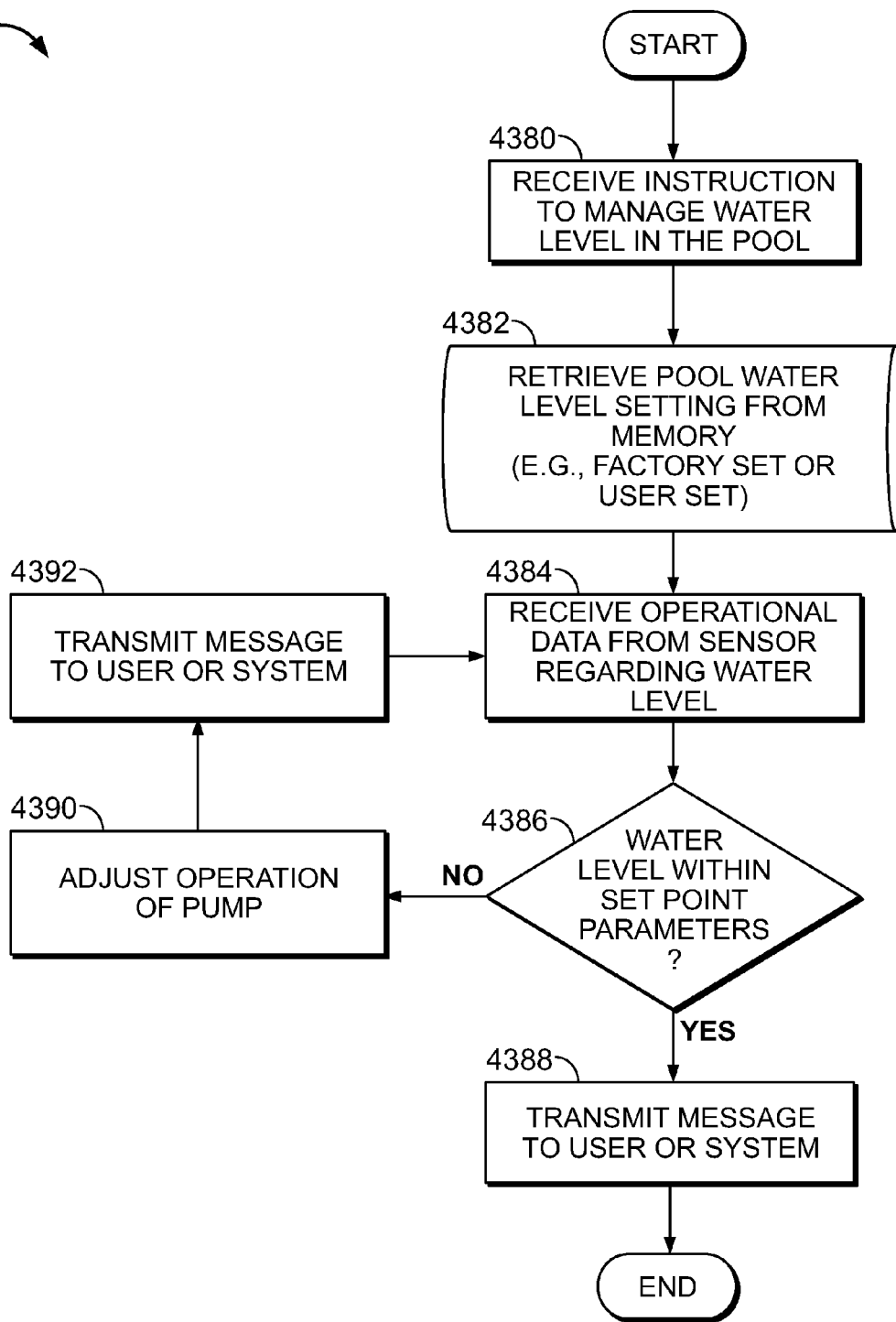


FIG. 19AO

84

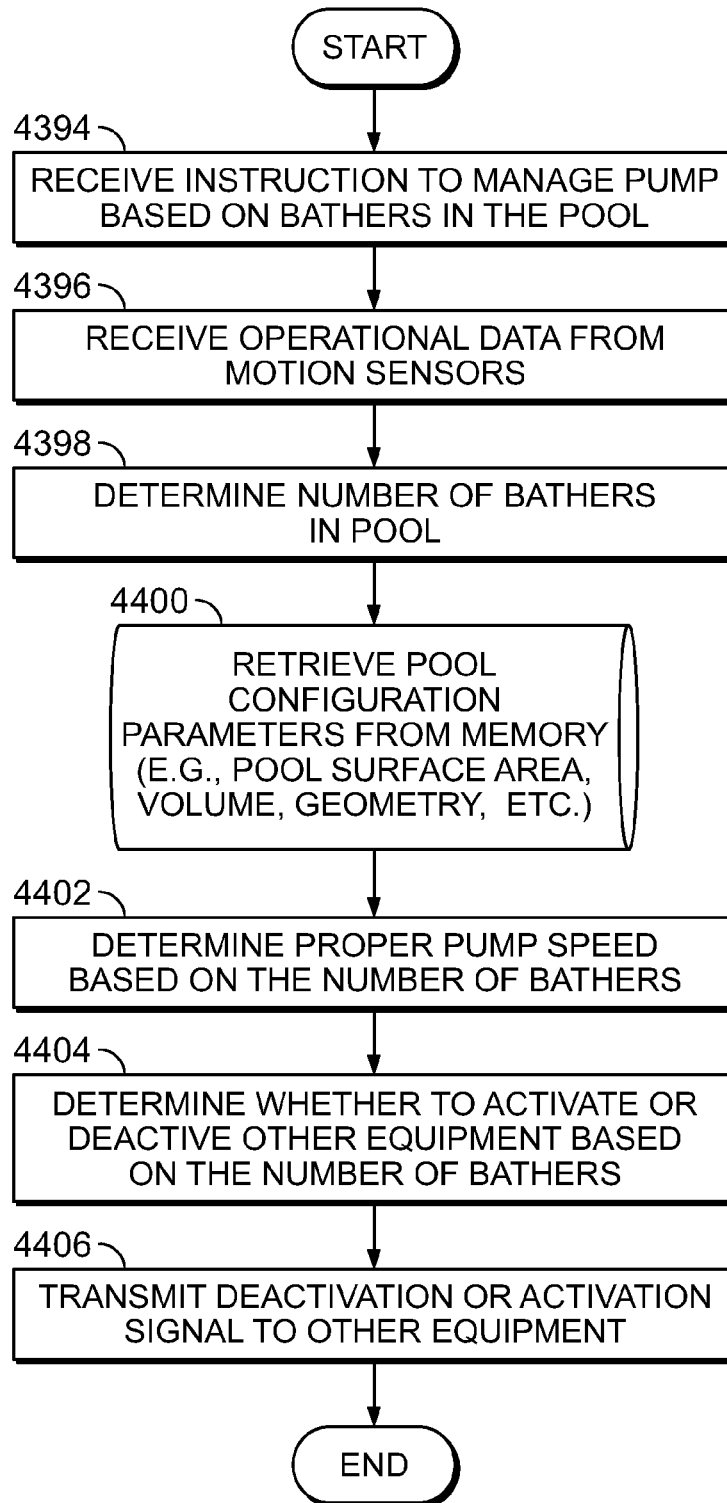


FIG. 19AP

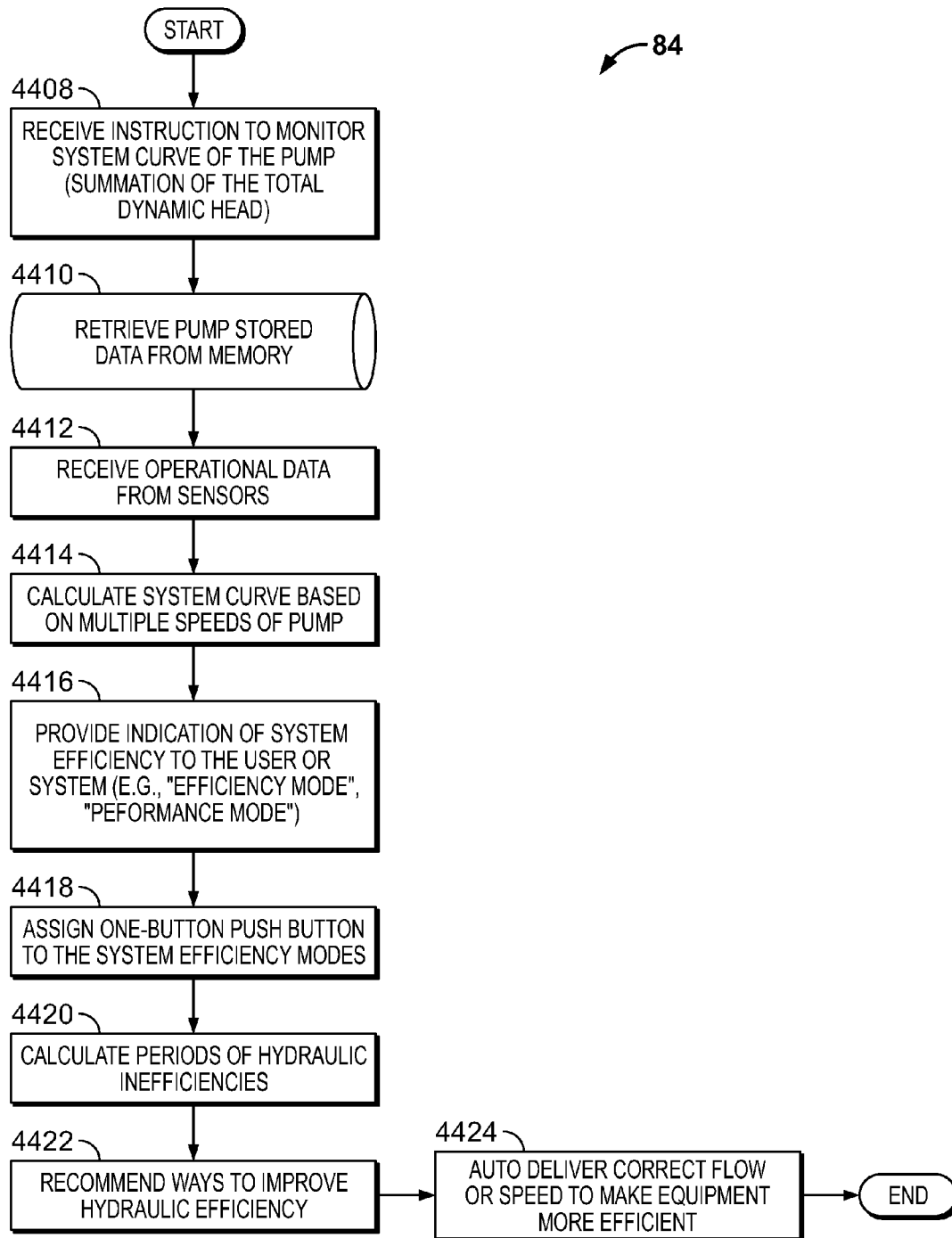


FIG. 19AQ

84 →

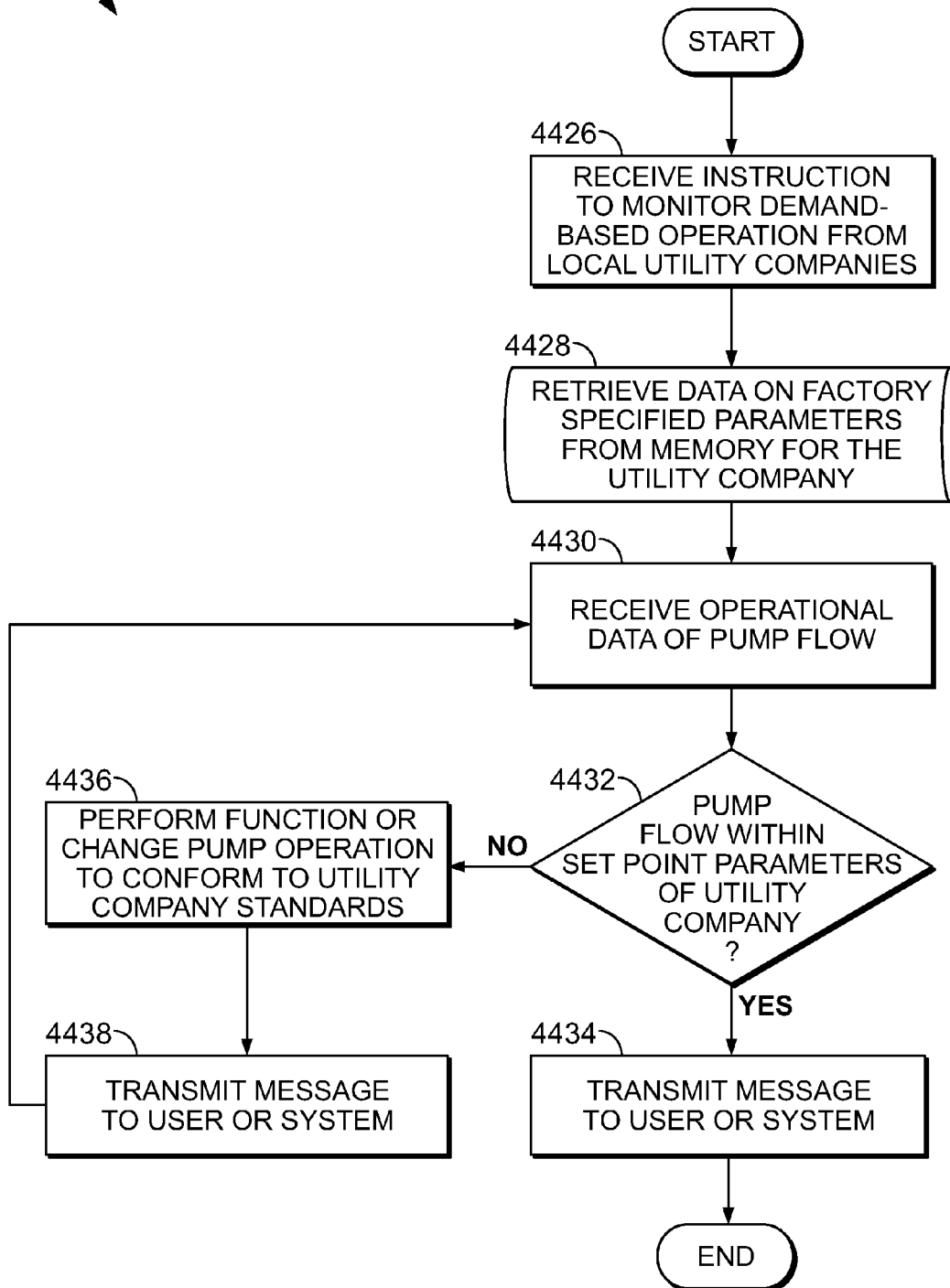


FIG. 19AR

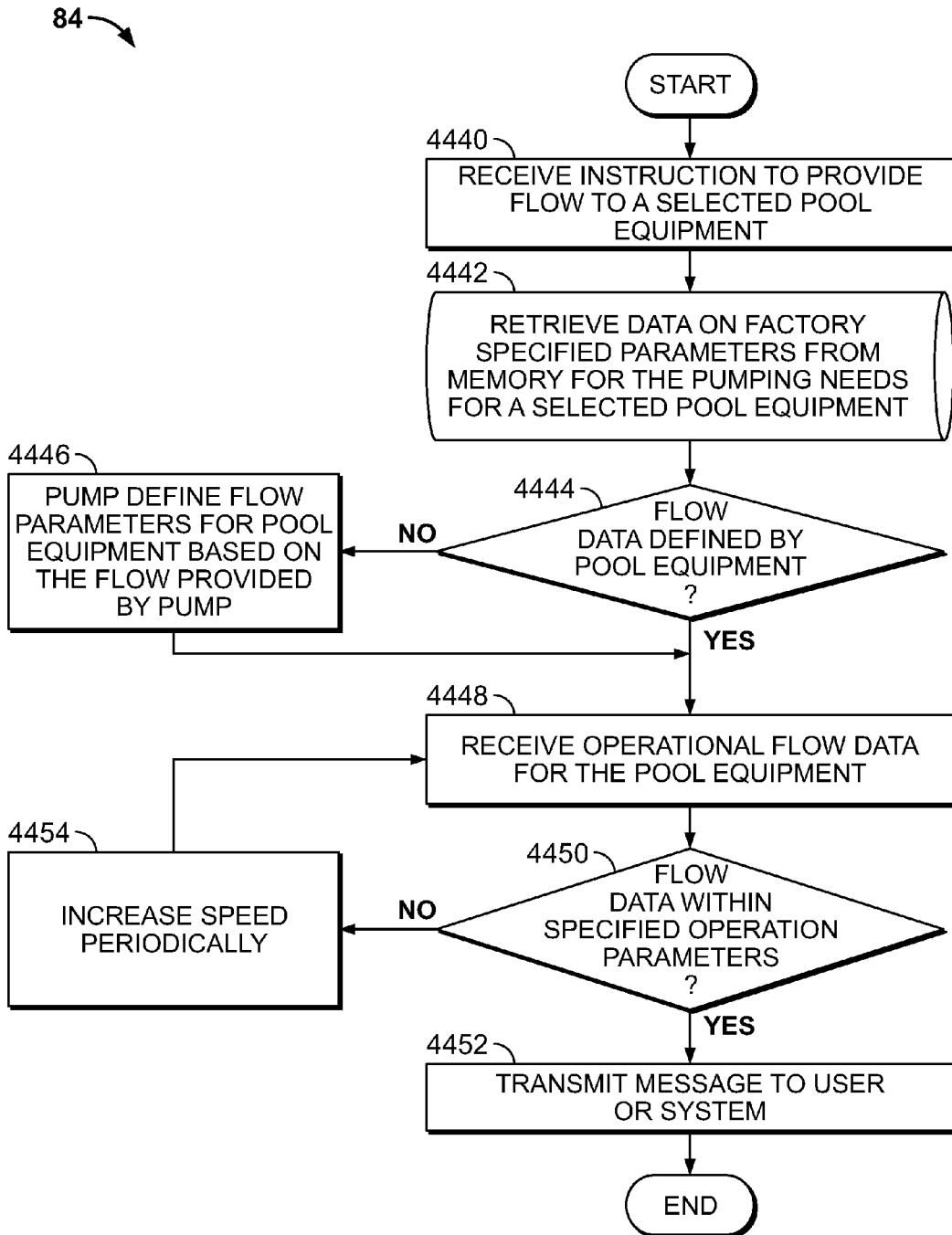


FIG. 19AS

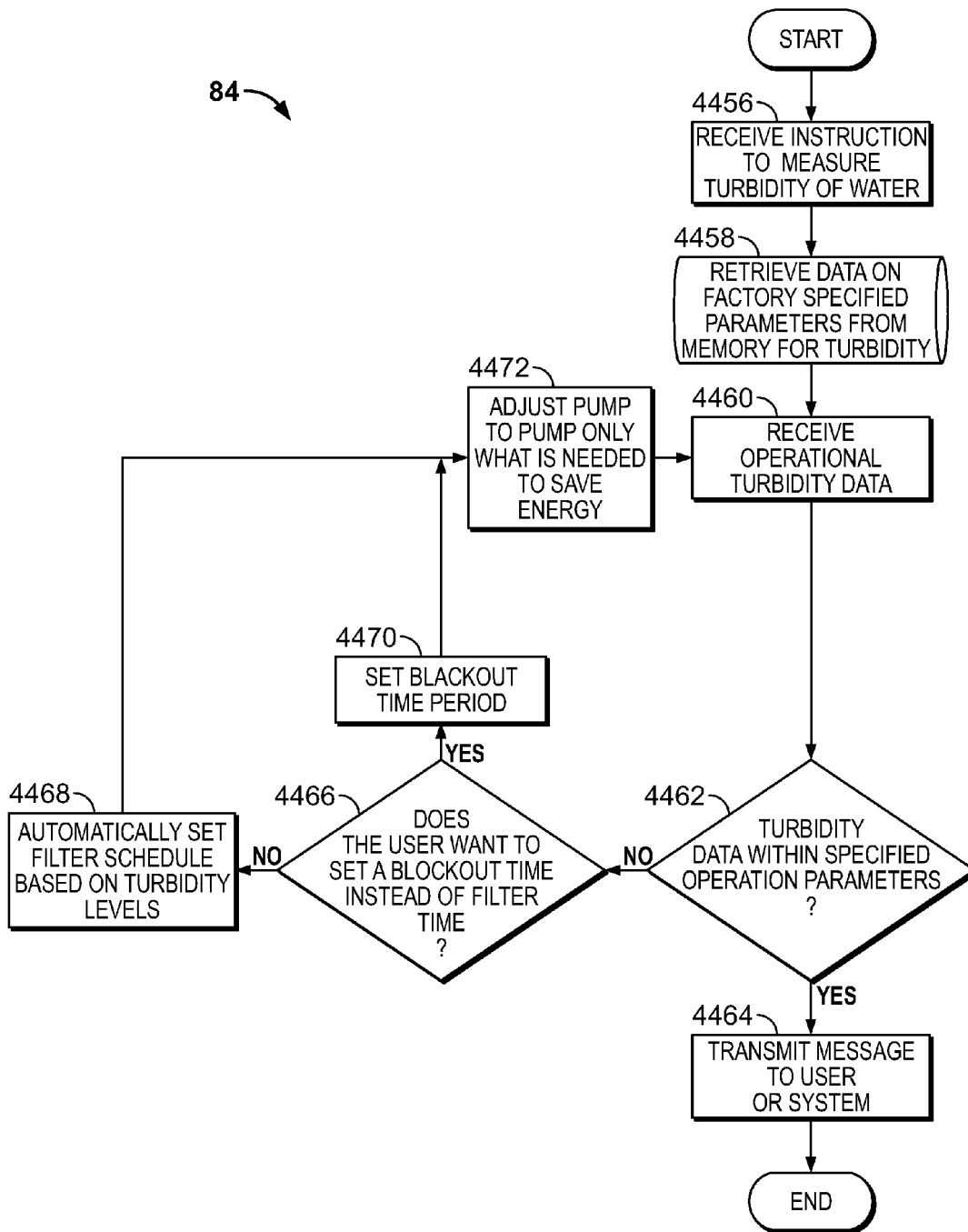


FIG. 19AT

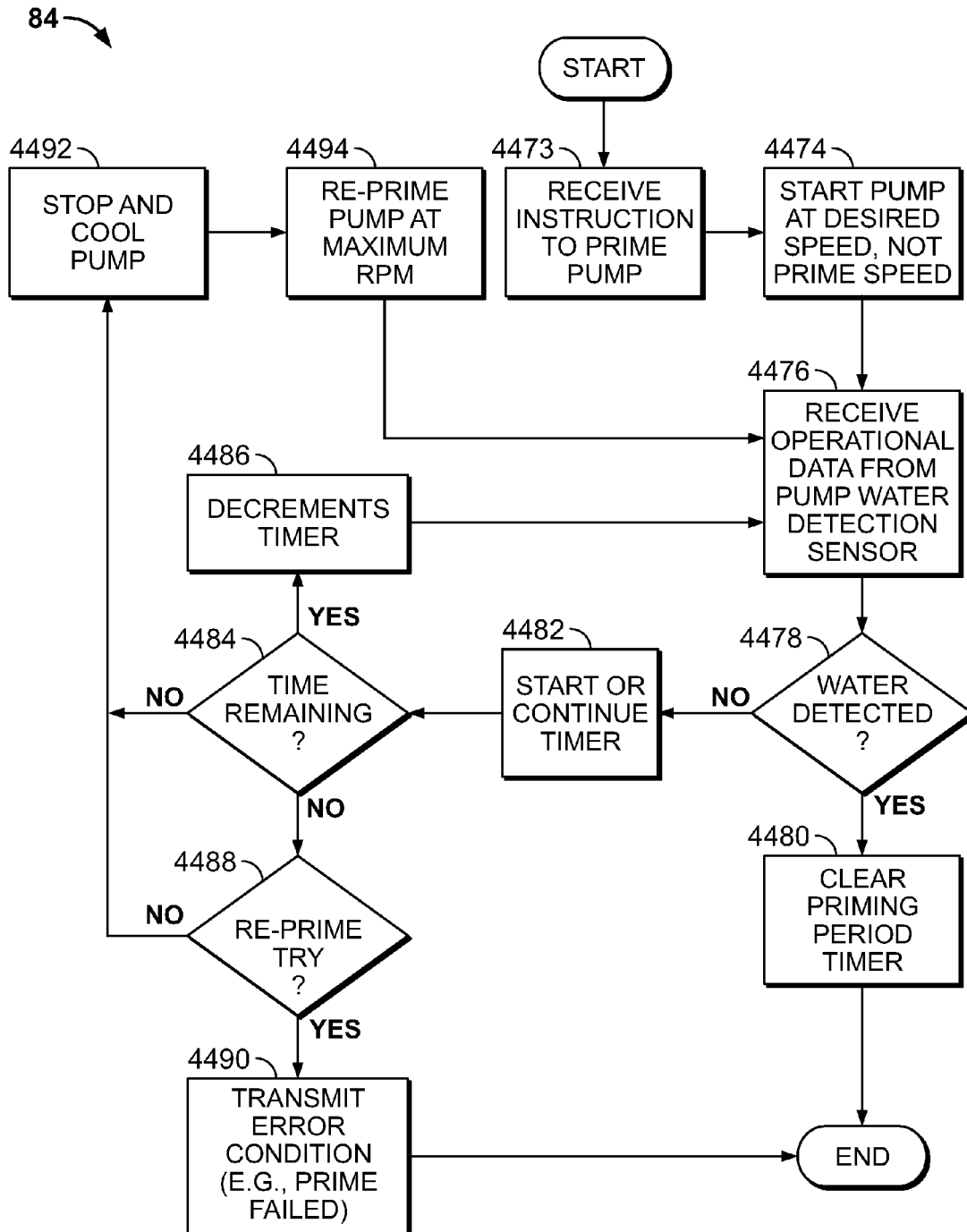


FIG. 19AU

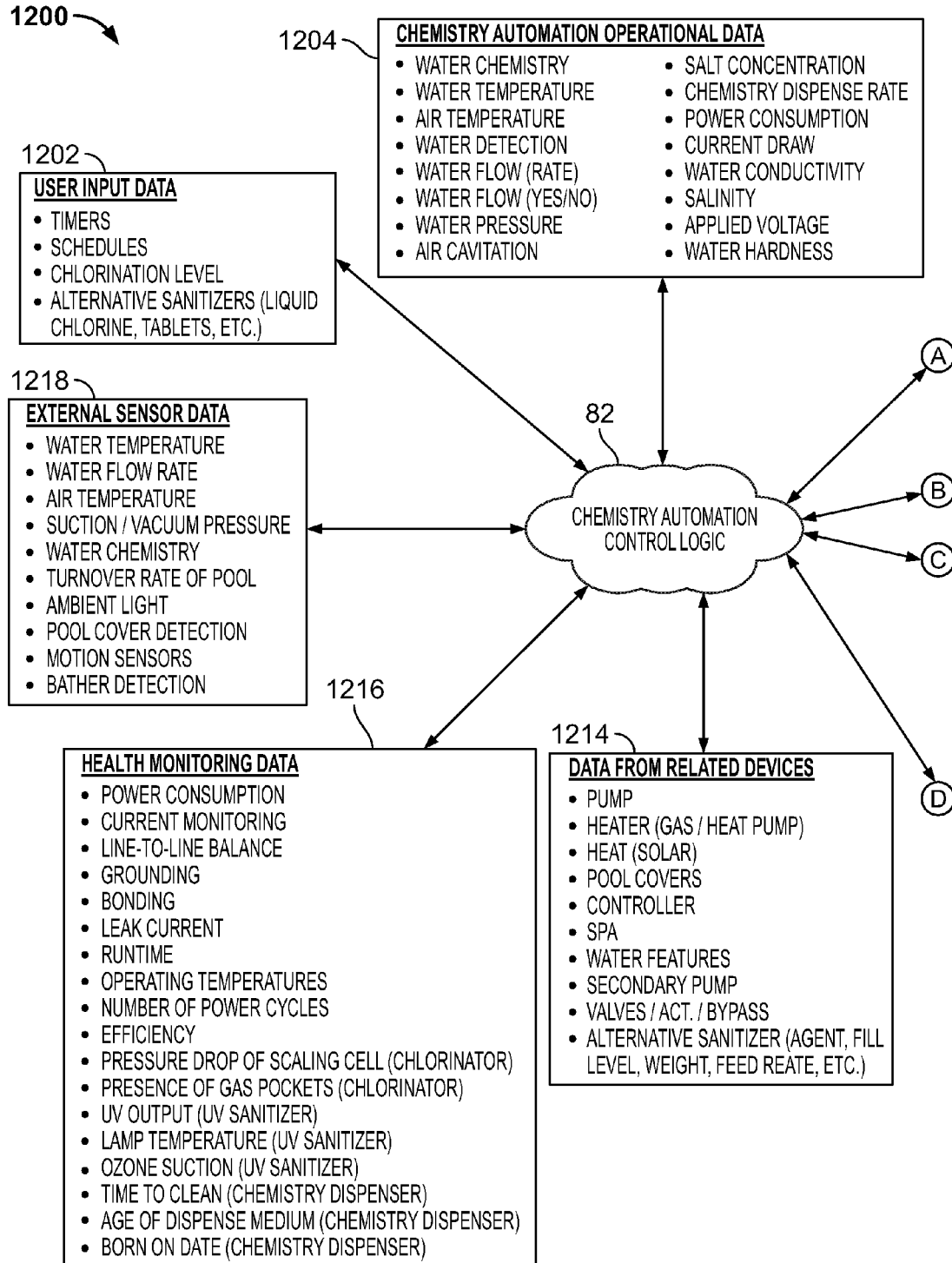


FIG. 20

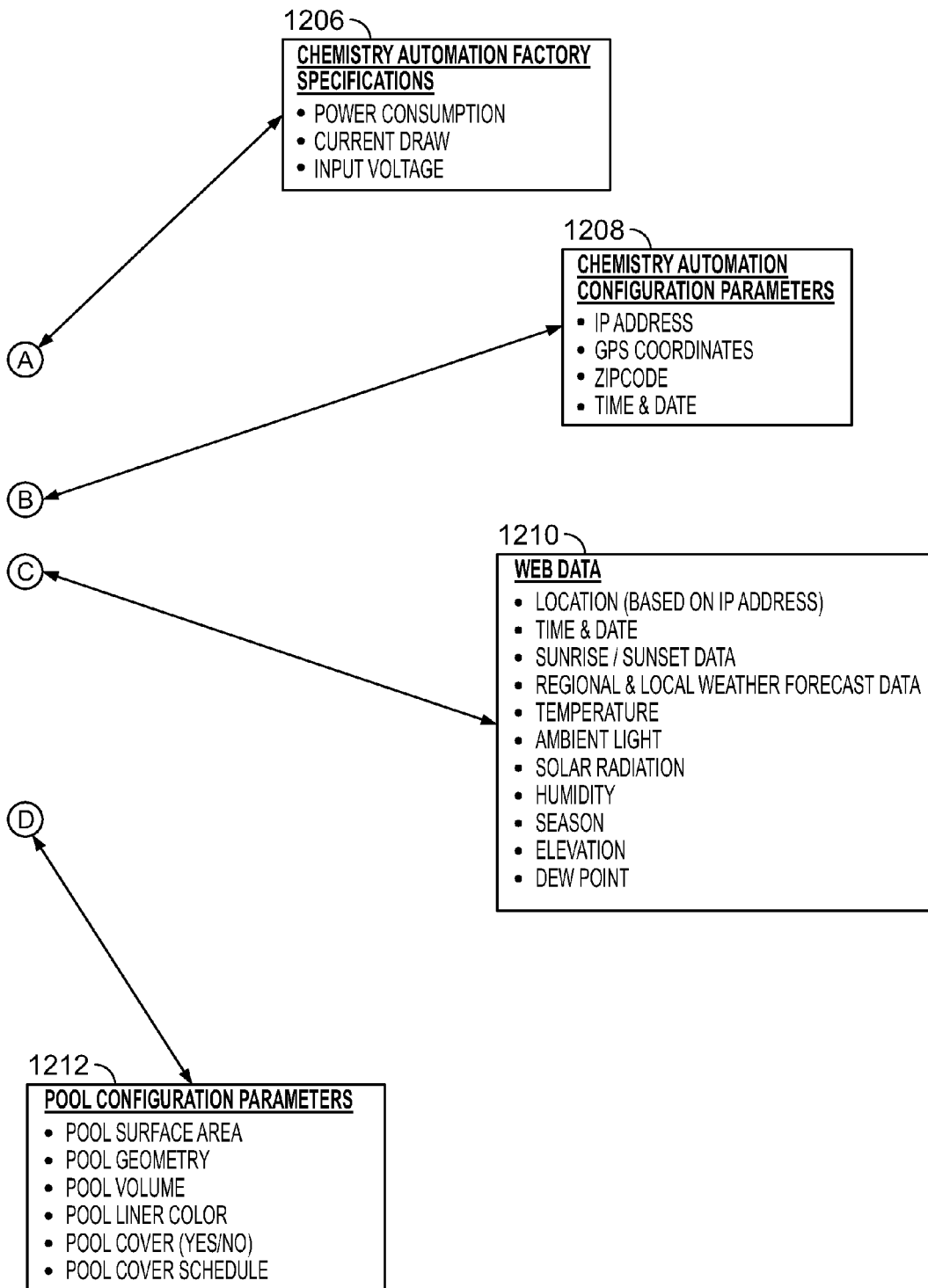


FIG. 20 (Cont.)

82 →

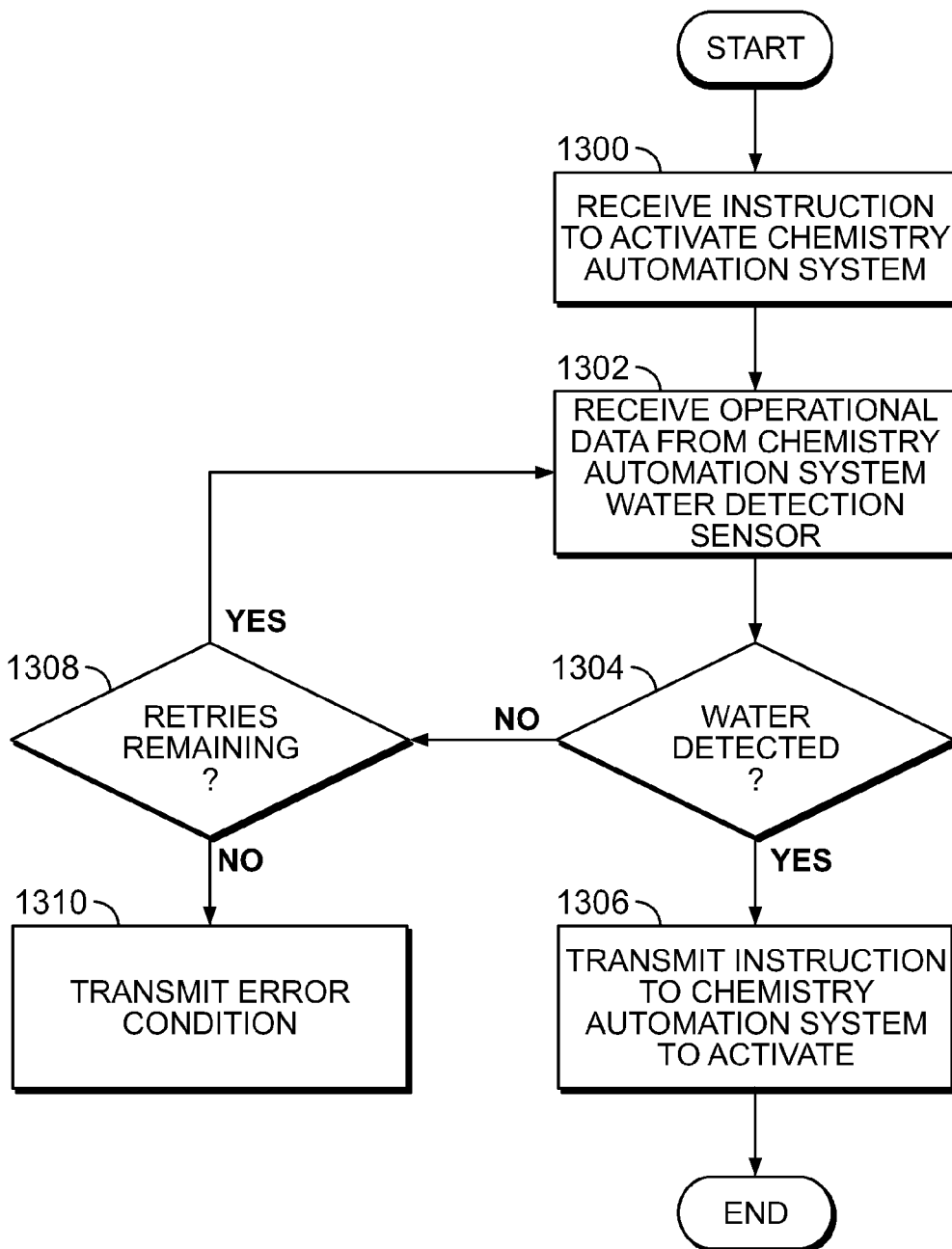


FIG. 21A

82 →

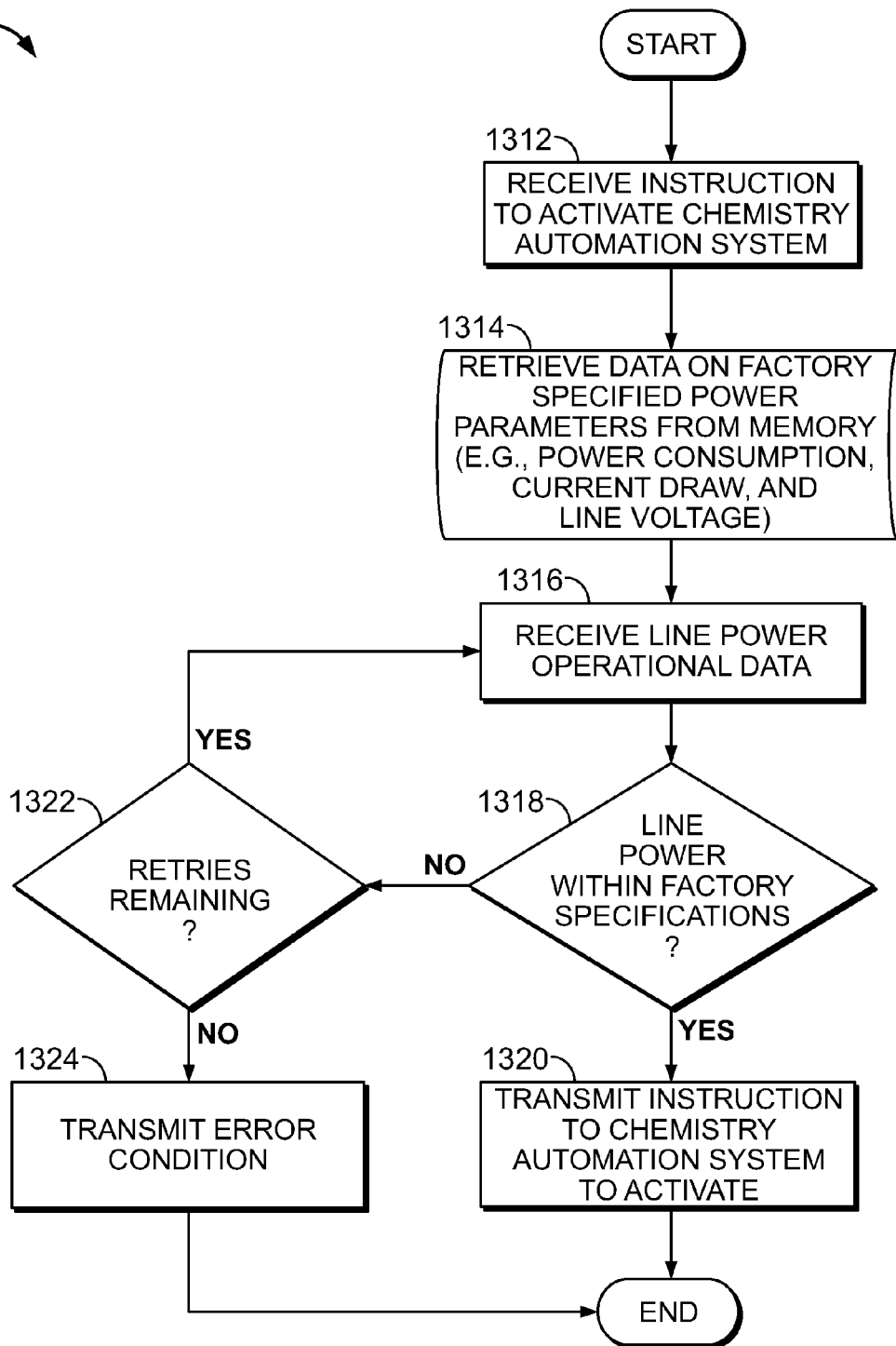


FIG. 21B

82 →

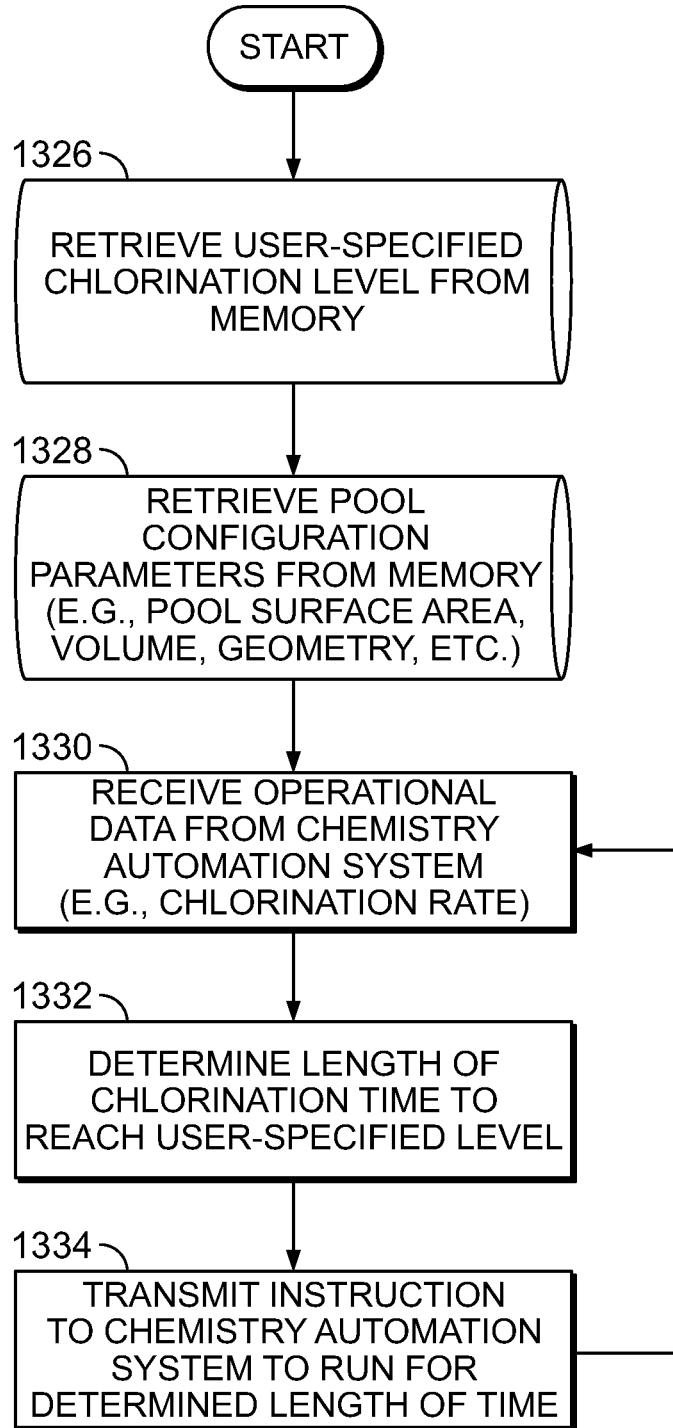


FIG. 21C

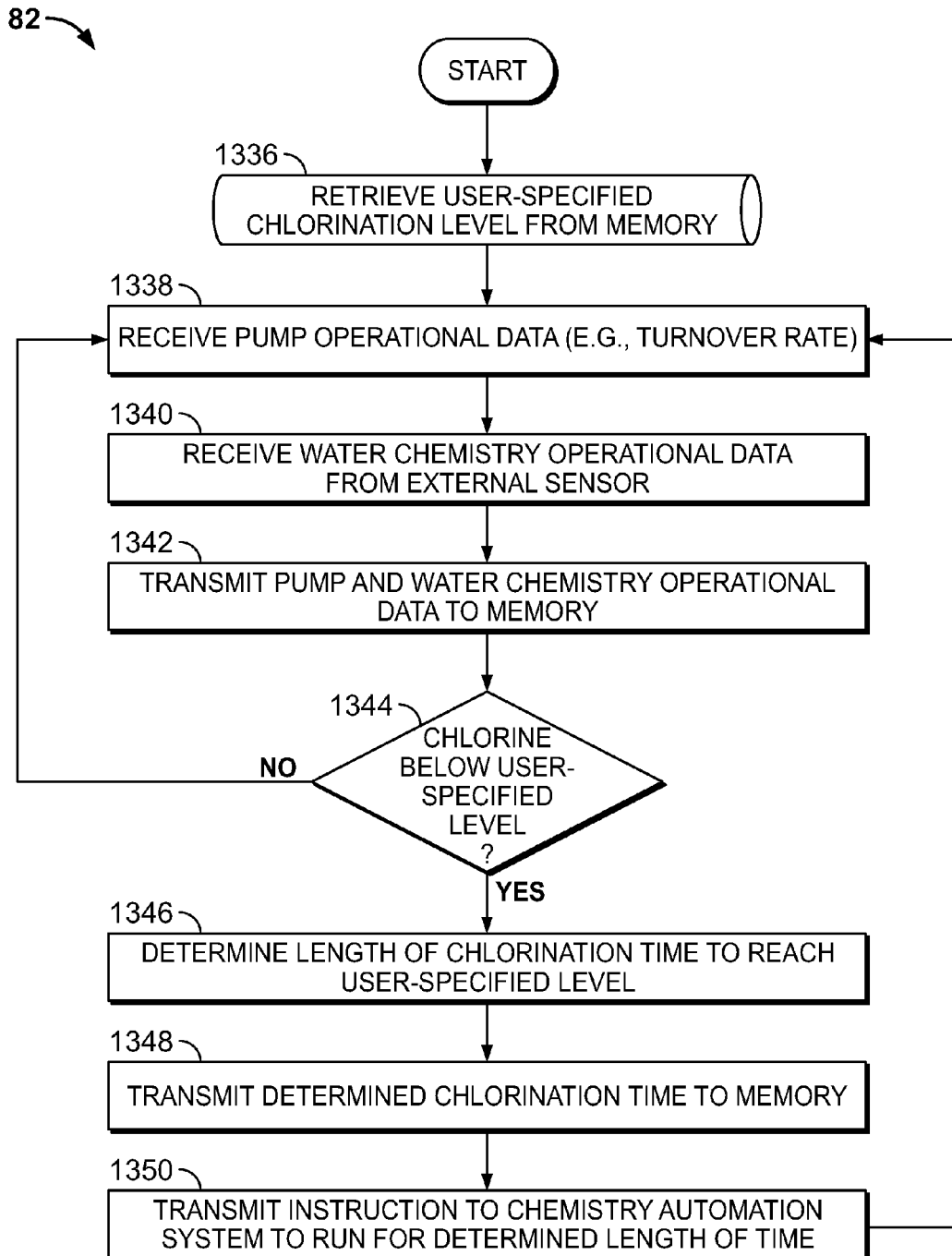


FIG. 21D

82 →

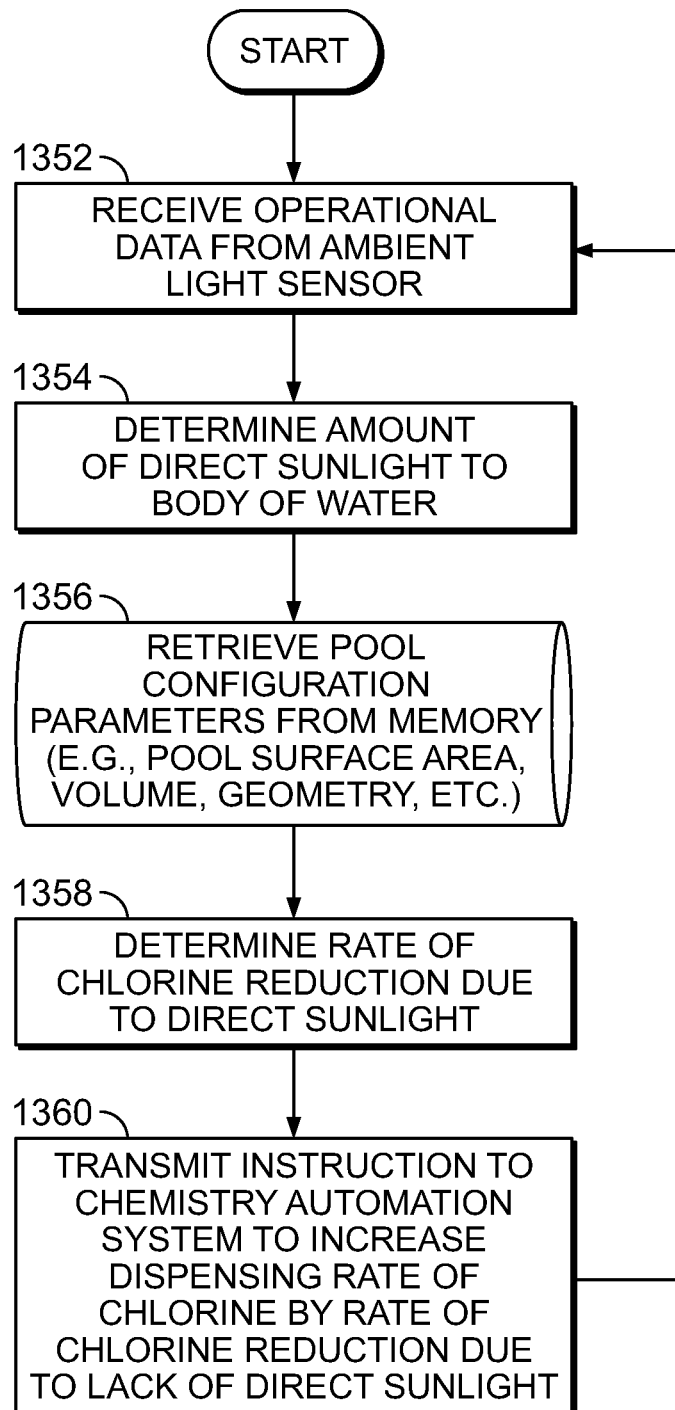


FIG. 21E

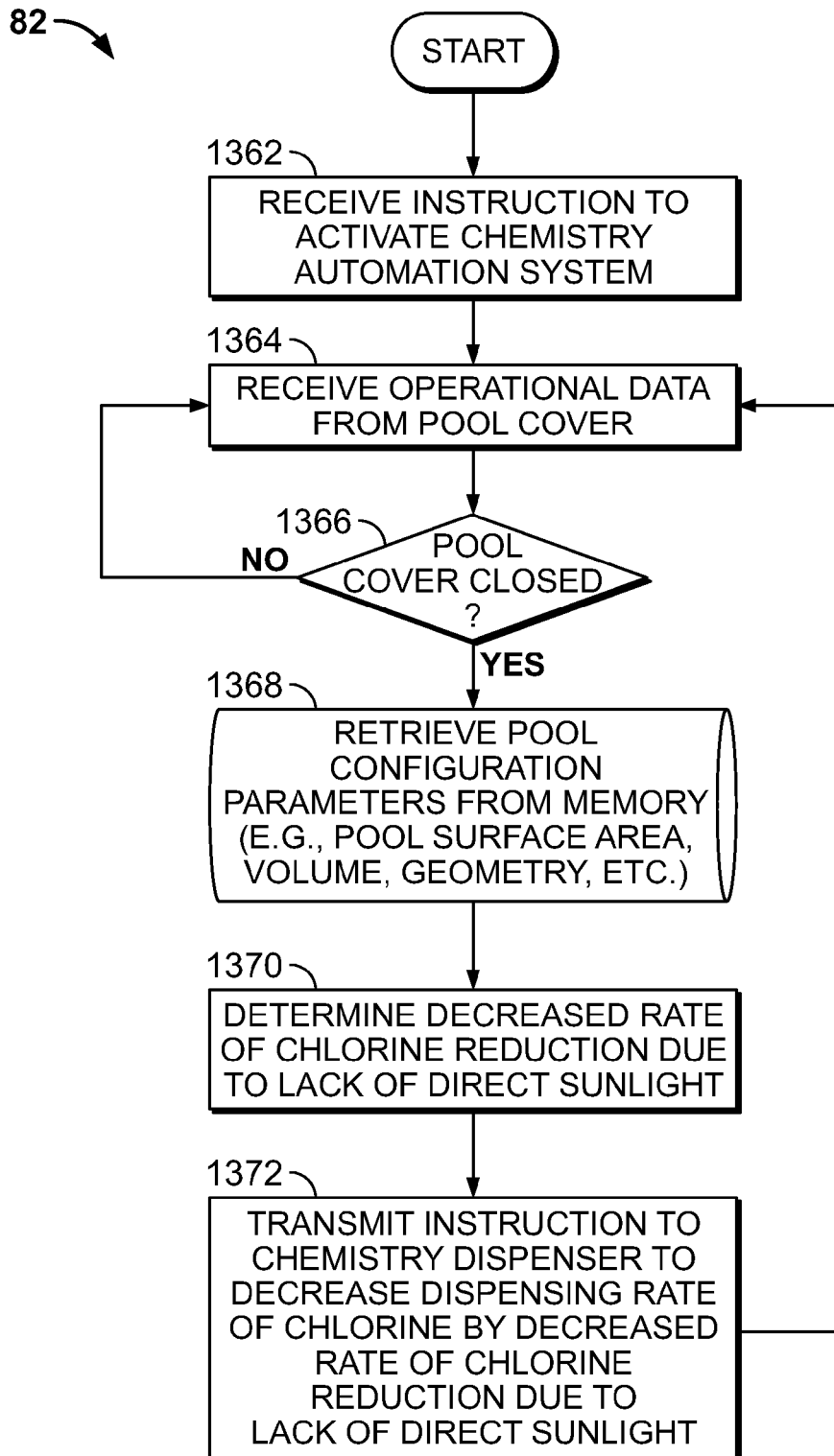


FIG. 21F

82 →

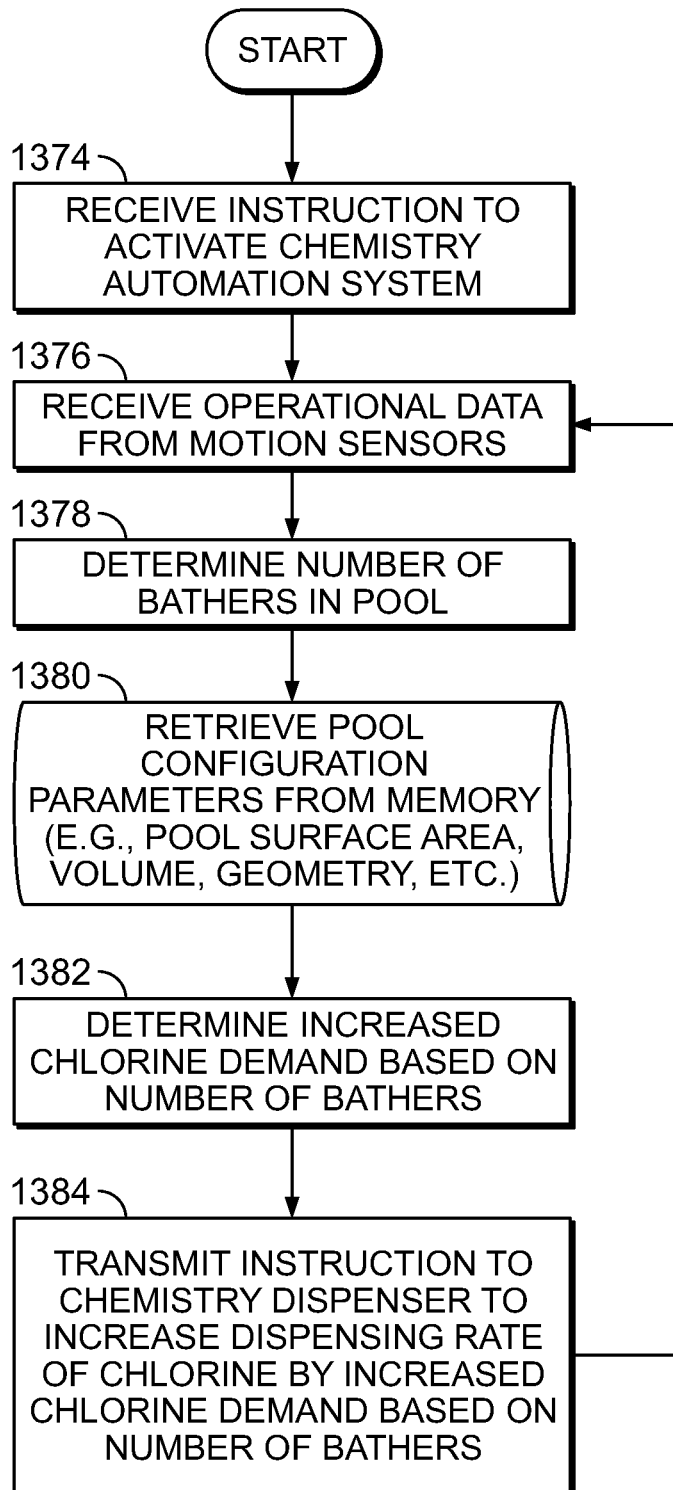


FIG. 21G

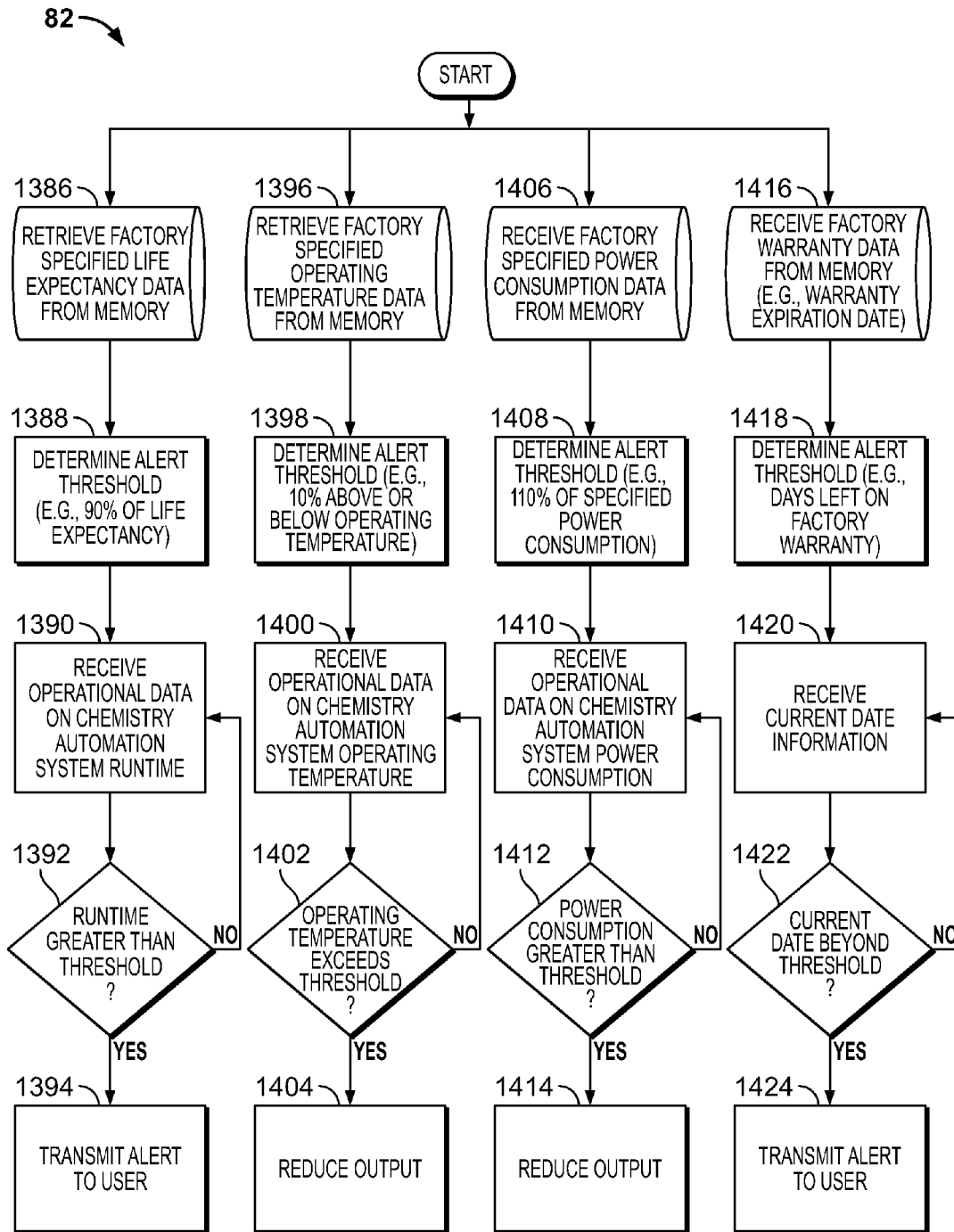


FIG. 21H

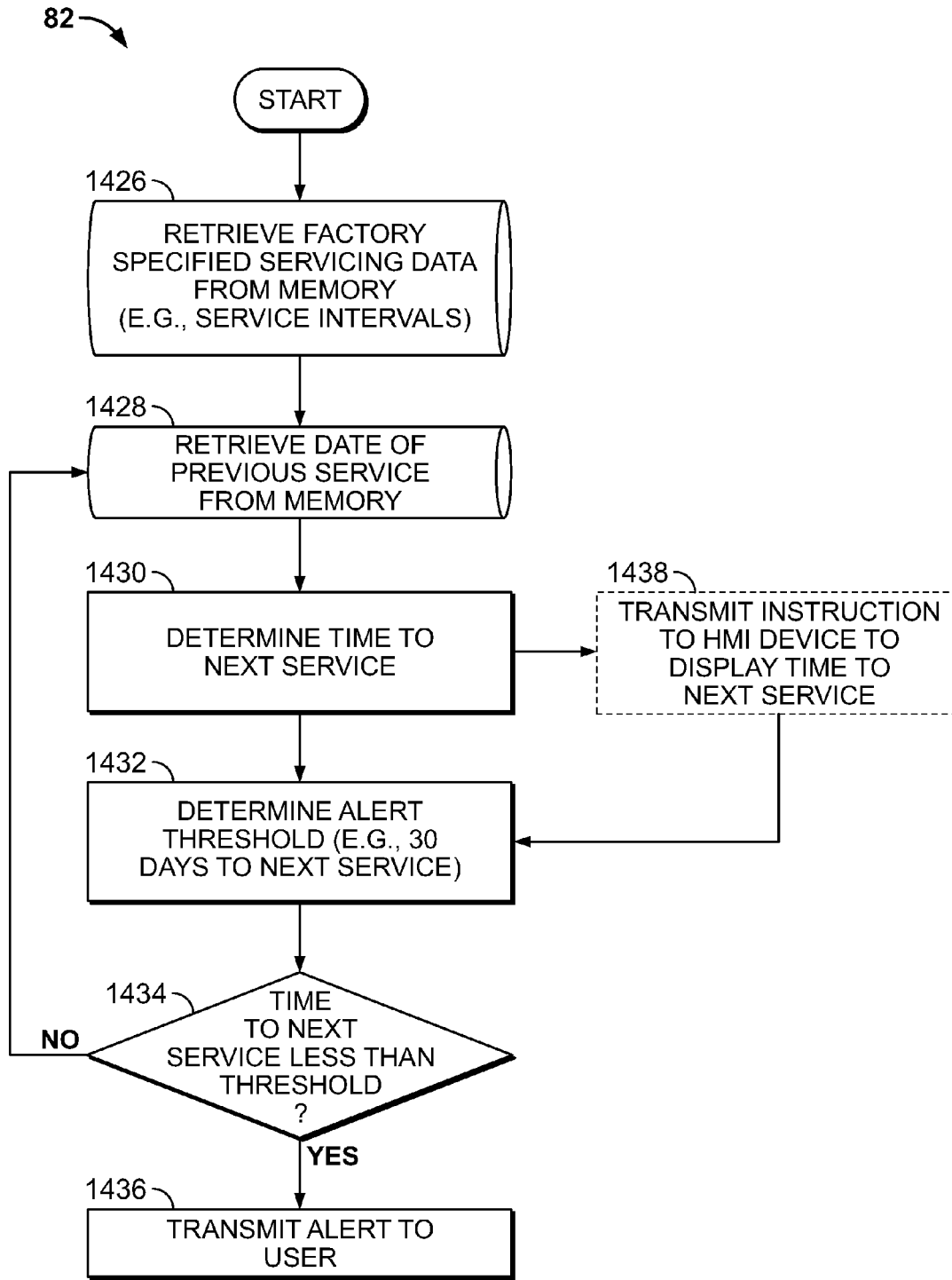


FIG. 21I

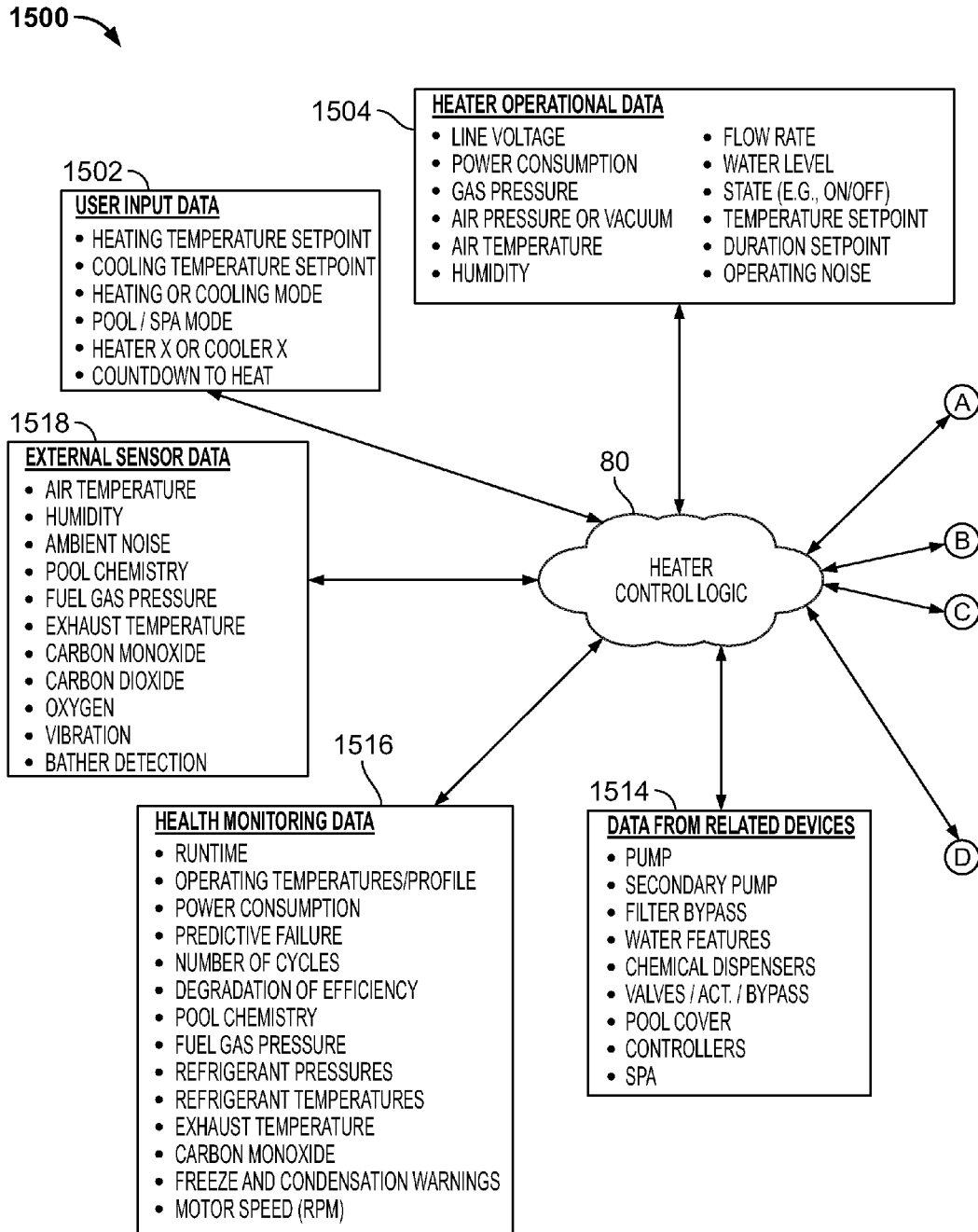


FIG. 22

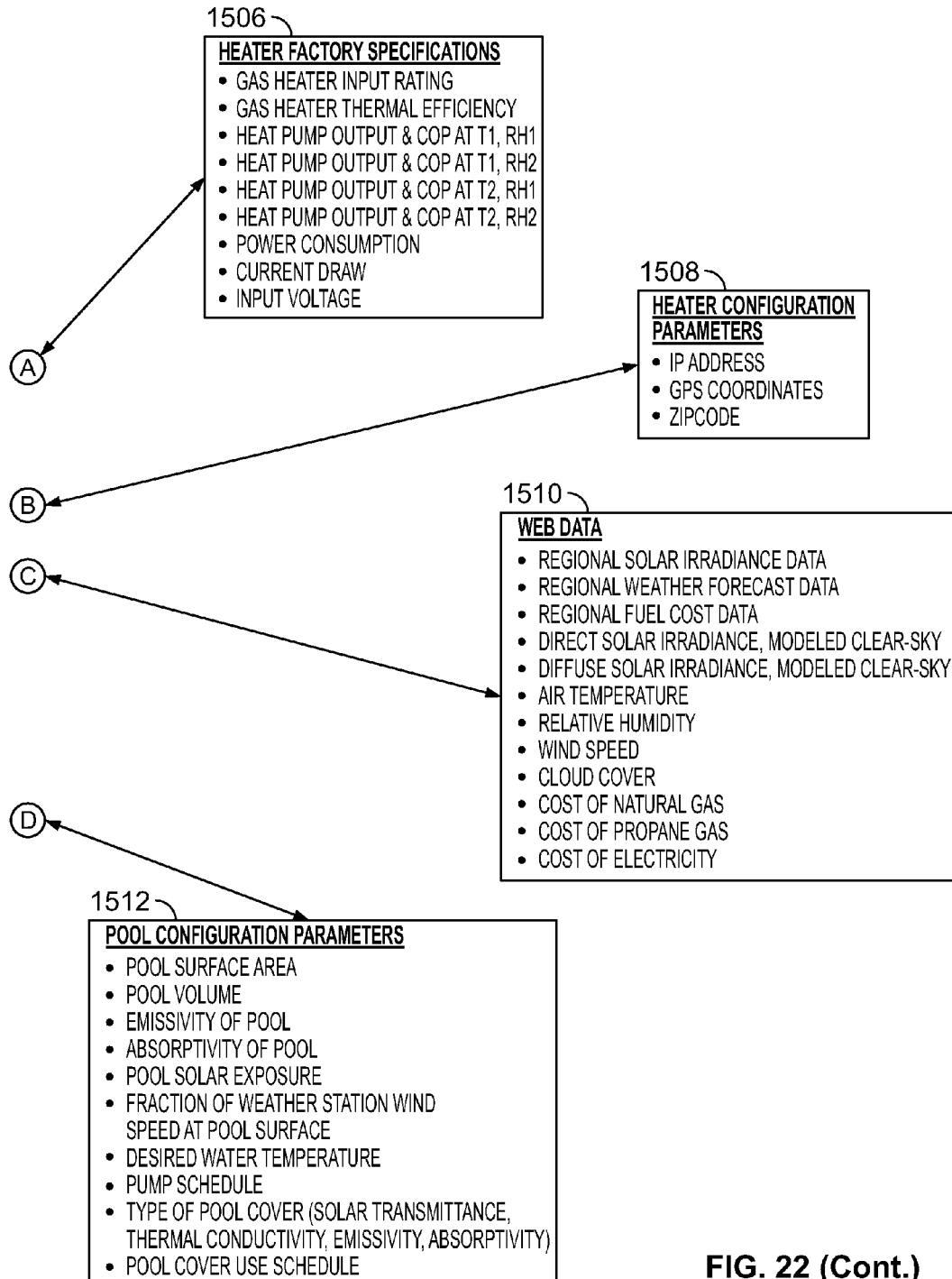


FIG. 22 (Cont.)

80 →

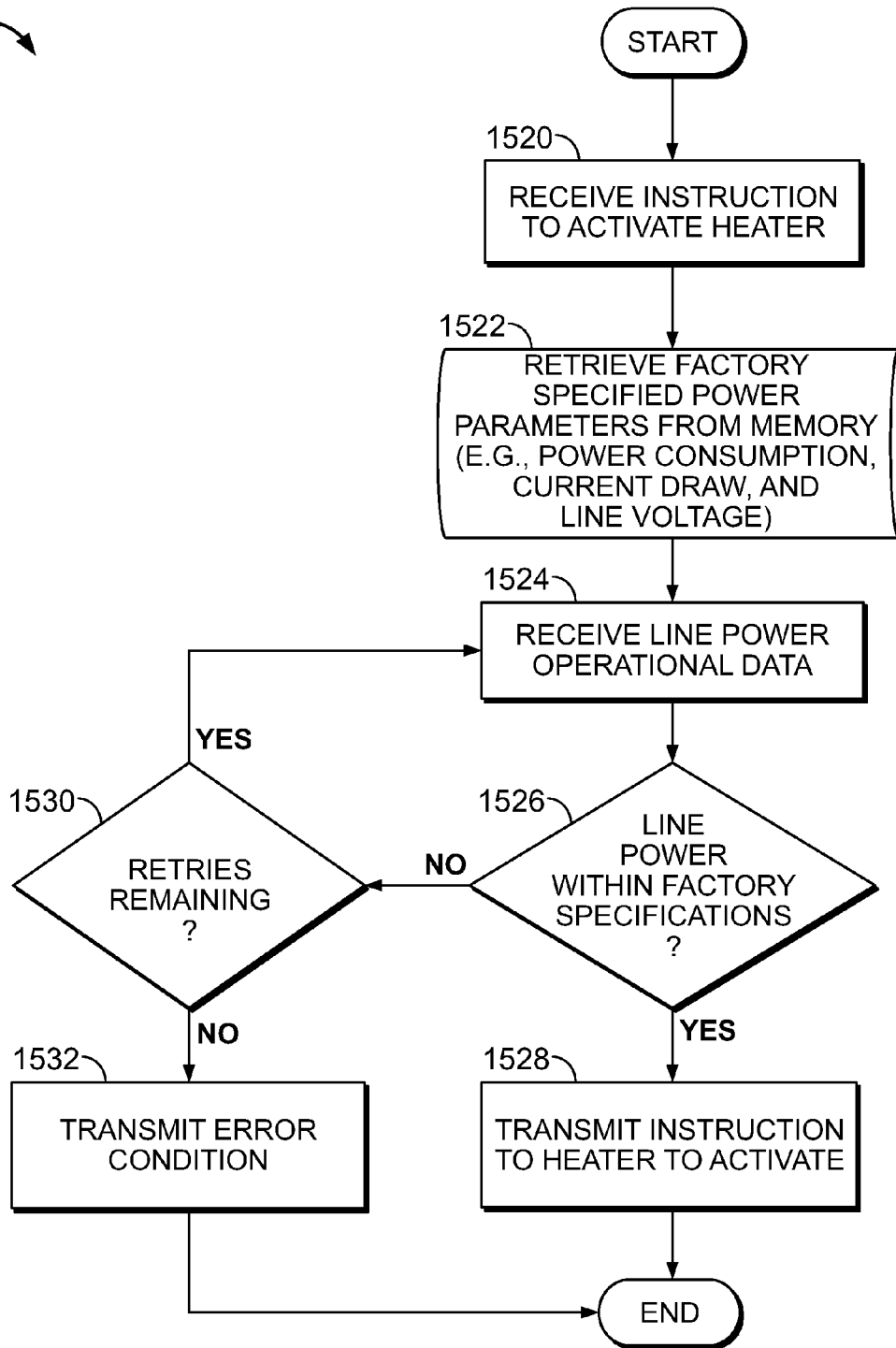


FIG. 23A

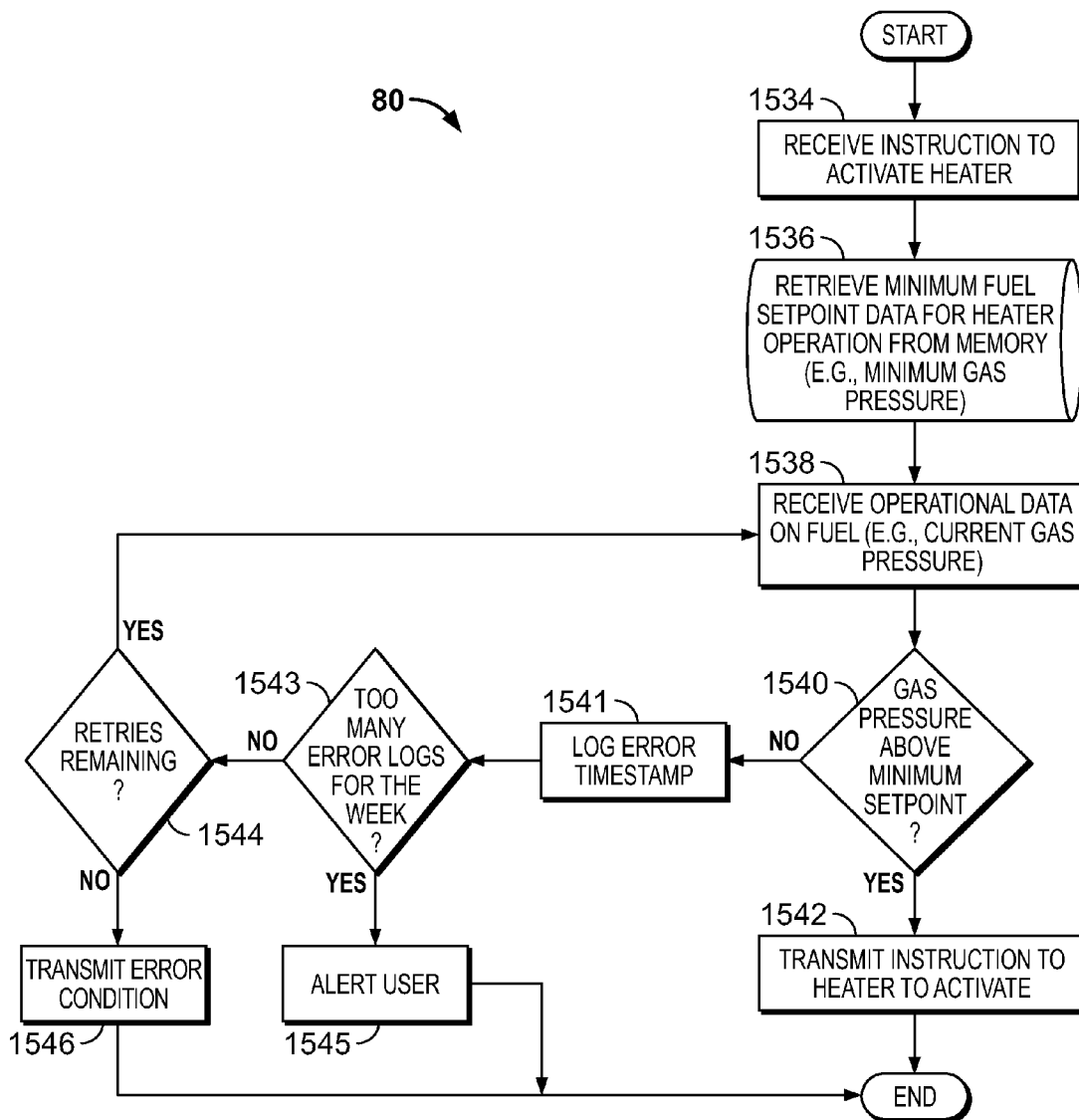


FIG. 23B

80 →

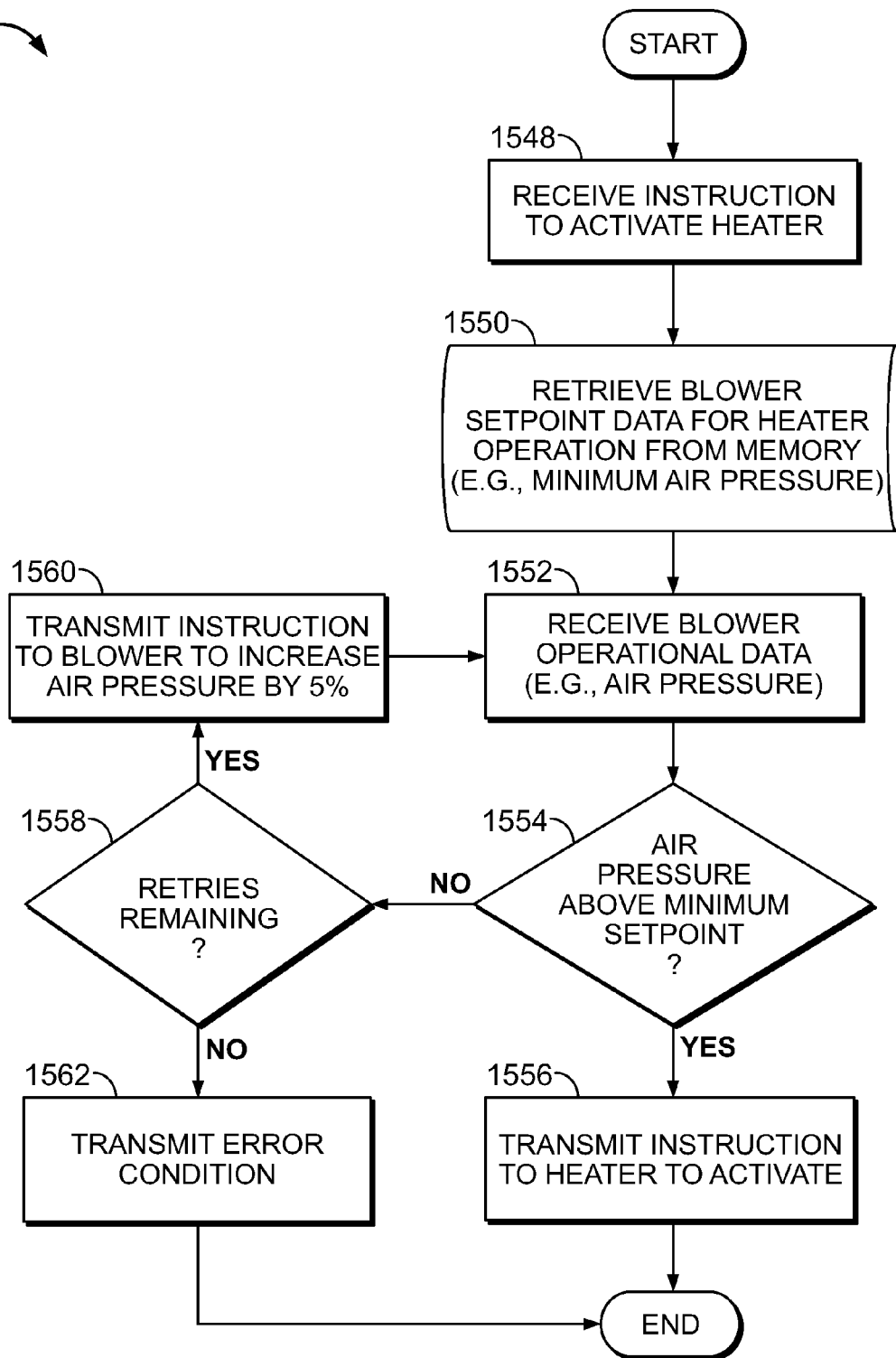


FIG. 23C

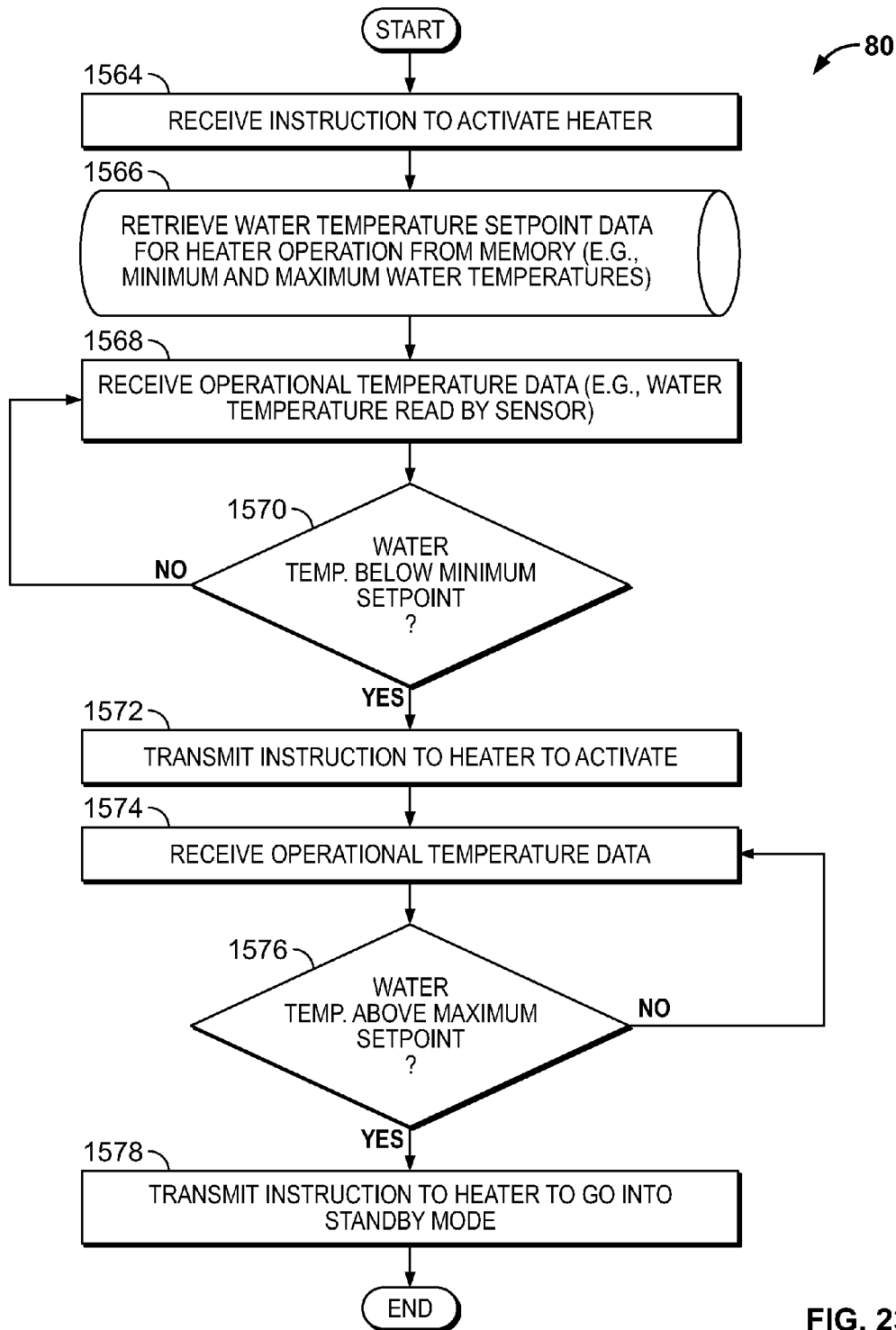


FIG. 23D

80

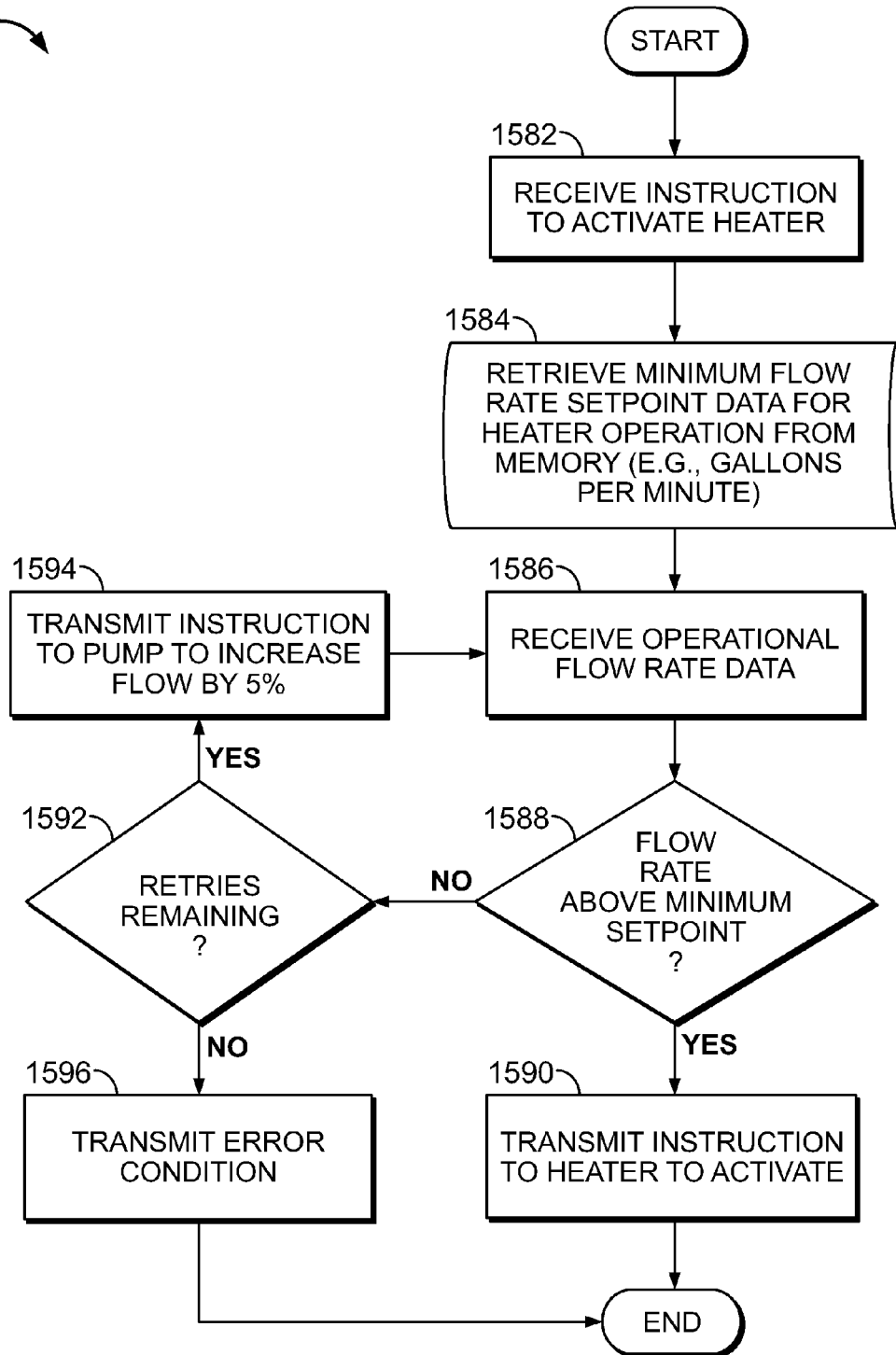


FIG. 23E

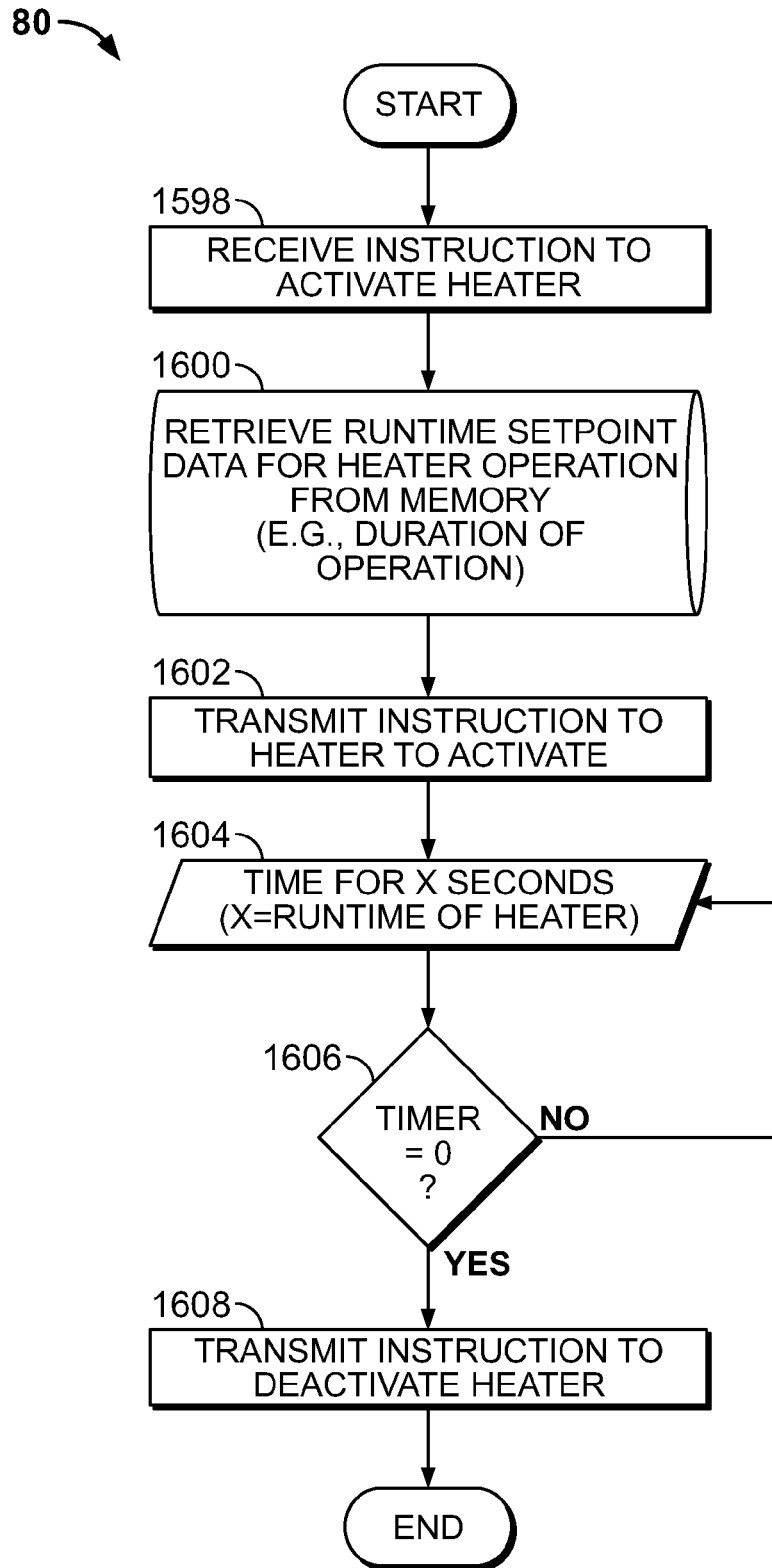


FIG. 23F

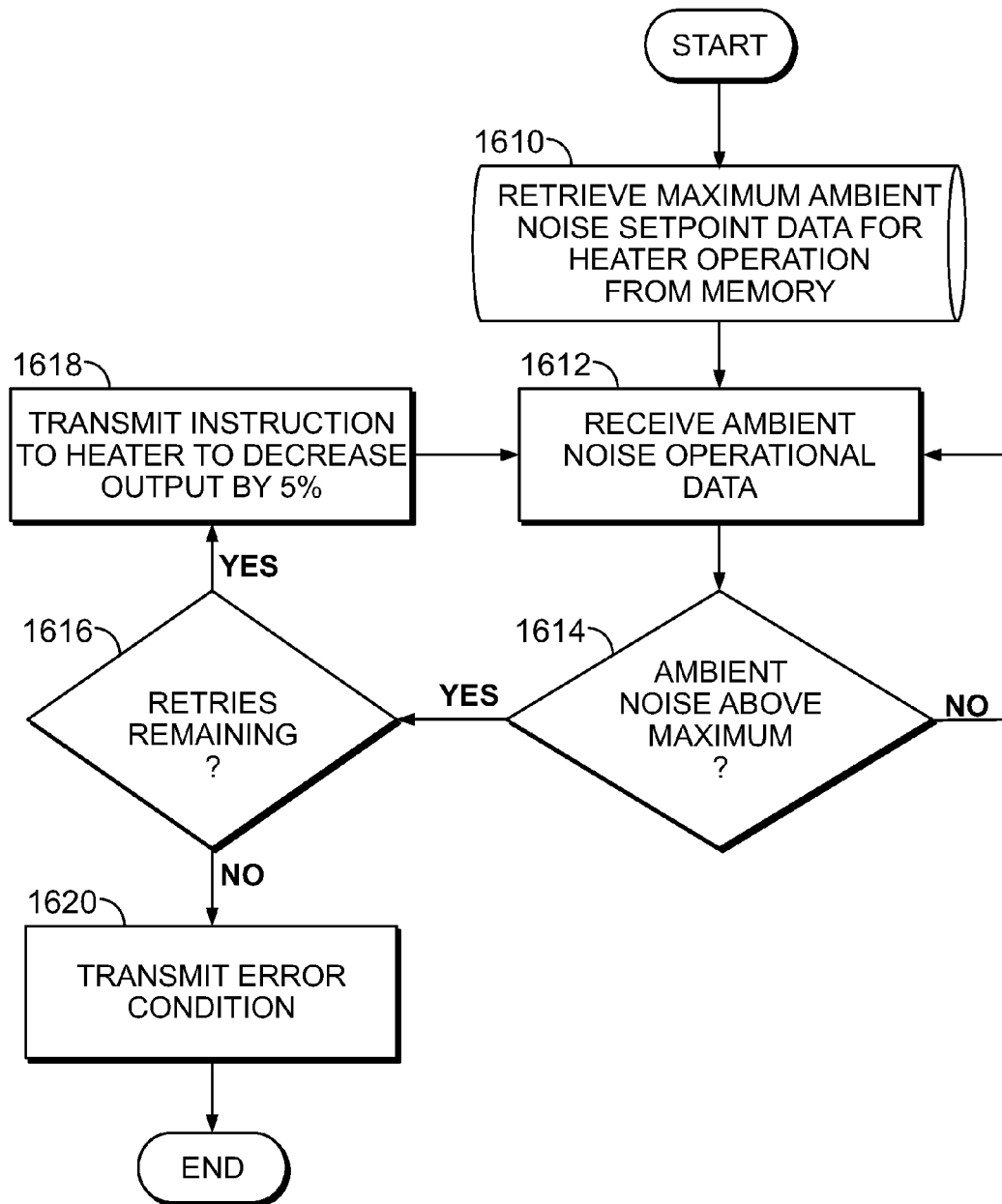


FIG. 23G

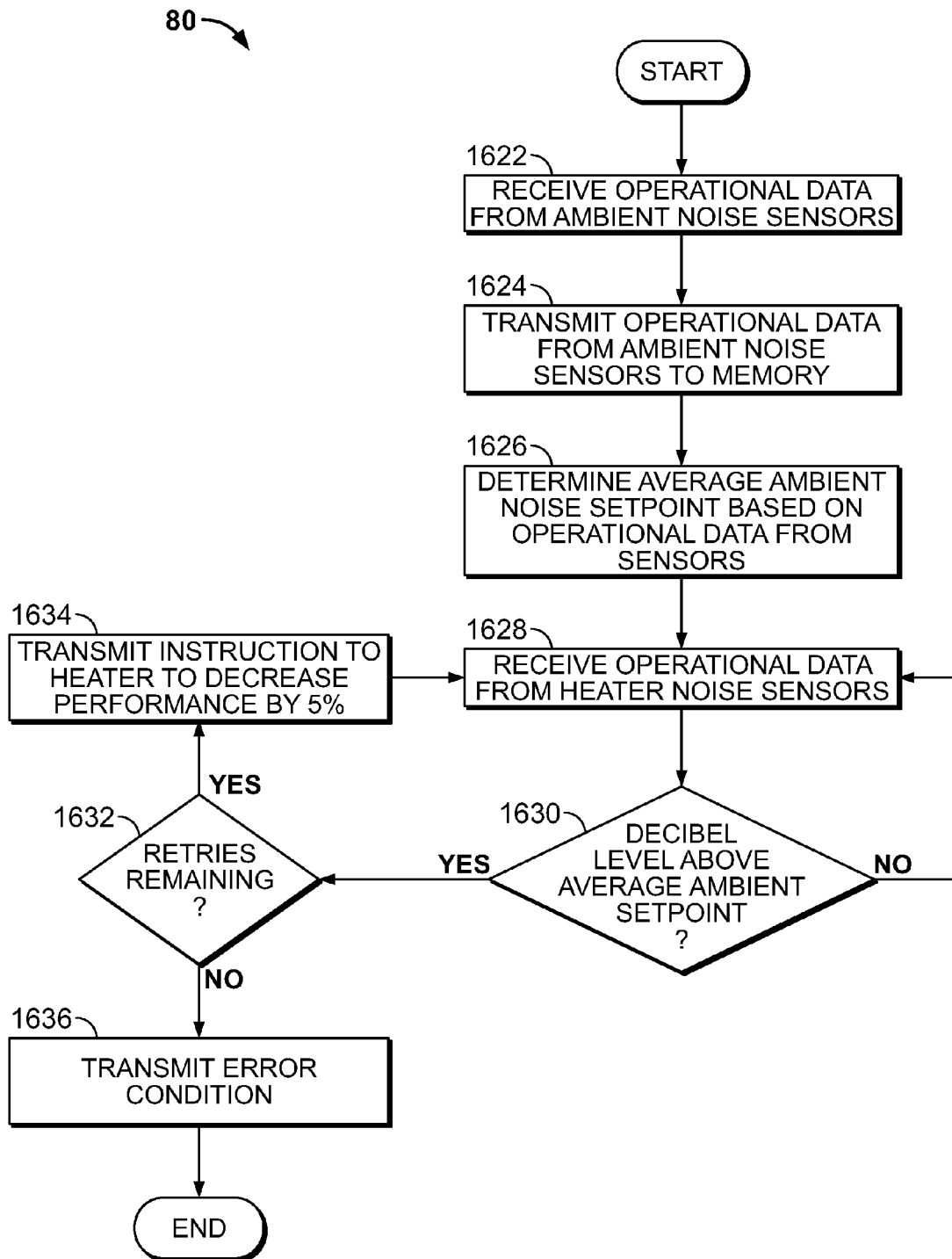


FIG. 23H

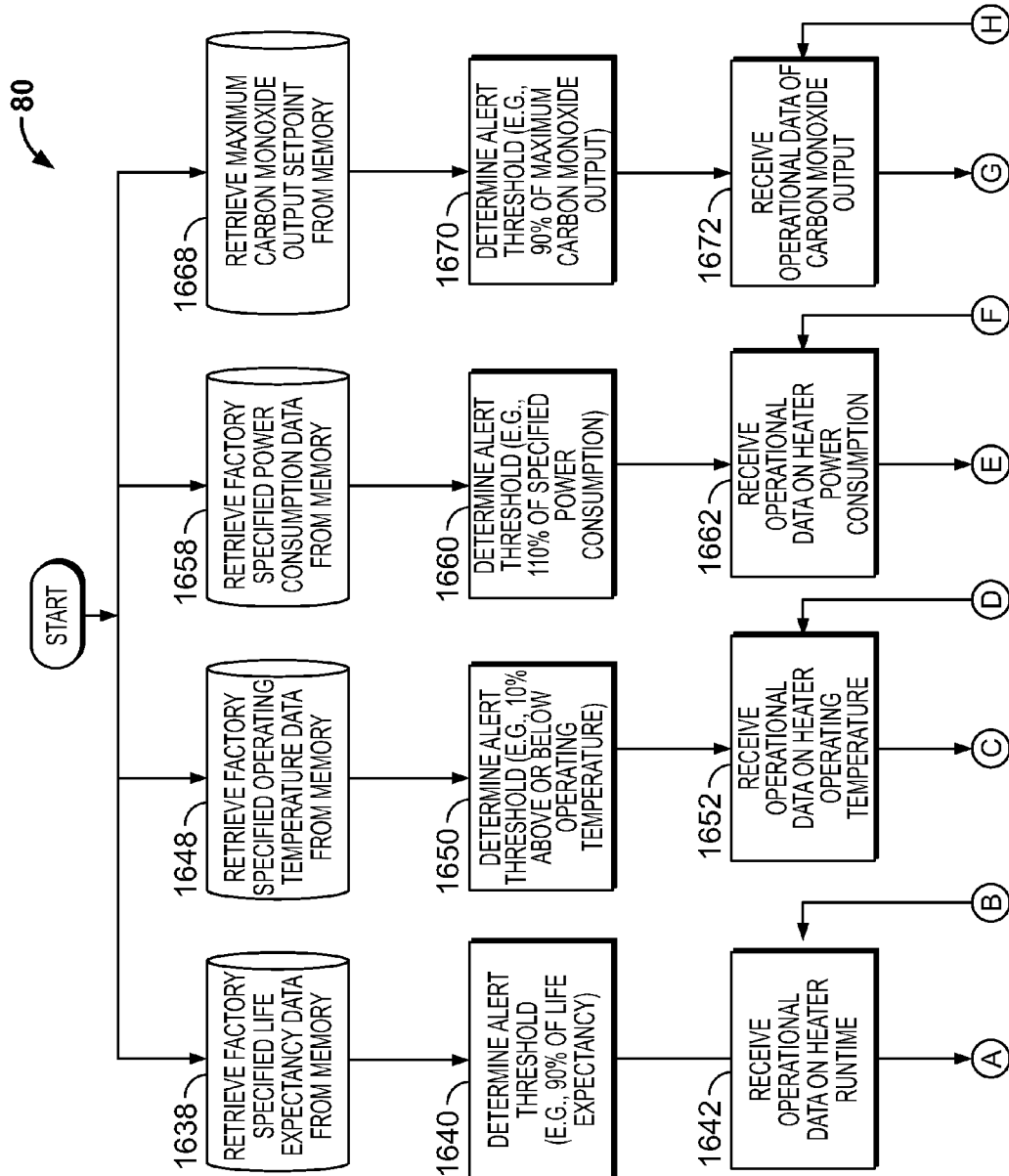


FIG. 231

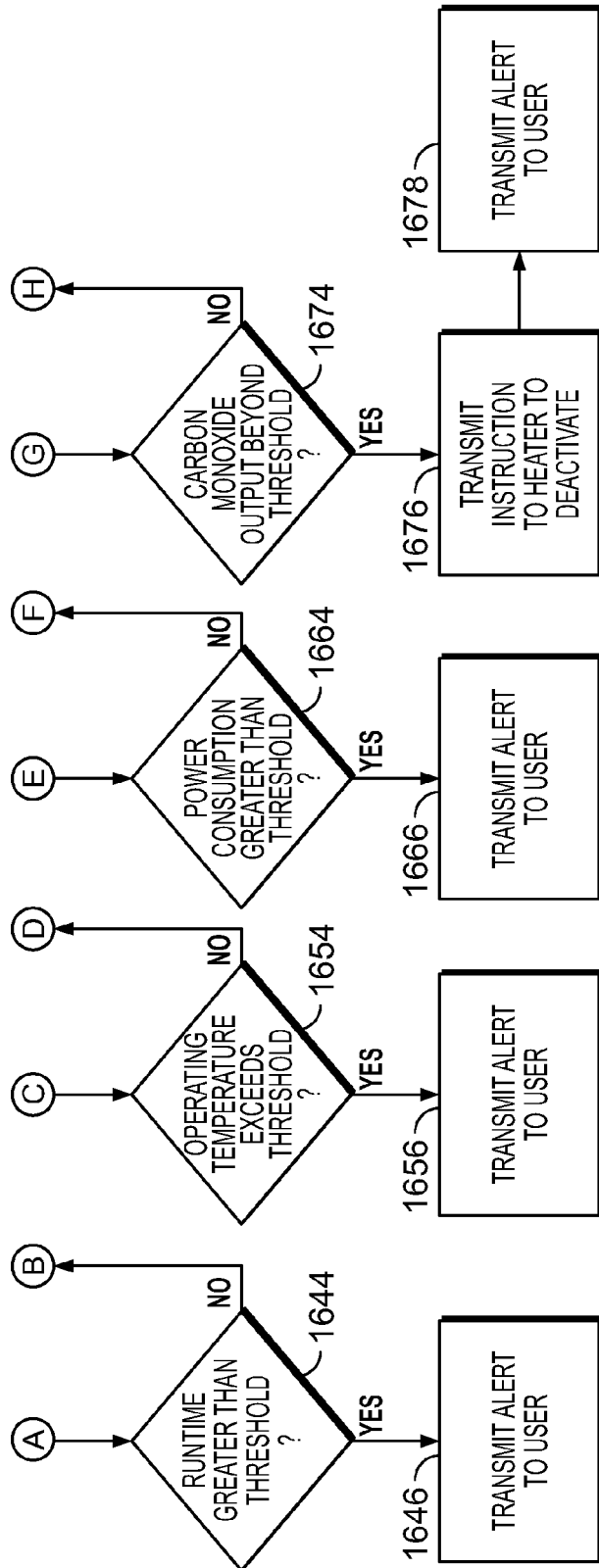


FIG. 23I (Cont.)

80

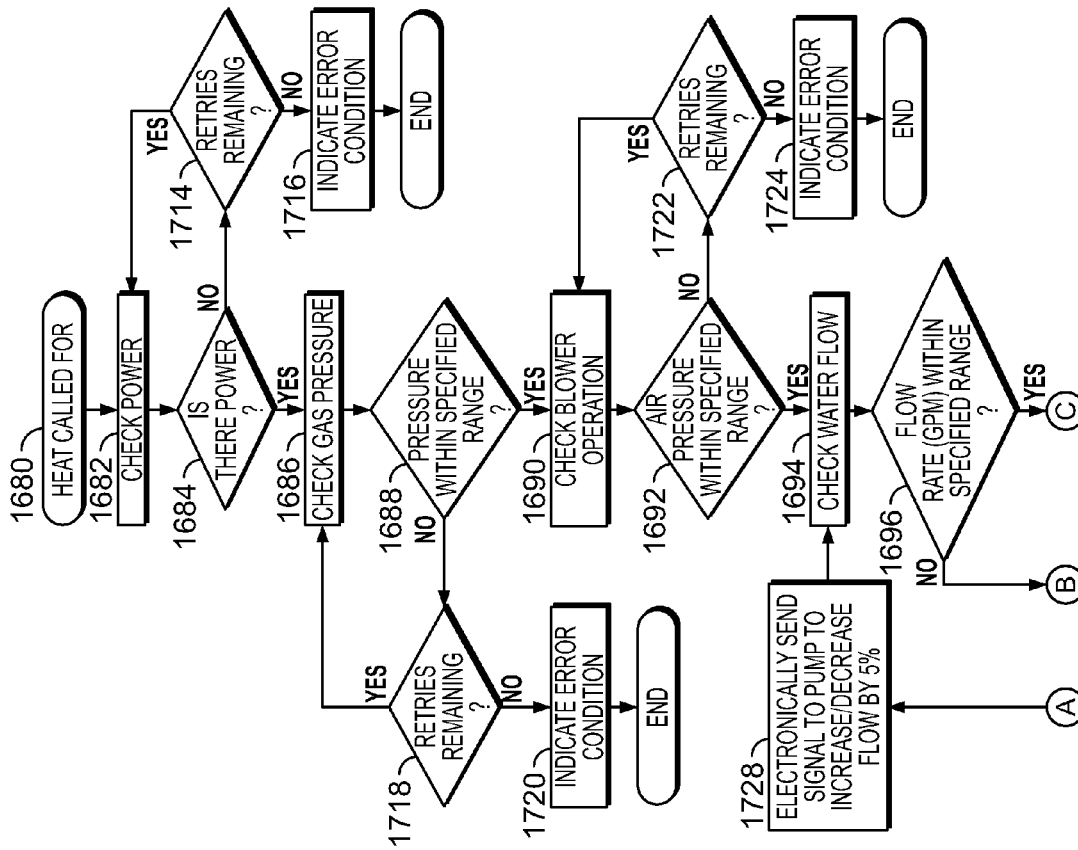


FIG. 23J

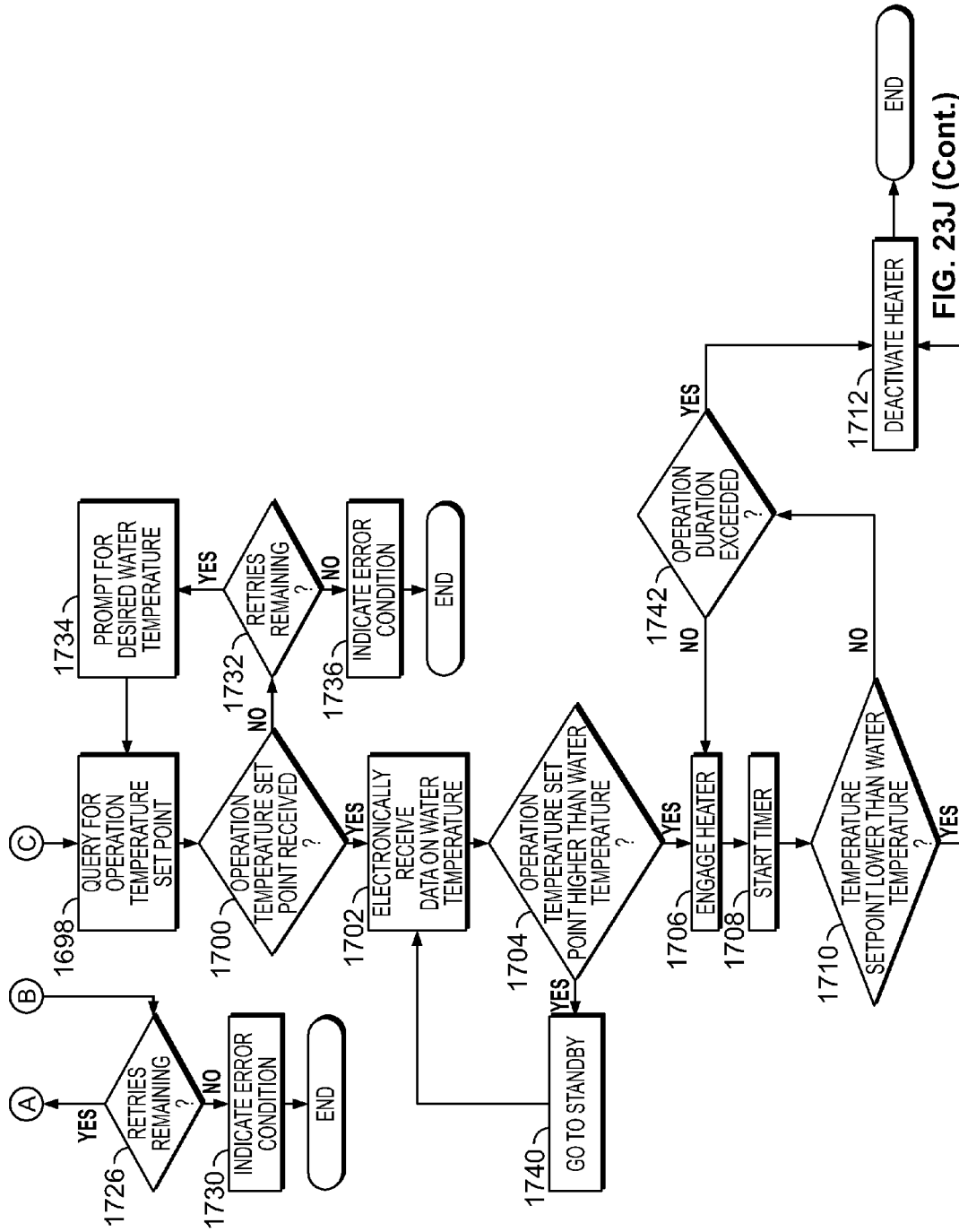


FIG. 23J (Cont.)

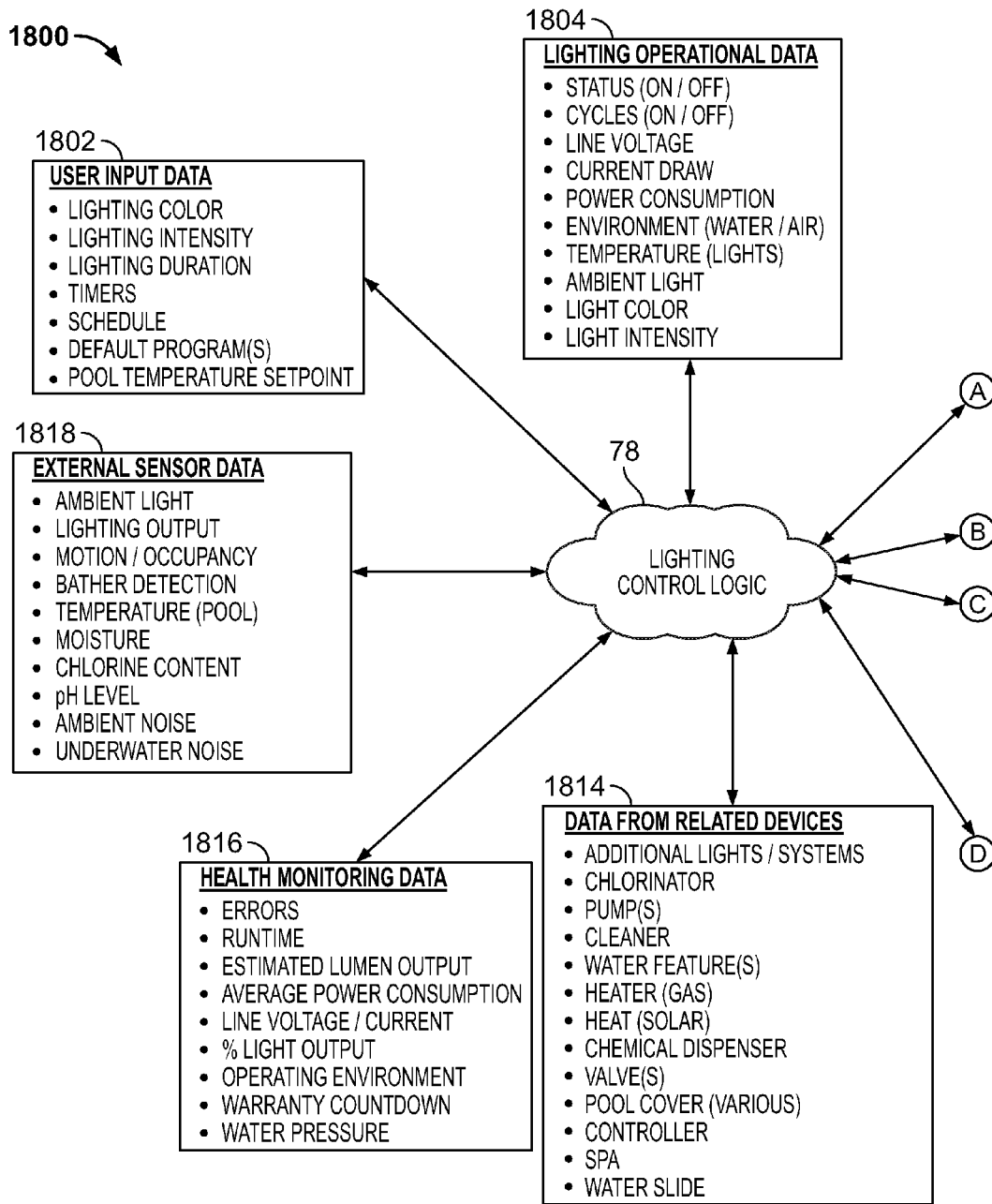


FIG. 24

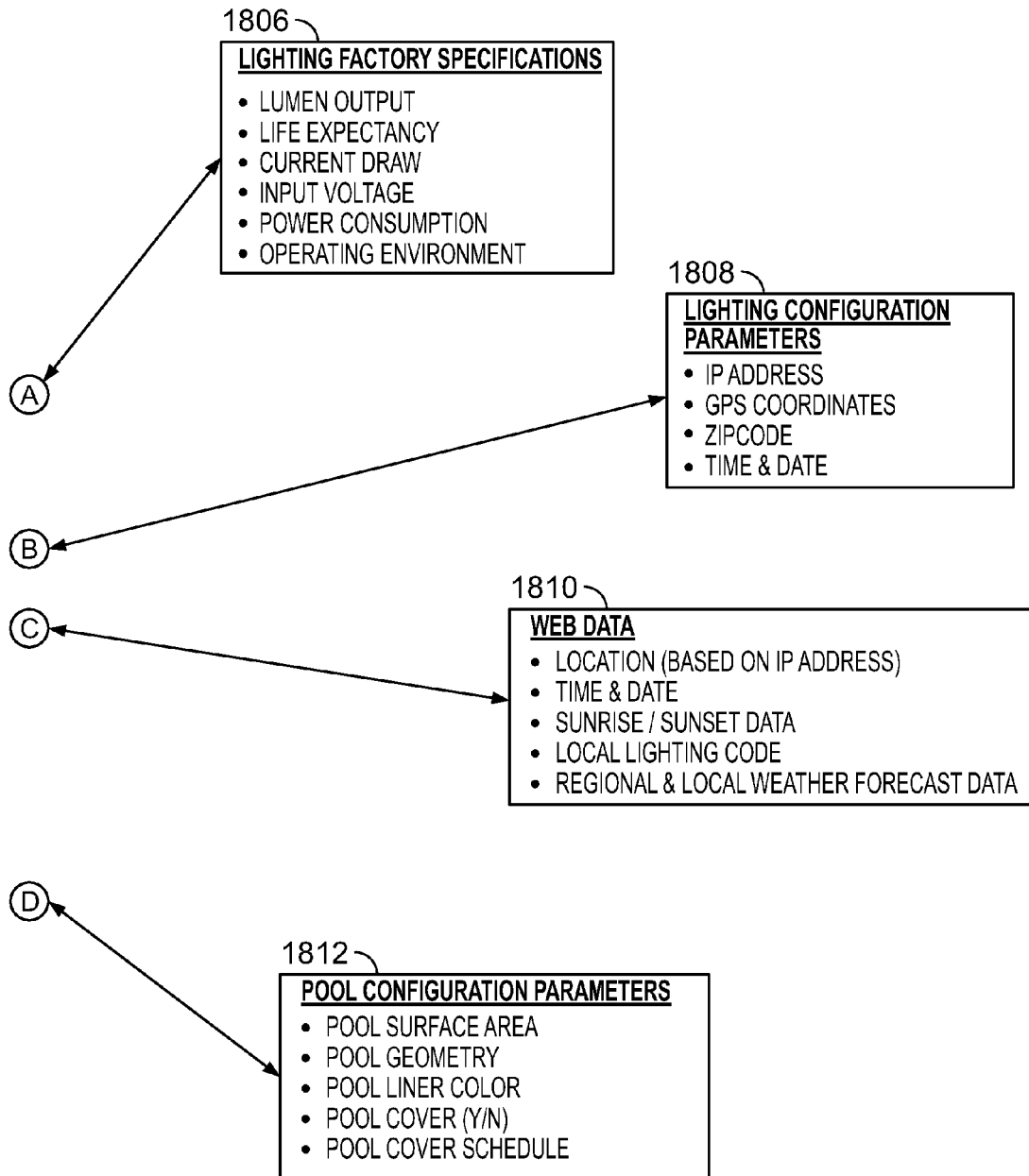


FIG. 24 (Cont.)

78 →

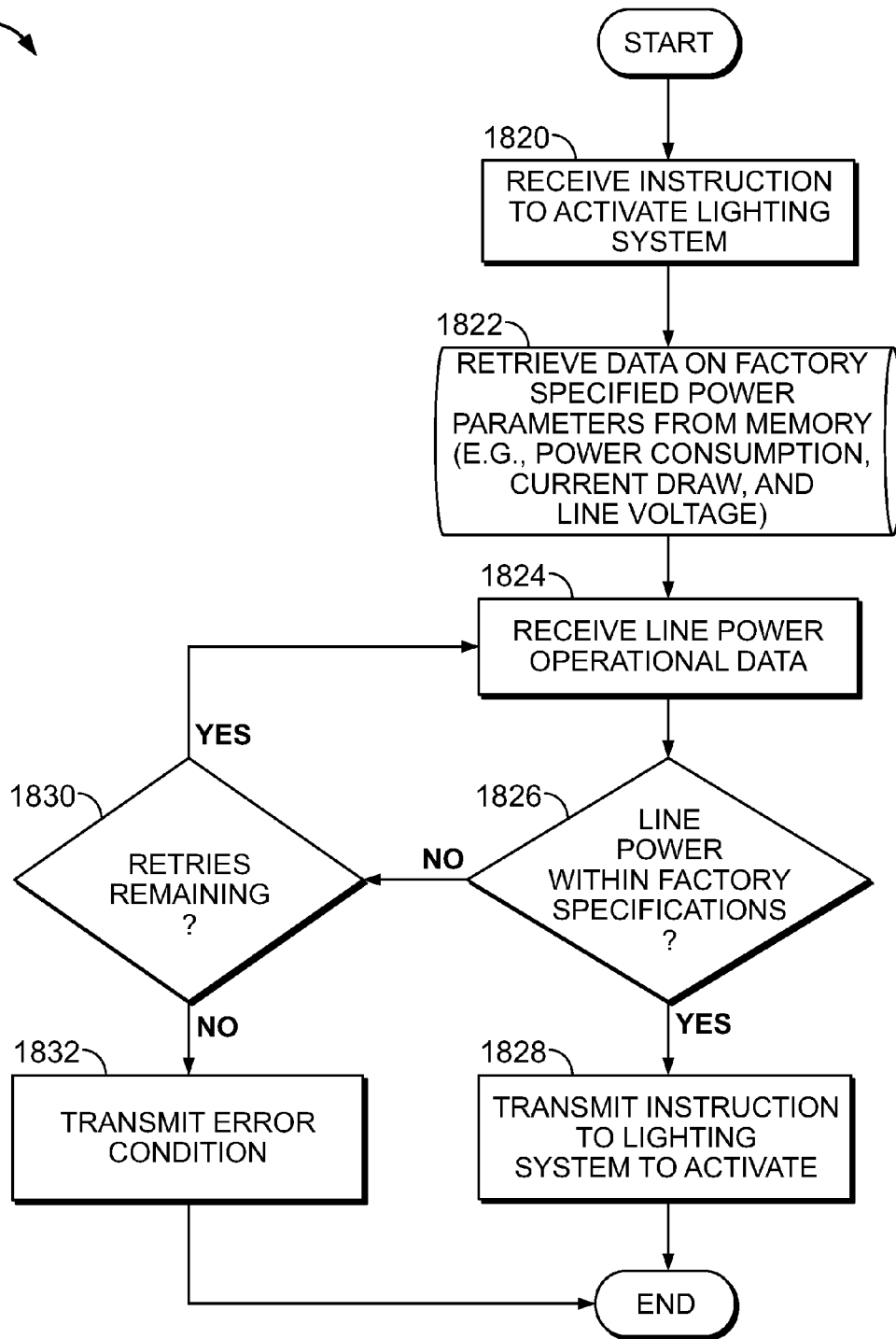


FIG. 25A

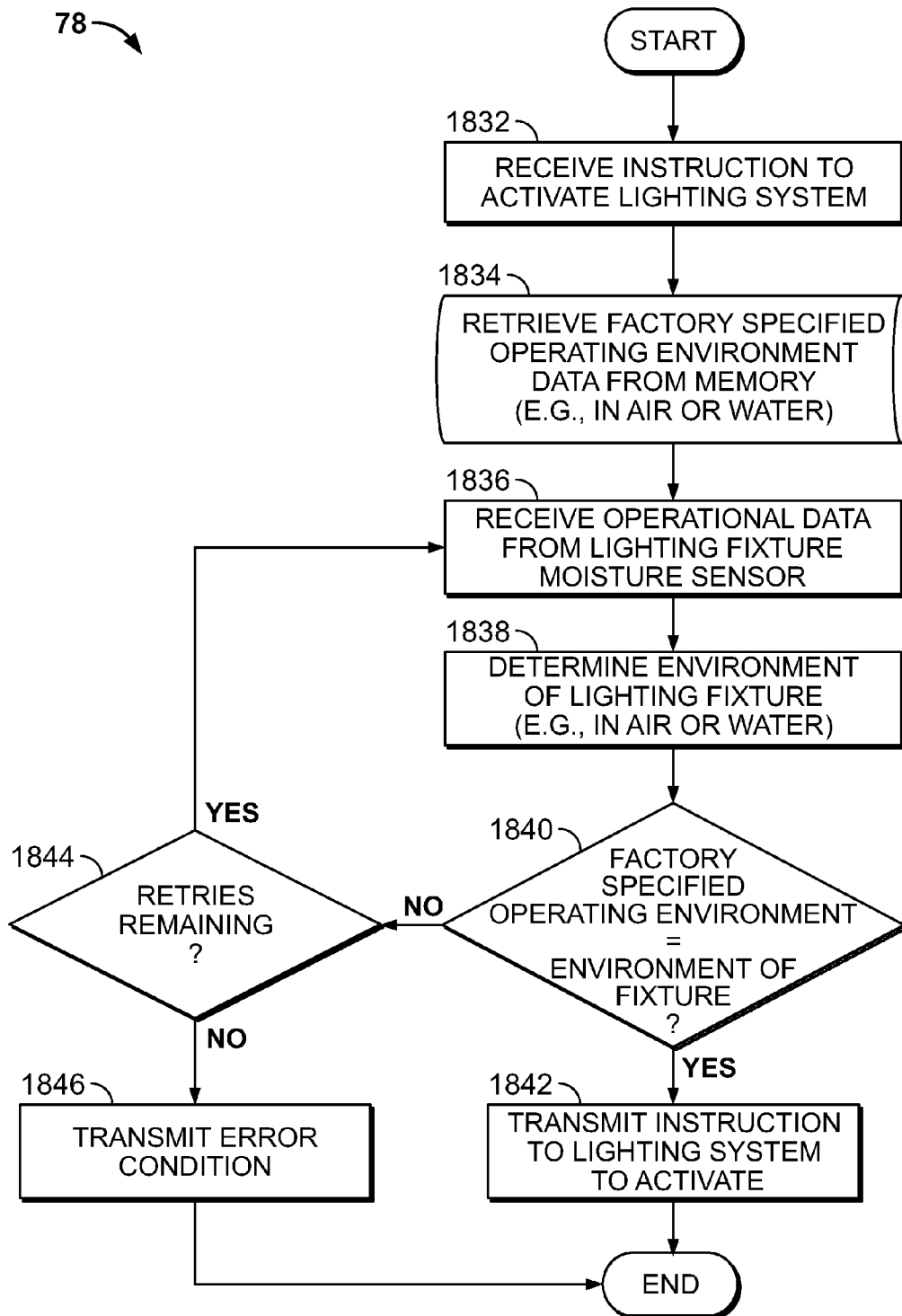


FIG. 25B

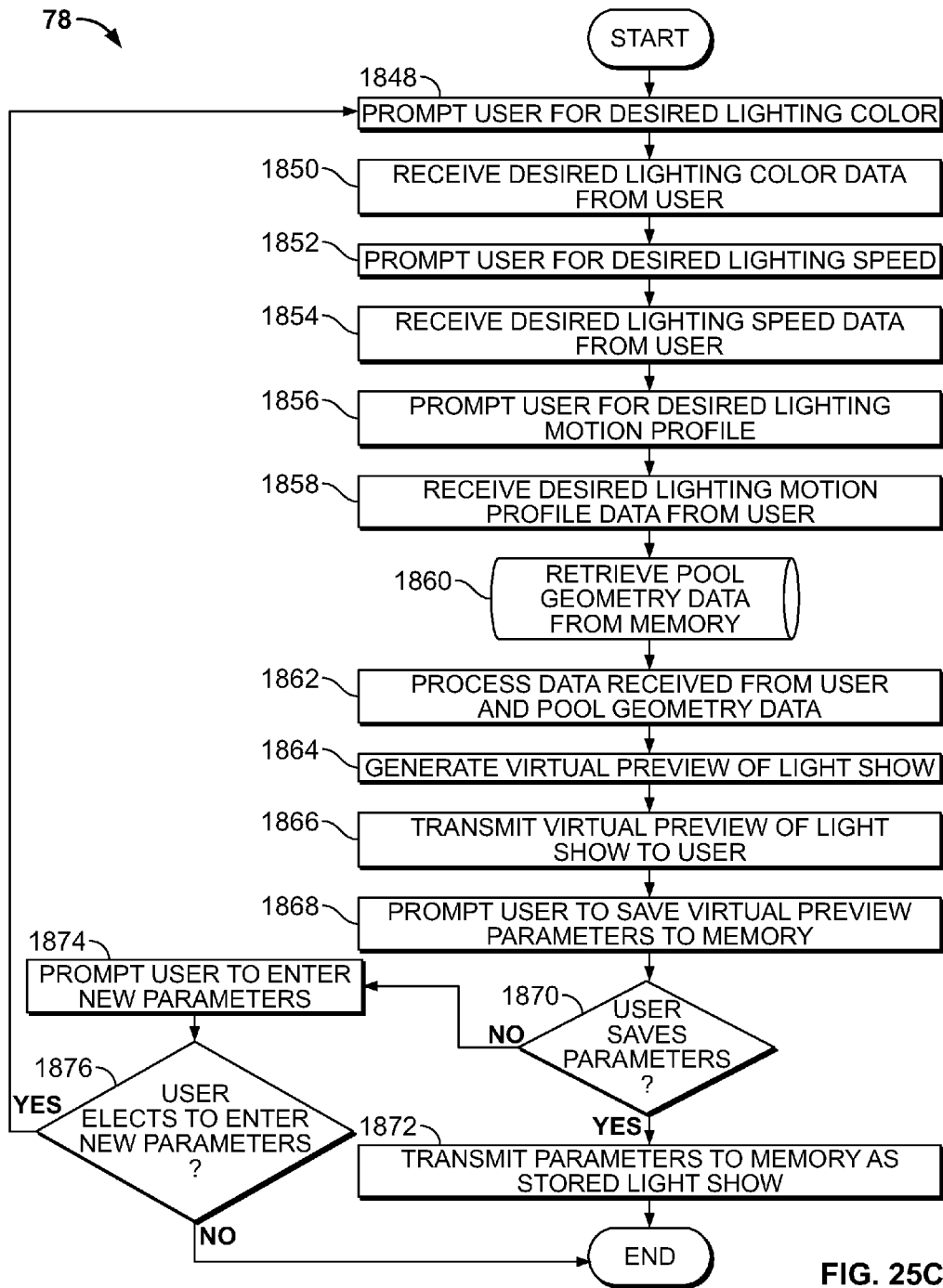


FIG. 25C

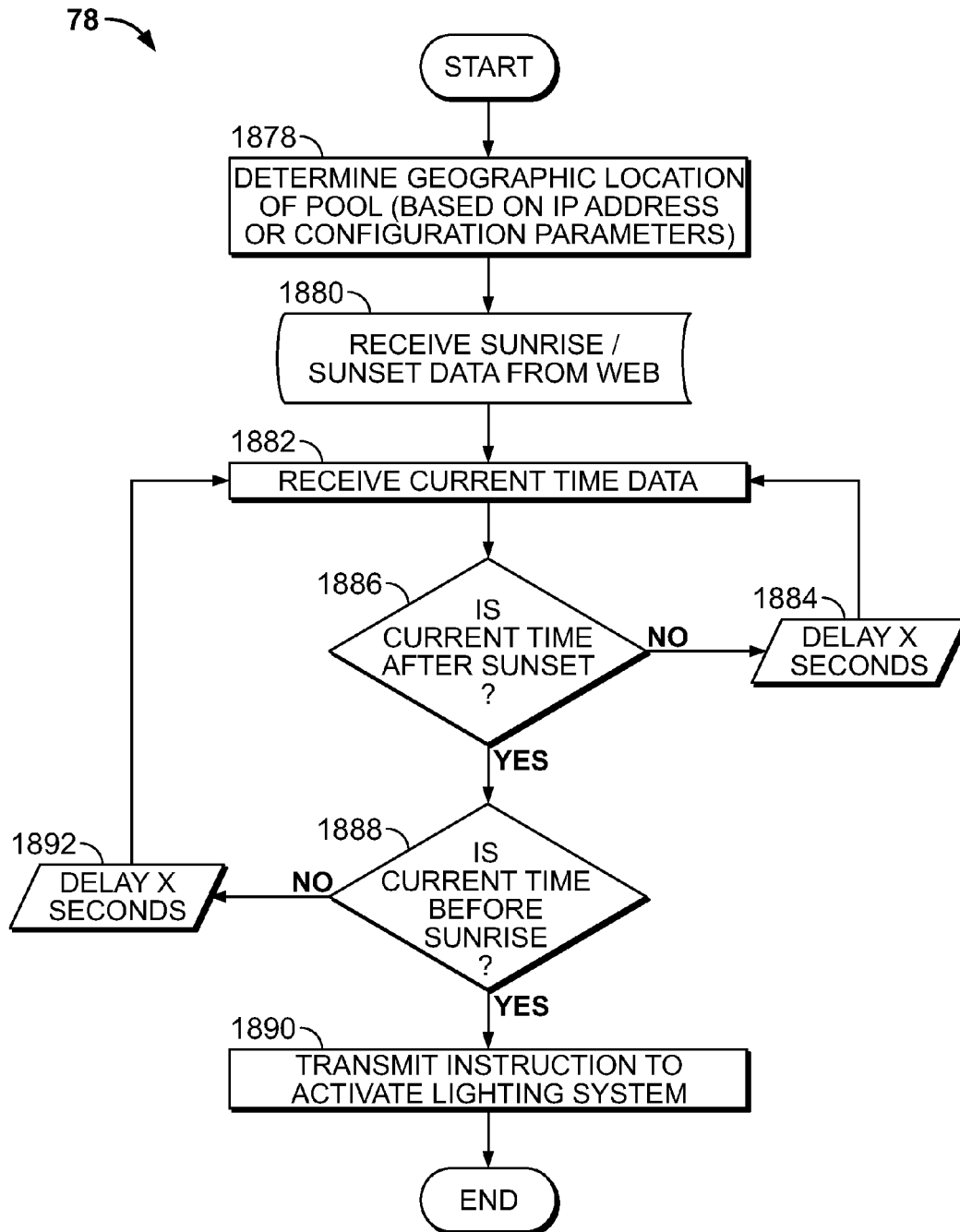


FIG. 25D

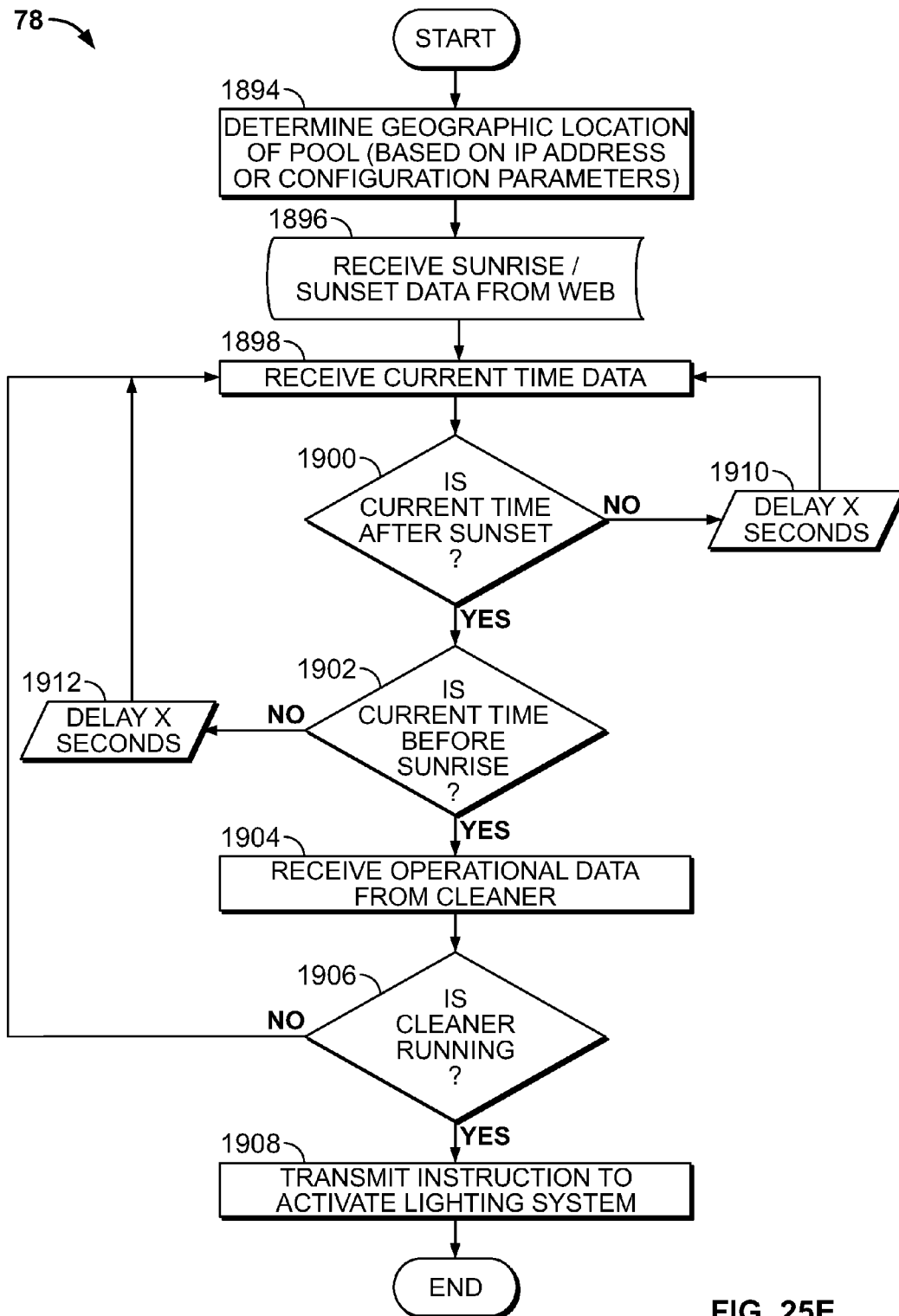


FIG. 25E

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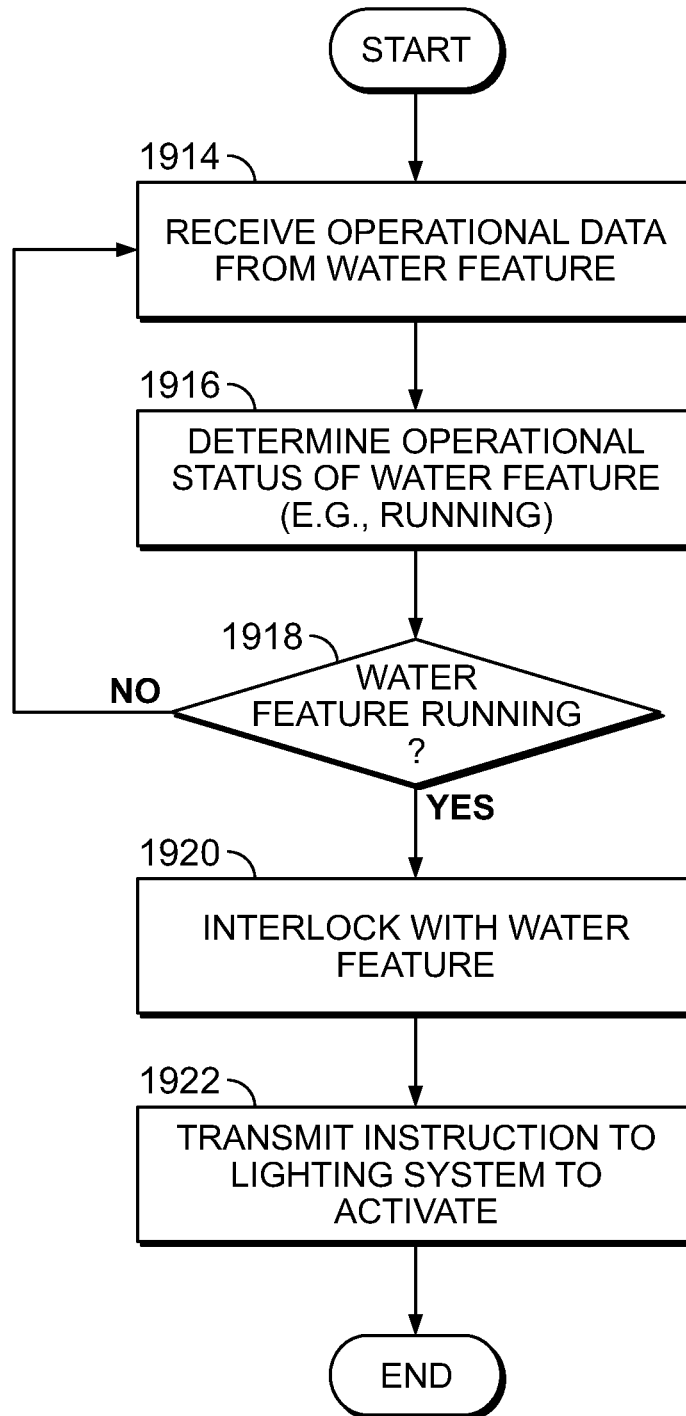


FIG. 25F

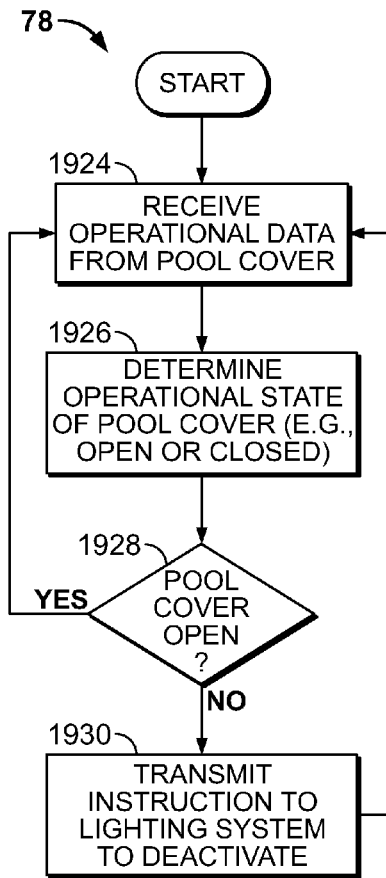


FIG. 25G

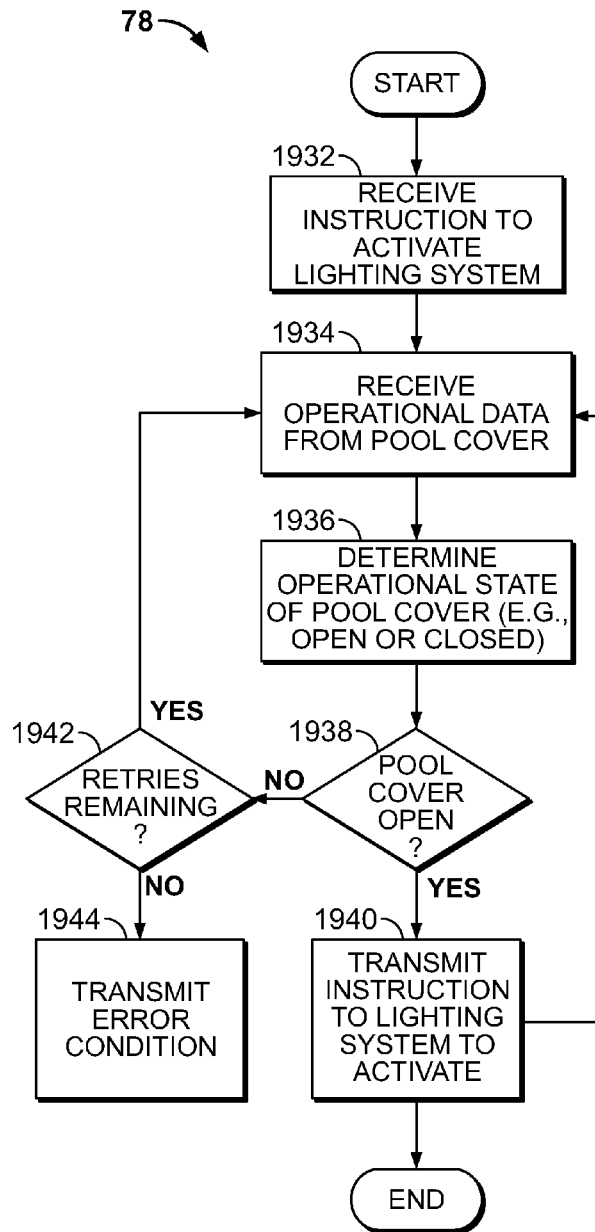


FIG. 25H

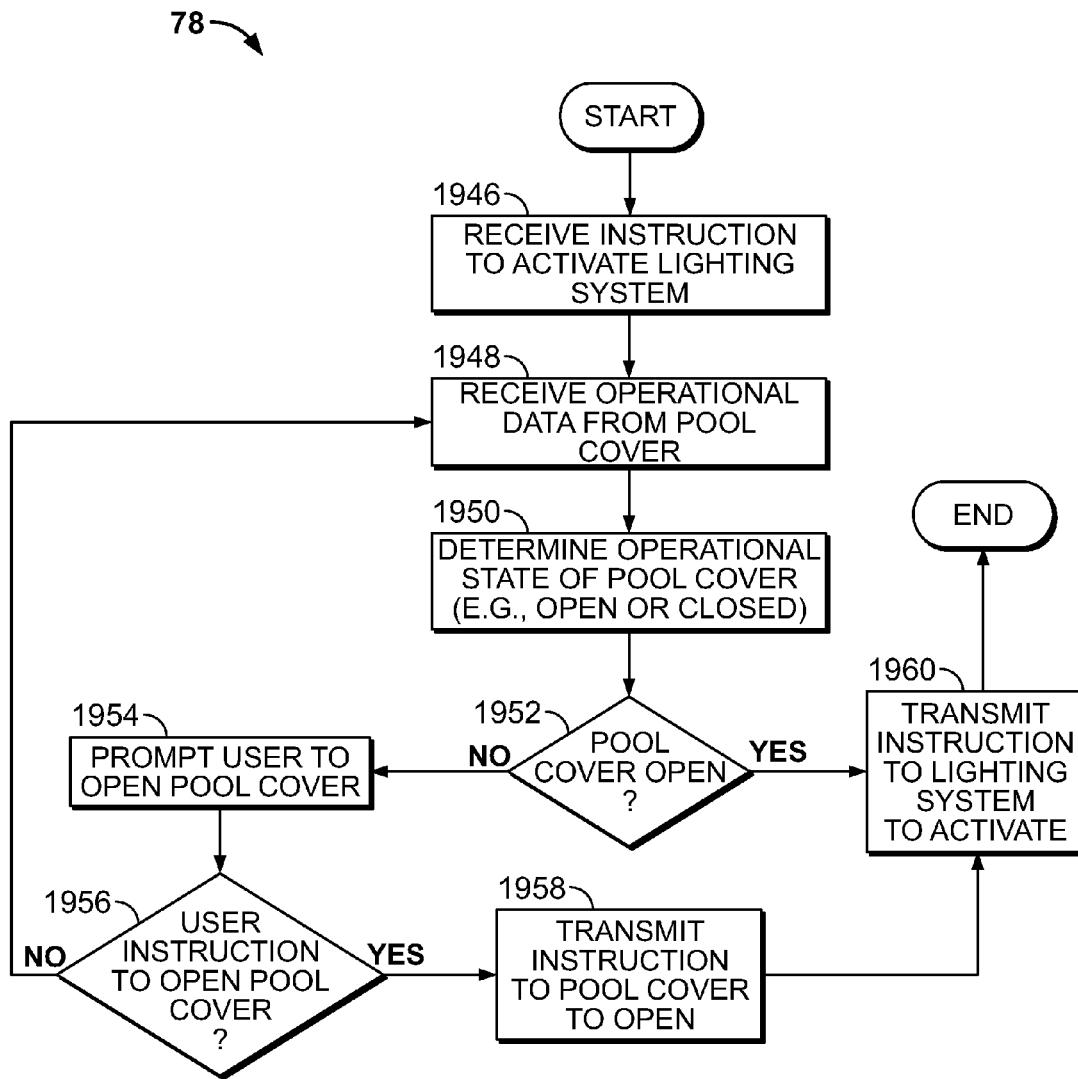


FIG. 25I

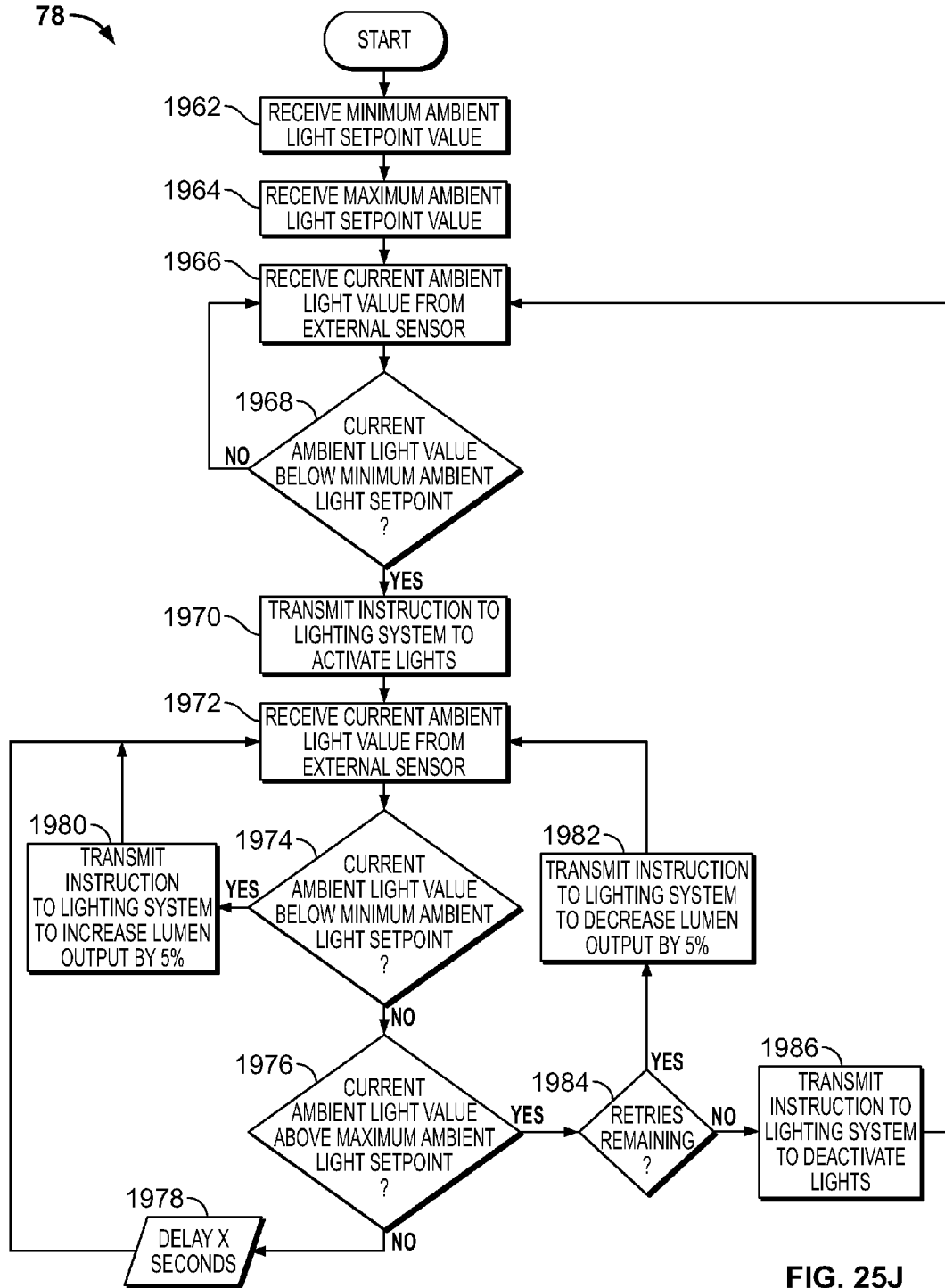


FIG. 25J

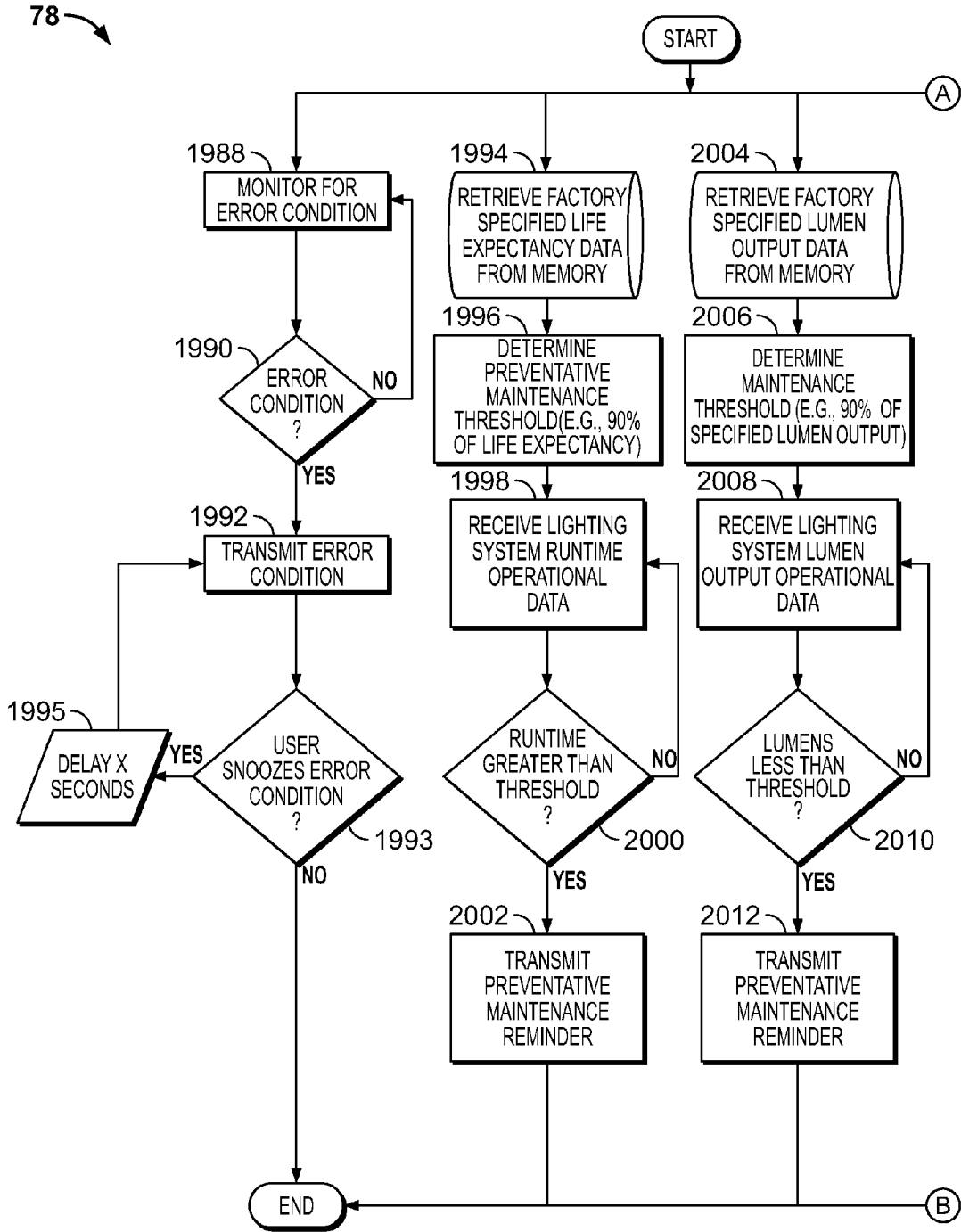


FIG. 25K

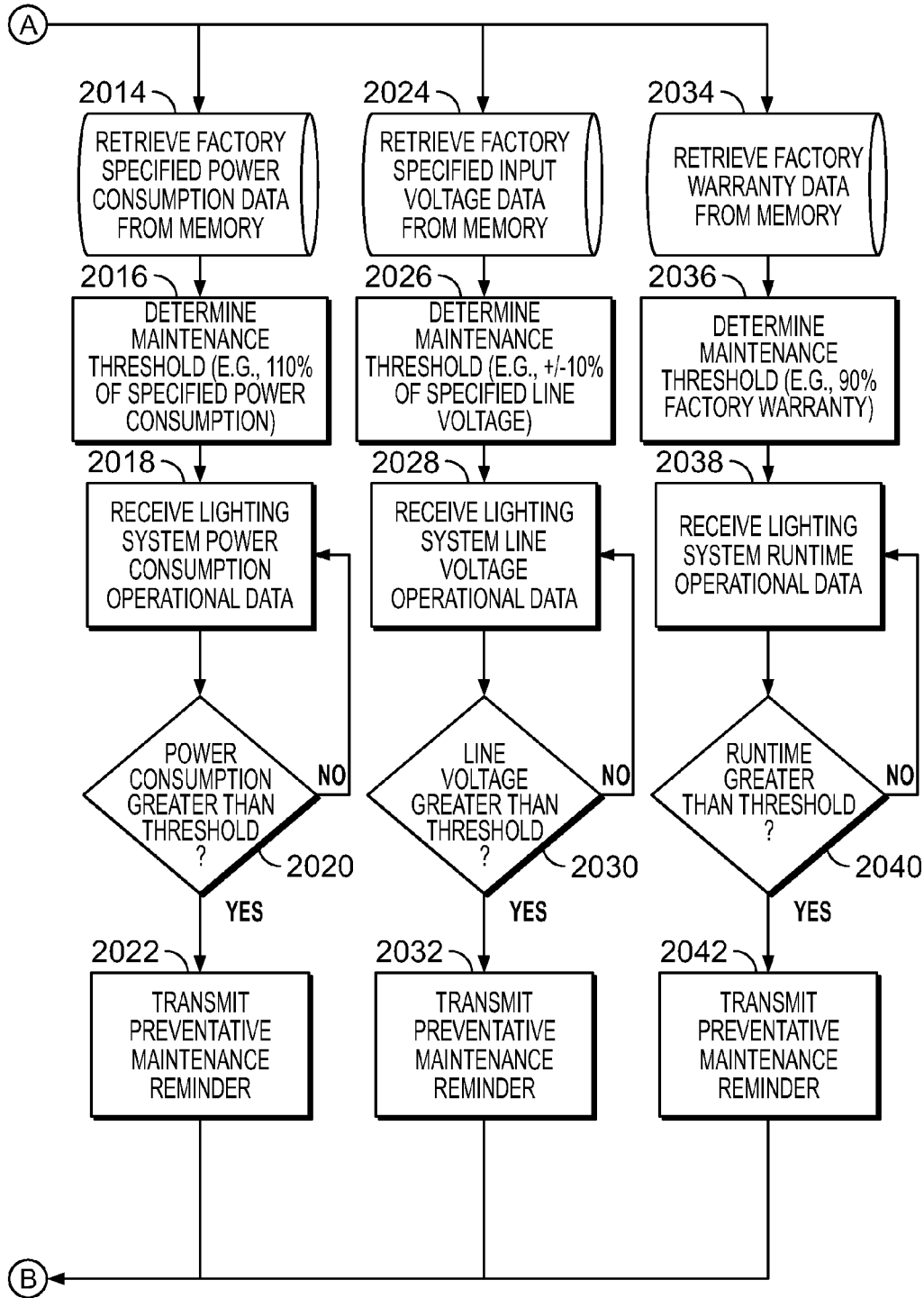


FIG. 25K (Cont.)

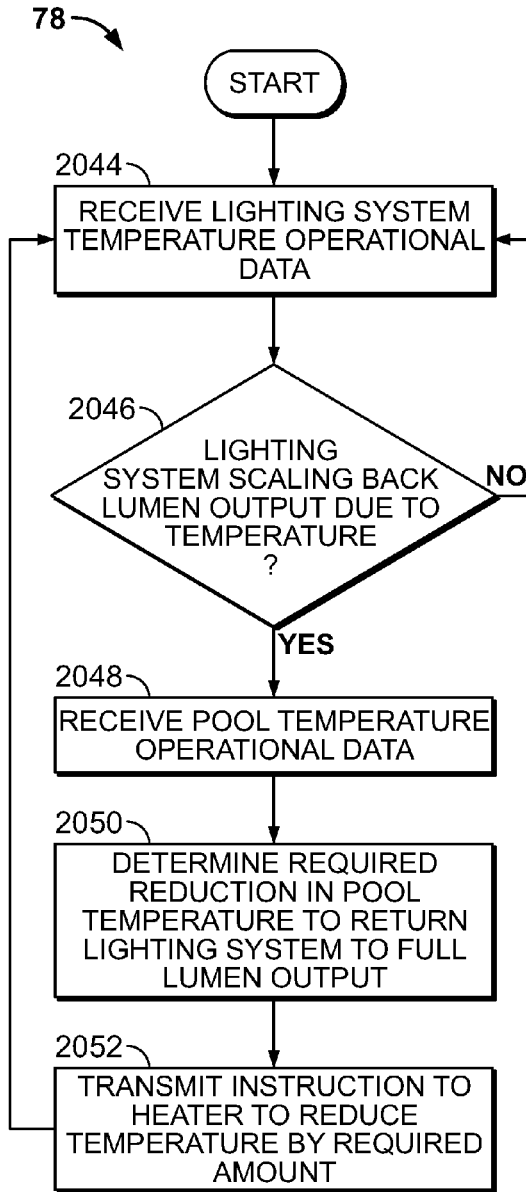


FIG. 25L

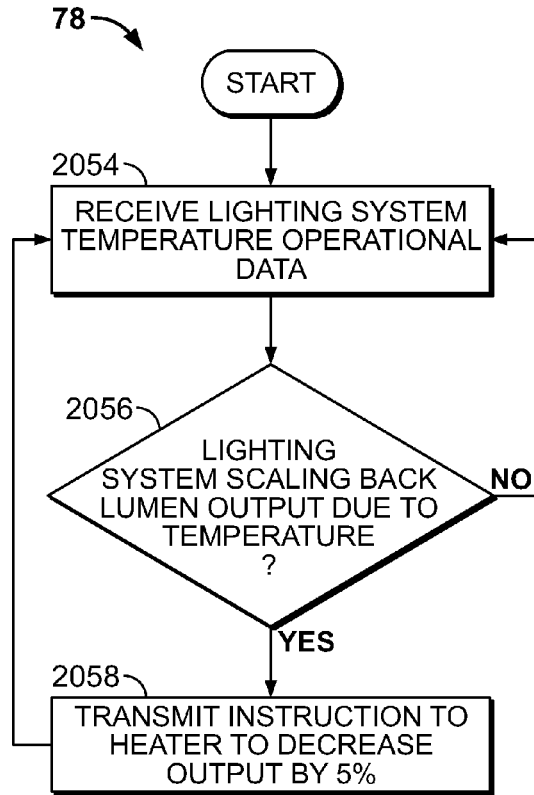


FIG. 25M

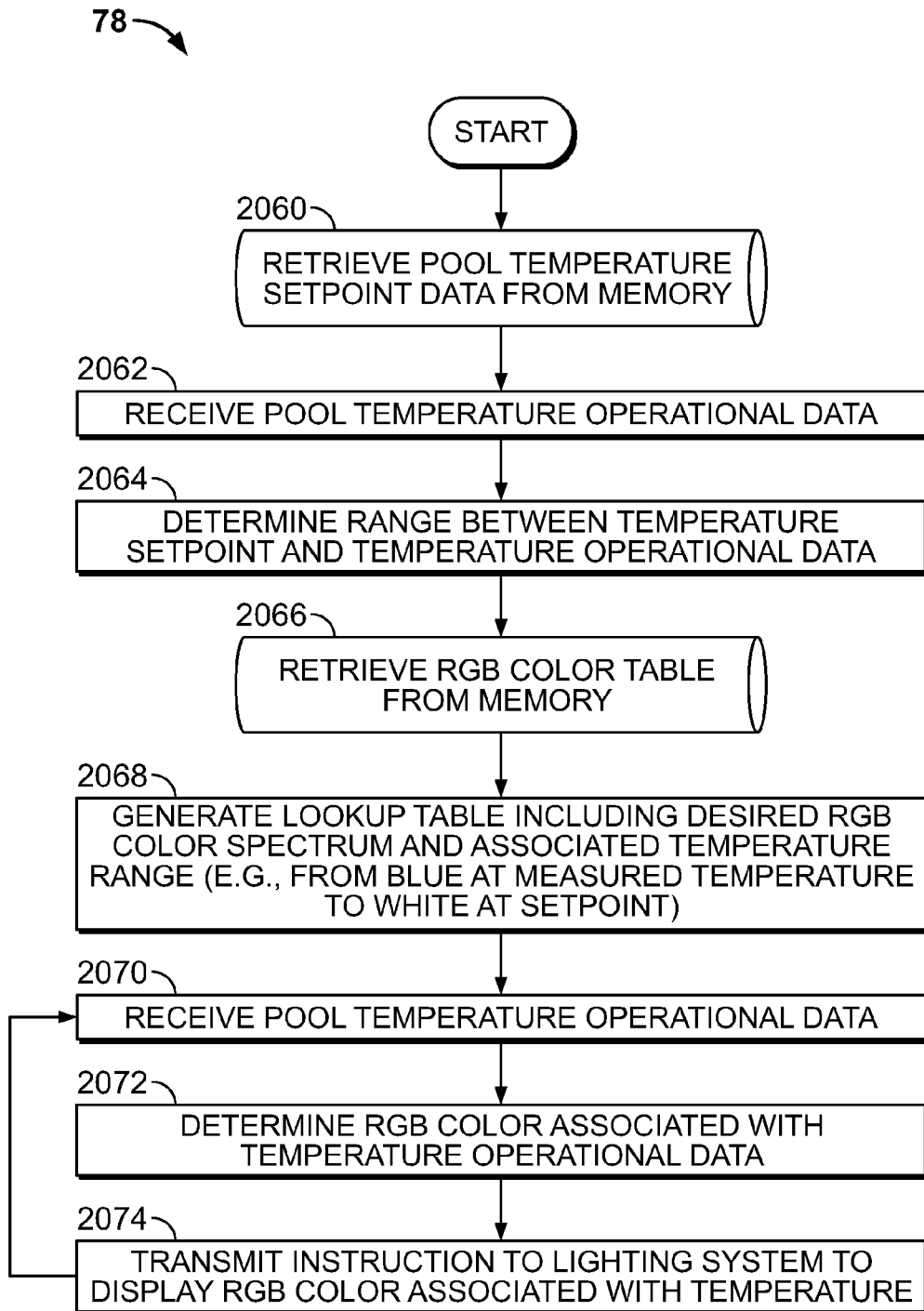


FIG. 25N

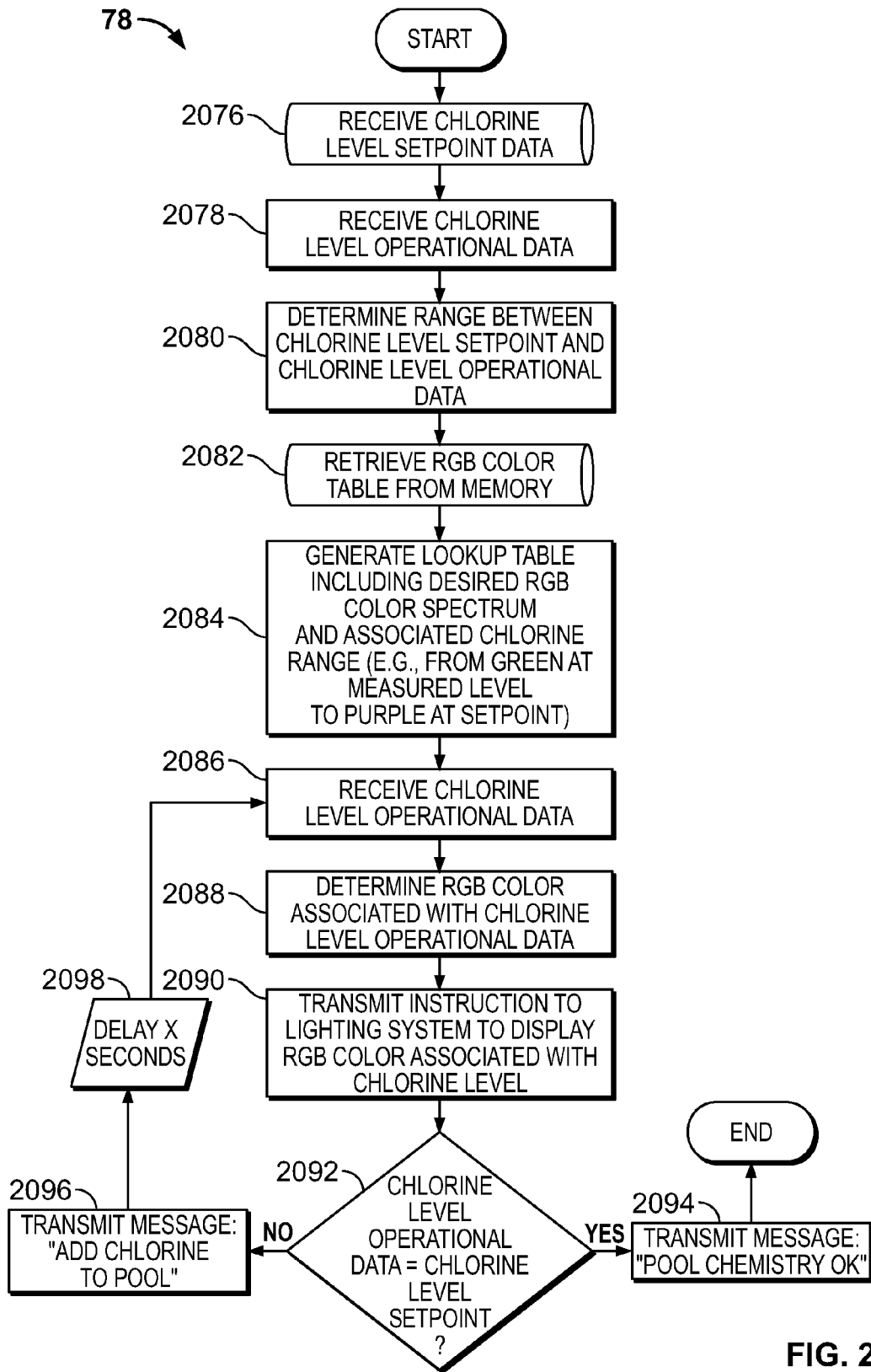


FIG. 250

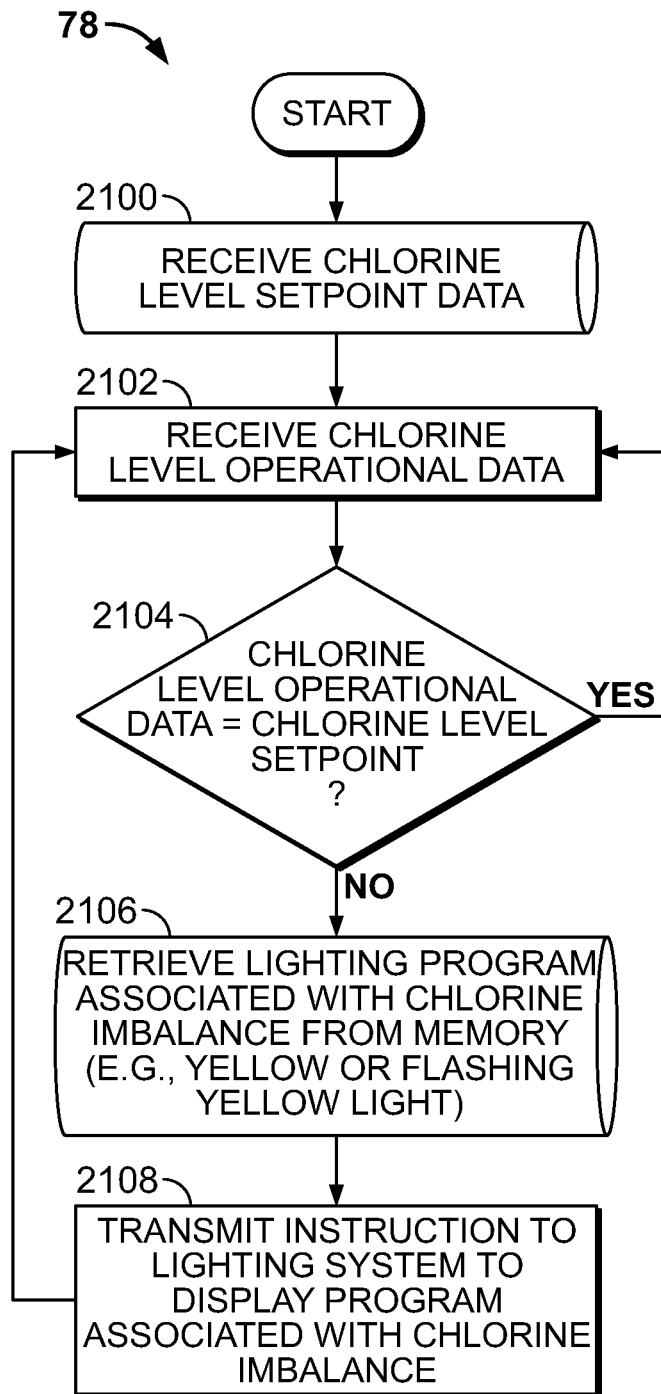


FIG. 25P

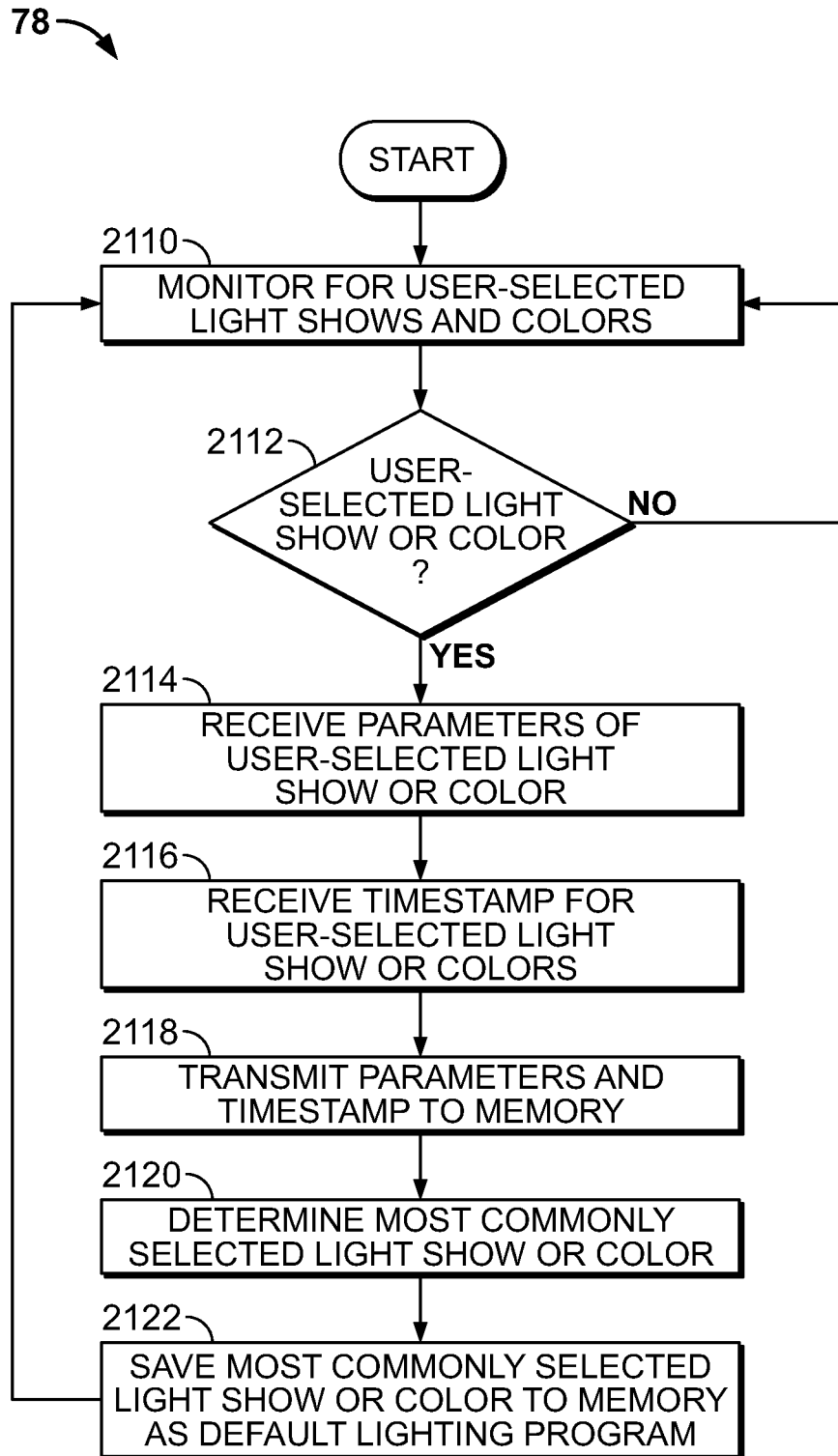


FIG. 25Q

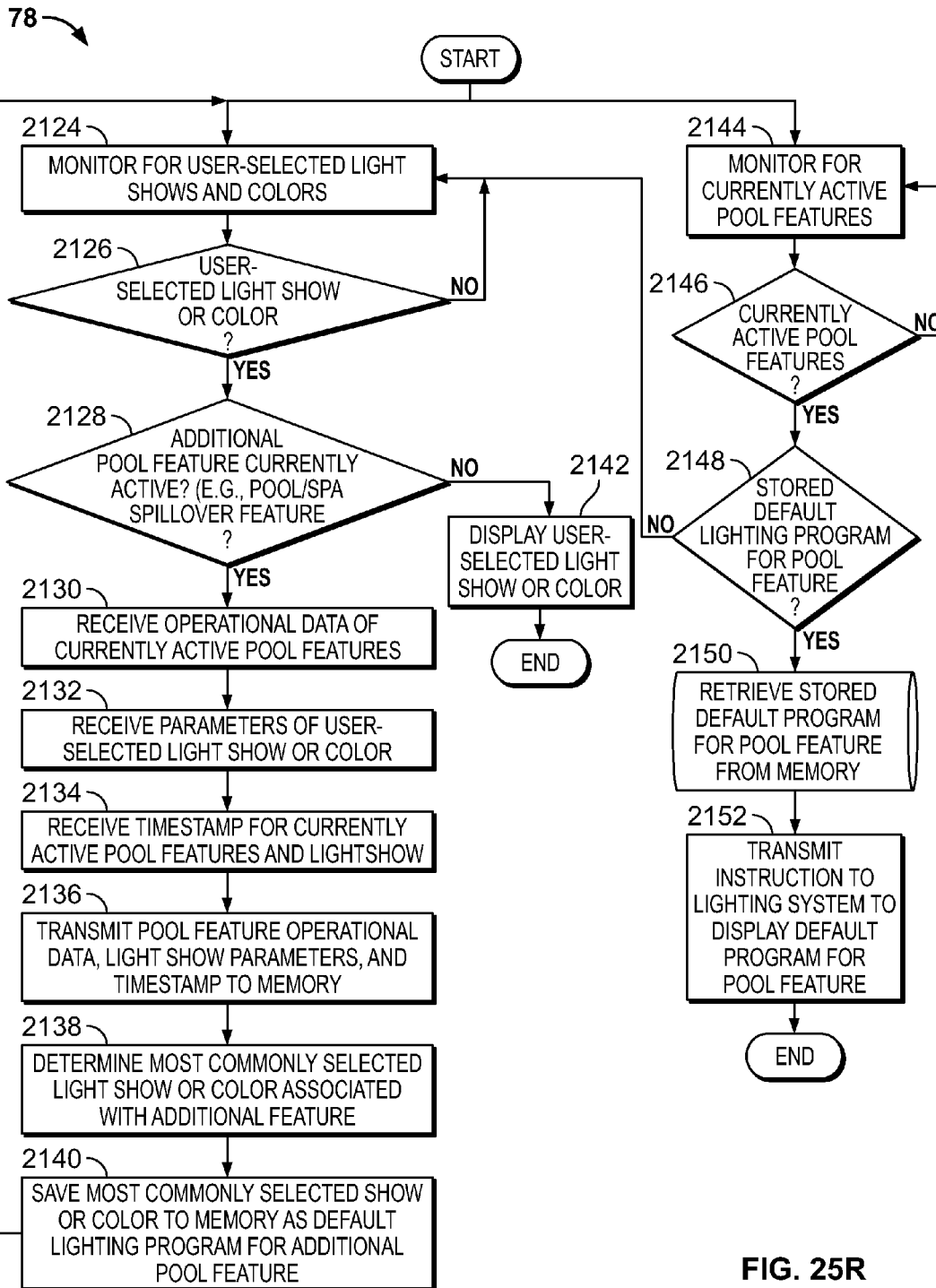


FIG. 25R

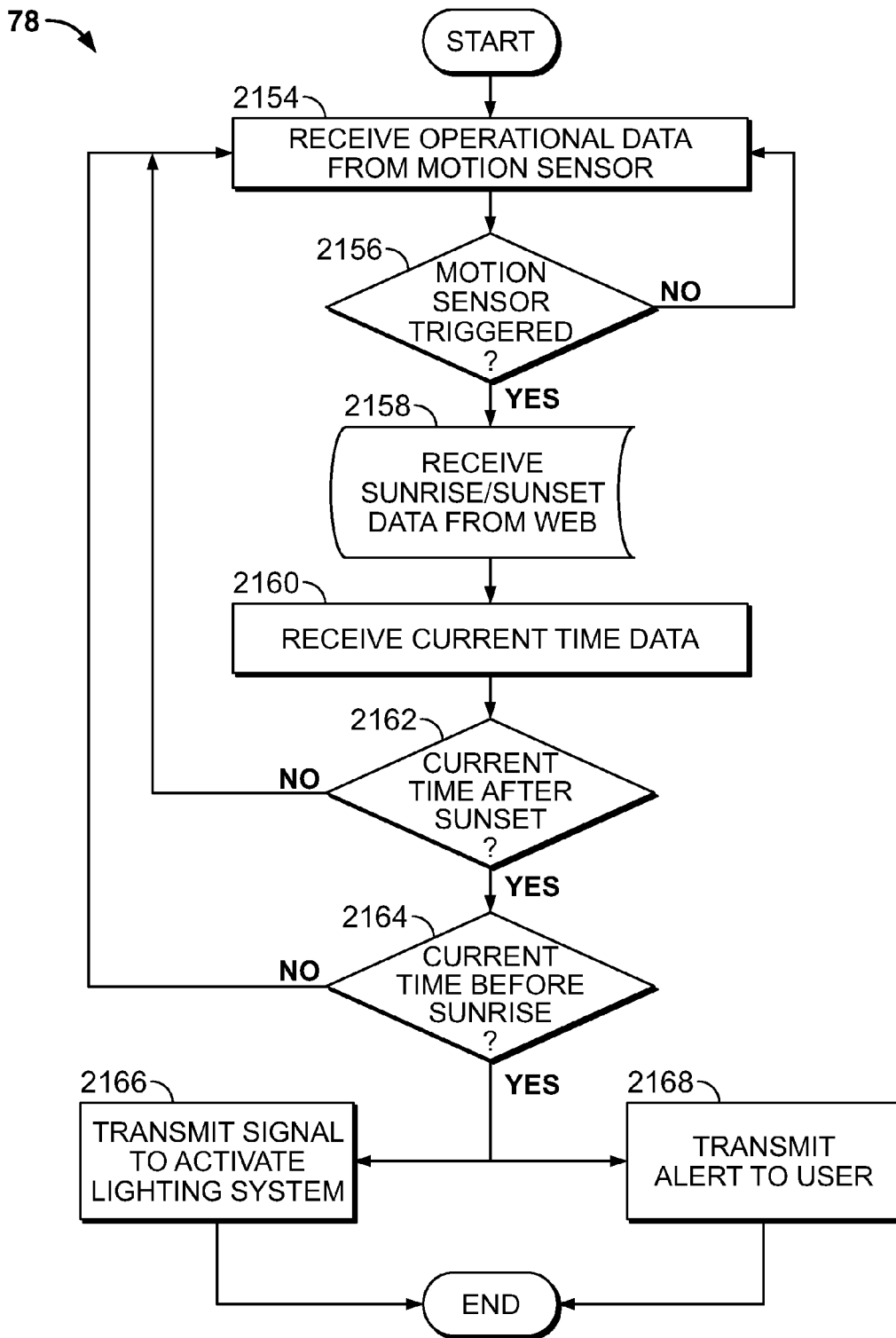


FIG. 25S

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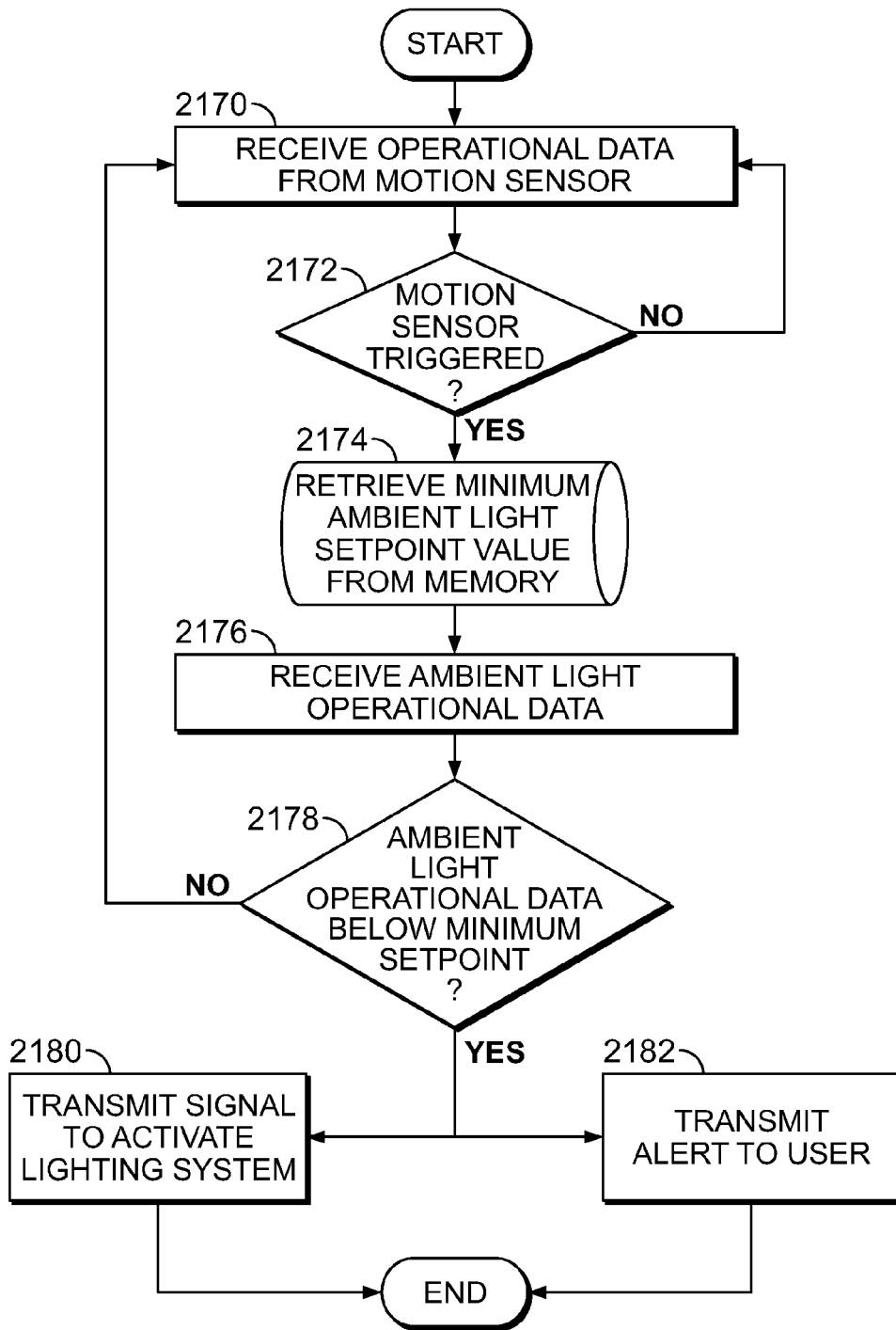


FIG. 25T

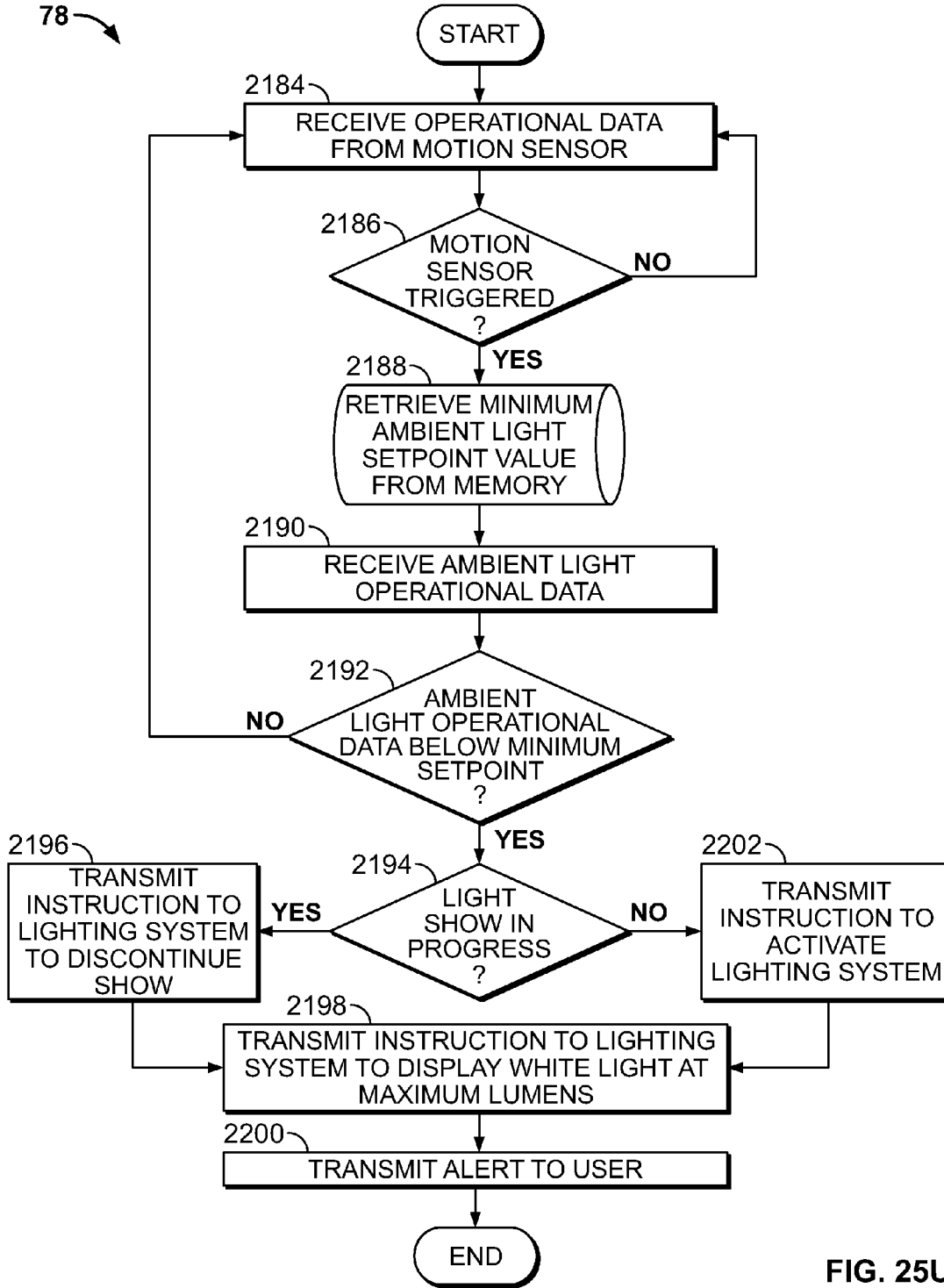


FIG. 25U

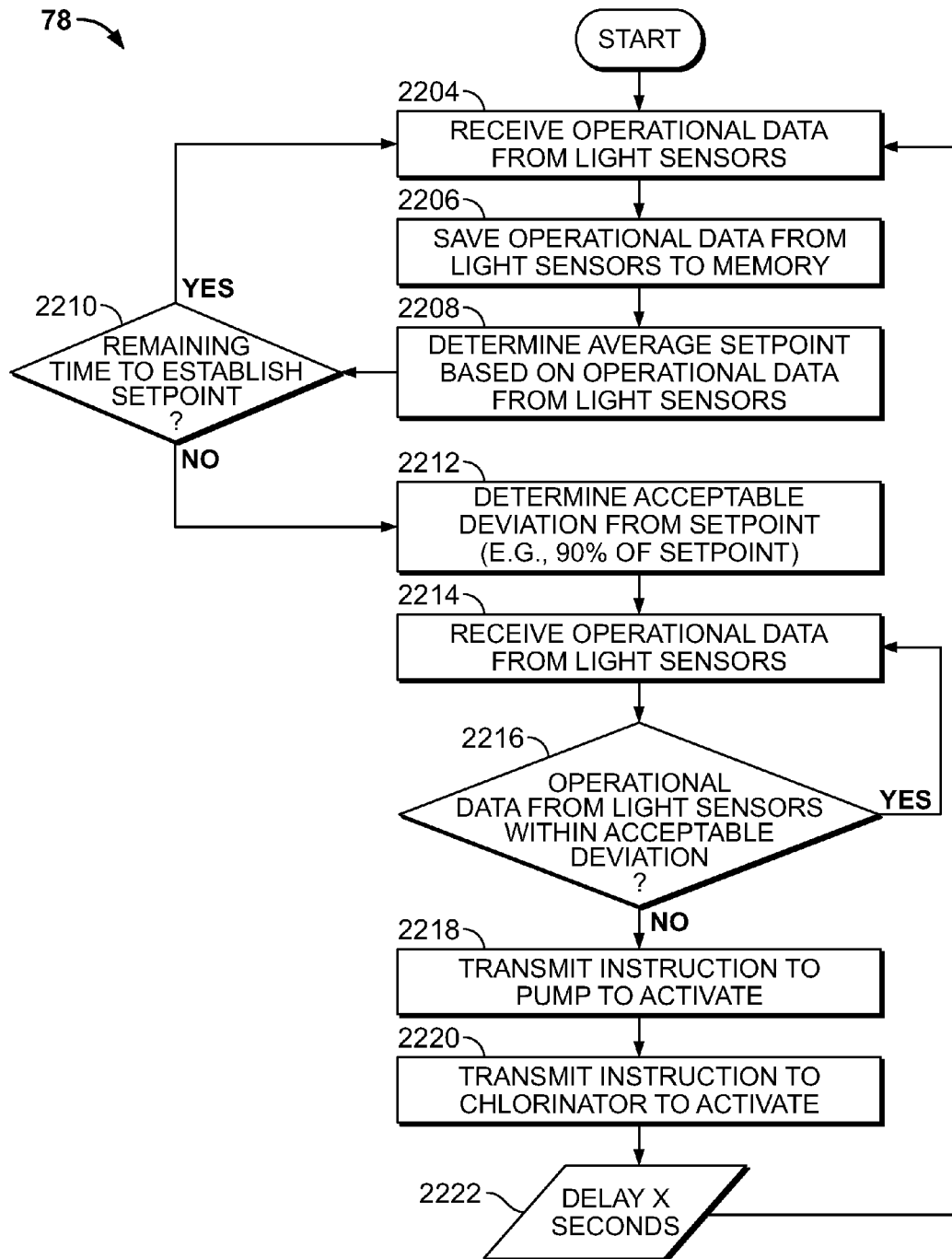


FIG. 25V

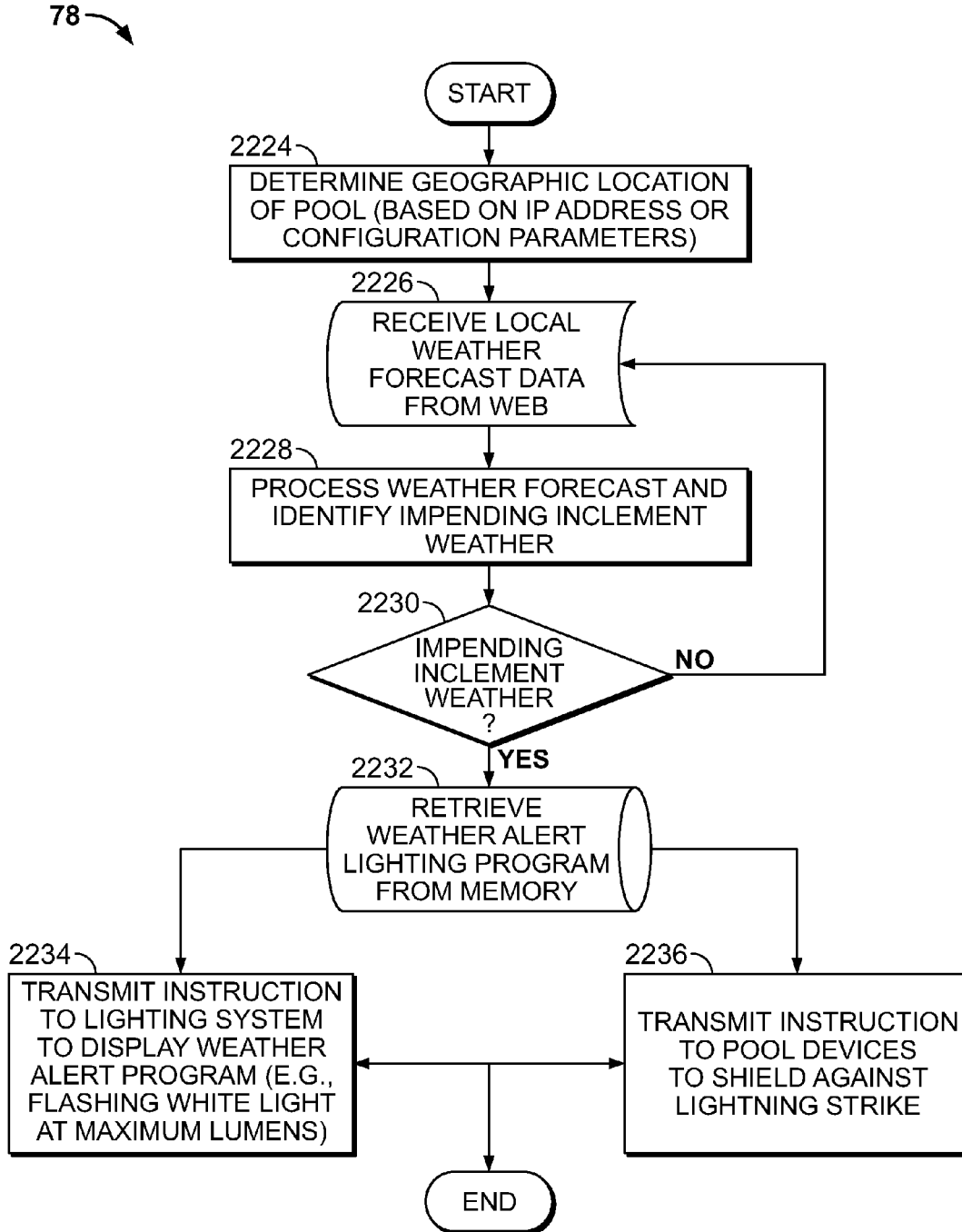


FIG. 25W

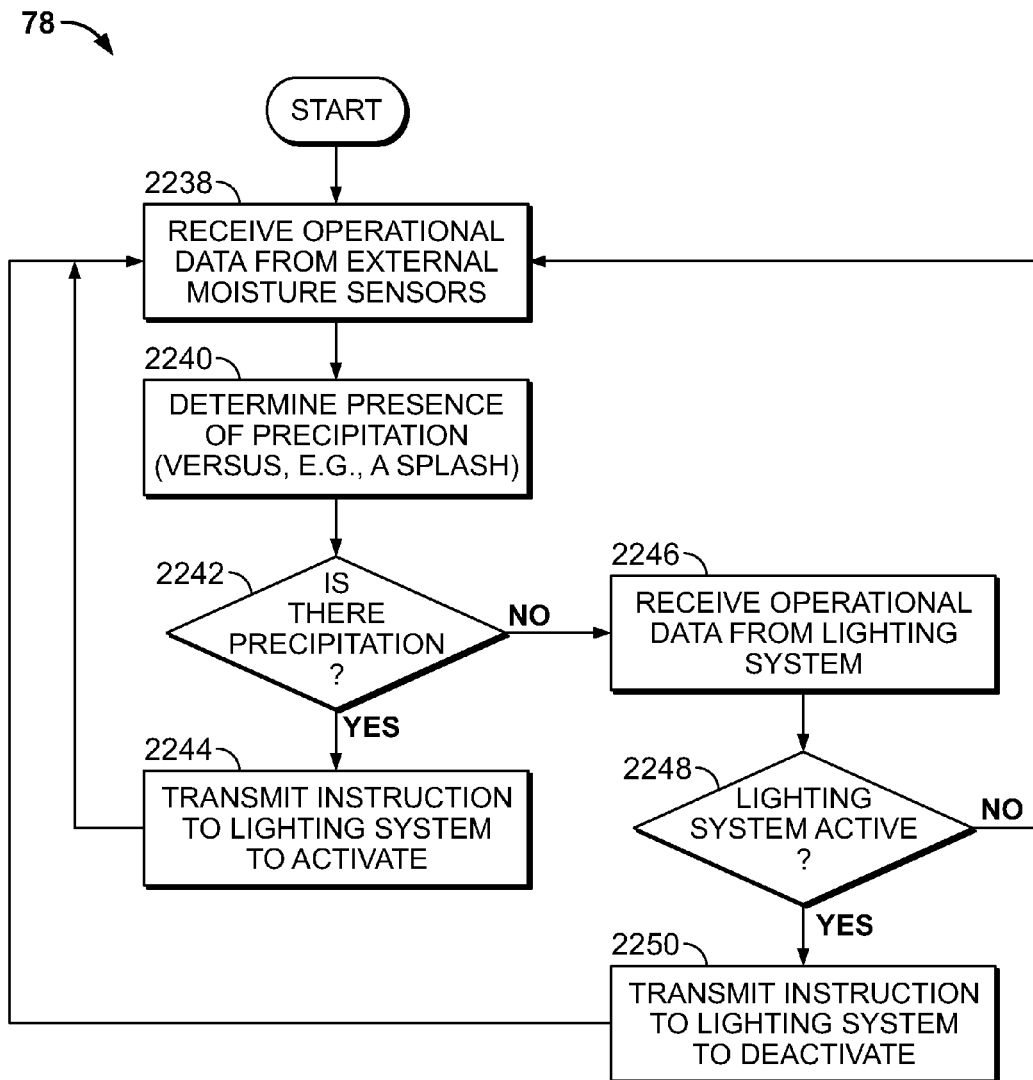


FIG. 25X

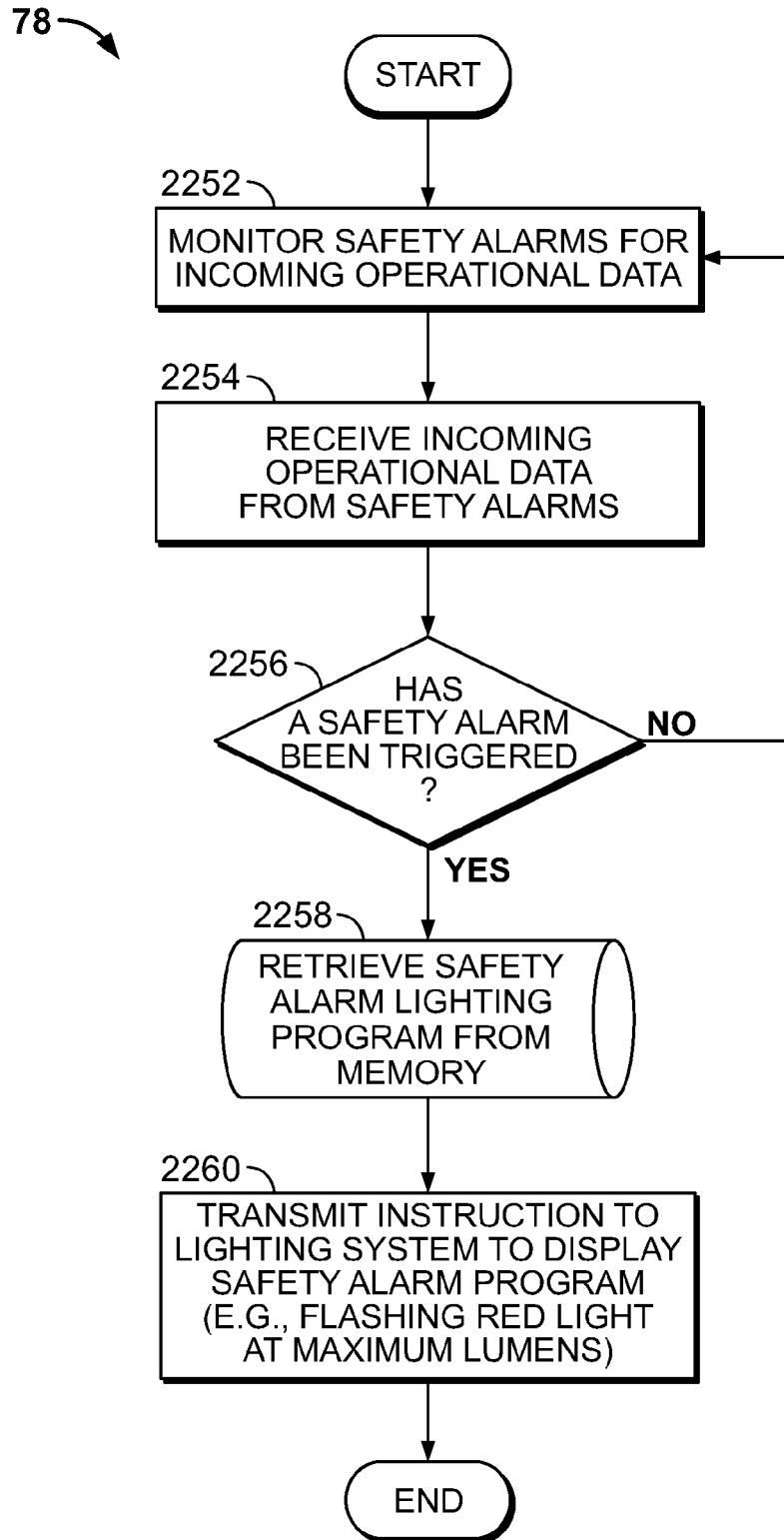


FIG. 25Y

78 ↗

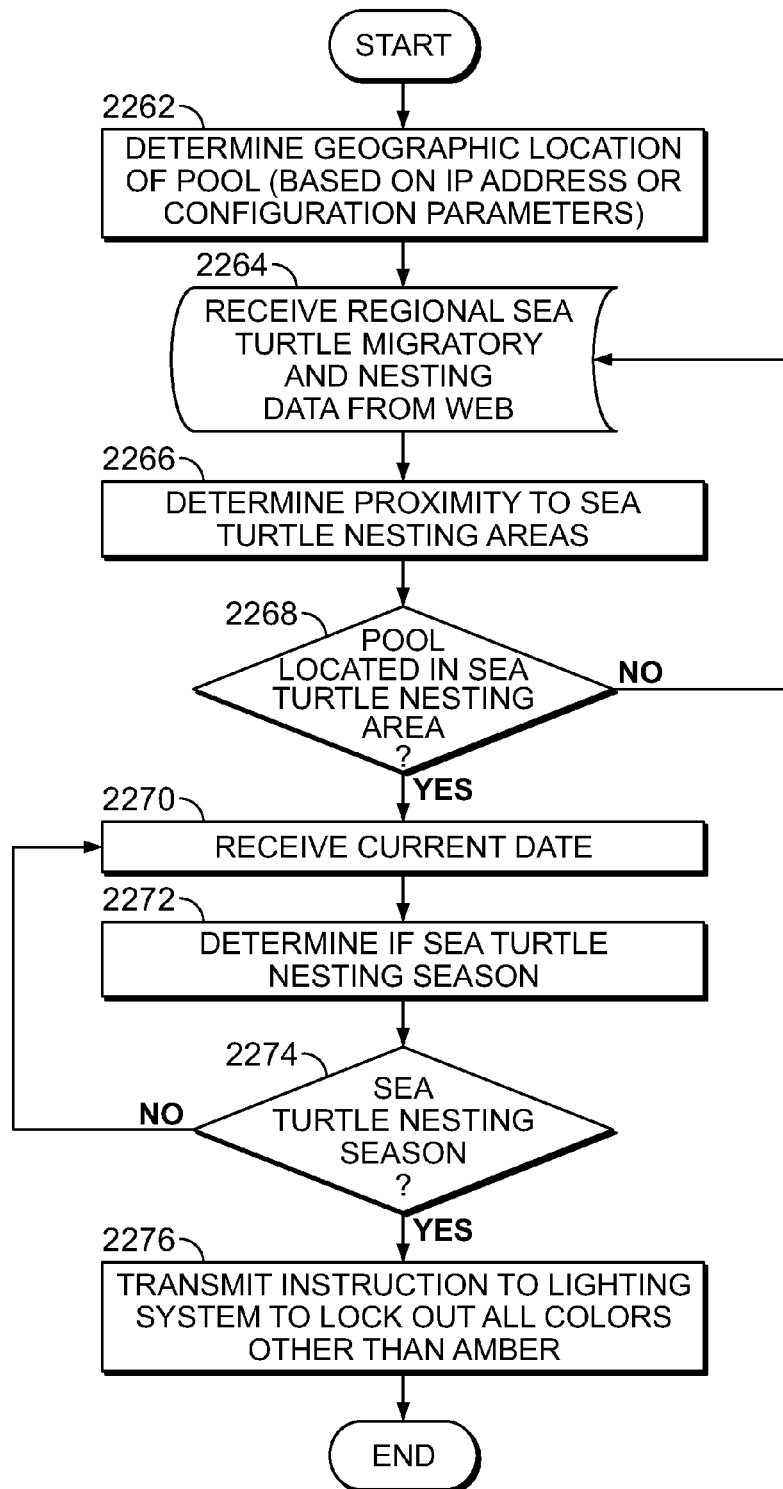


FIG. 25Z

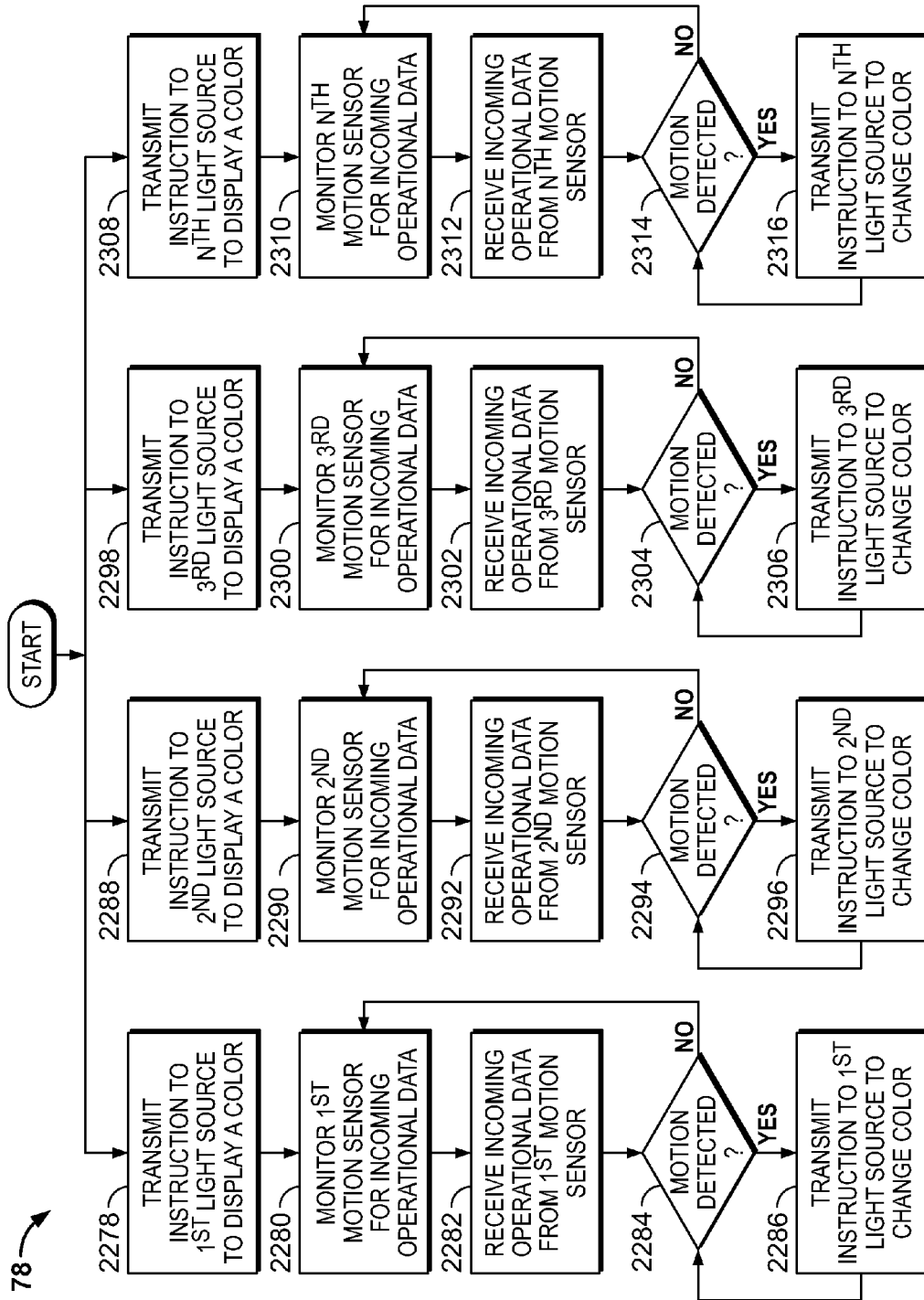


FIG. 25AA

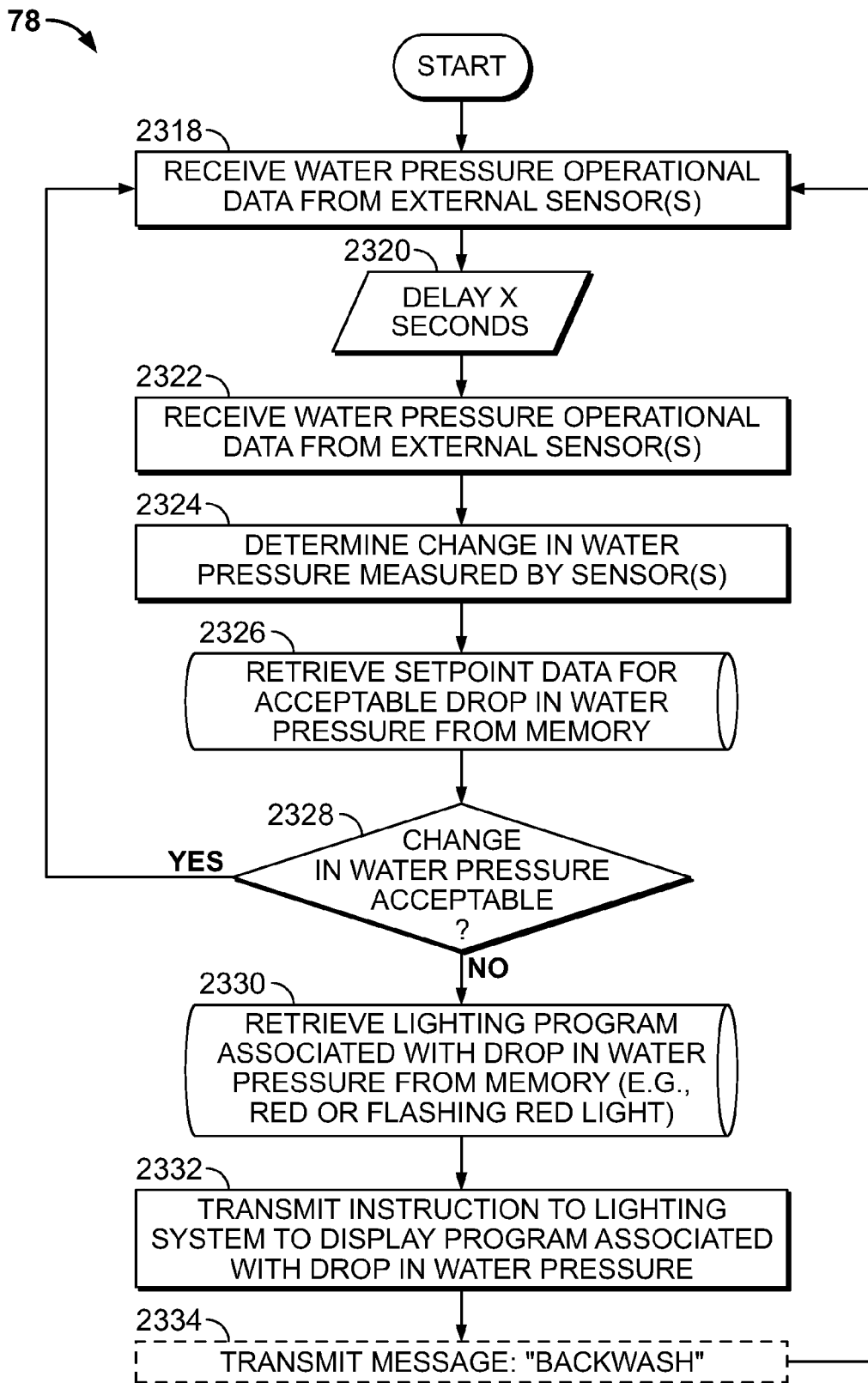


FIG. 25AB

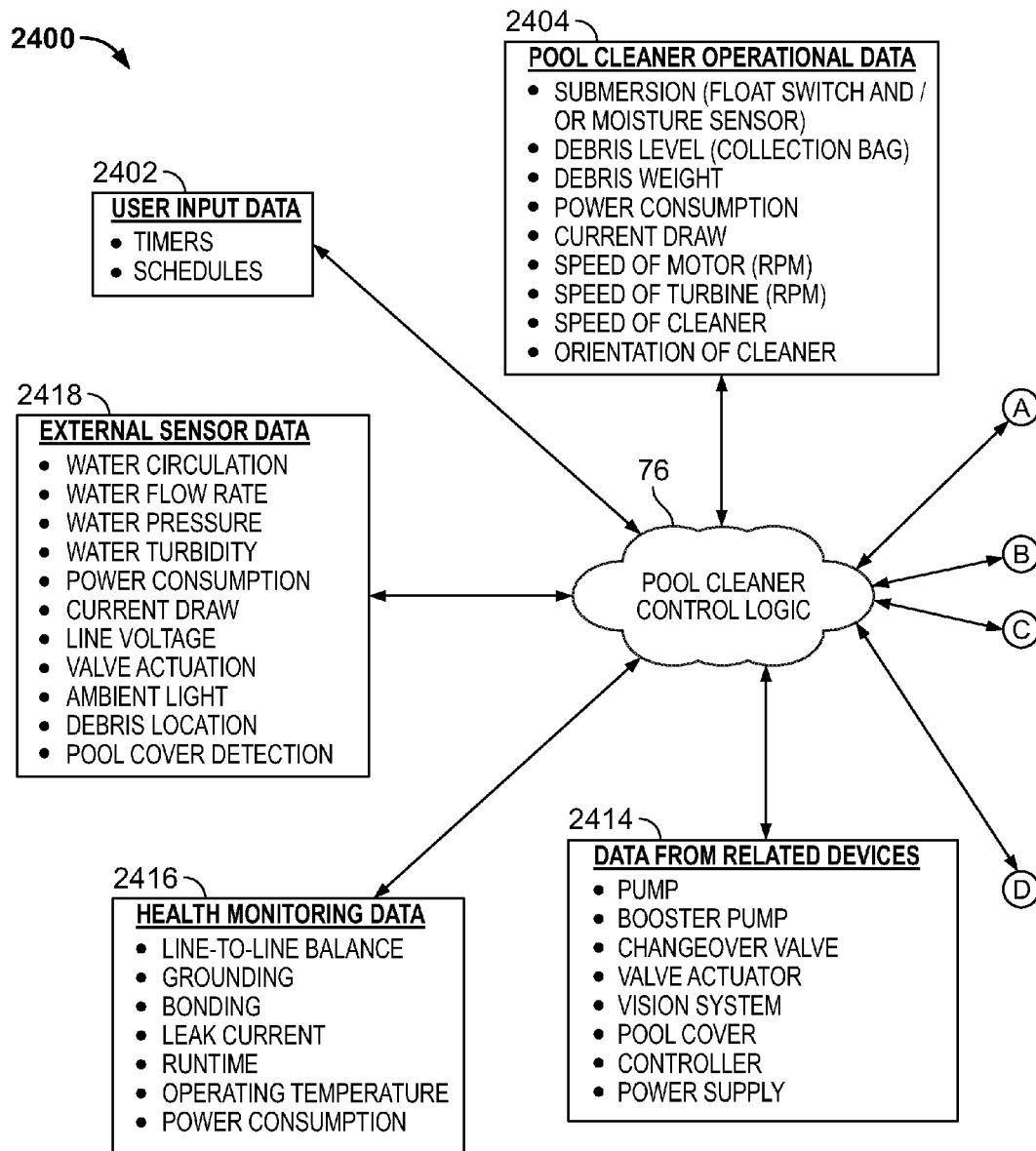


FIG. 26

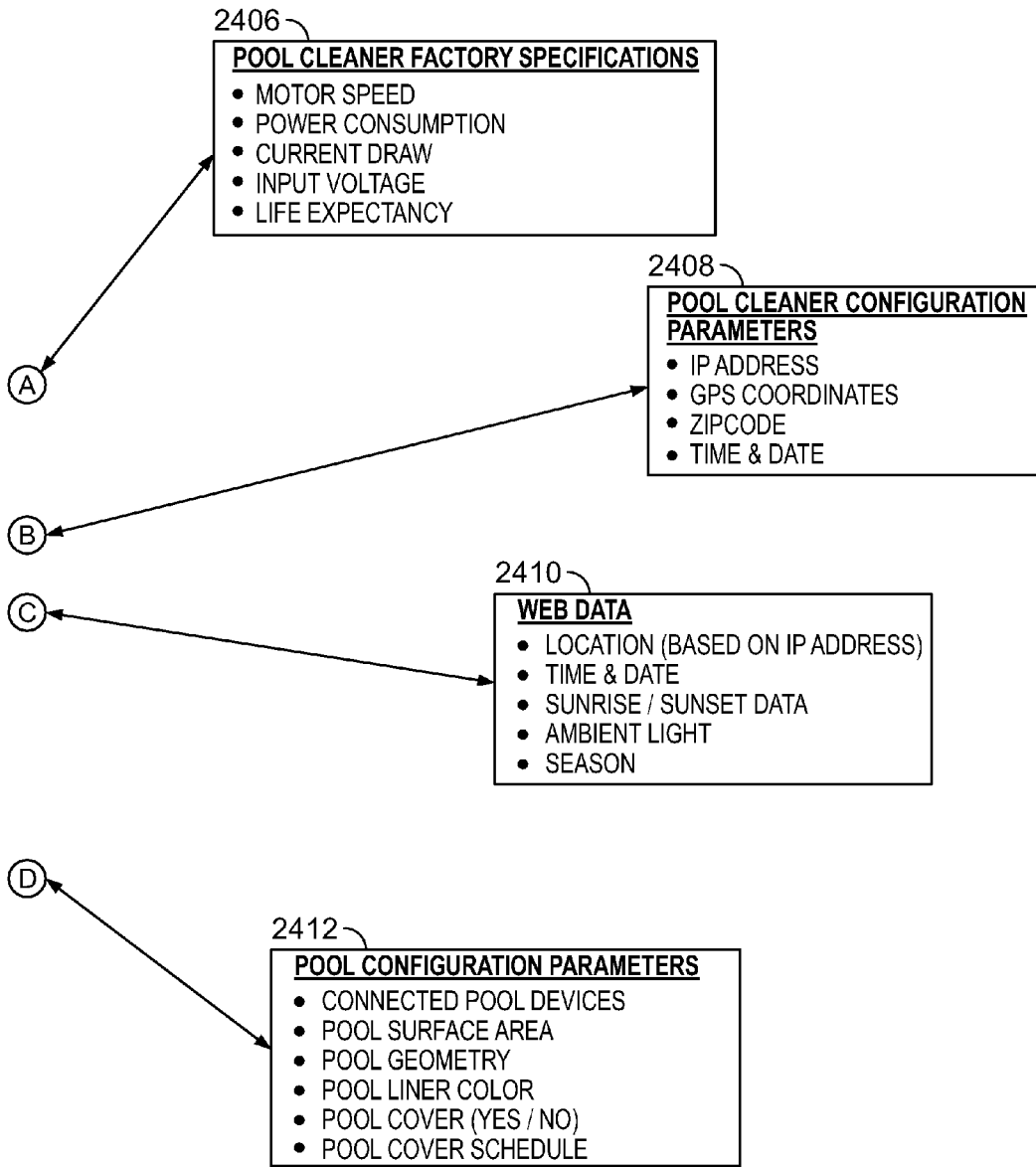


FIG. 26 (Cont.)

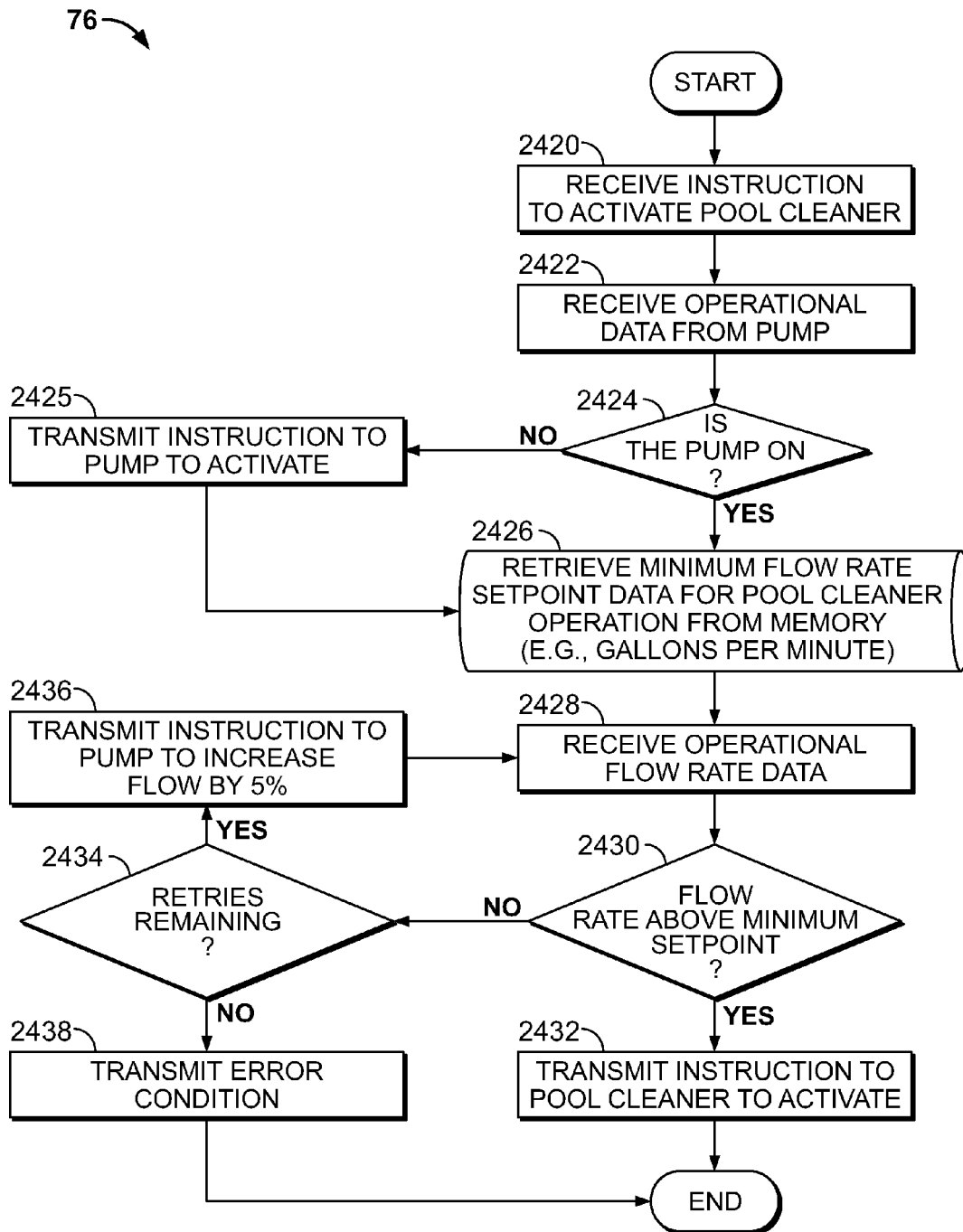


FIG. 27A

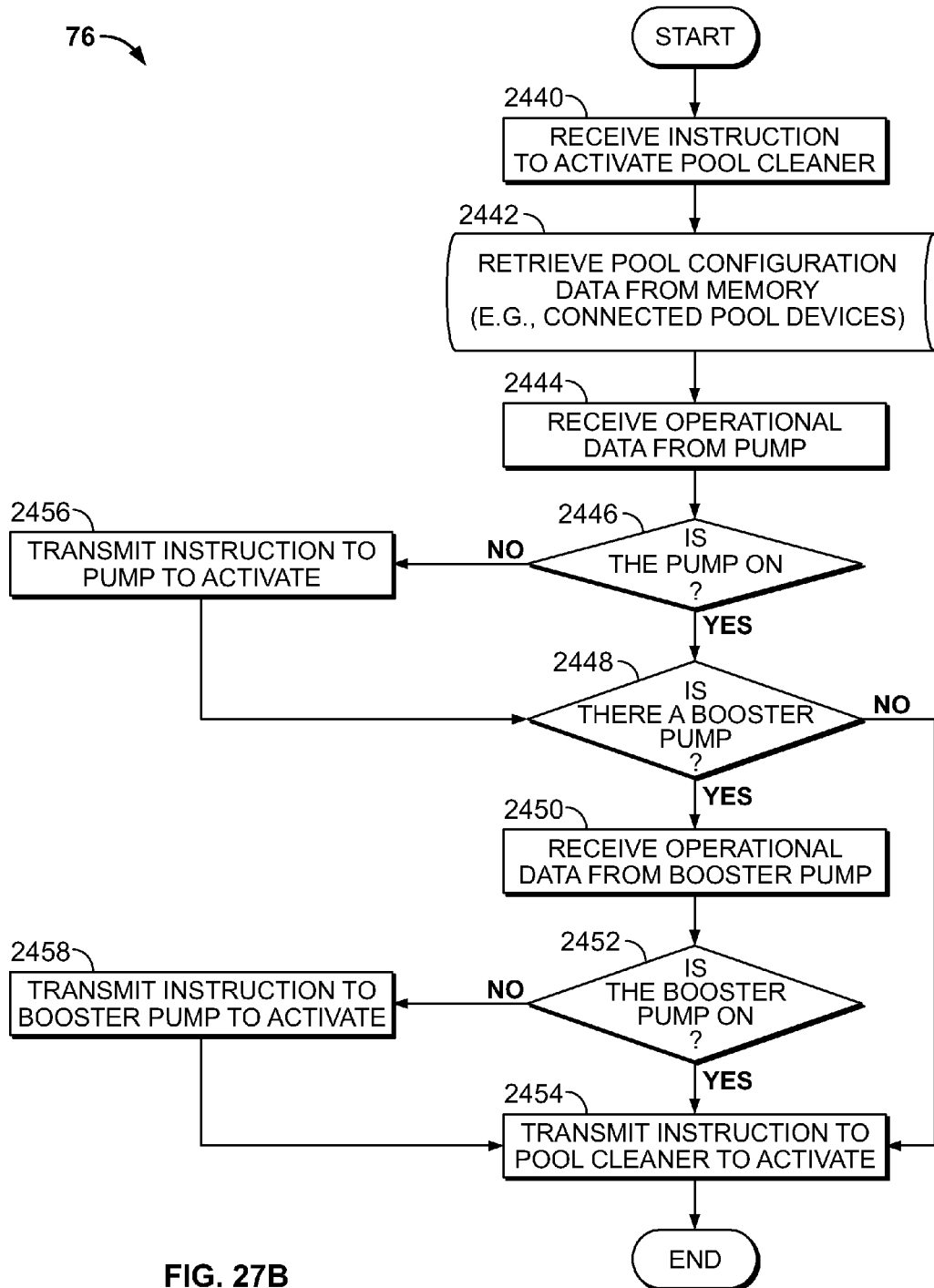


FIG. 27B

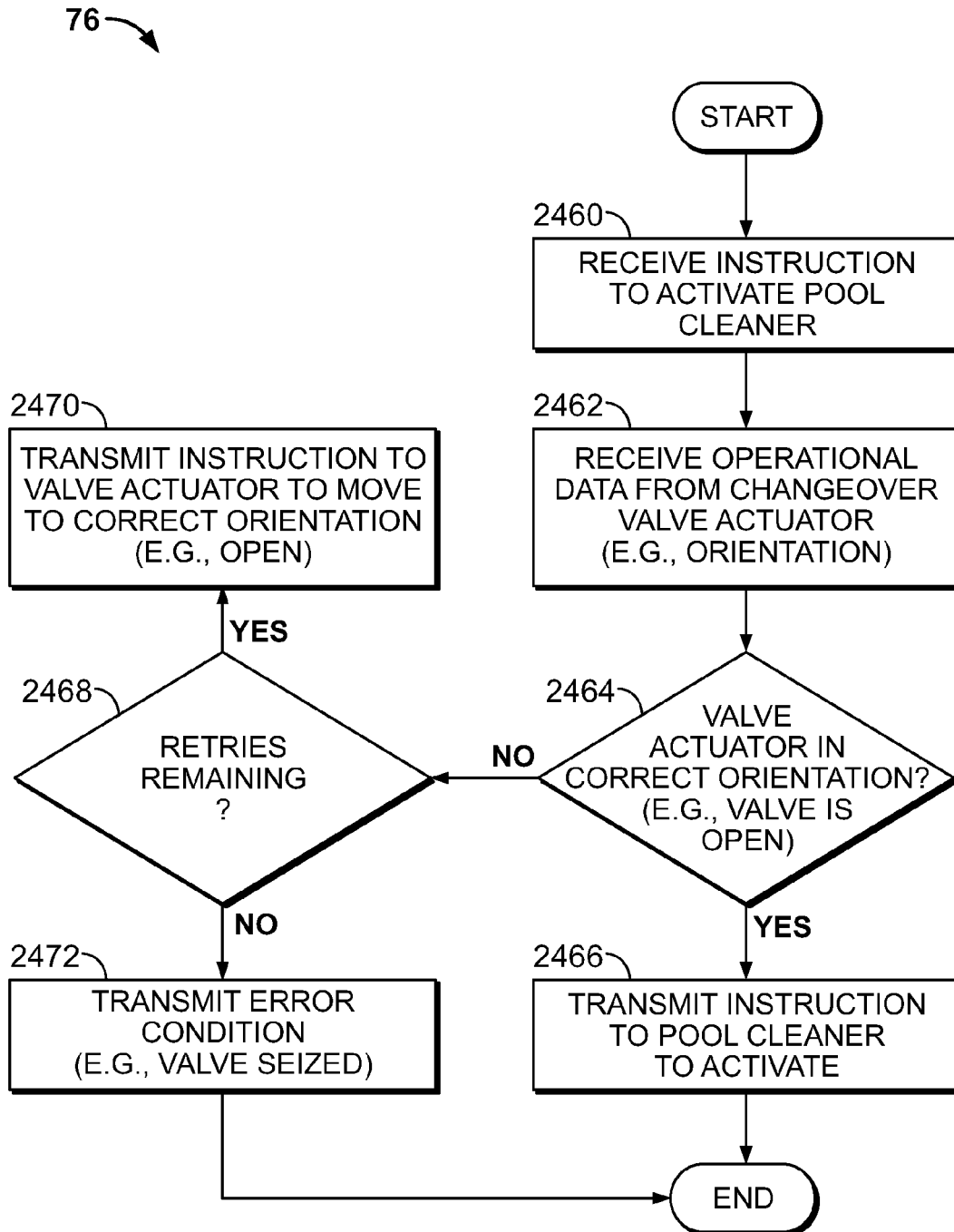


FIG. 27C

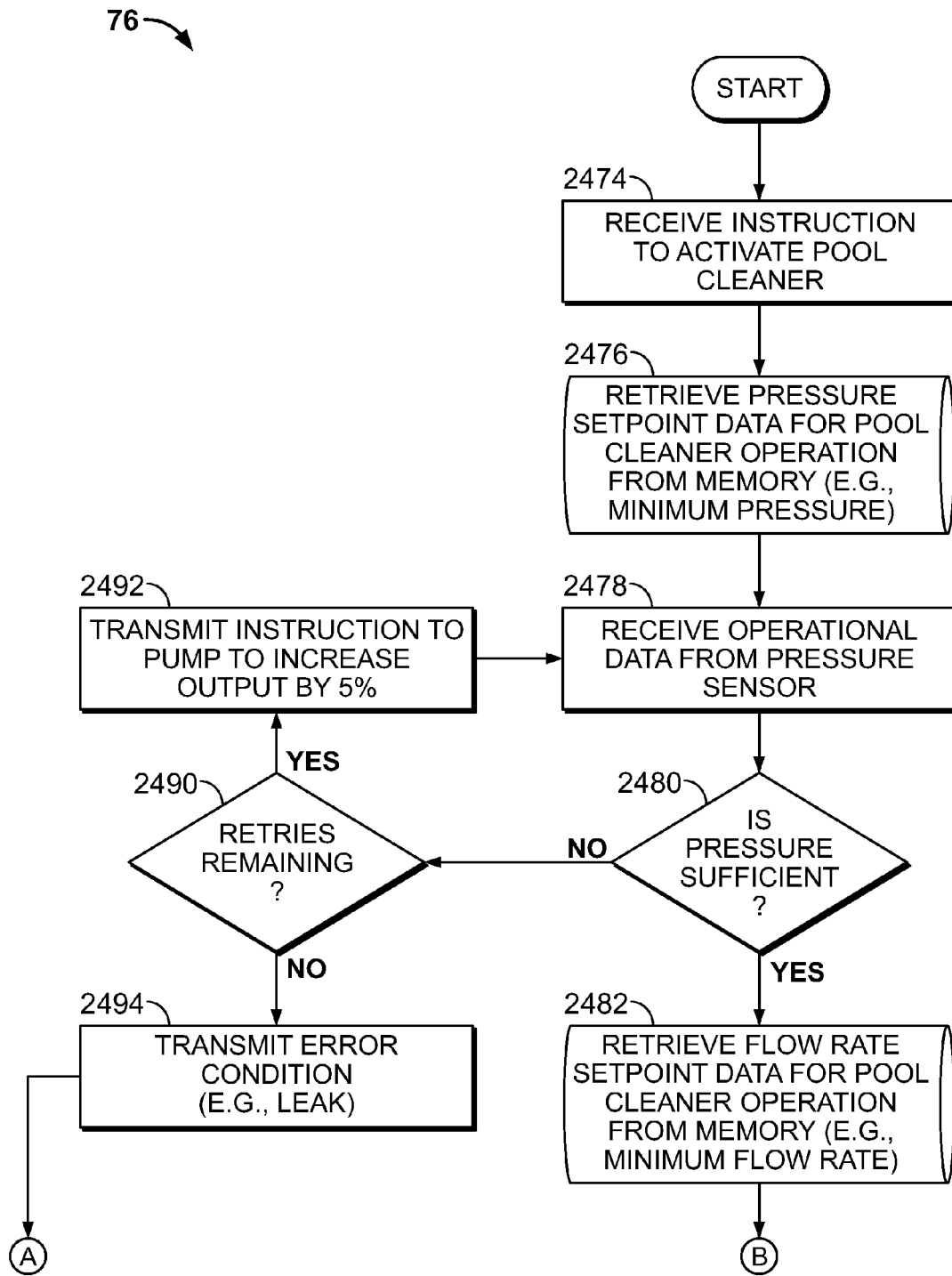


FIG. 27D

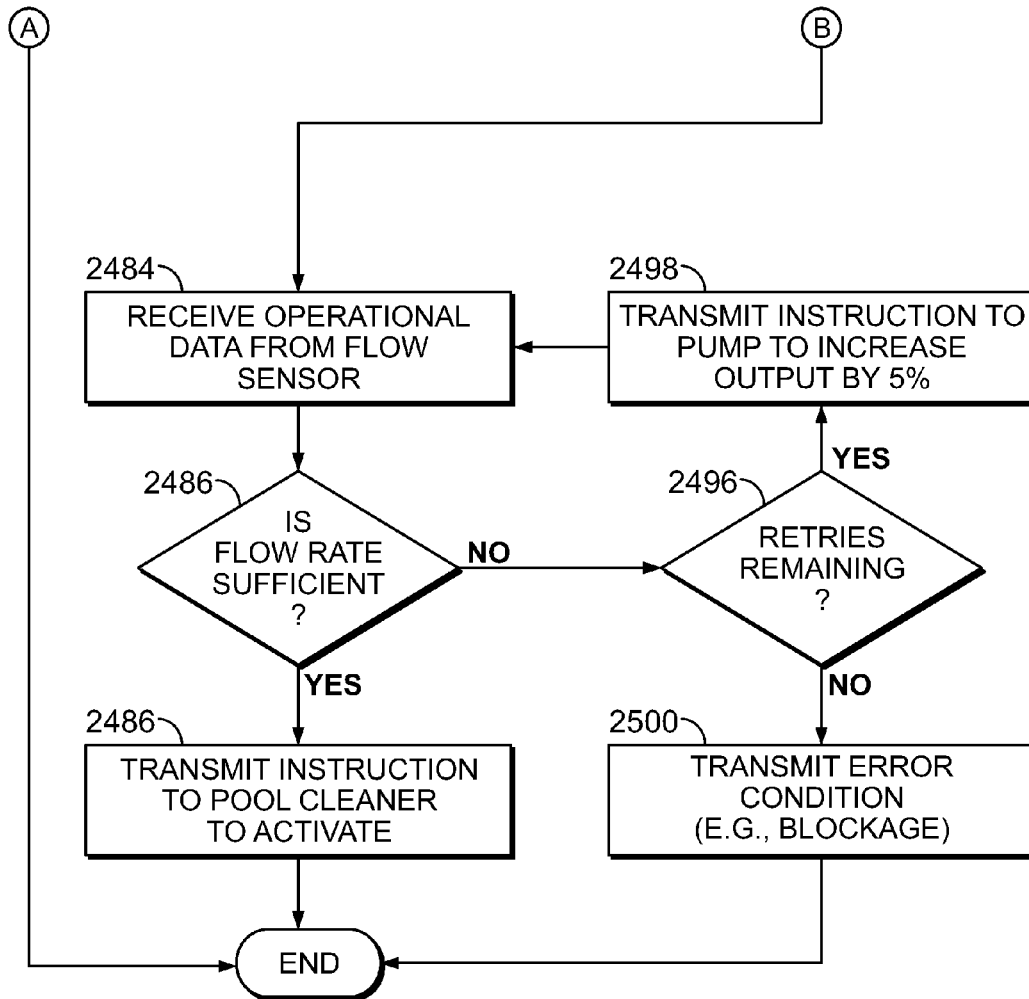


FIG. 27D (Cont.)

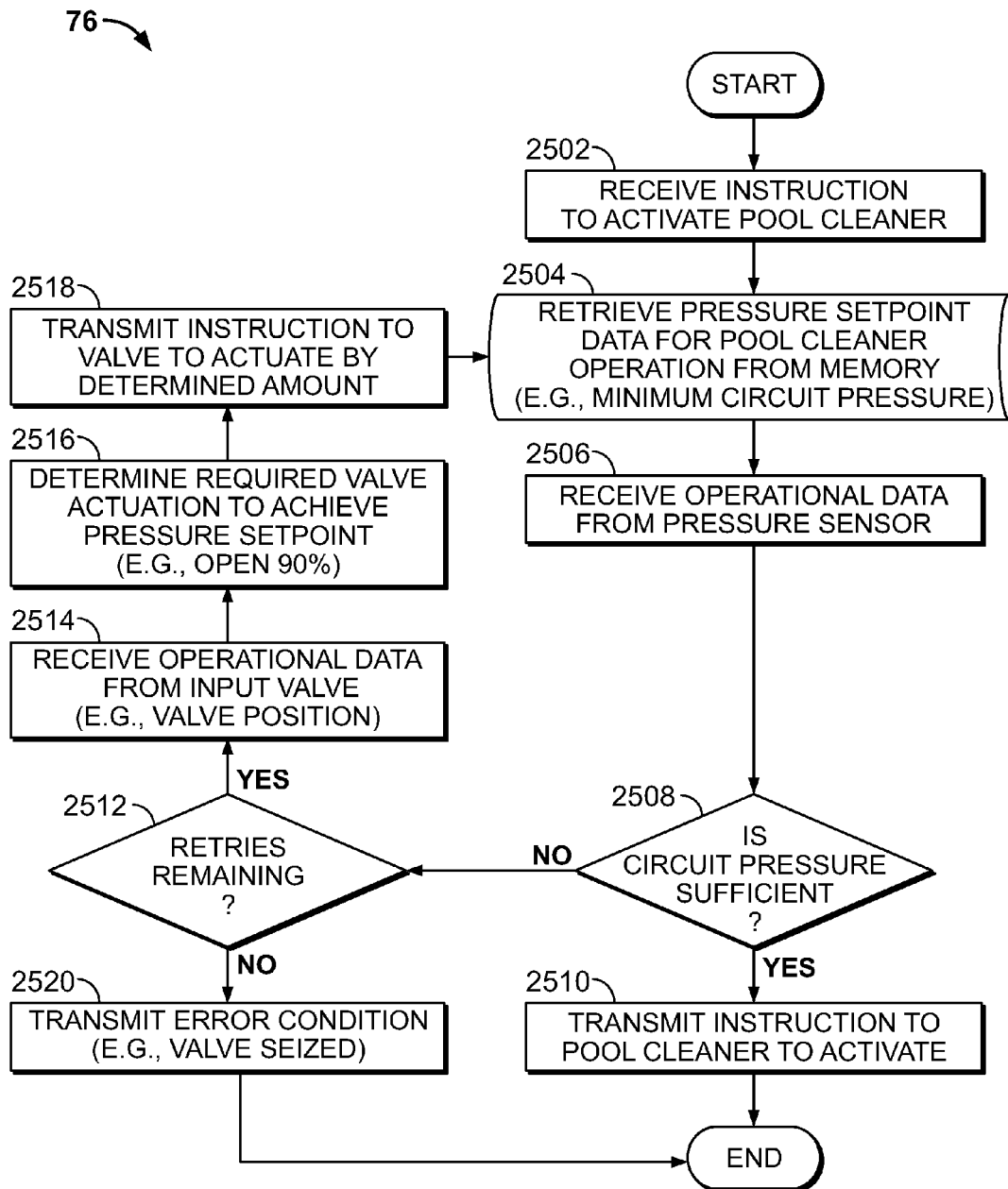


FIG. 27E

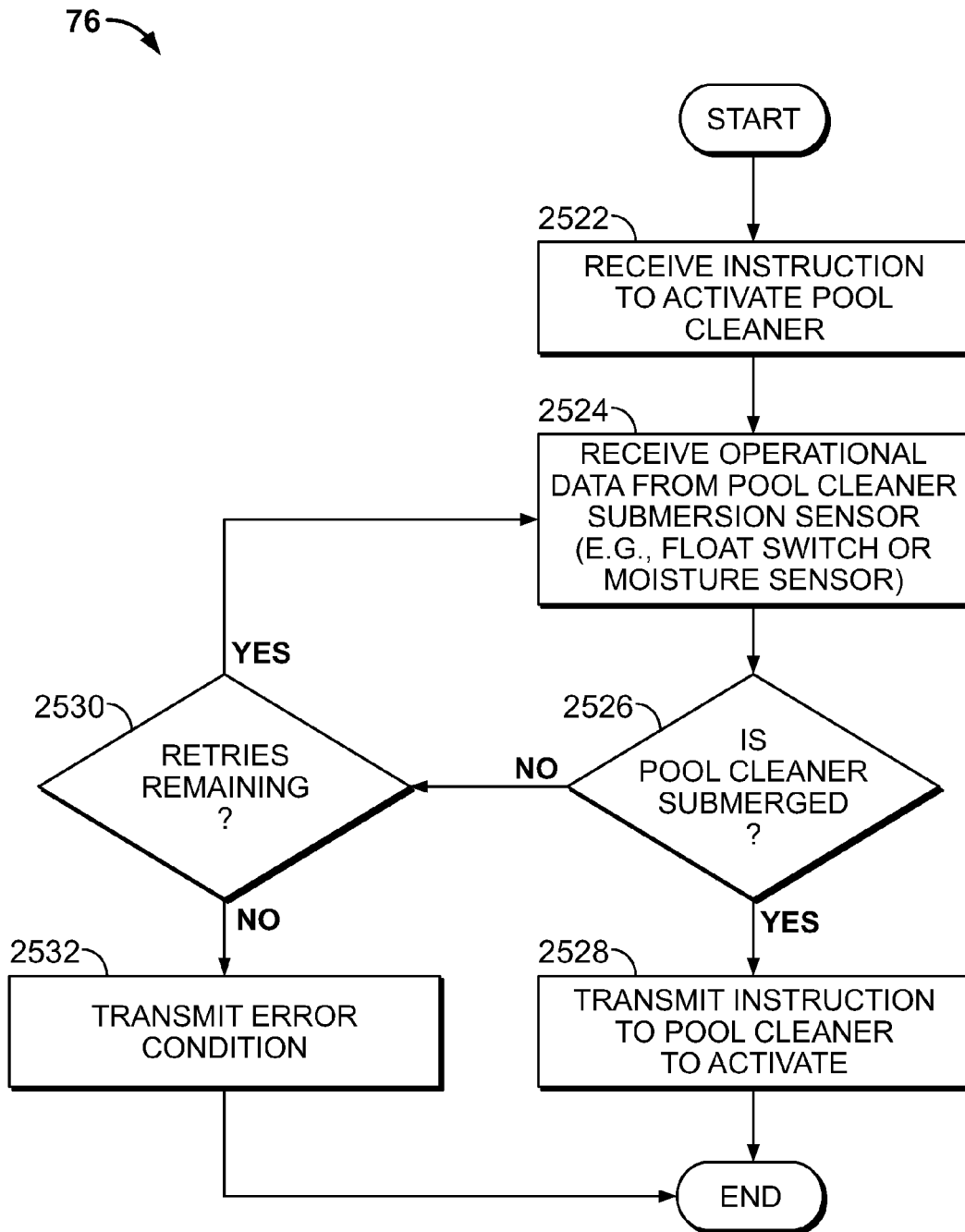


FIG. 27F

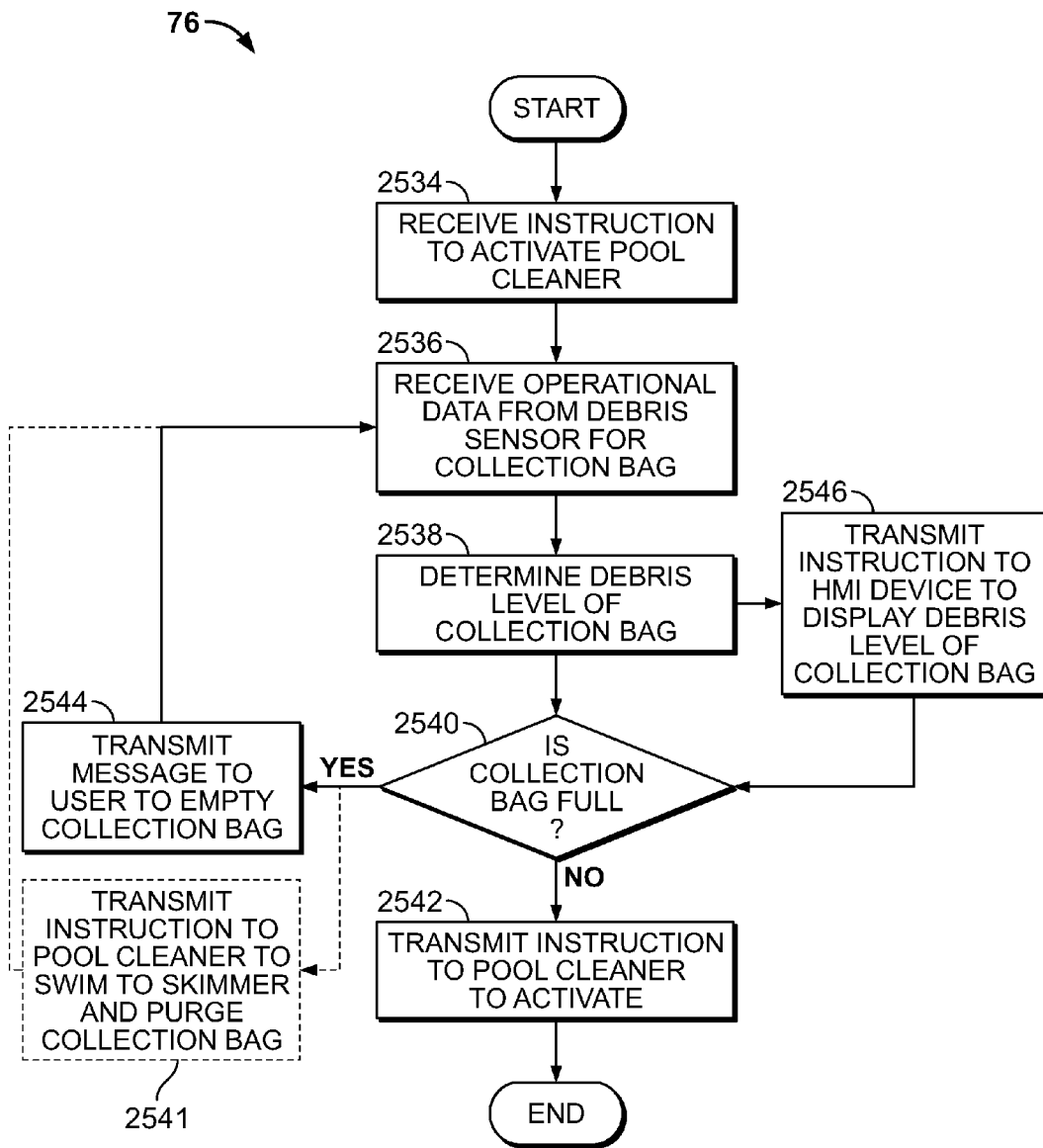


FIG. 27G

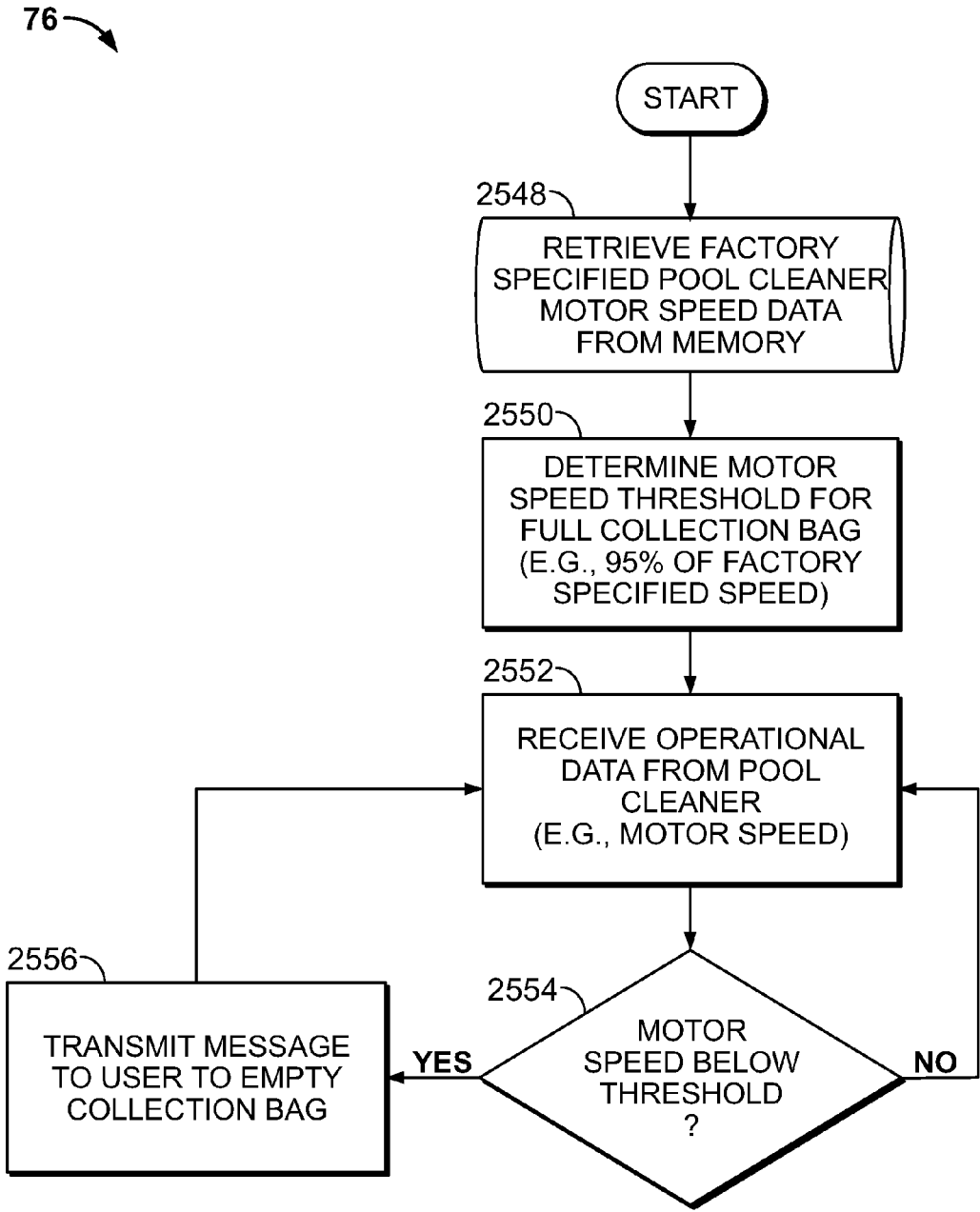


FIG. 27H

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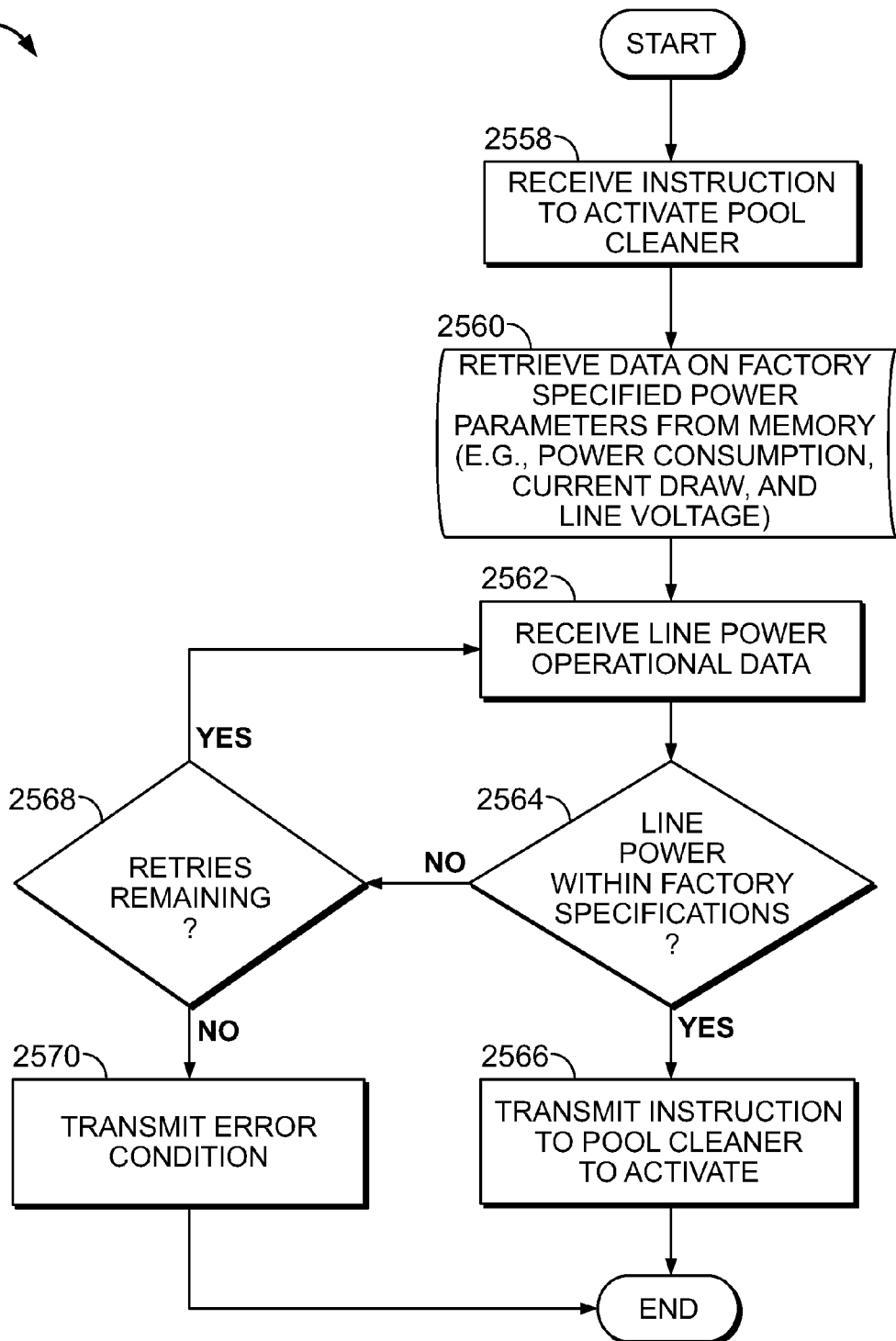


FIG. 271

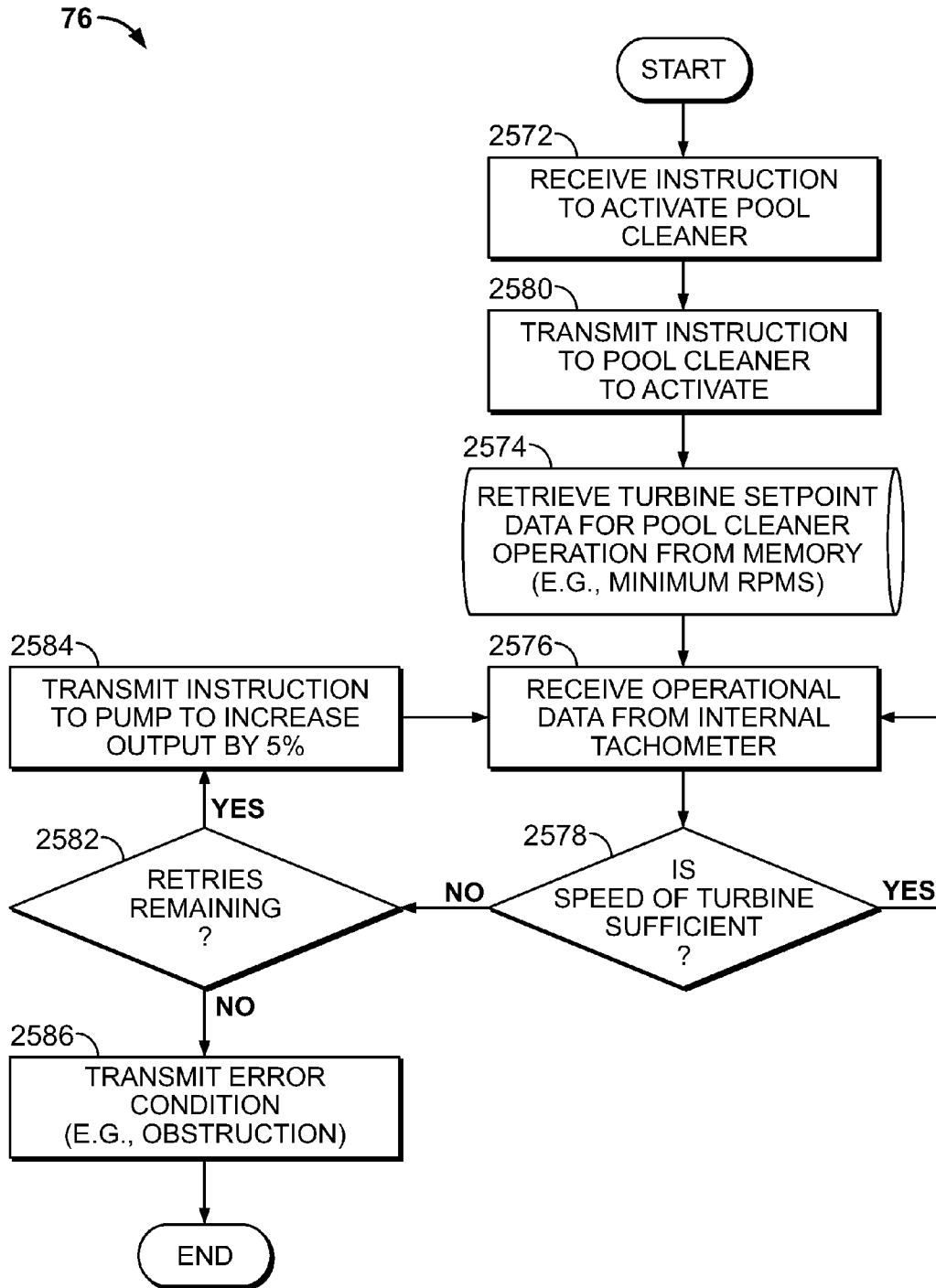


FIG. 27J

76 →

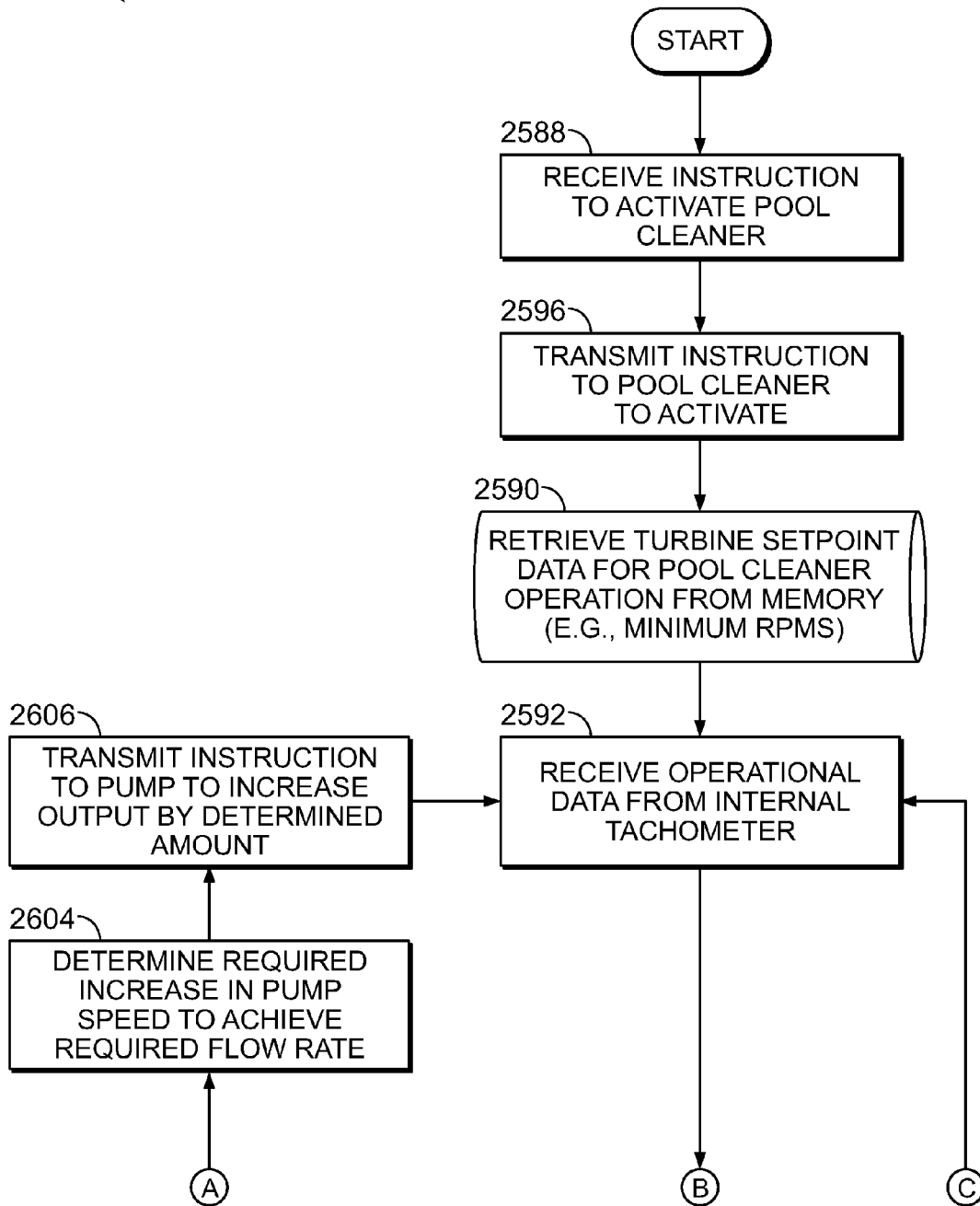


FIG. 27K

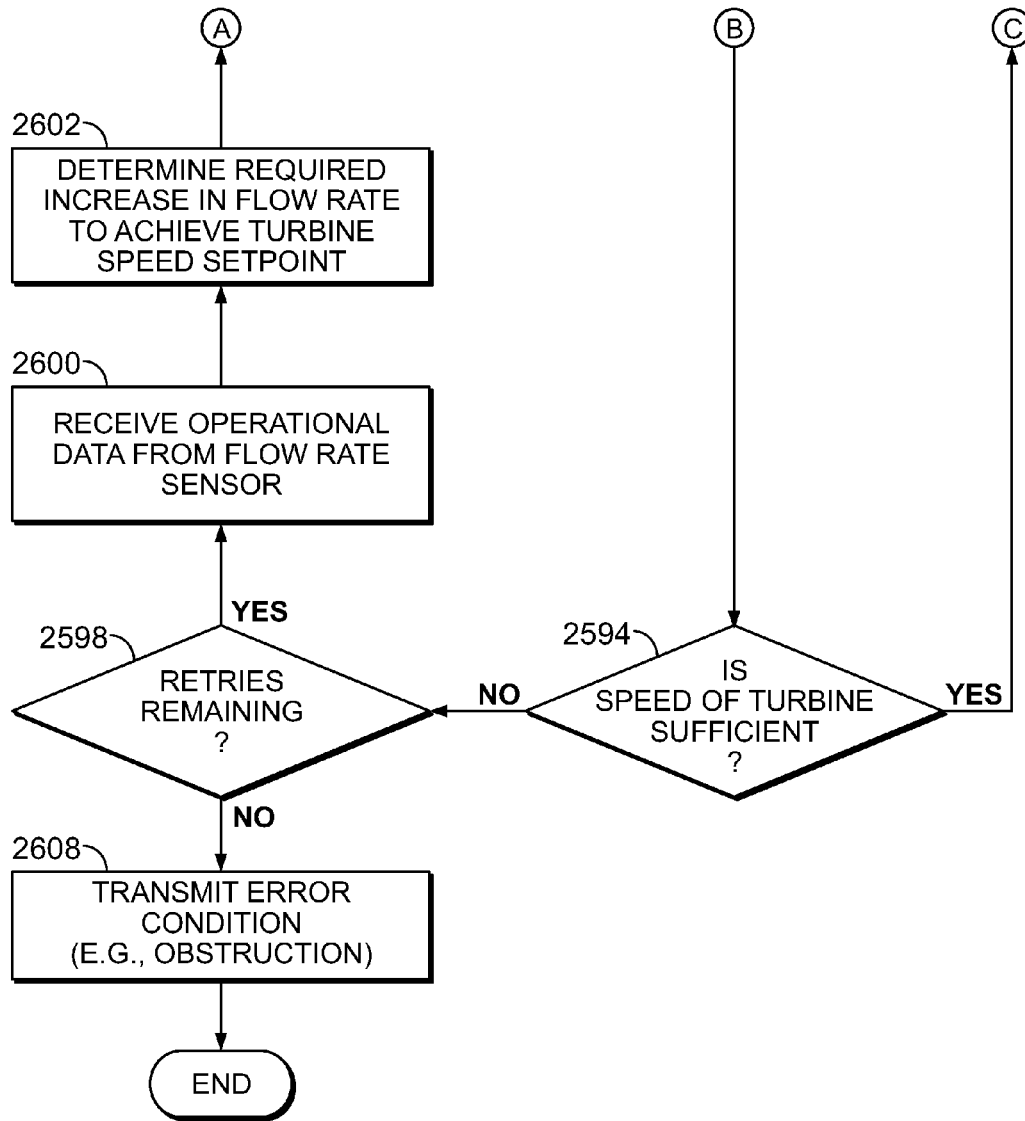


FIG. 27K (Cont.)

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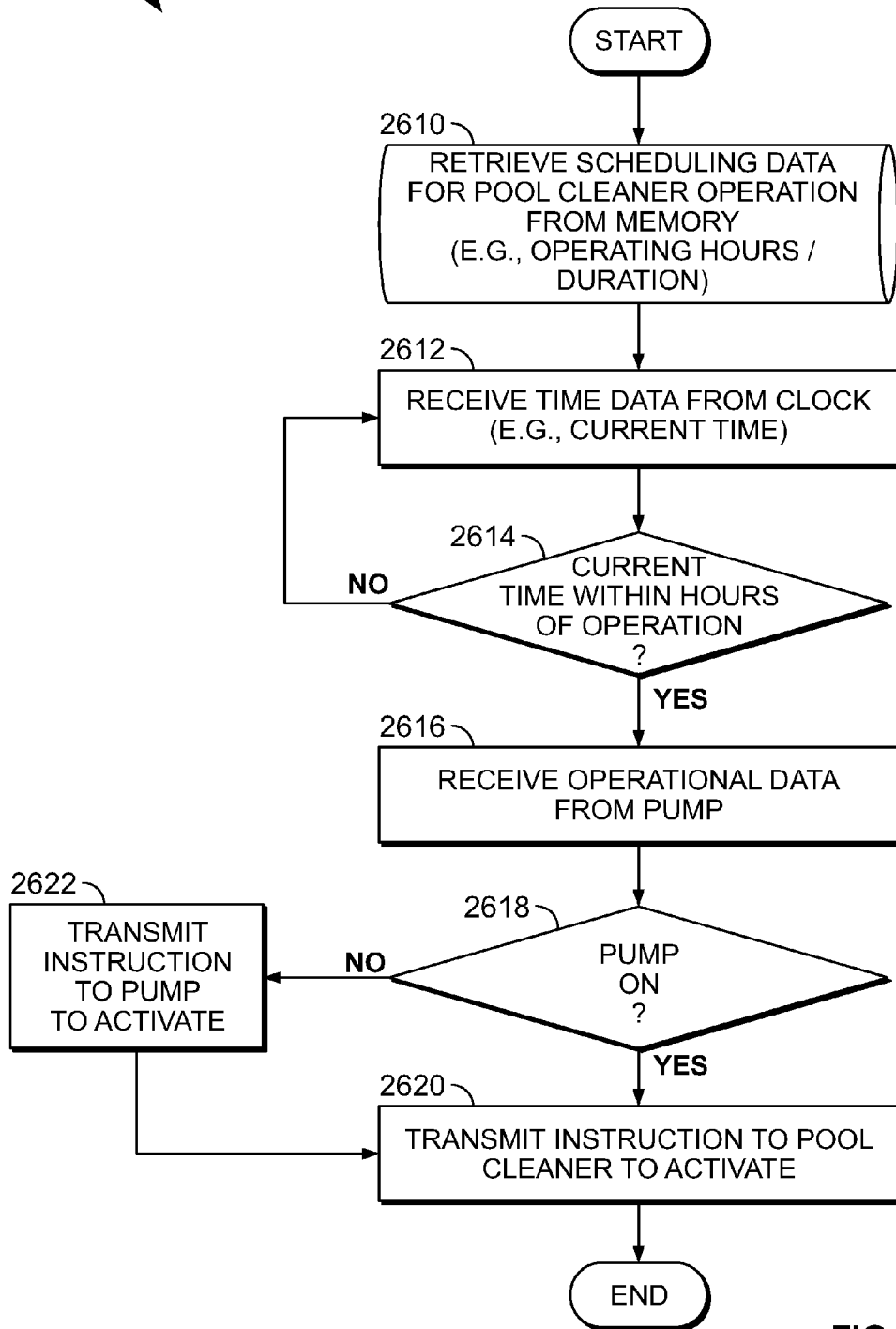


FIG. 27L

76 →

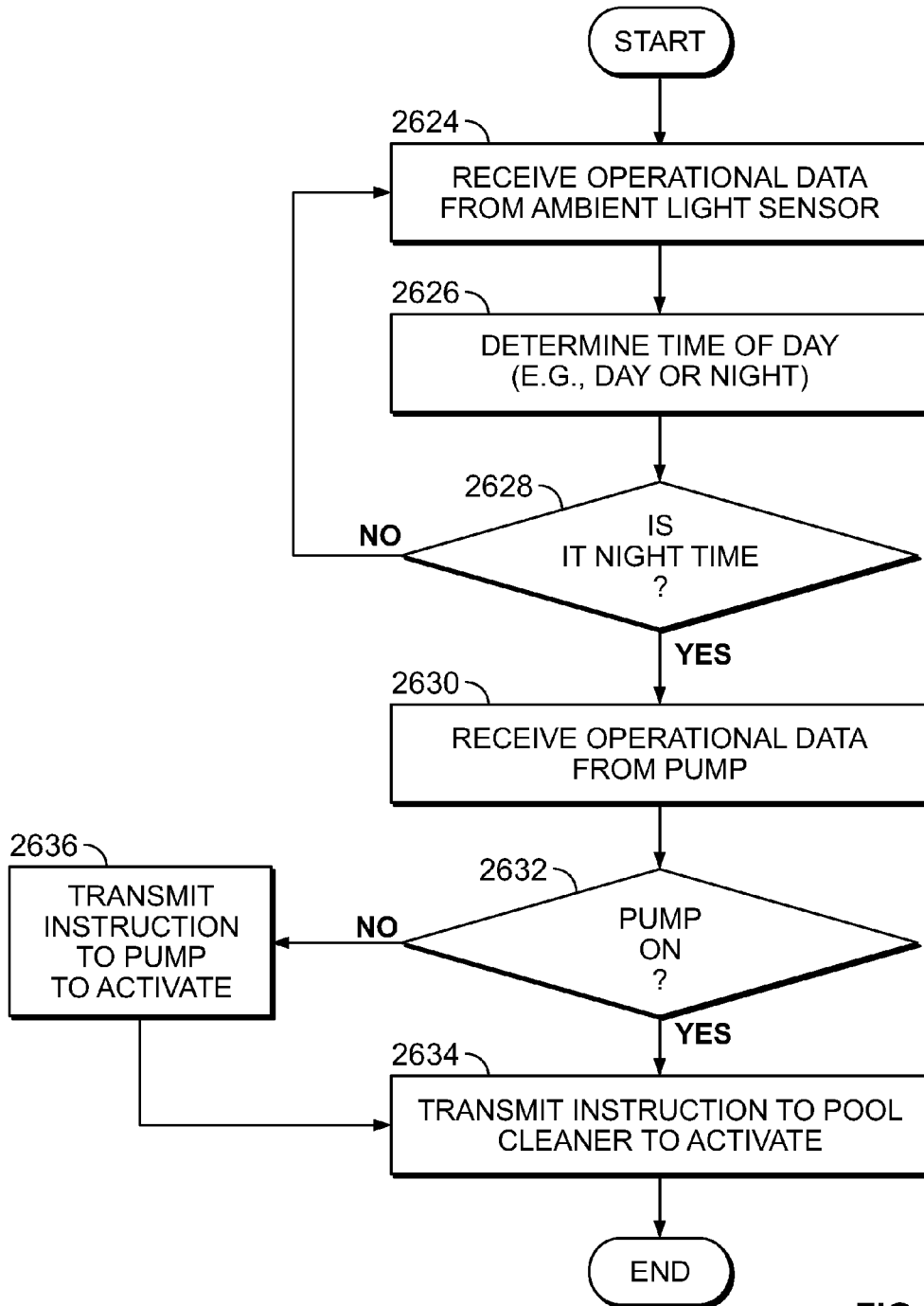


FIG. 27M

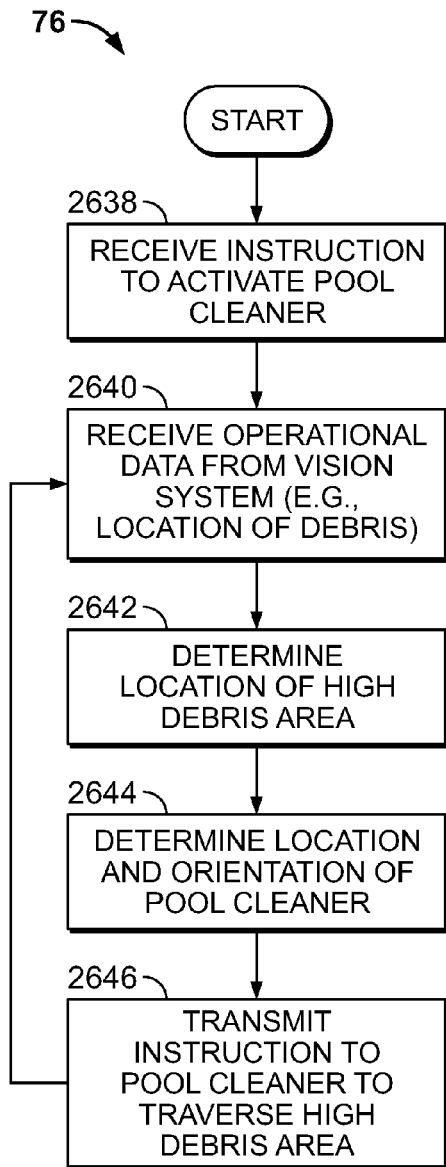


FIG. 27N

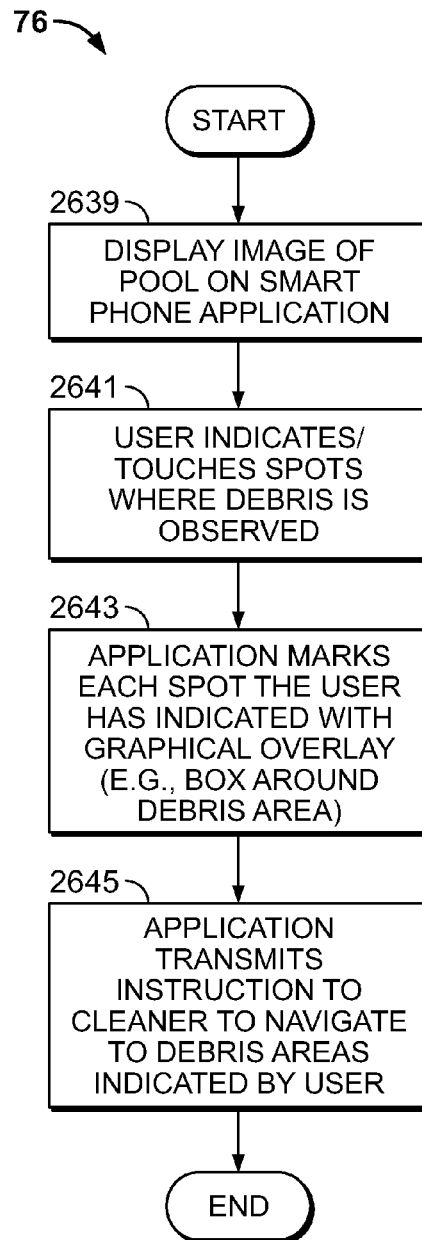


FIG. 27O

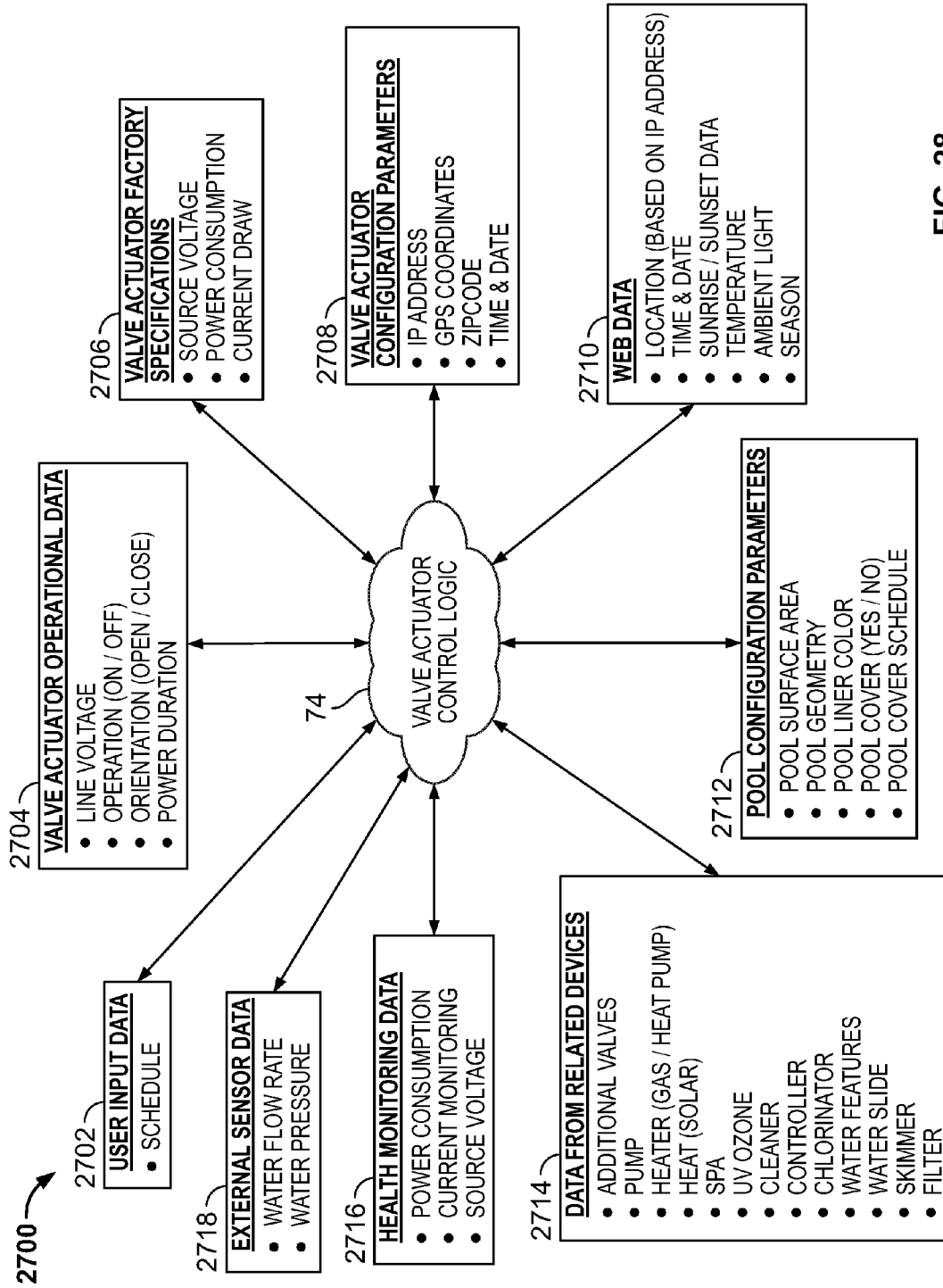


FIG. 28

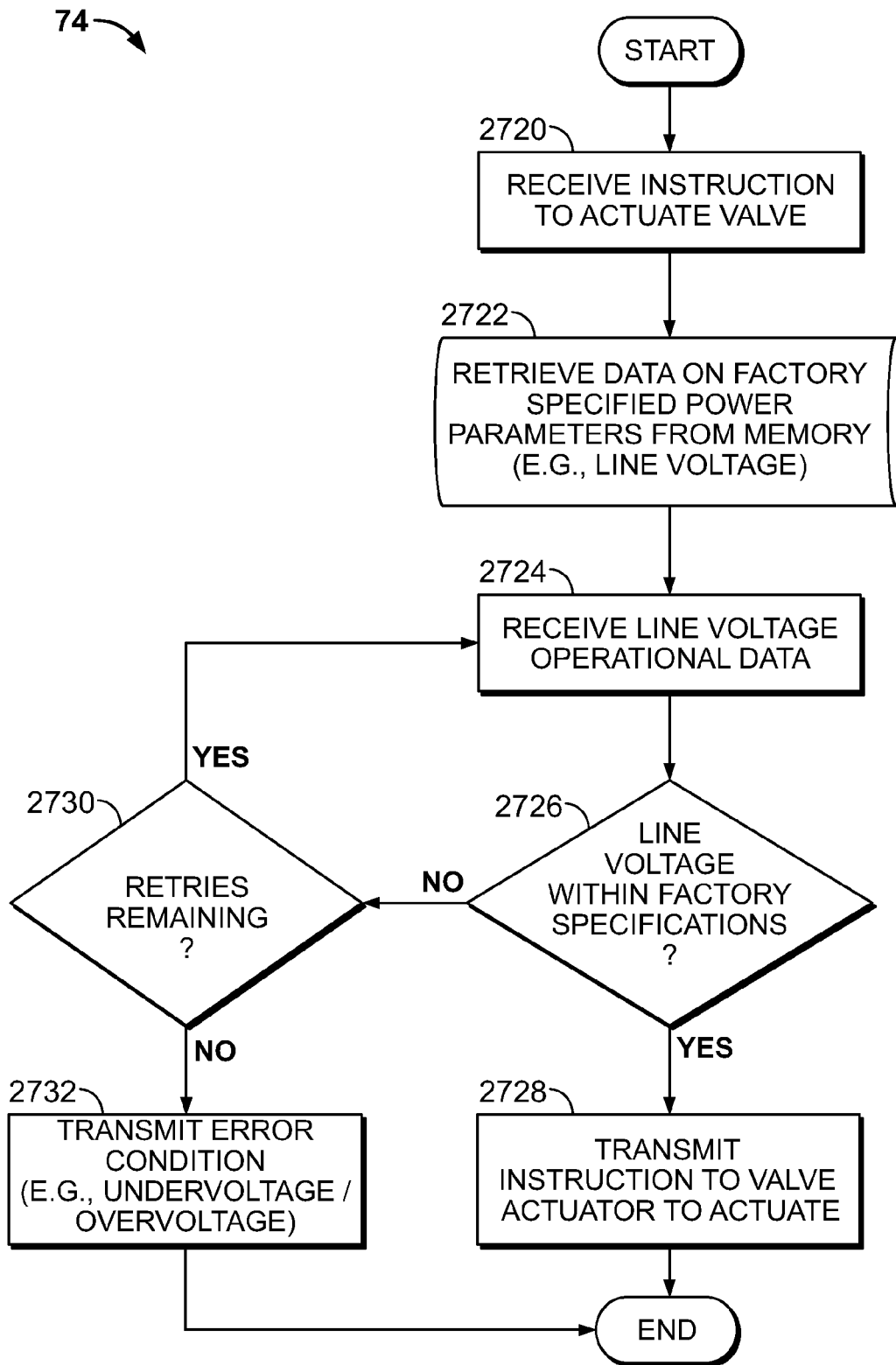


FIG. 29A

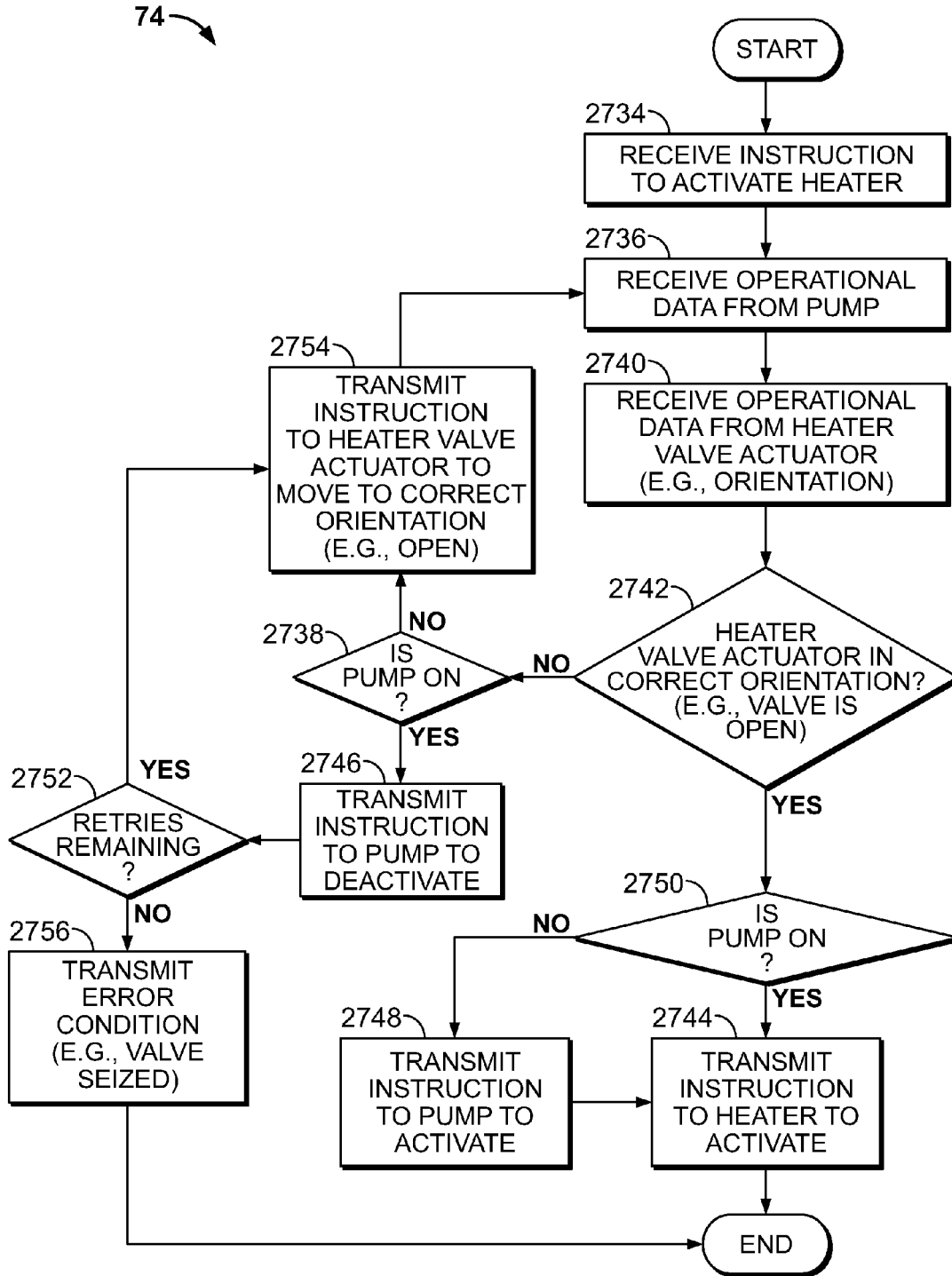


FIG. 29B

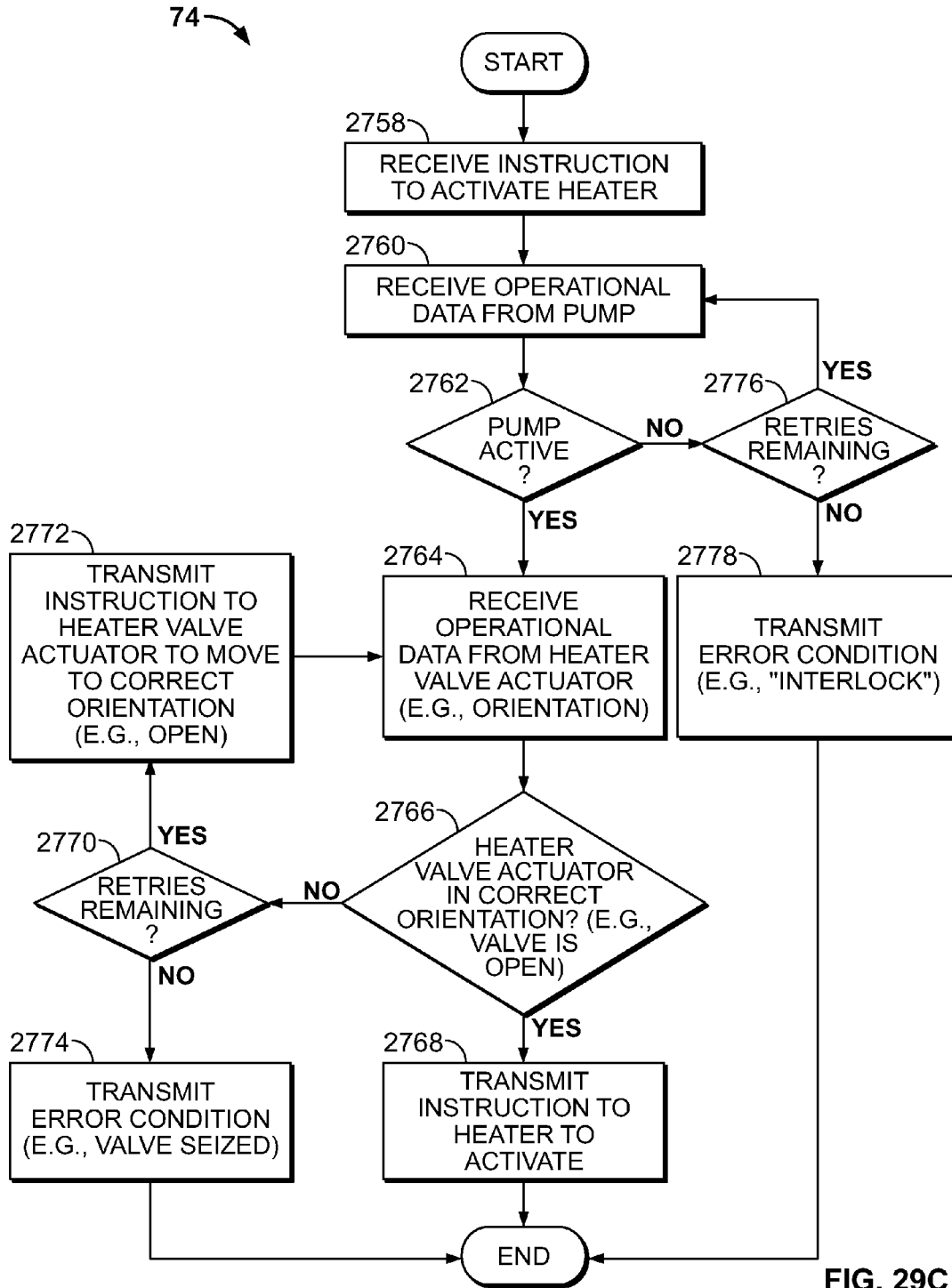


FIG. 29C

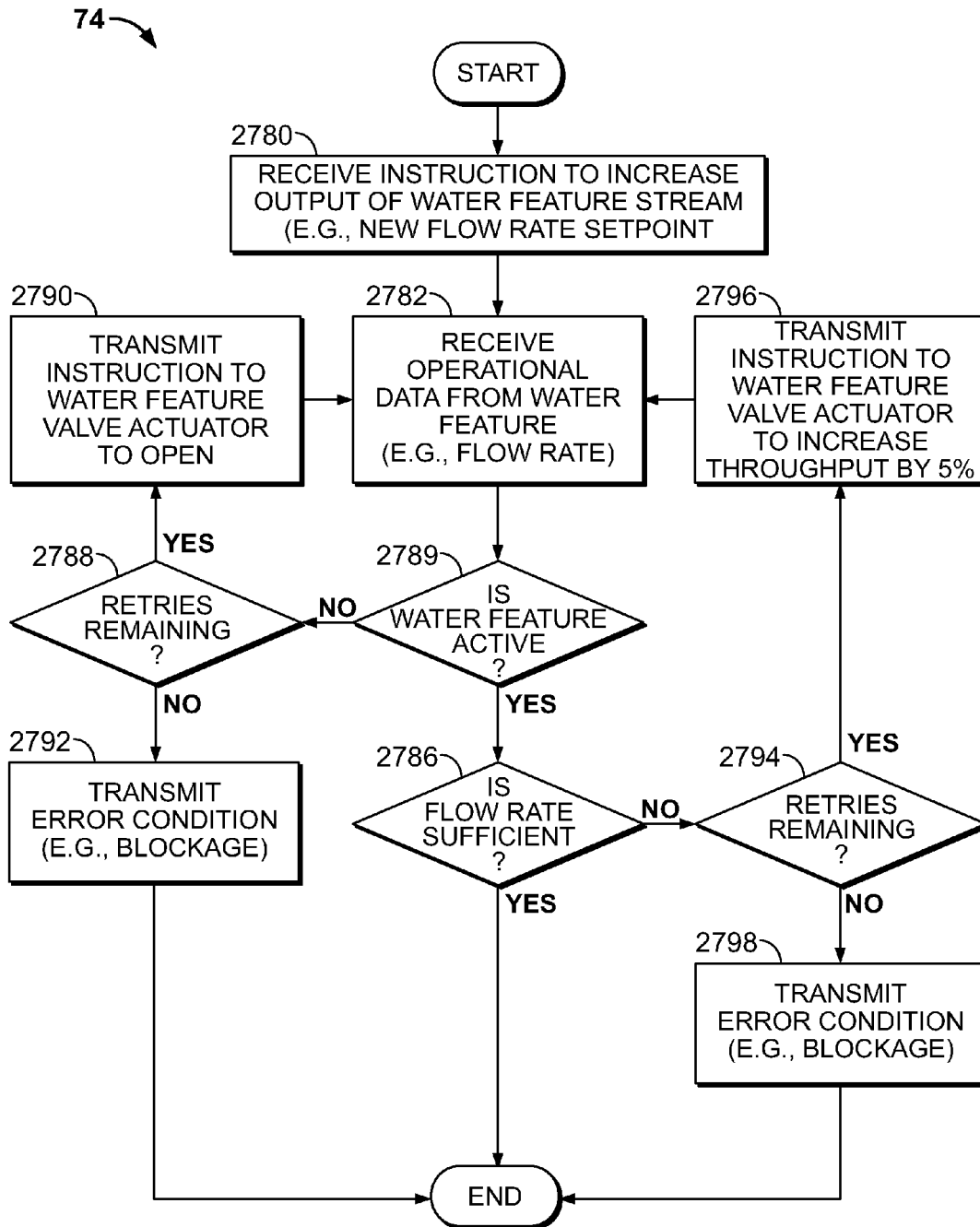


FIG. 29D

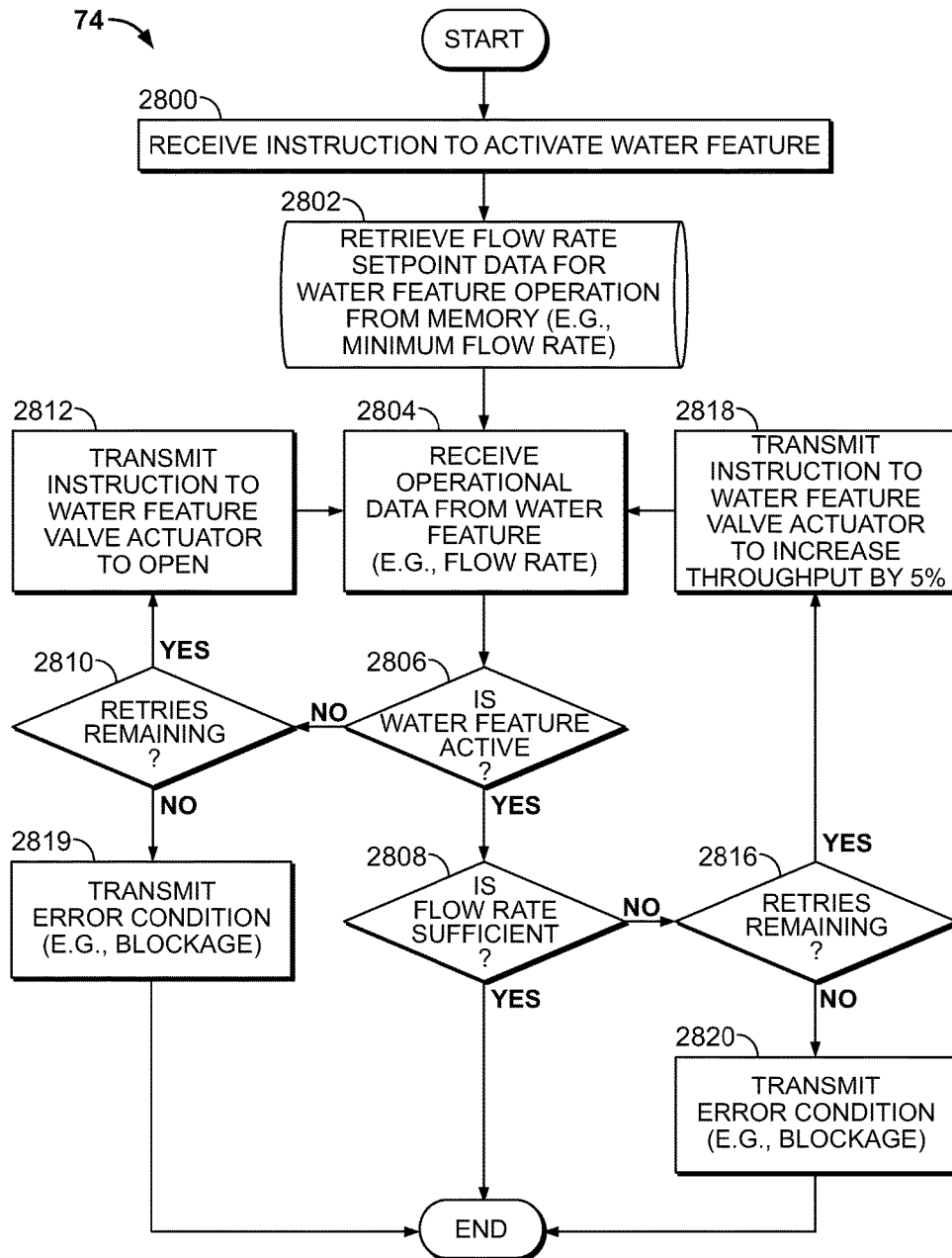


FIG. 29E

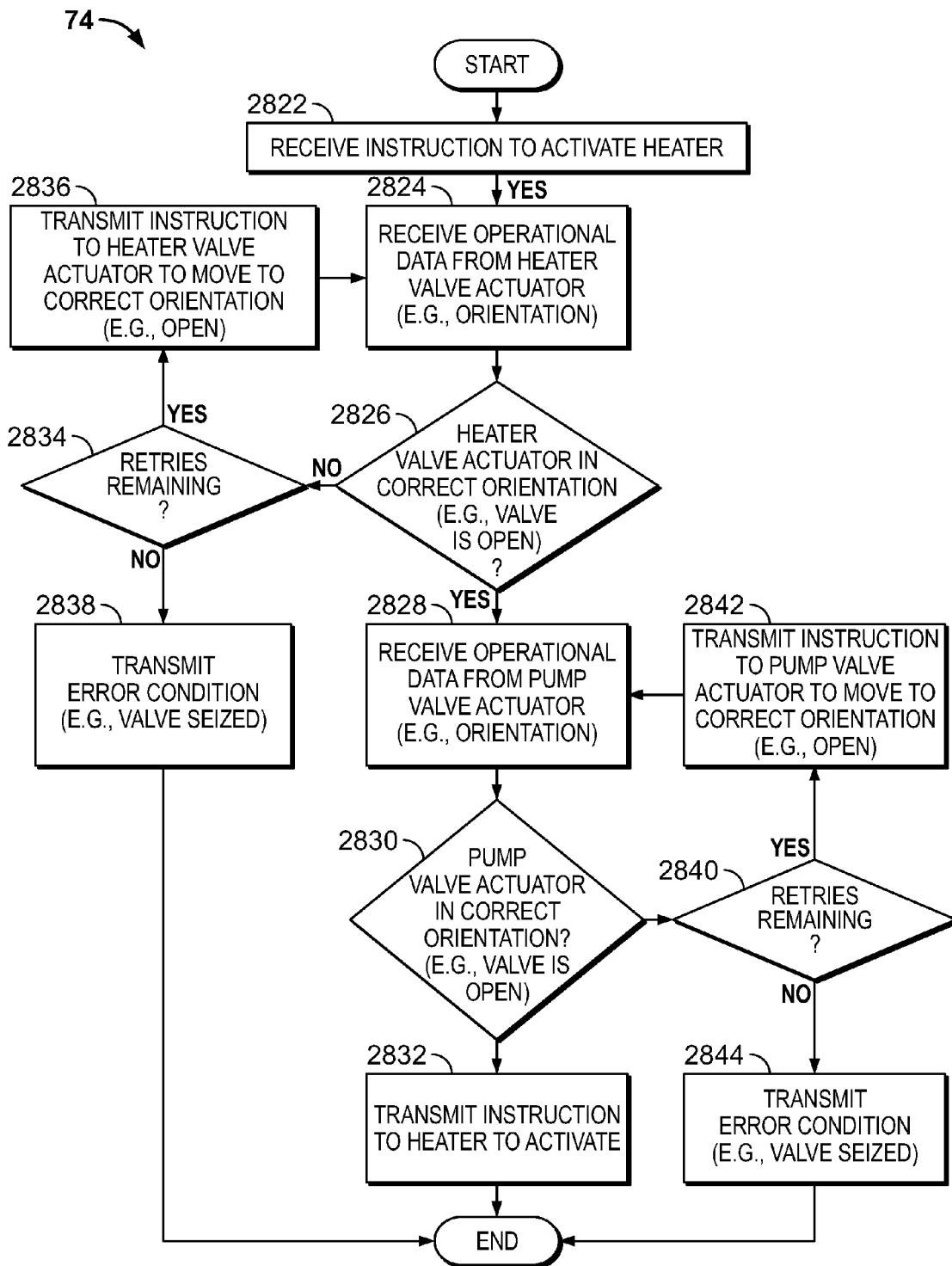


FIG. 29F

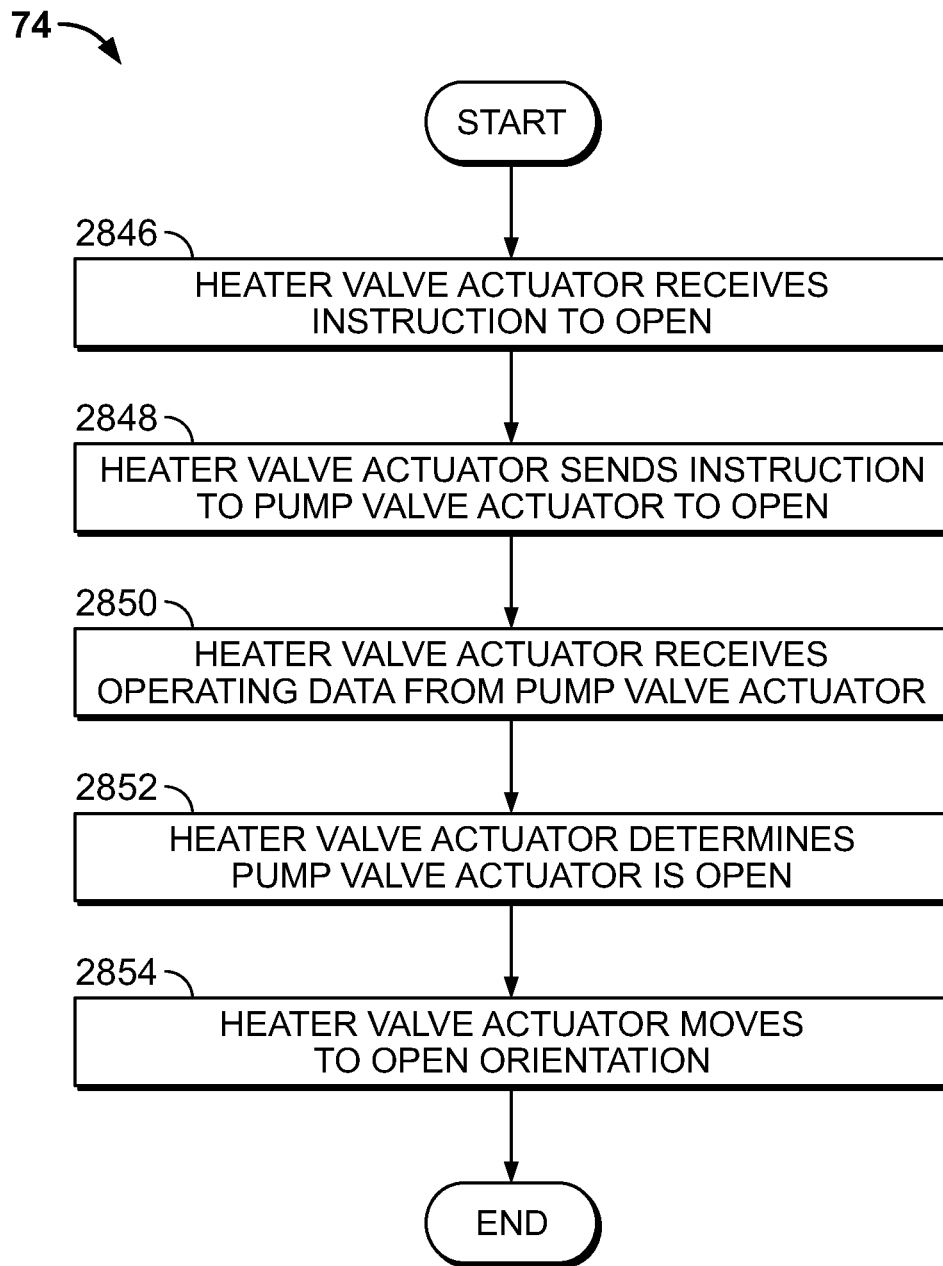


FIG. 29G

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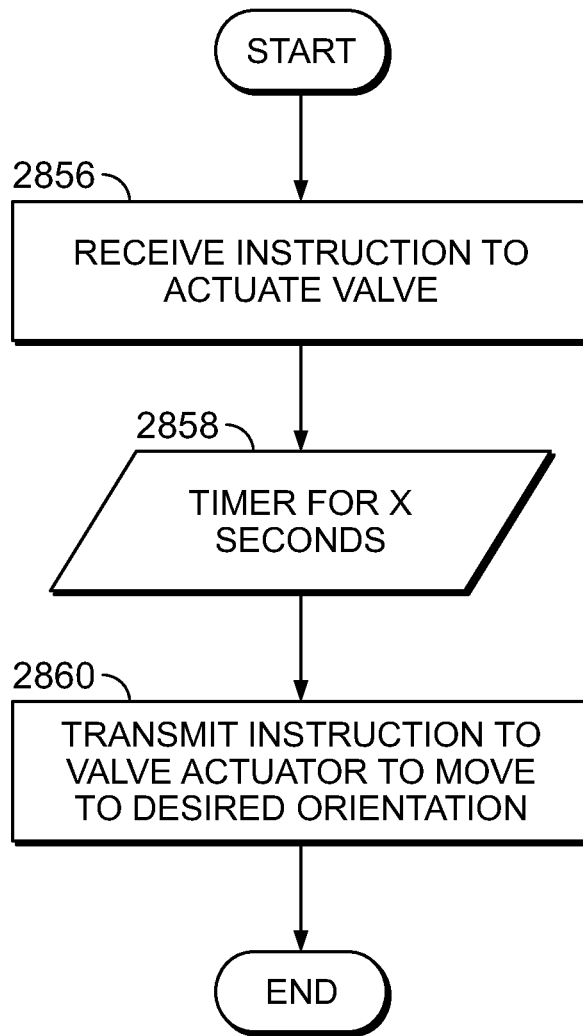


FIG. 29H

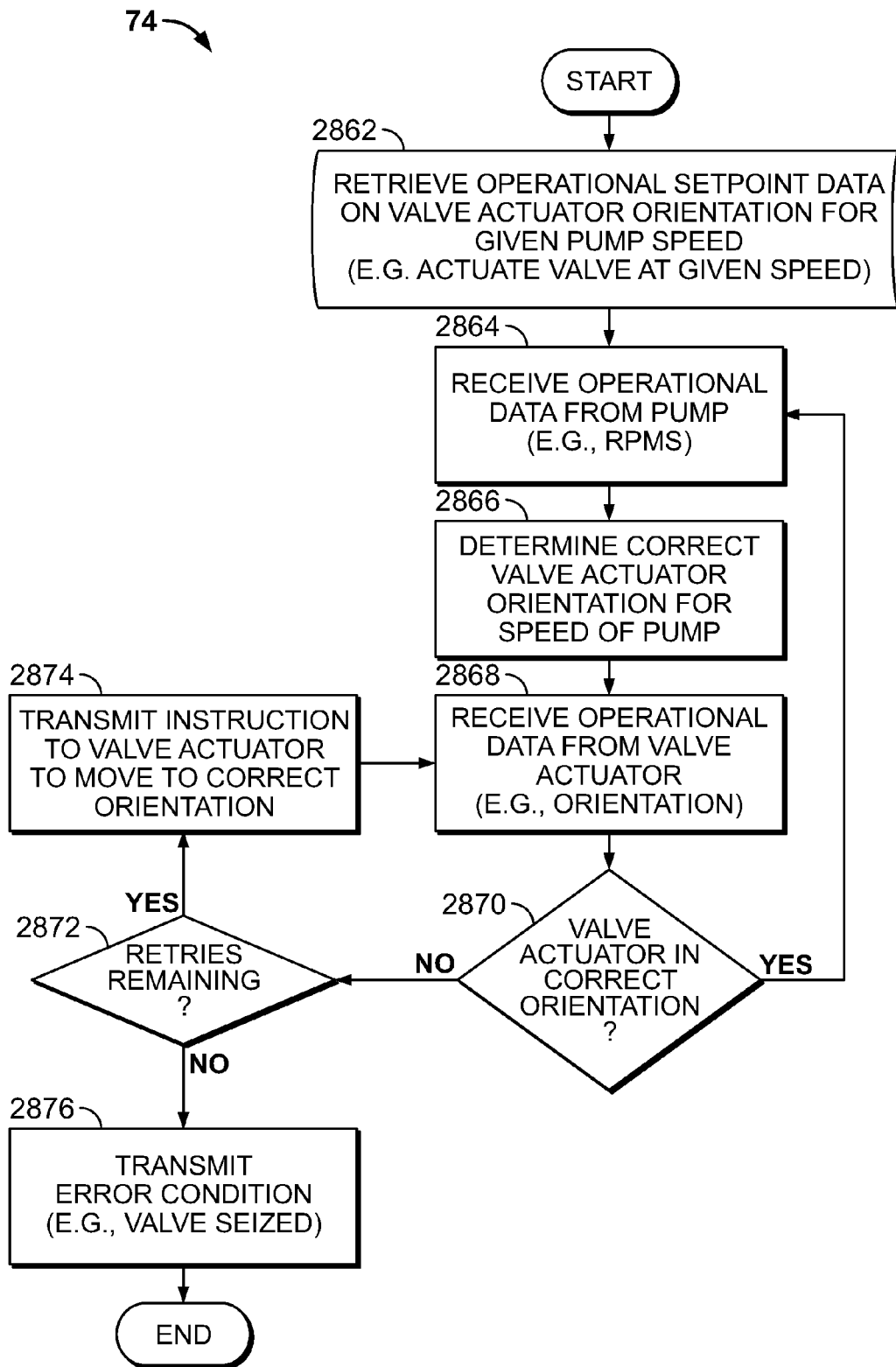


FIG. 29I

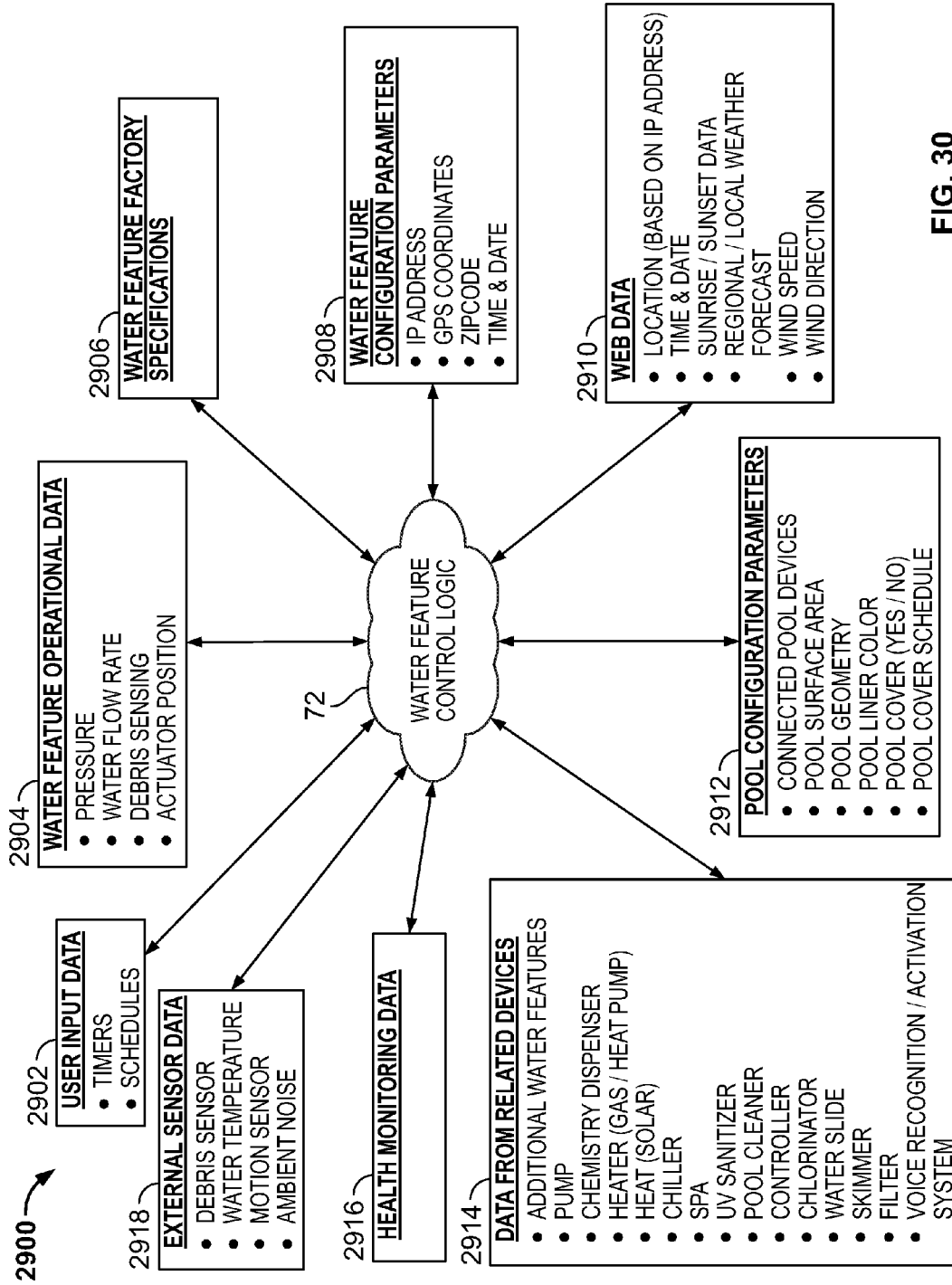


FIG. 30

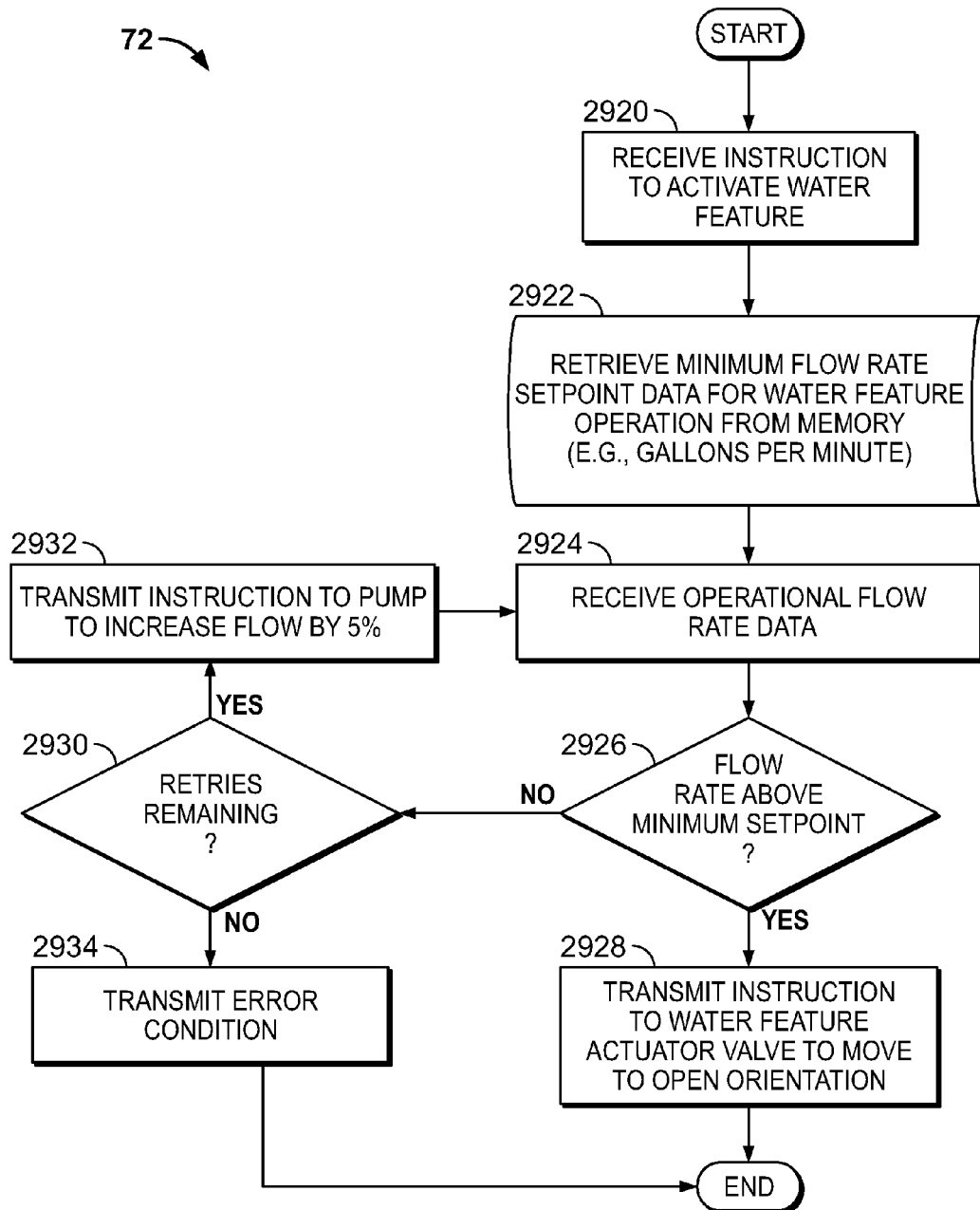


FIG. 31A

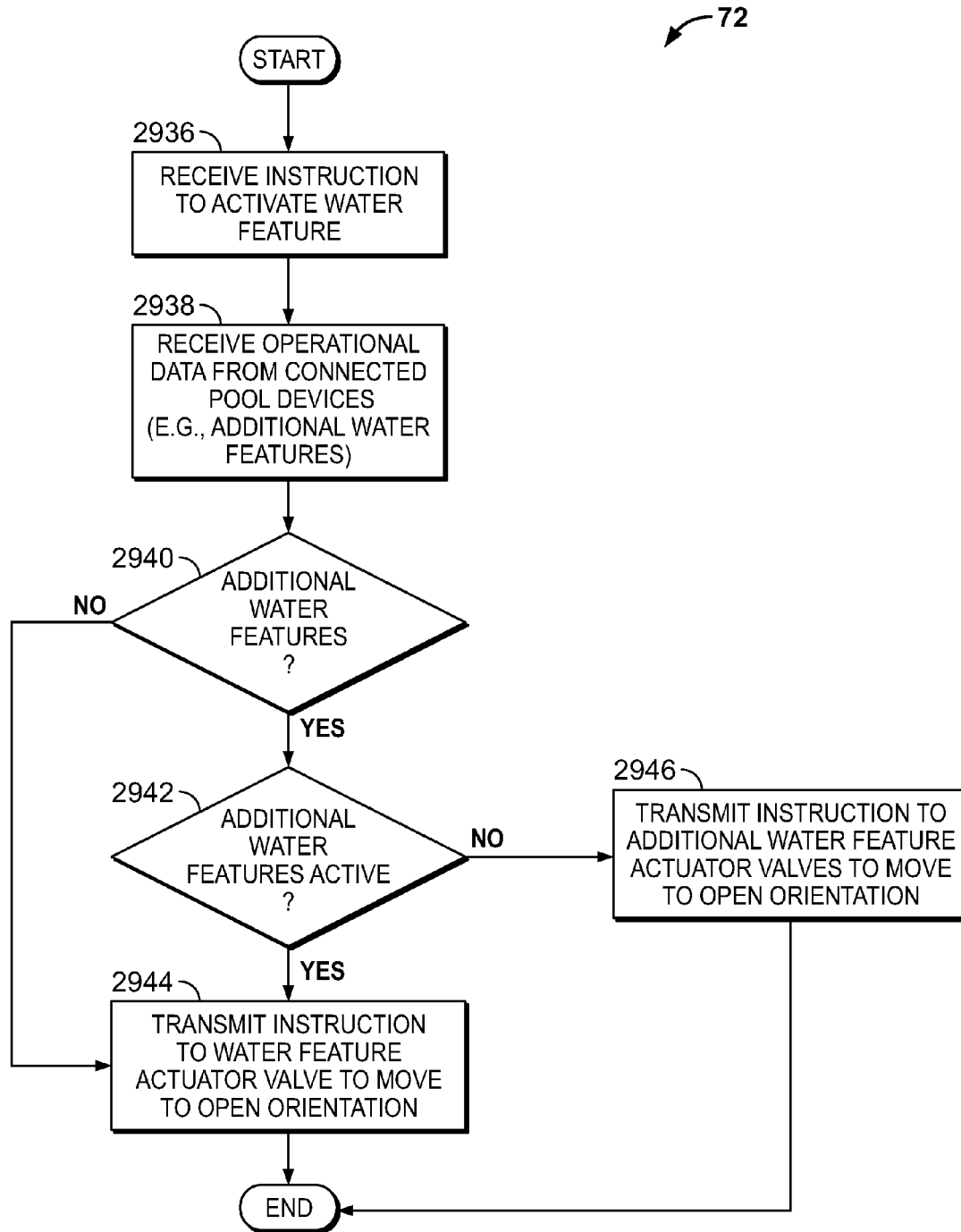


FIG. 31B

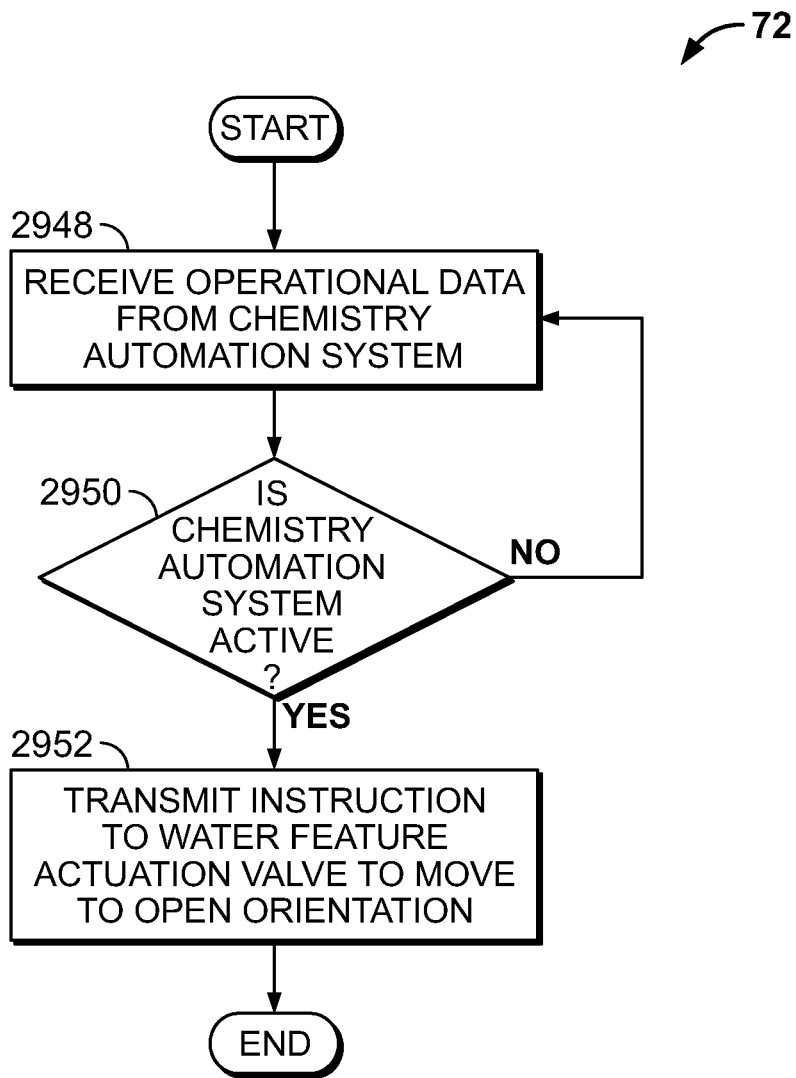


FIG. 31C

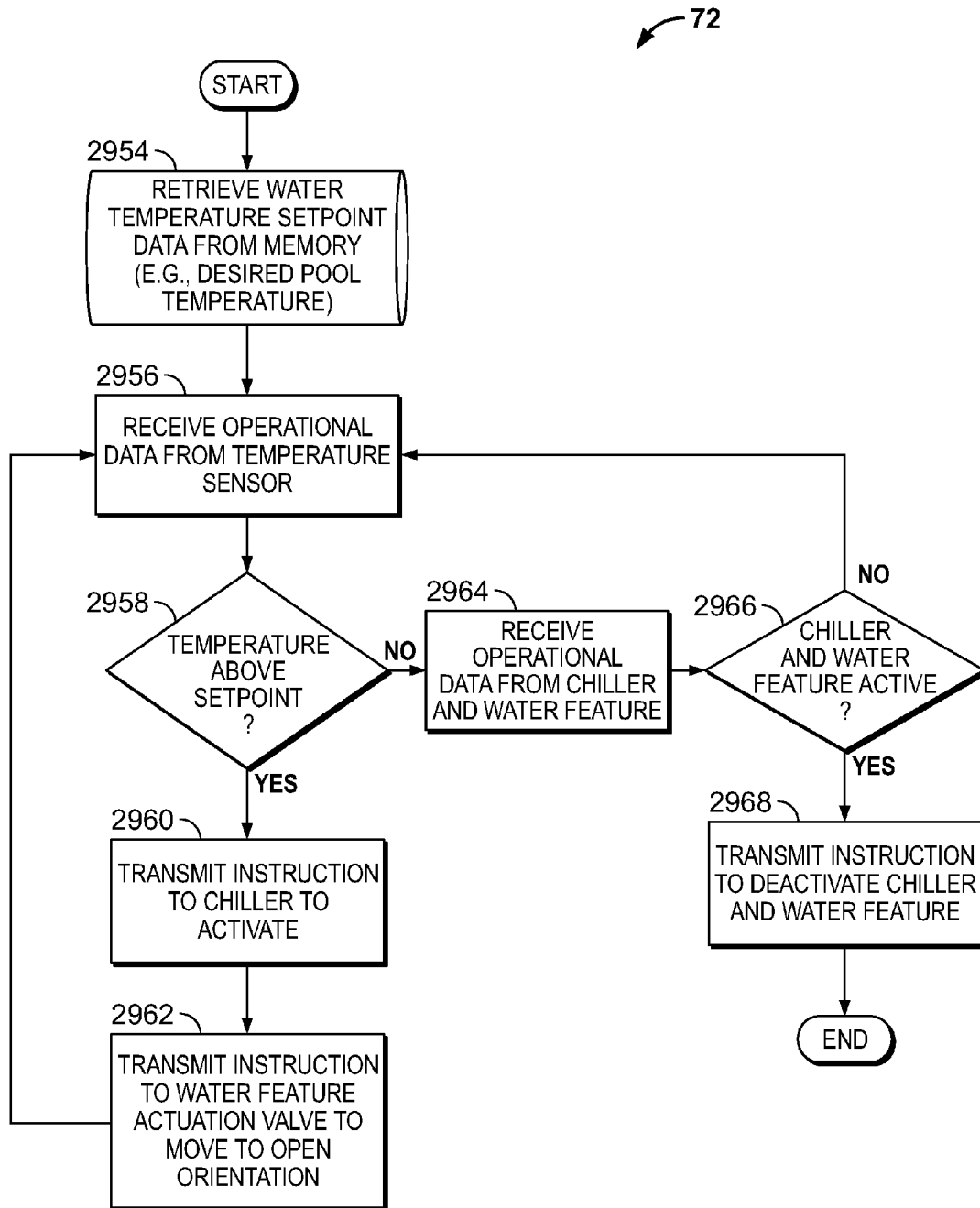


FIG. 31D

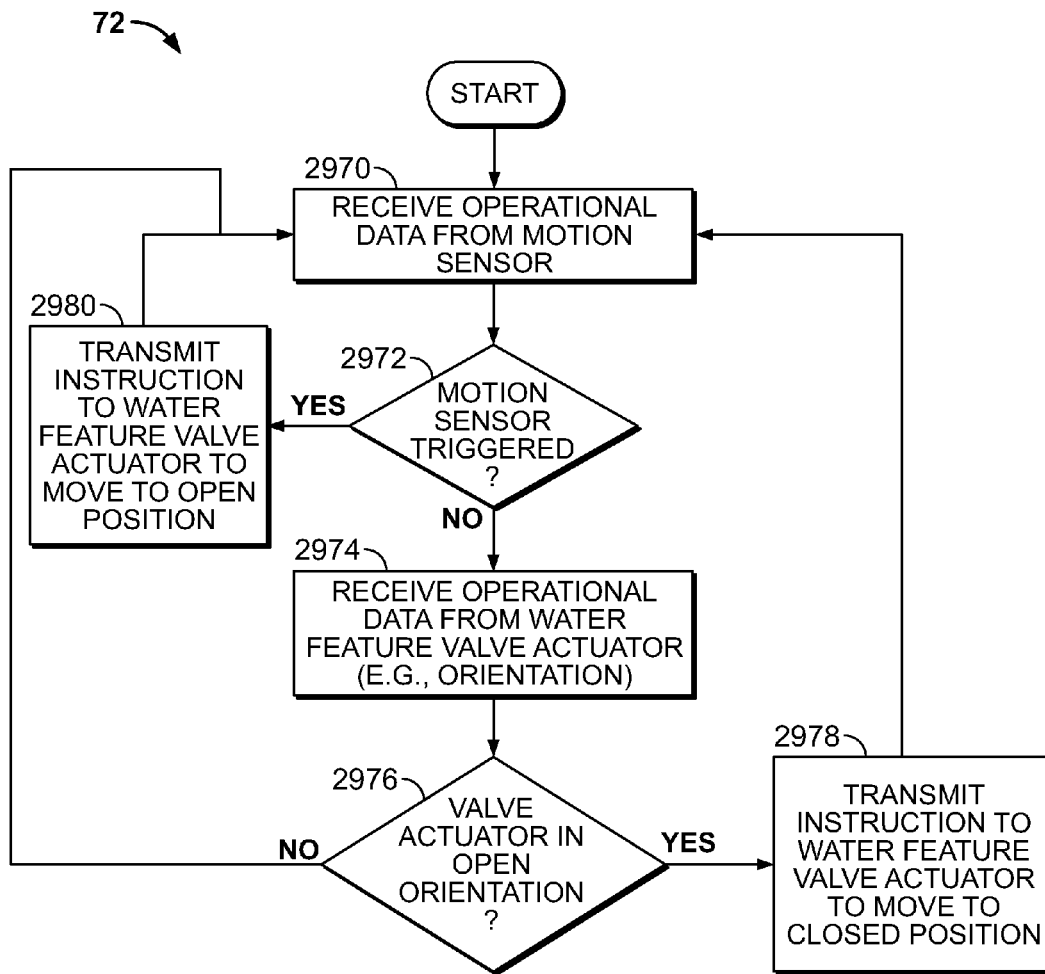


FIG. 31E

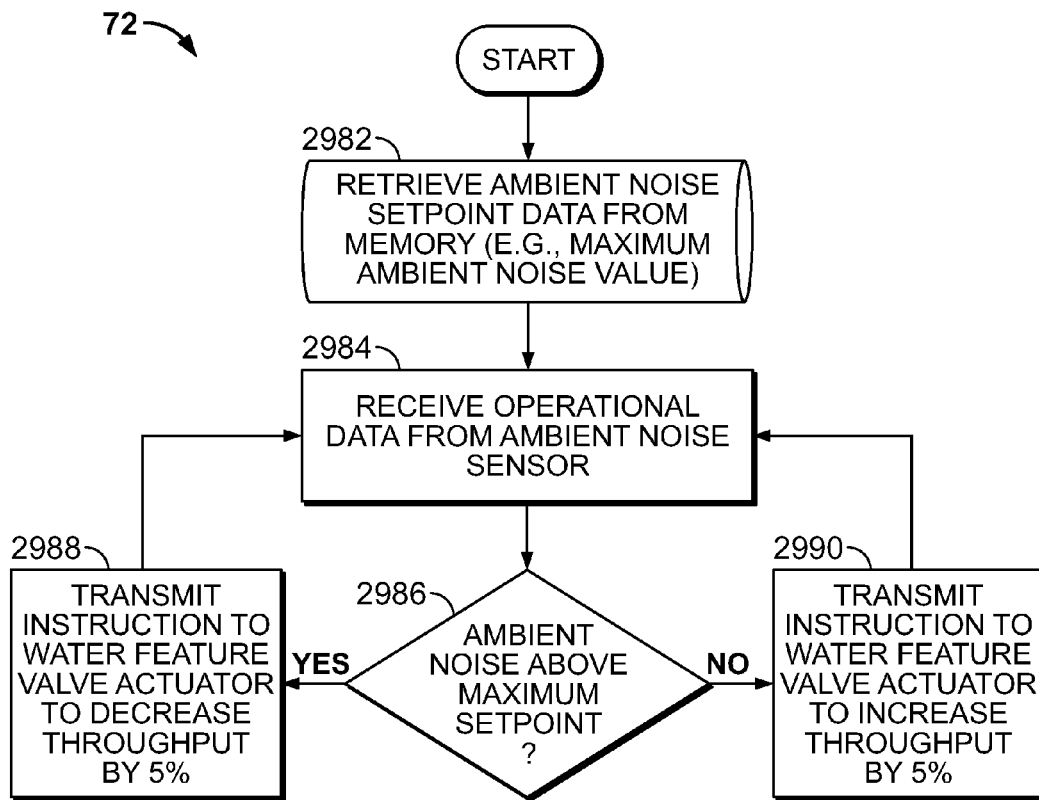


FIG. 31F

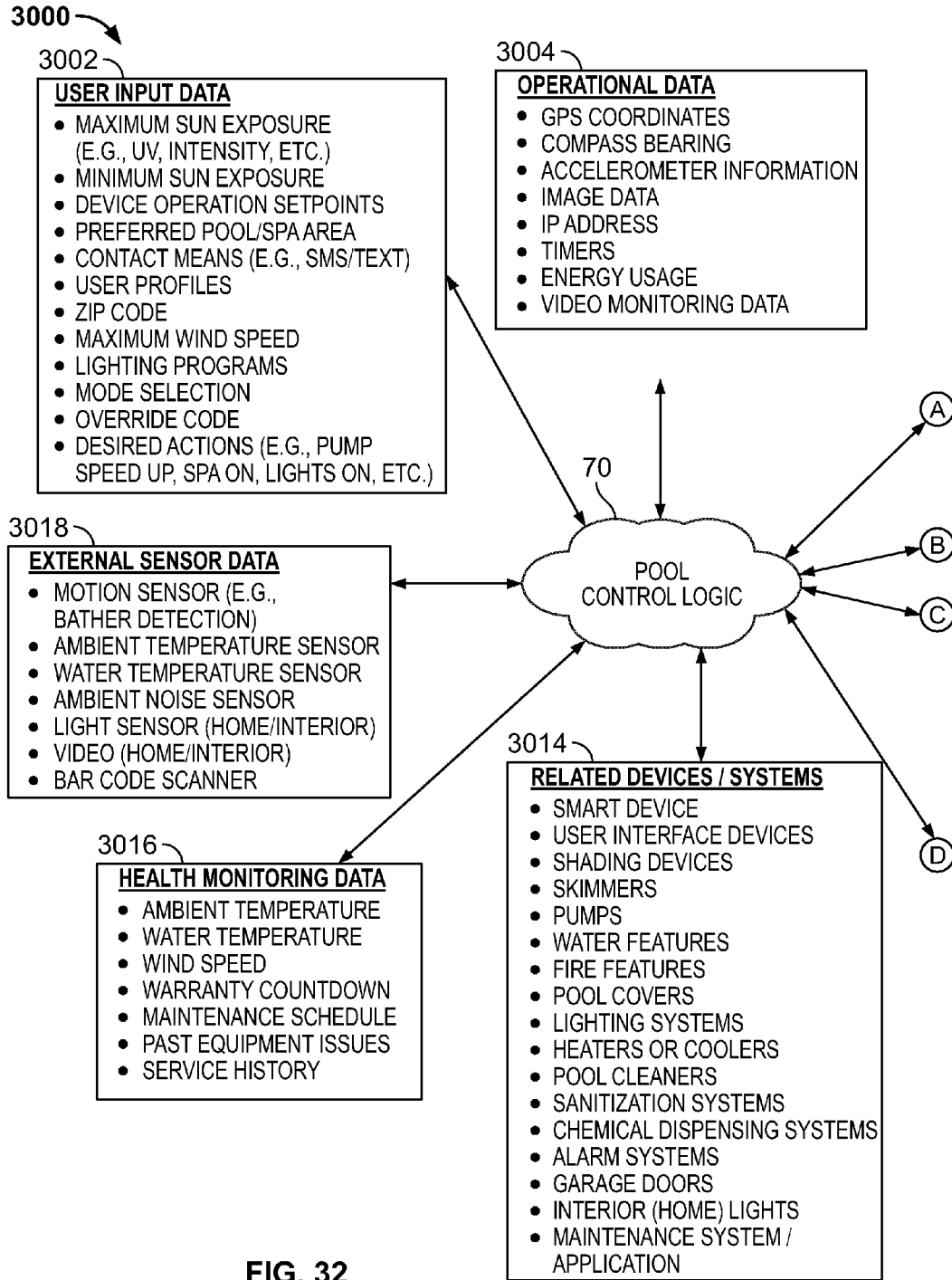


FIG. 32

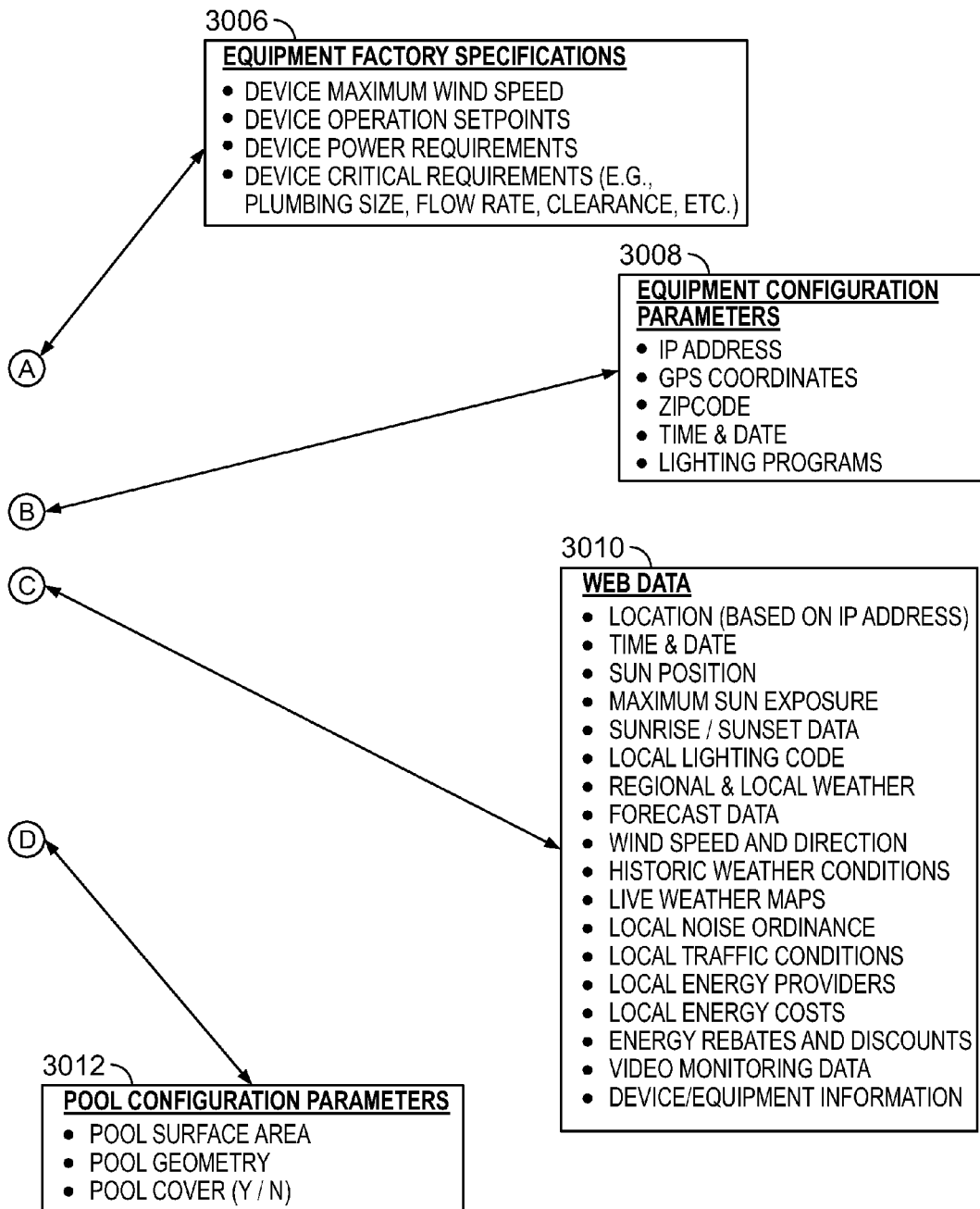


FIG. 32 (Cont.)

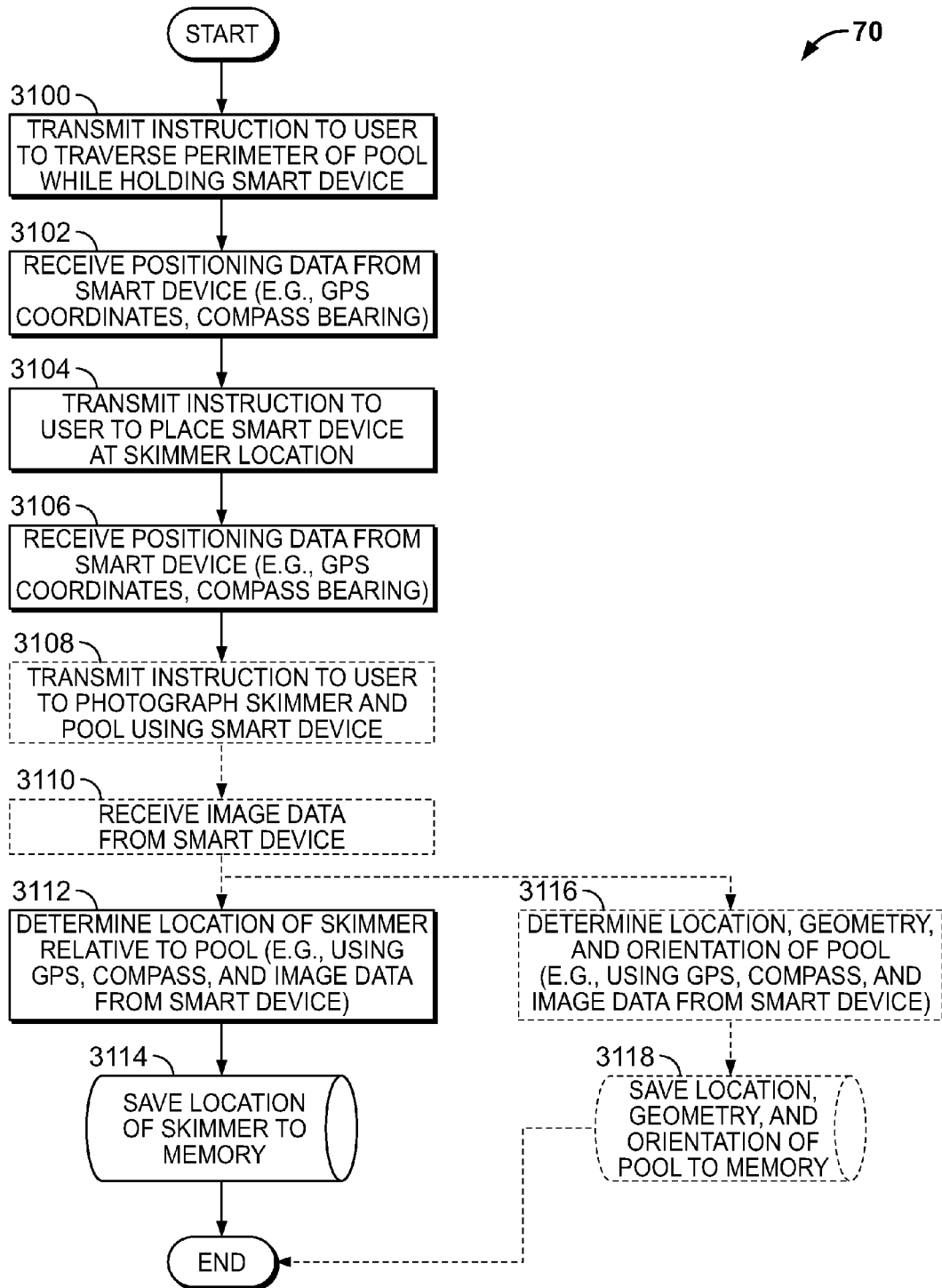


FIG. 33A

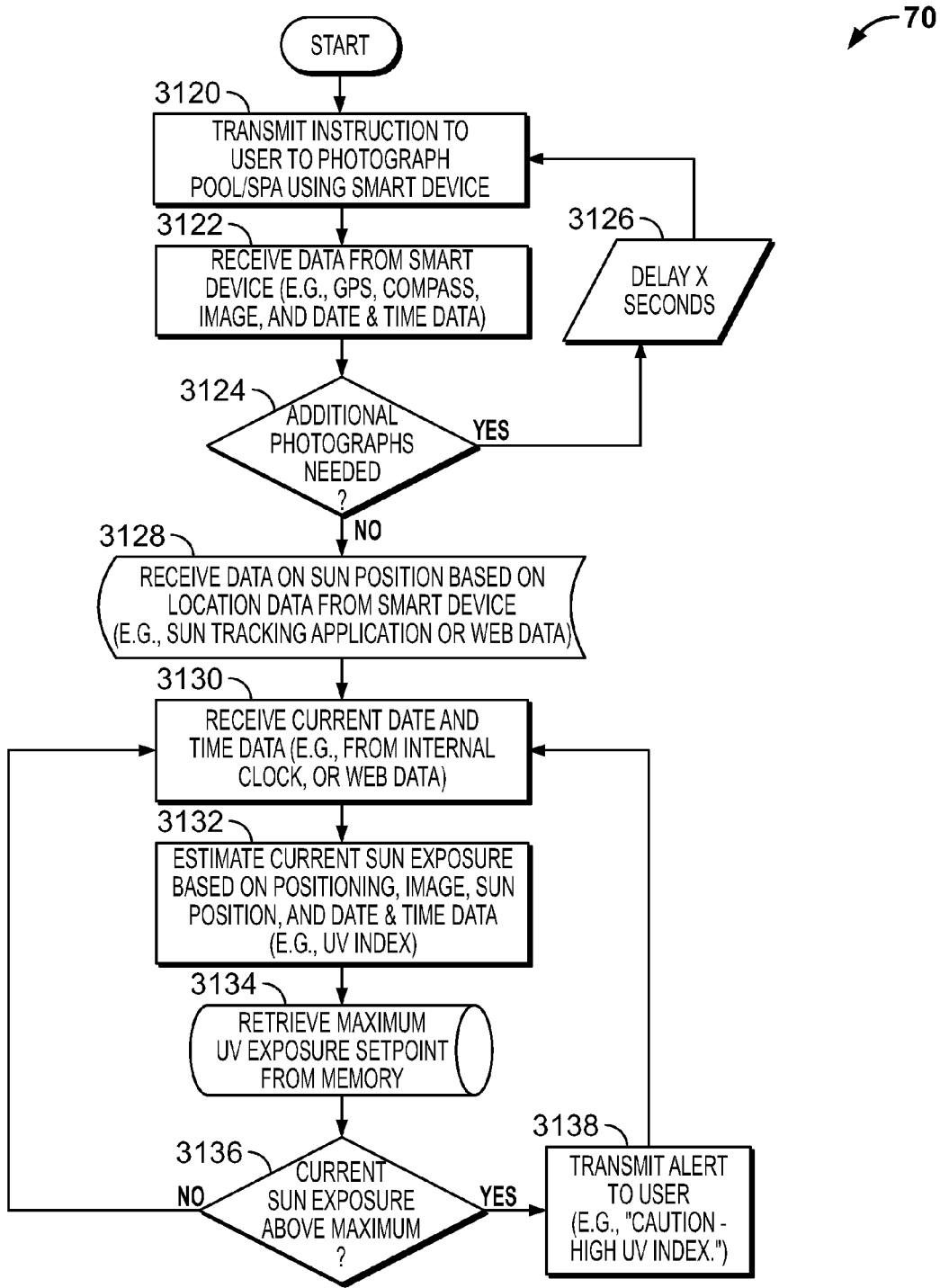


FIG. 33B

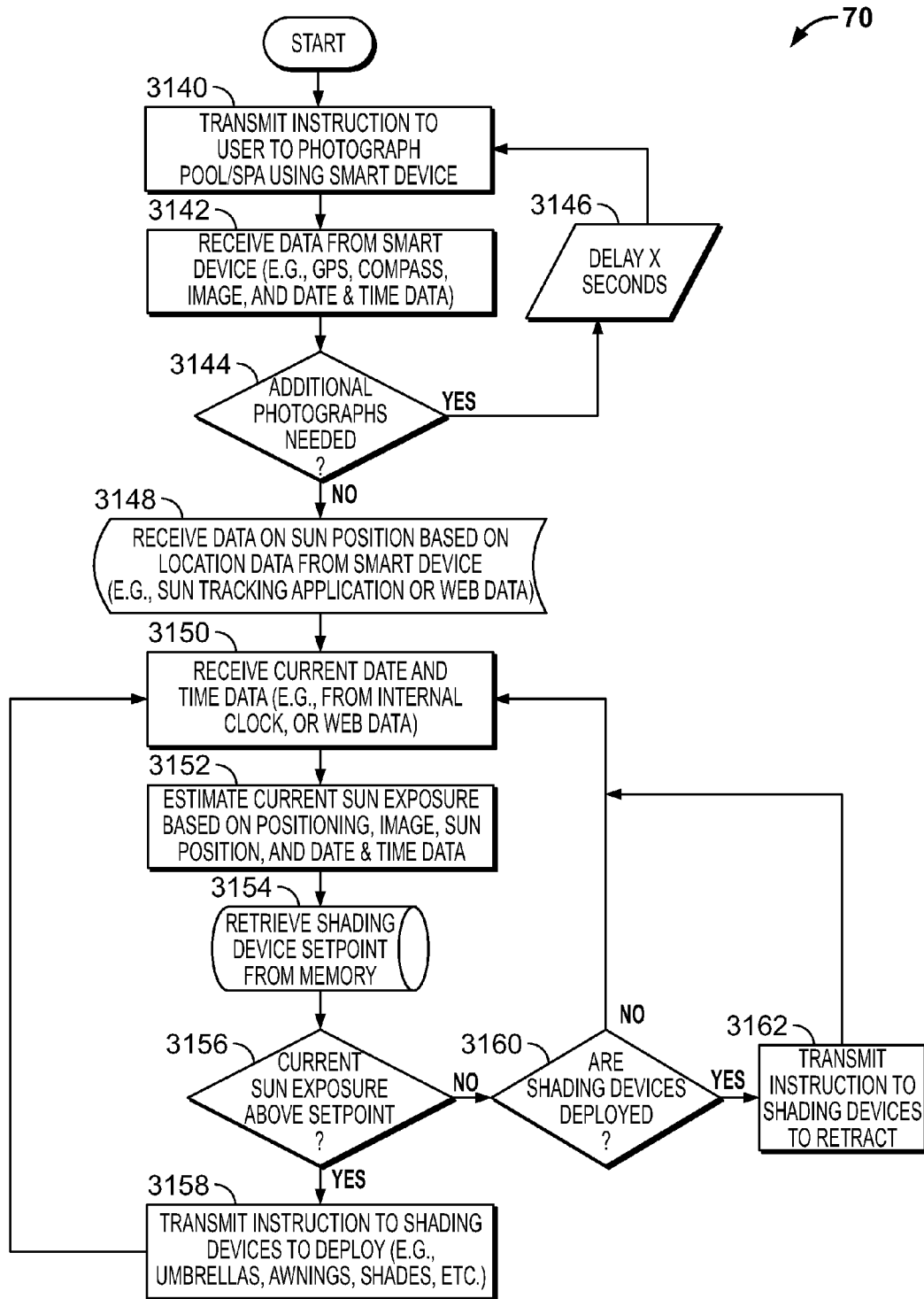
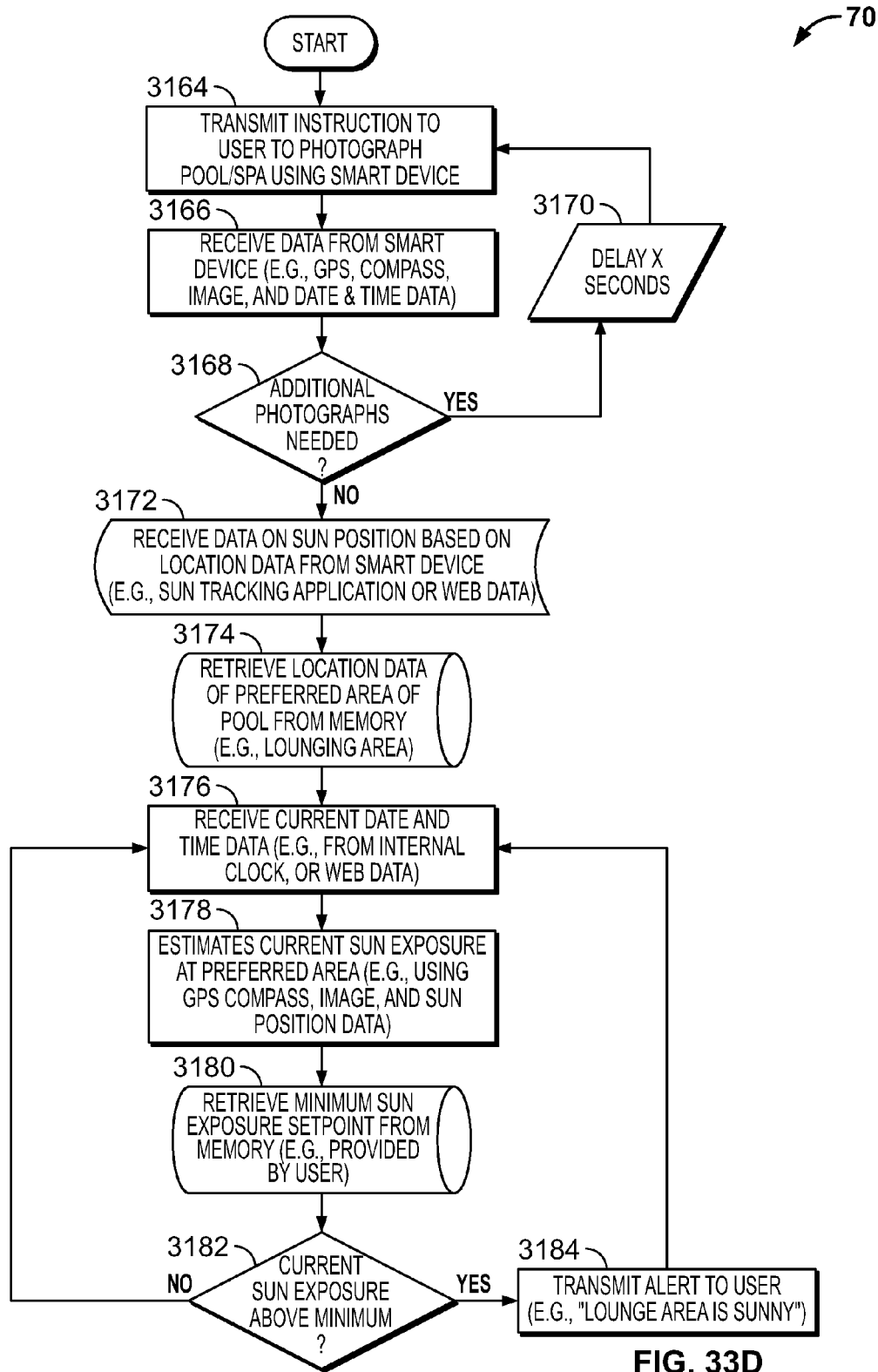


FIG. 33C



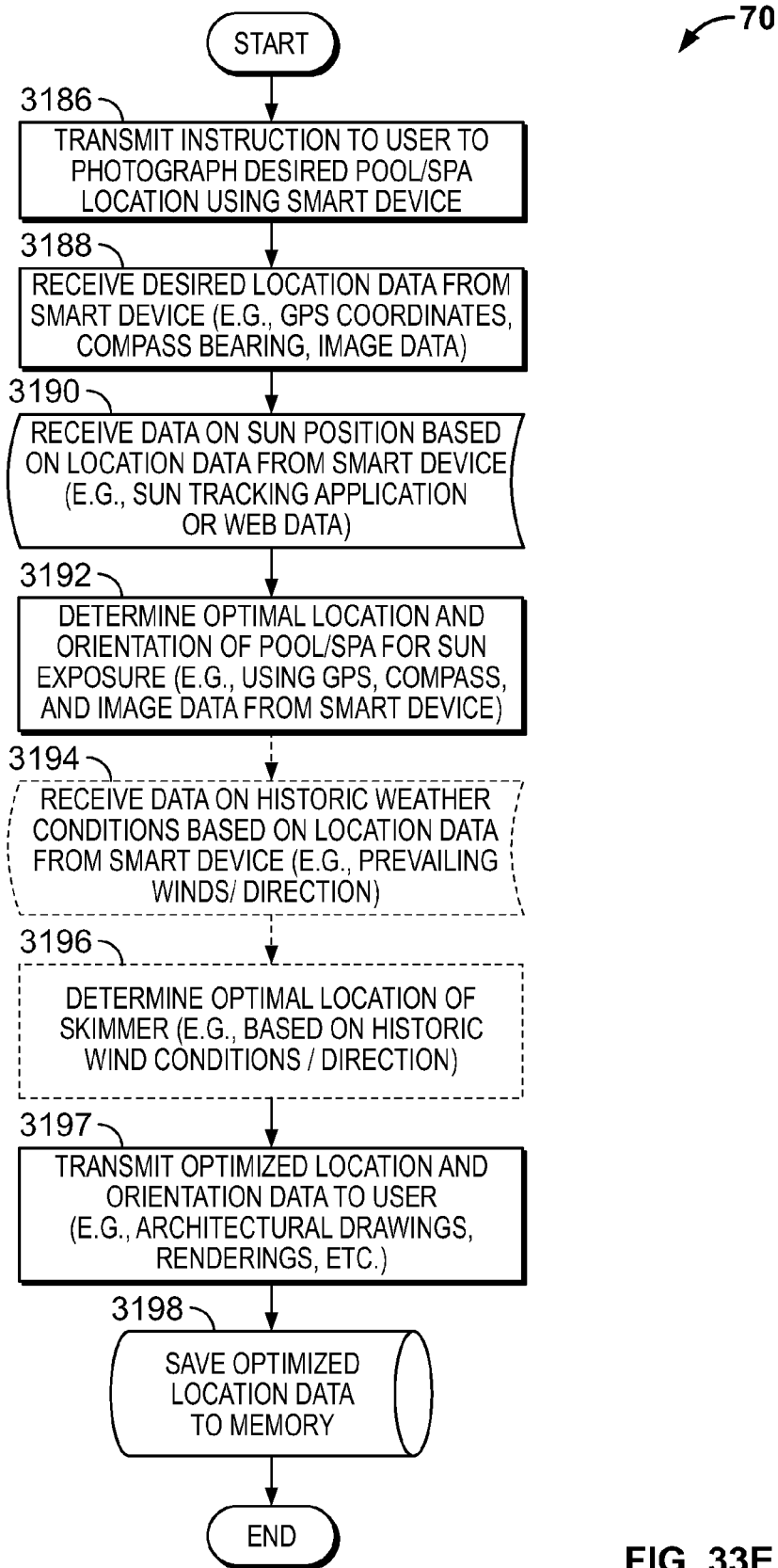


FIG. 33E

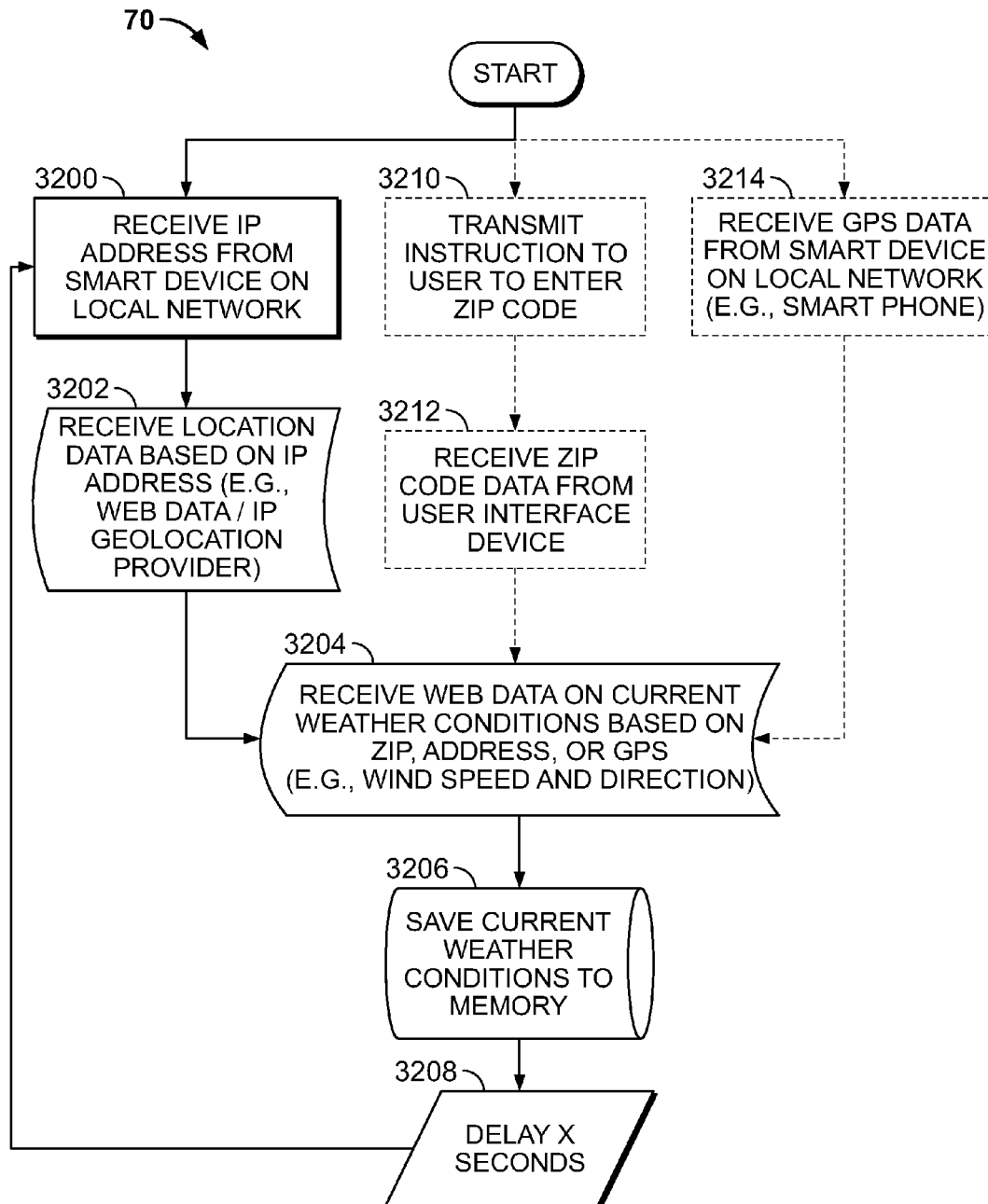


FIG. 33F

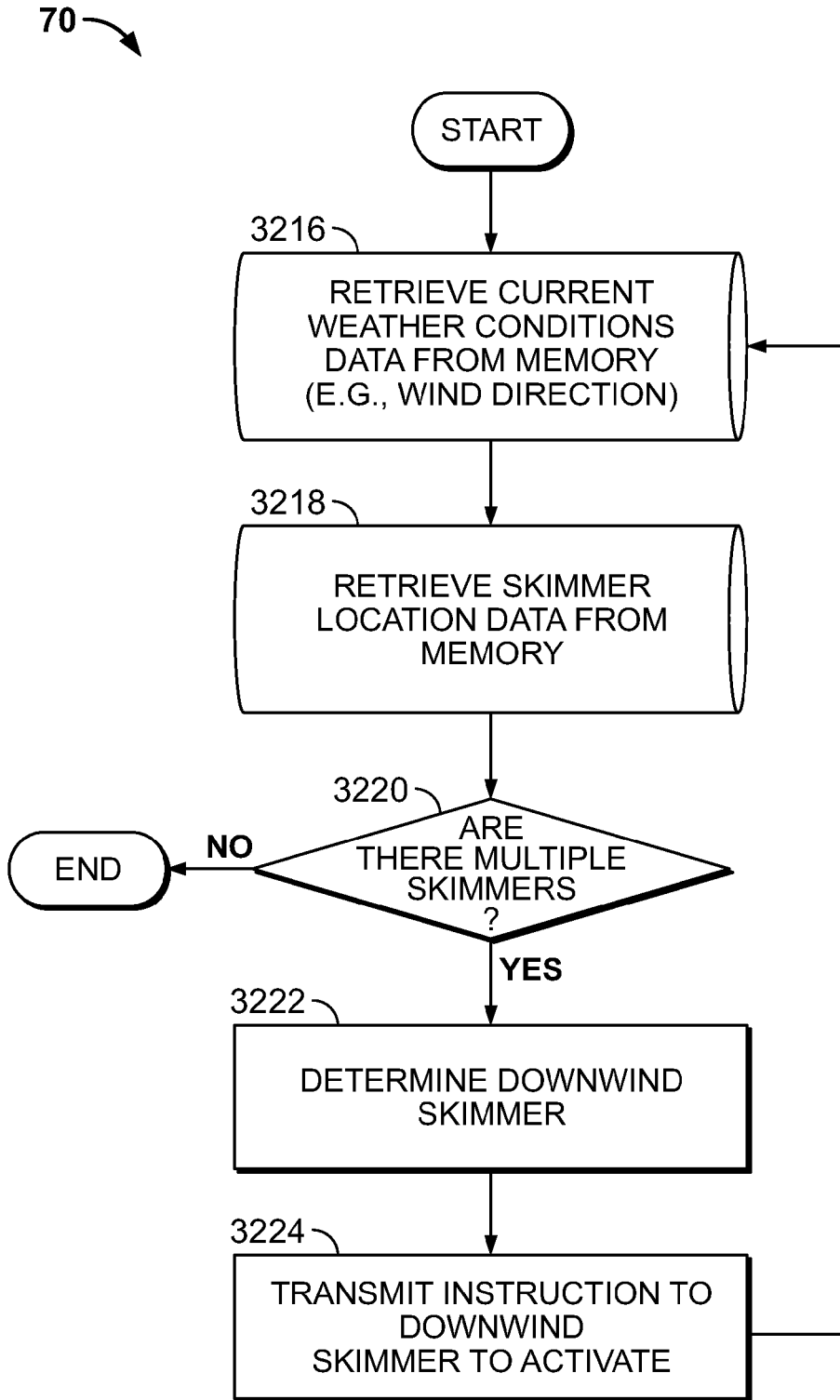


FIG. 33G

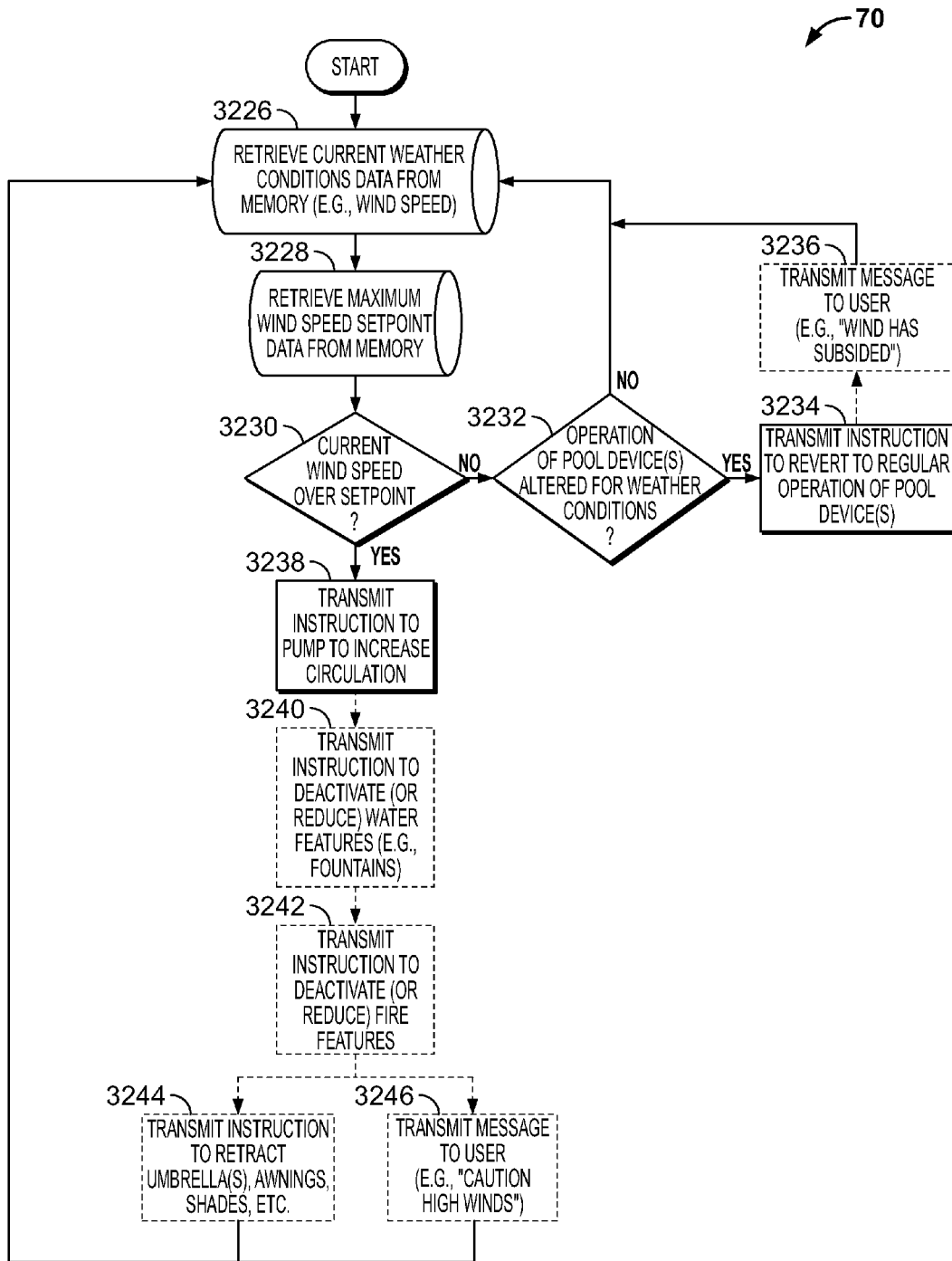


FIG. 33H

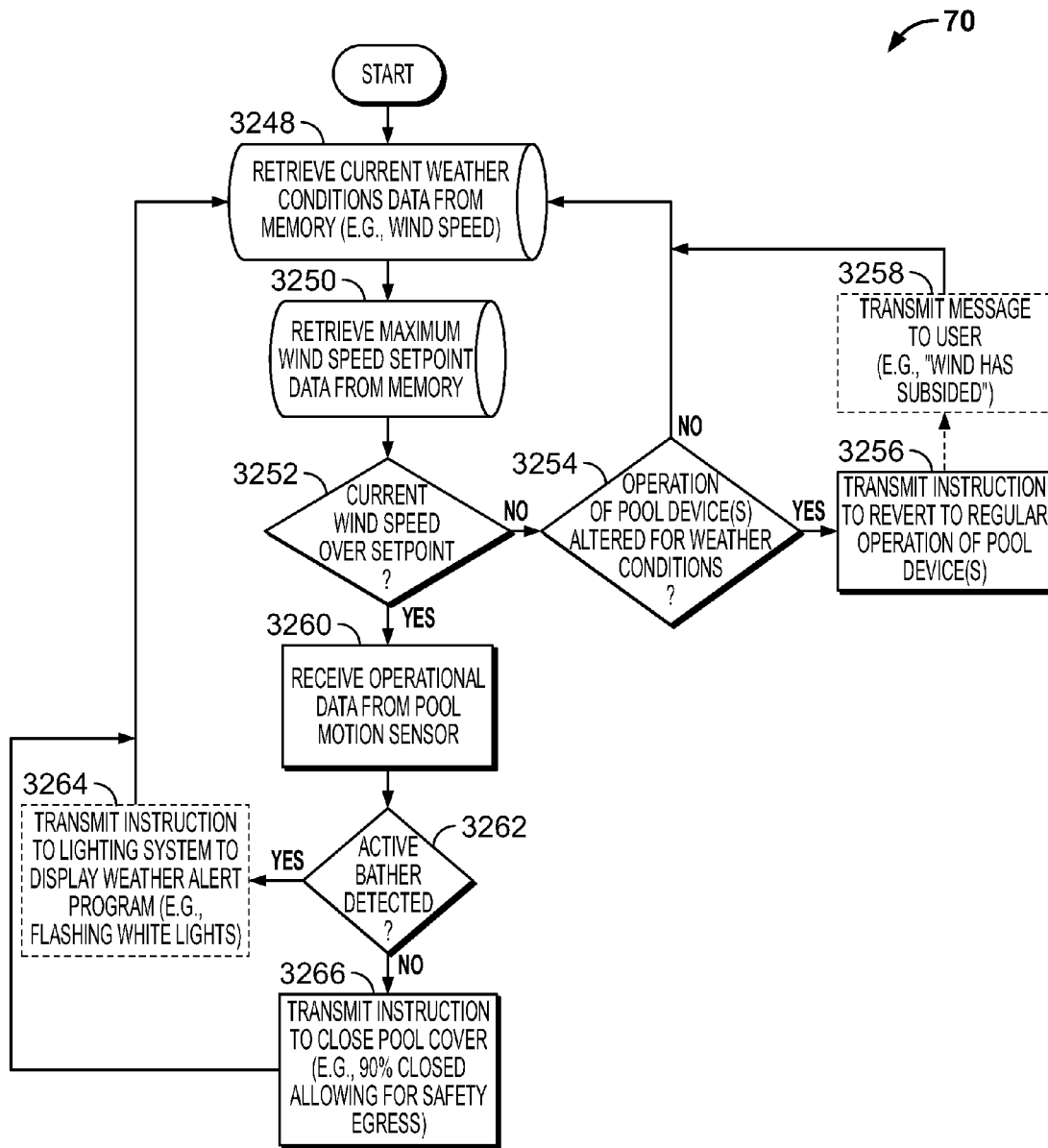


FIG. 331

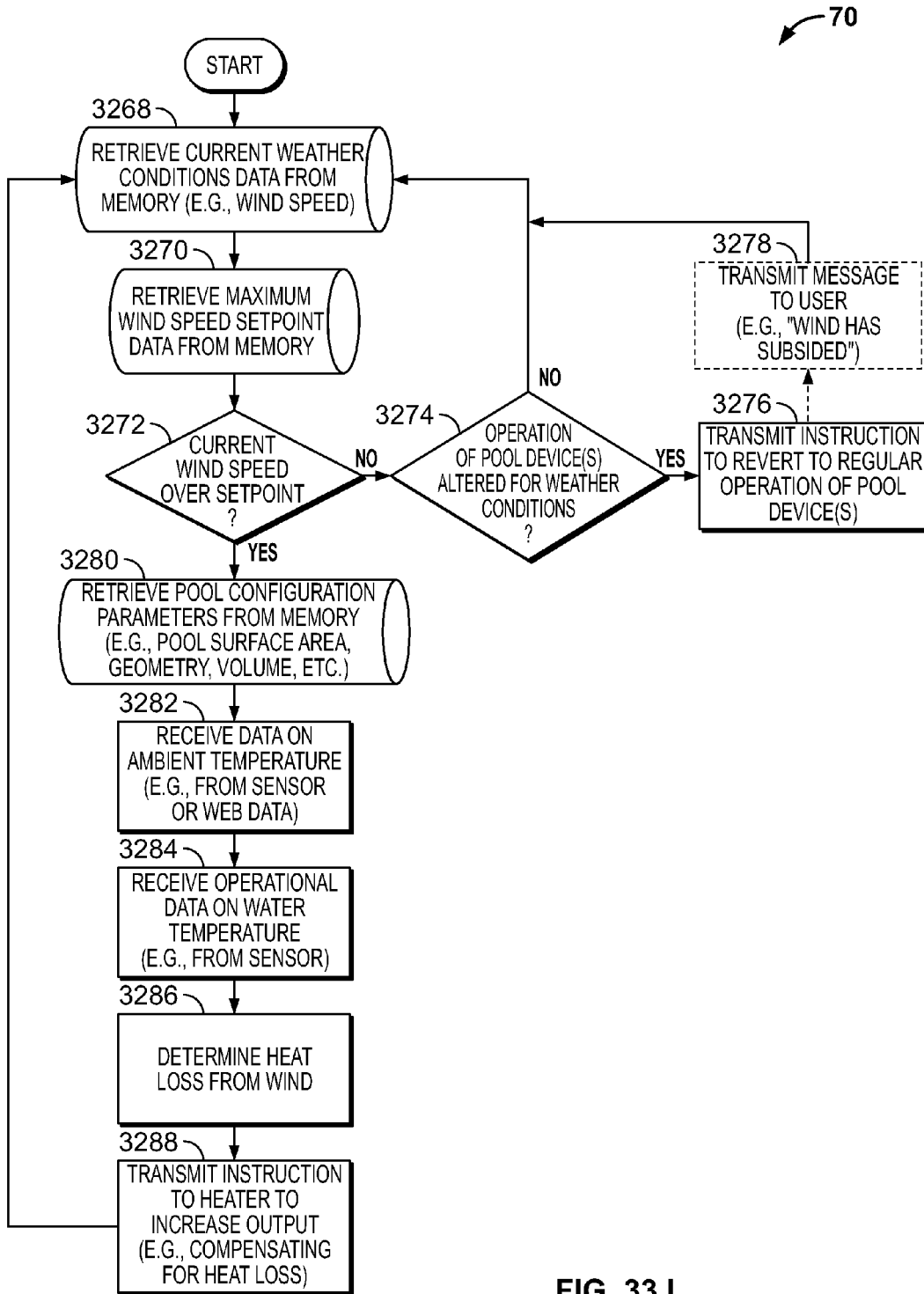


FIG. 33J

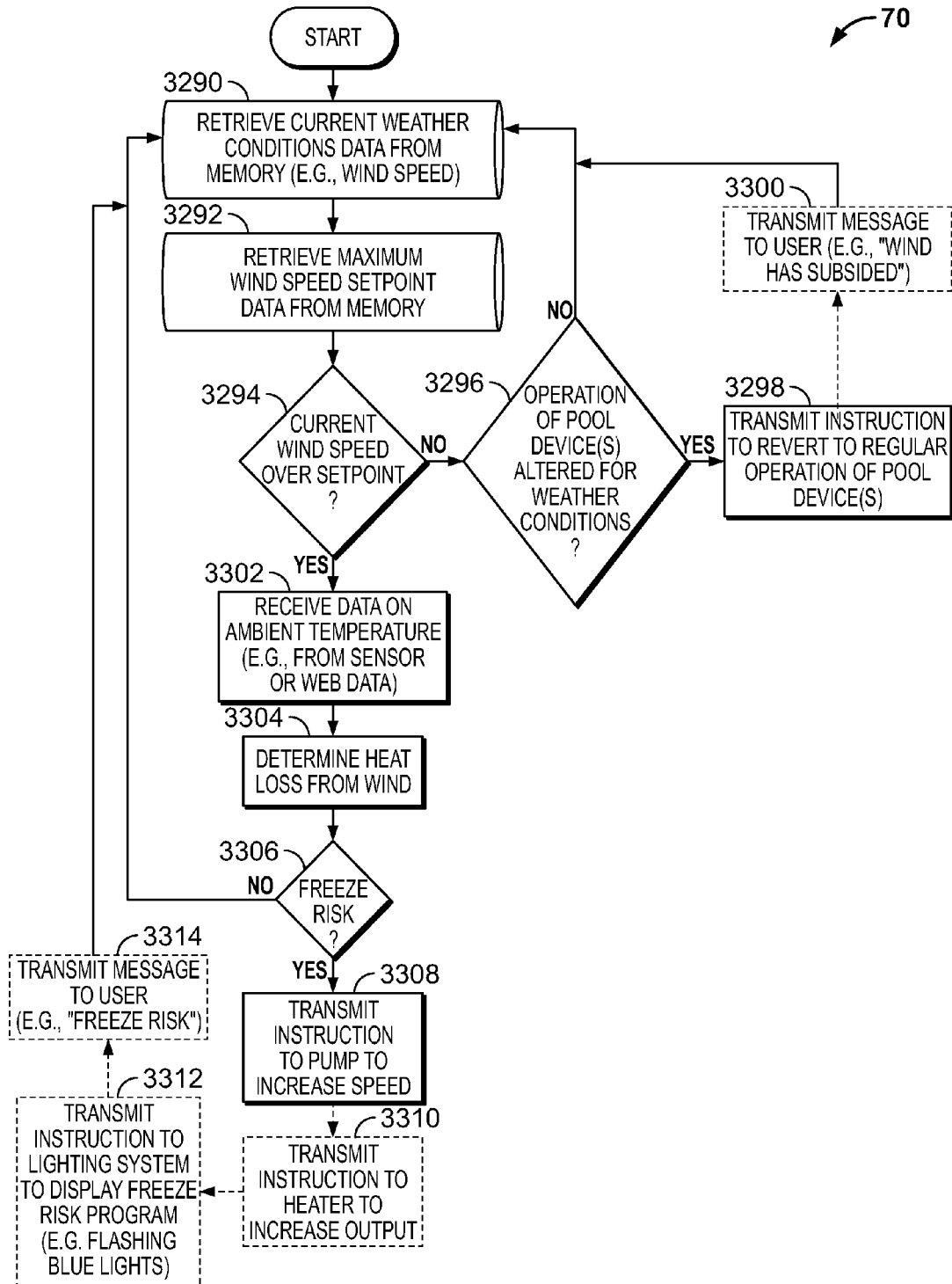


FIG. 33K

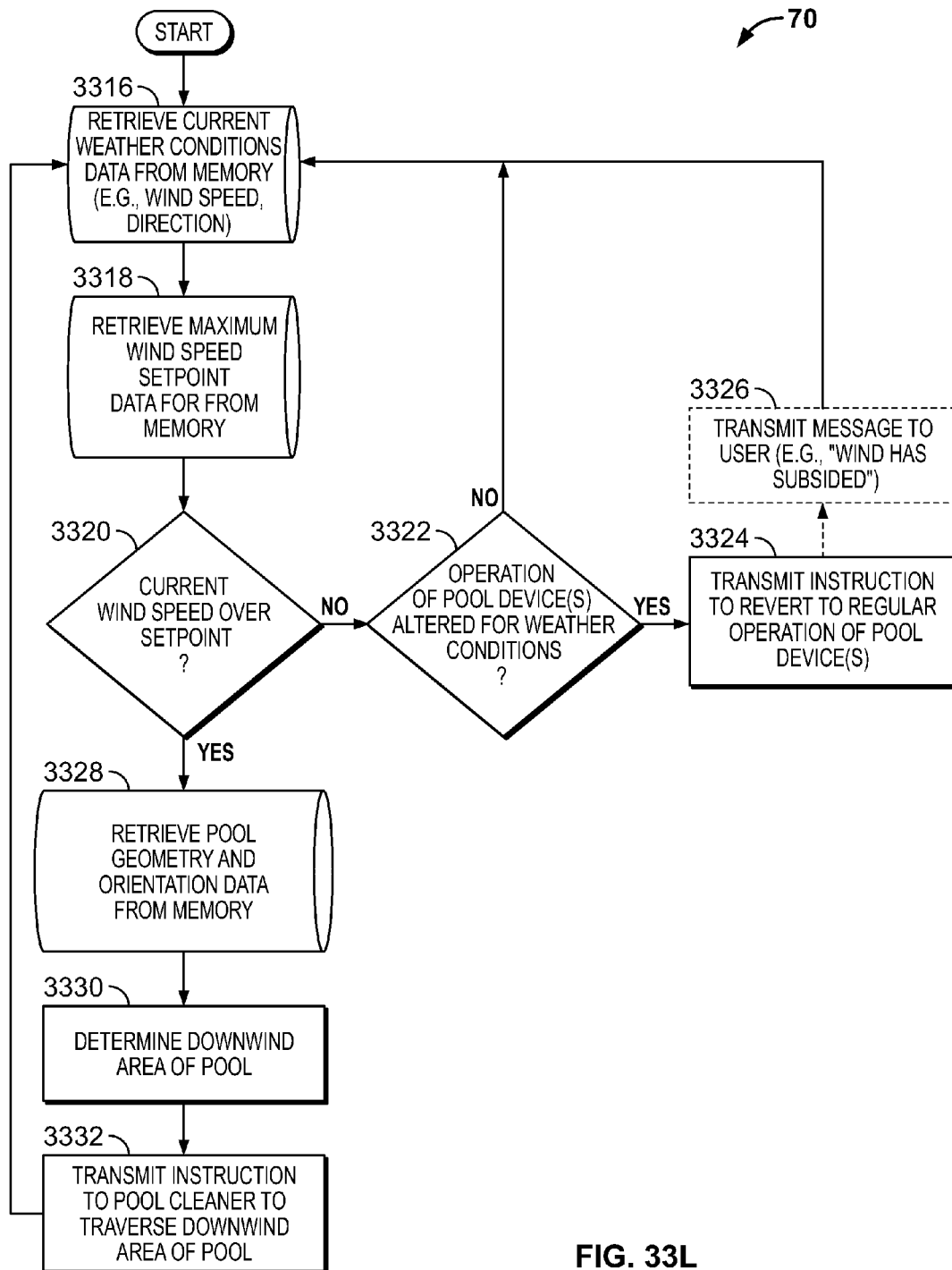


FIG. 33L

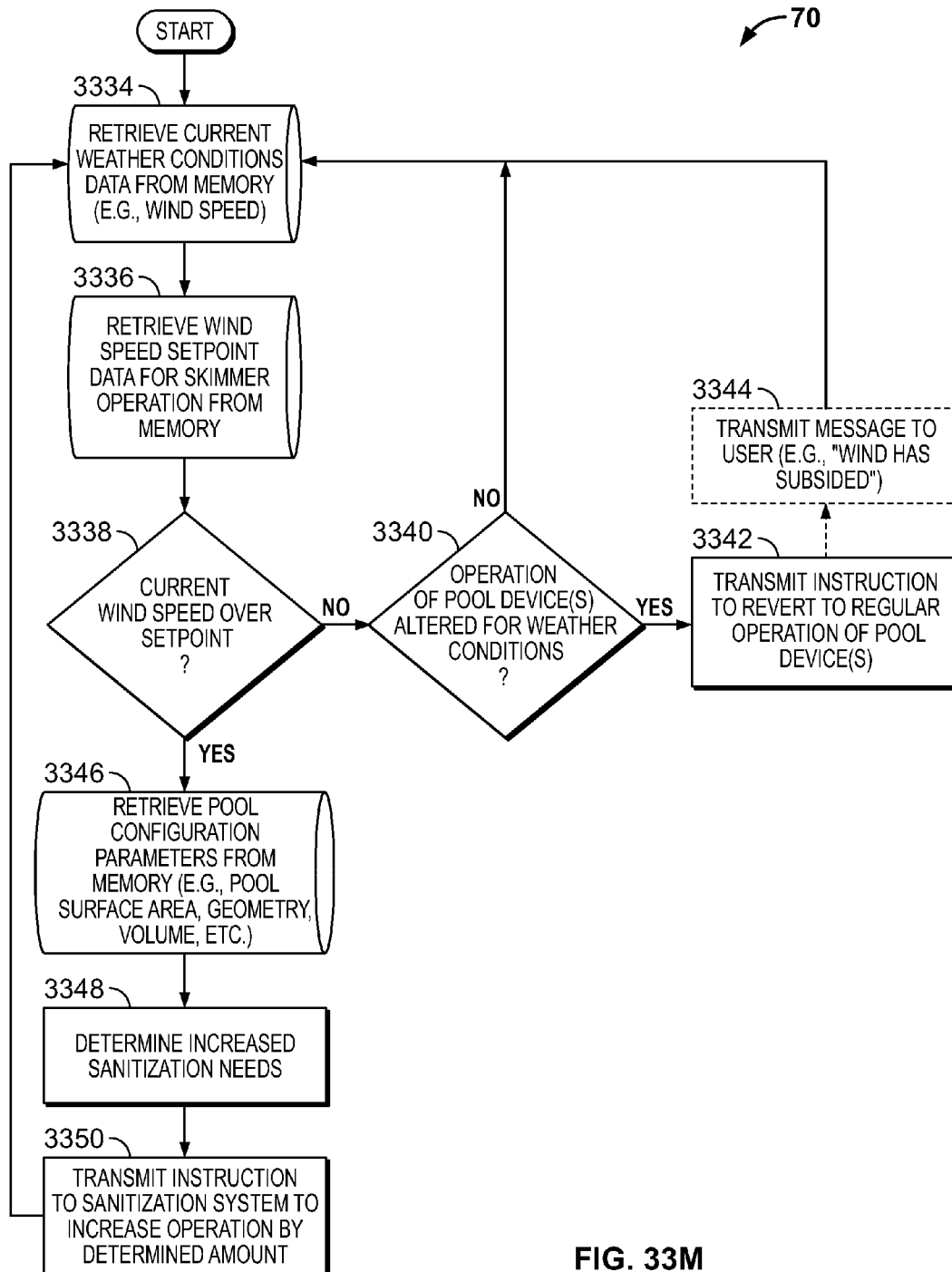


FIG. 33M

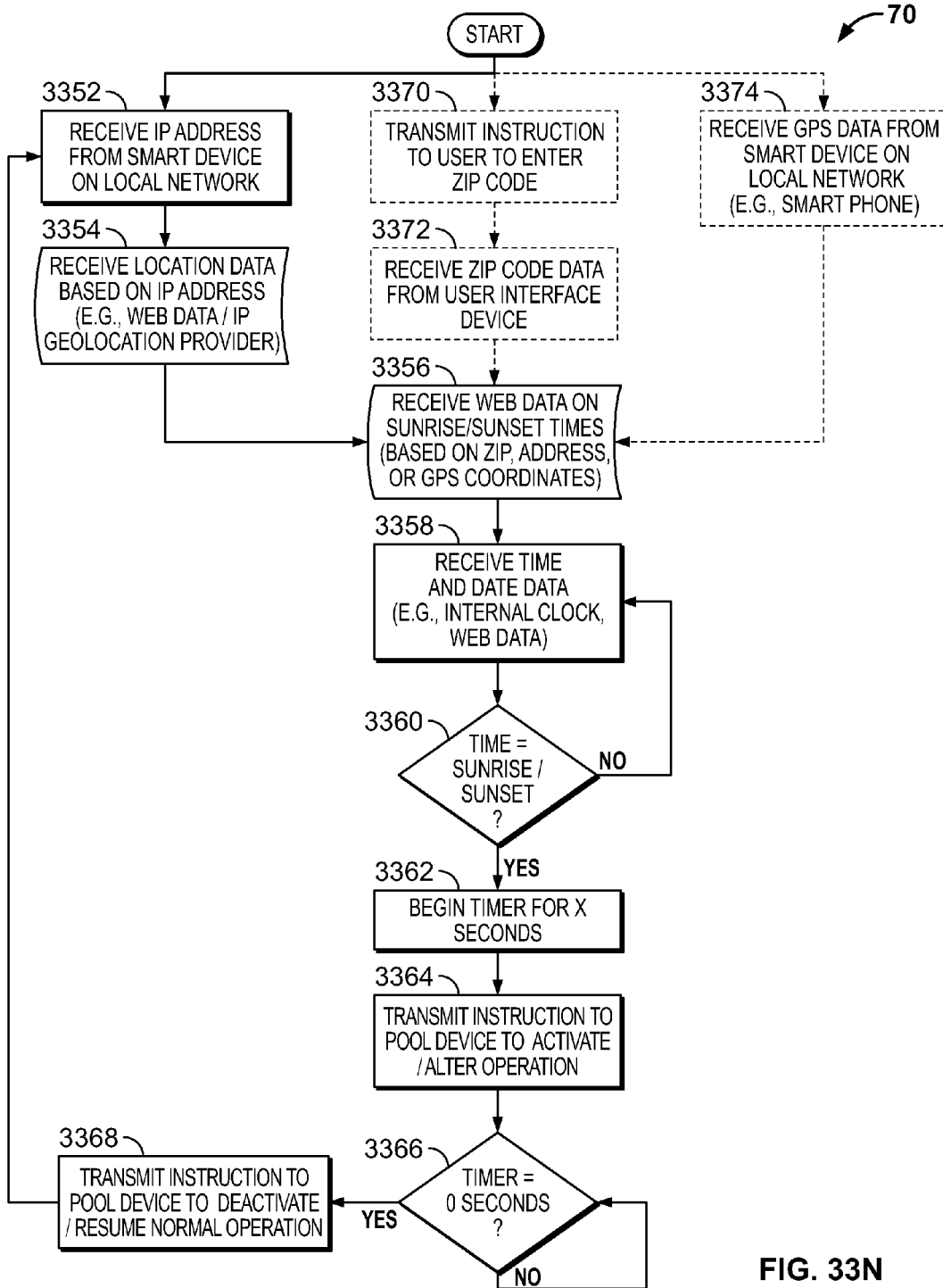


FIG. 33N

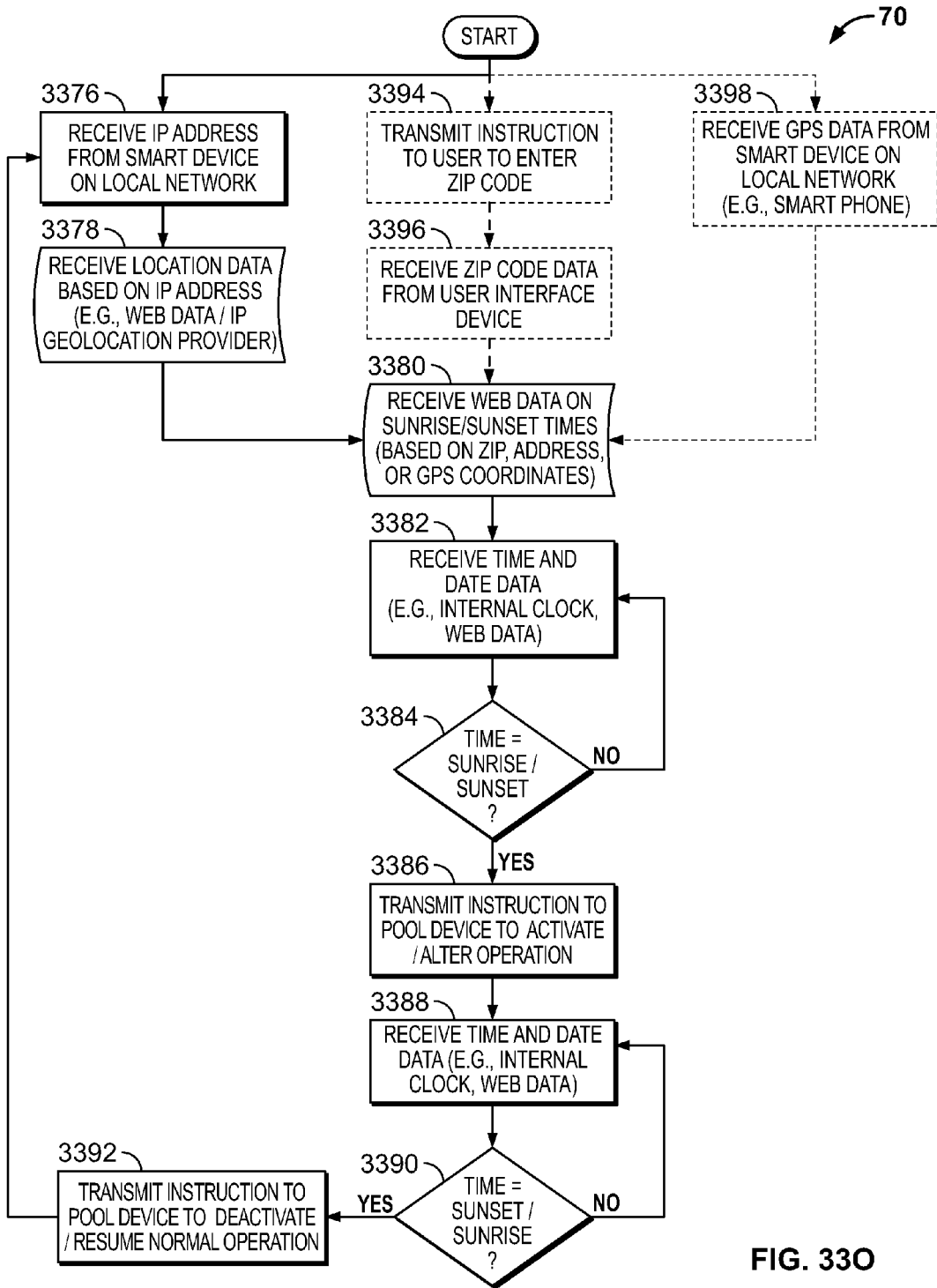


FIG. 330

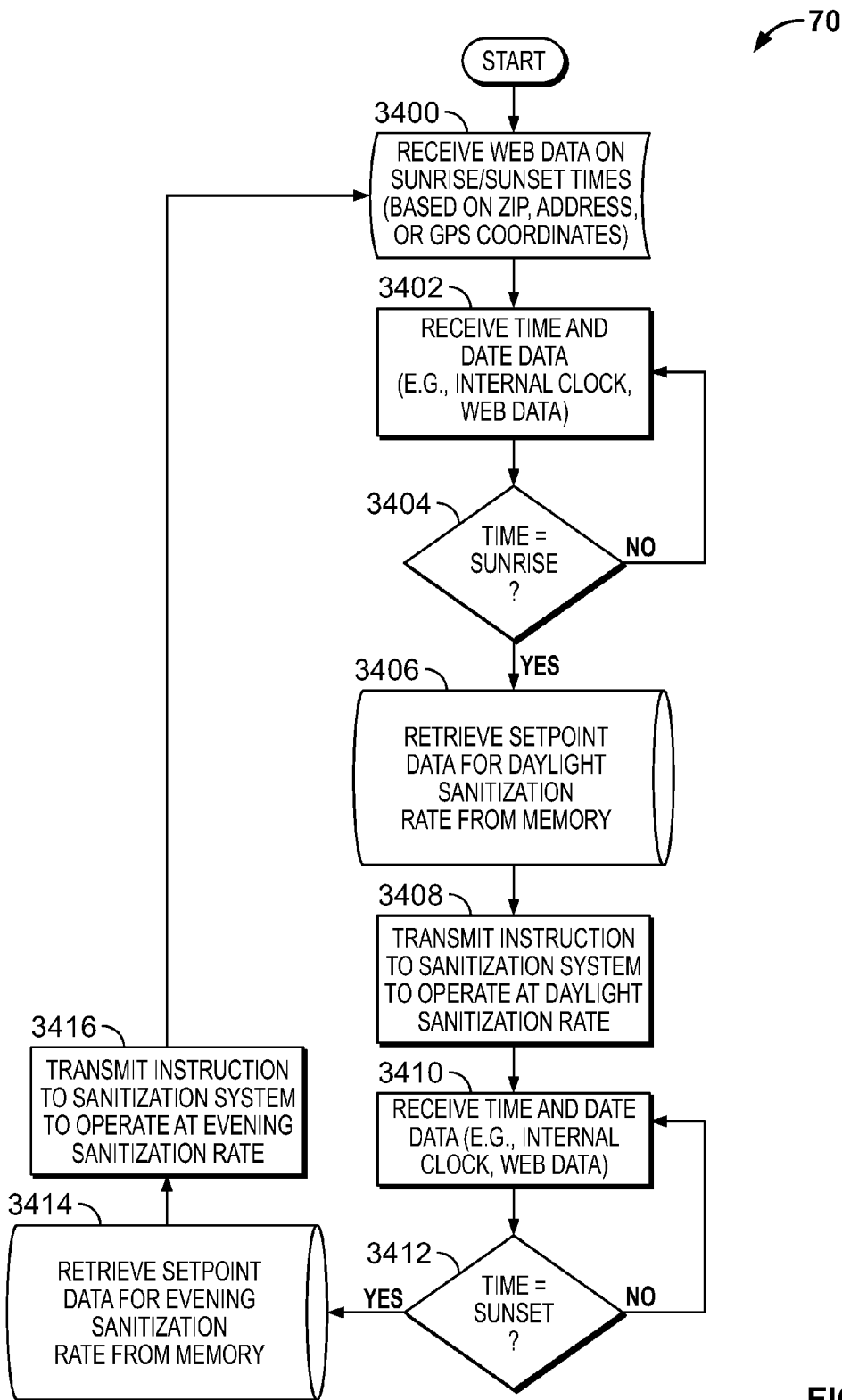


FIG. 33P

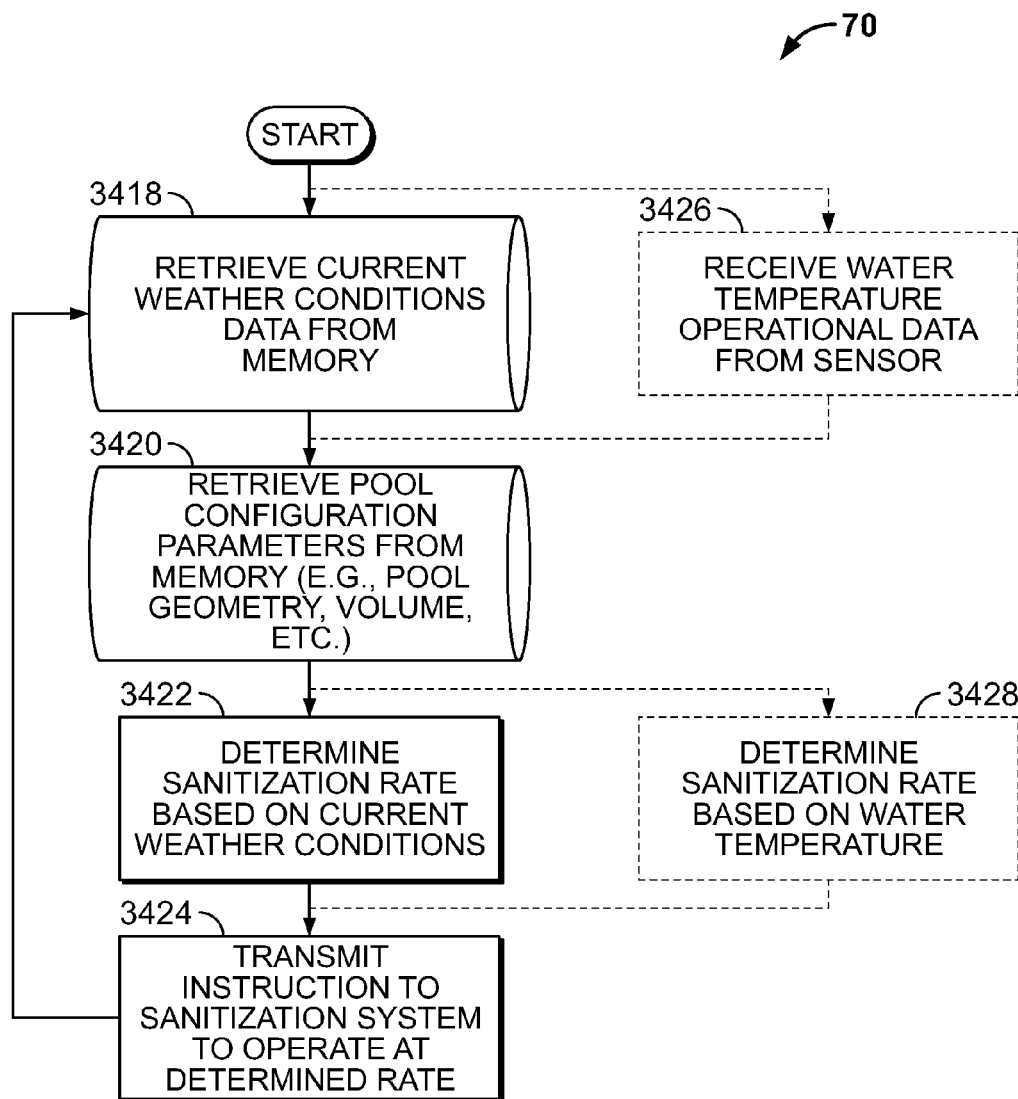


FIG. 33Q

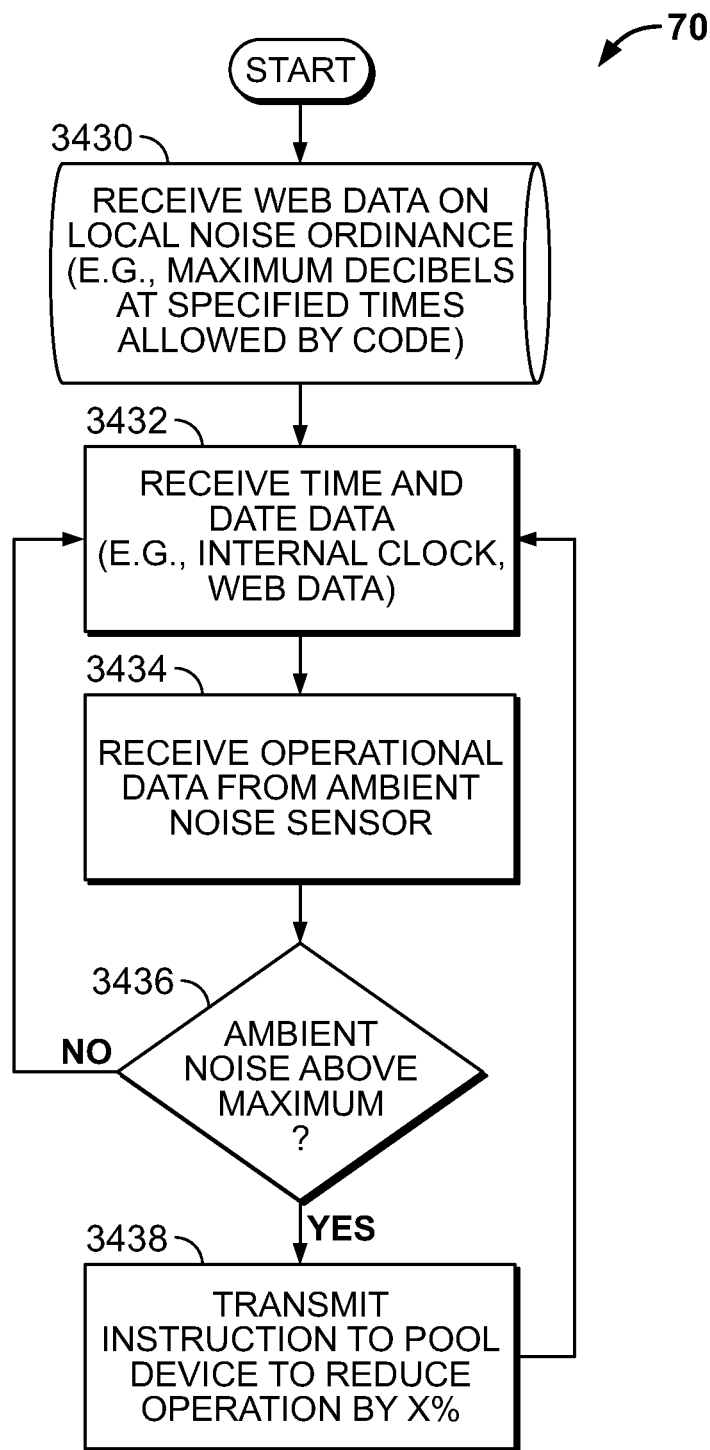


FIG. 33R

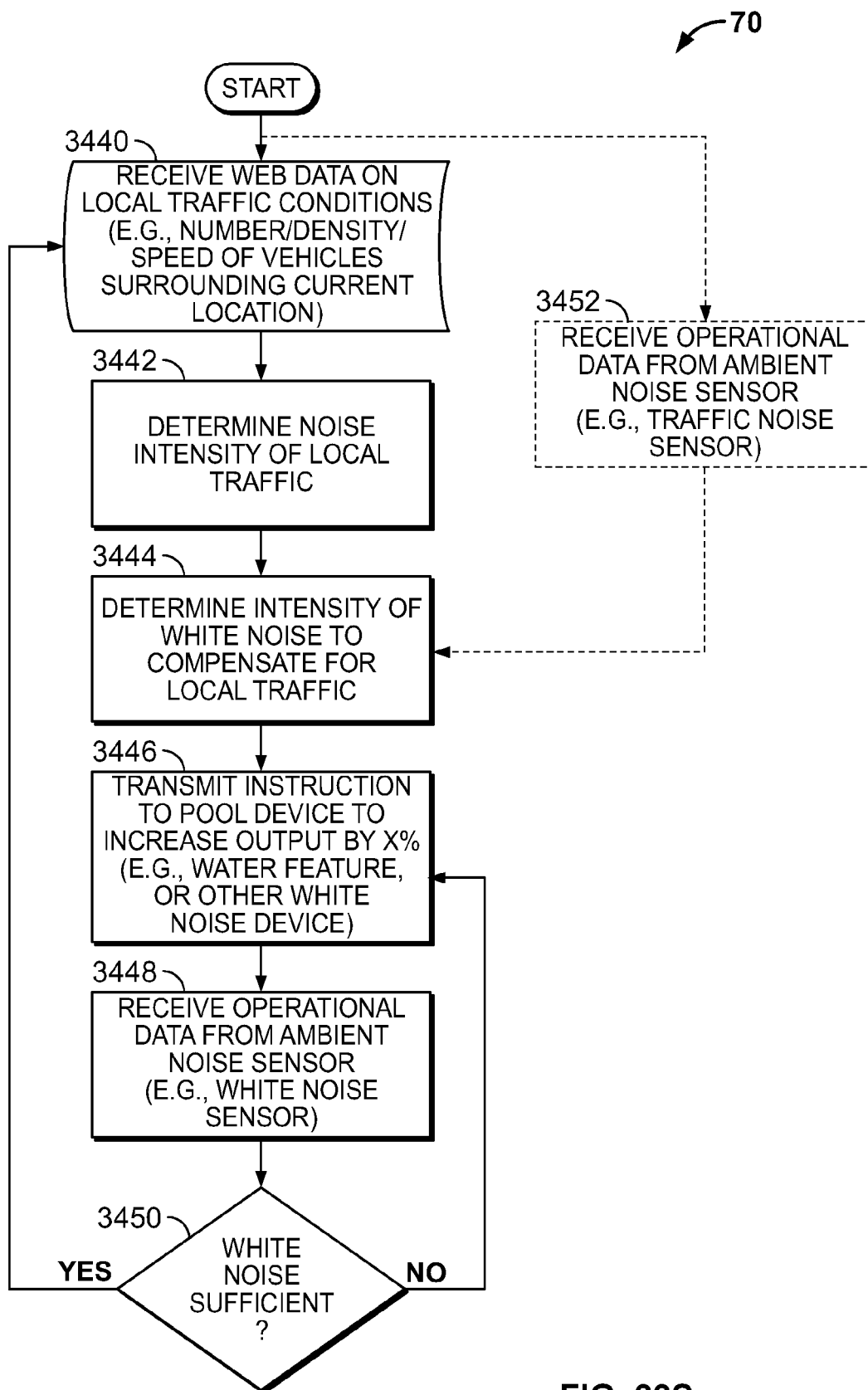


FIG. 33S

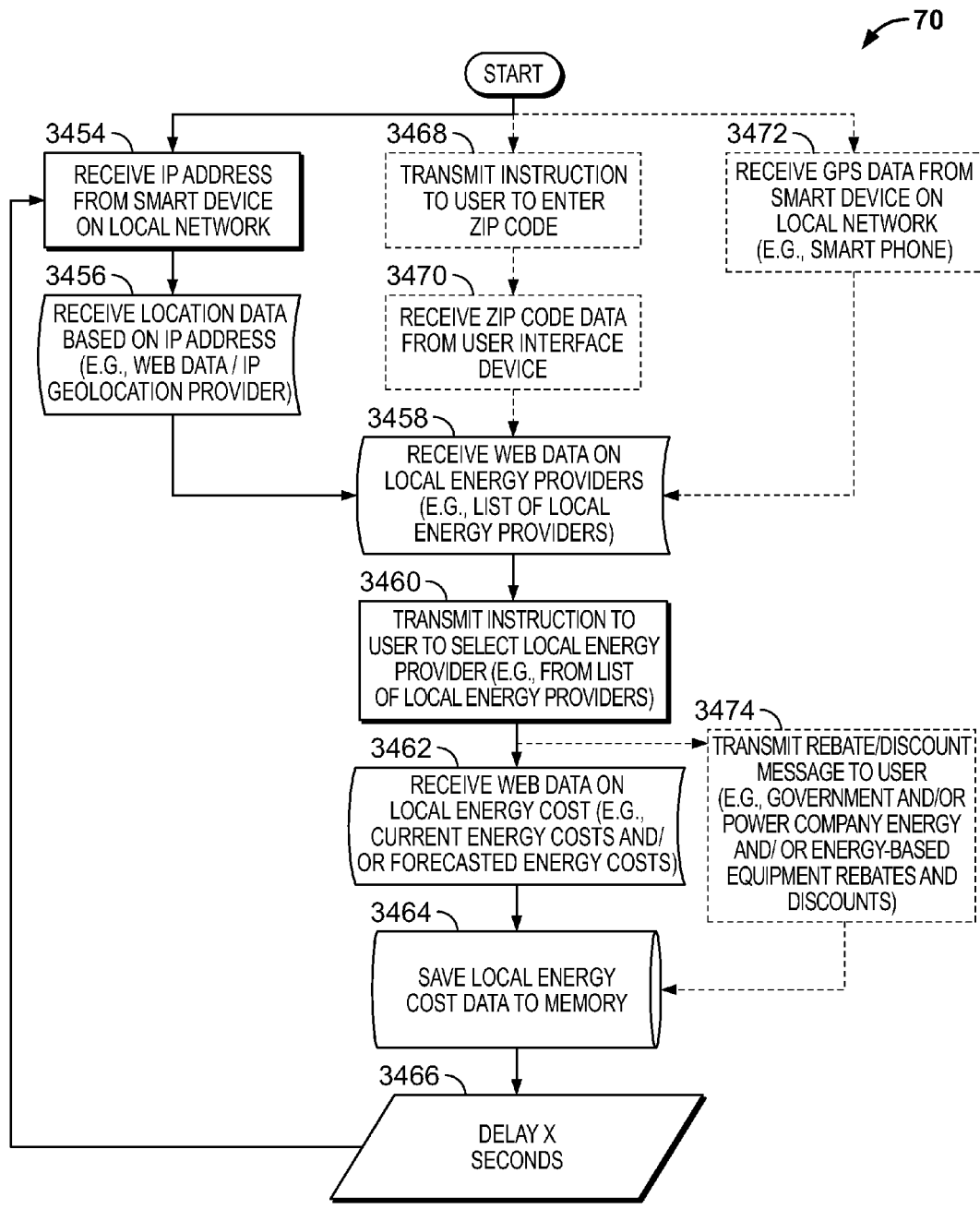


FIG. 33T

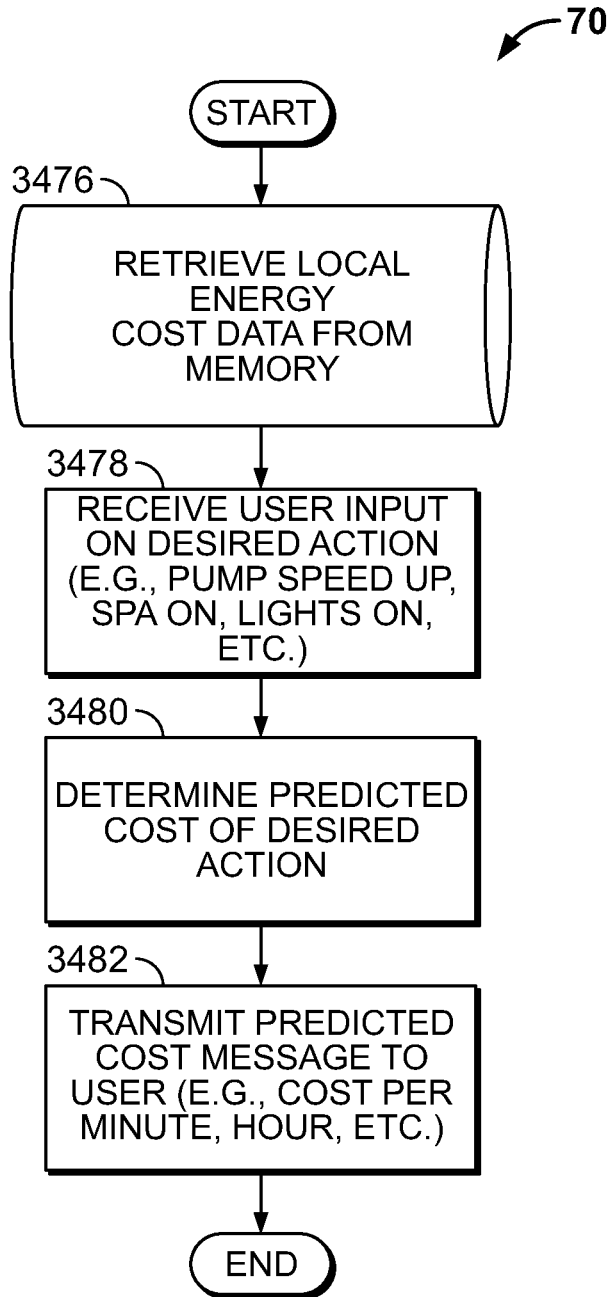


FIG. 33U

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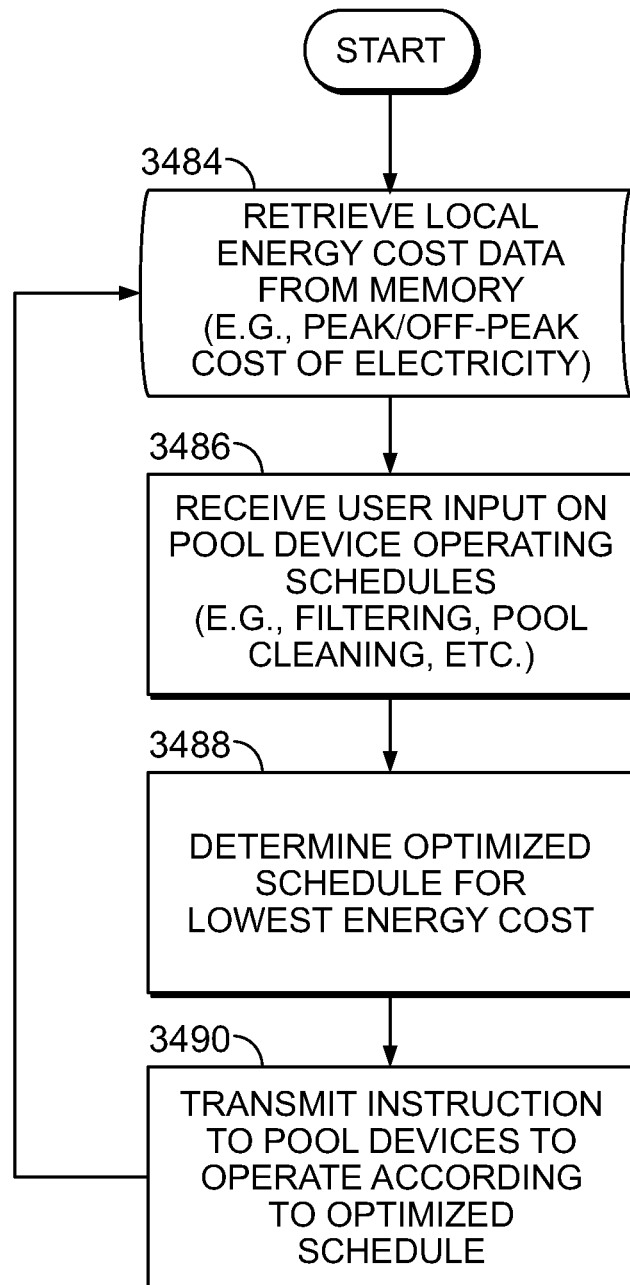


FIG. 33V

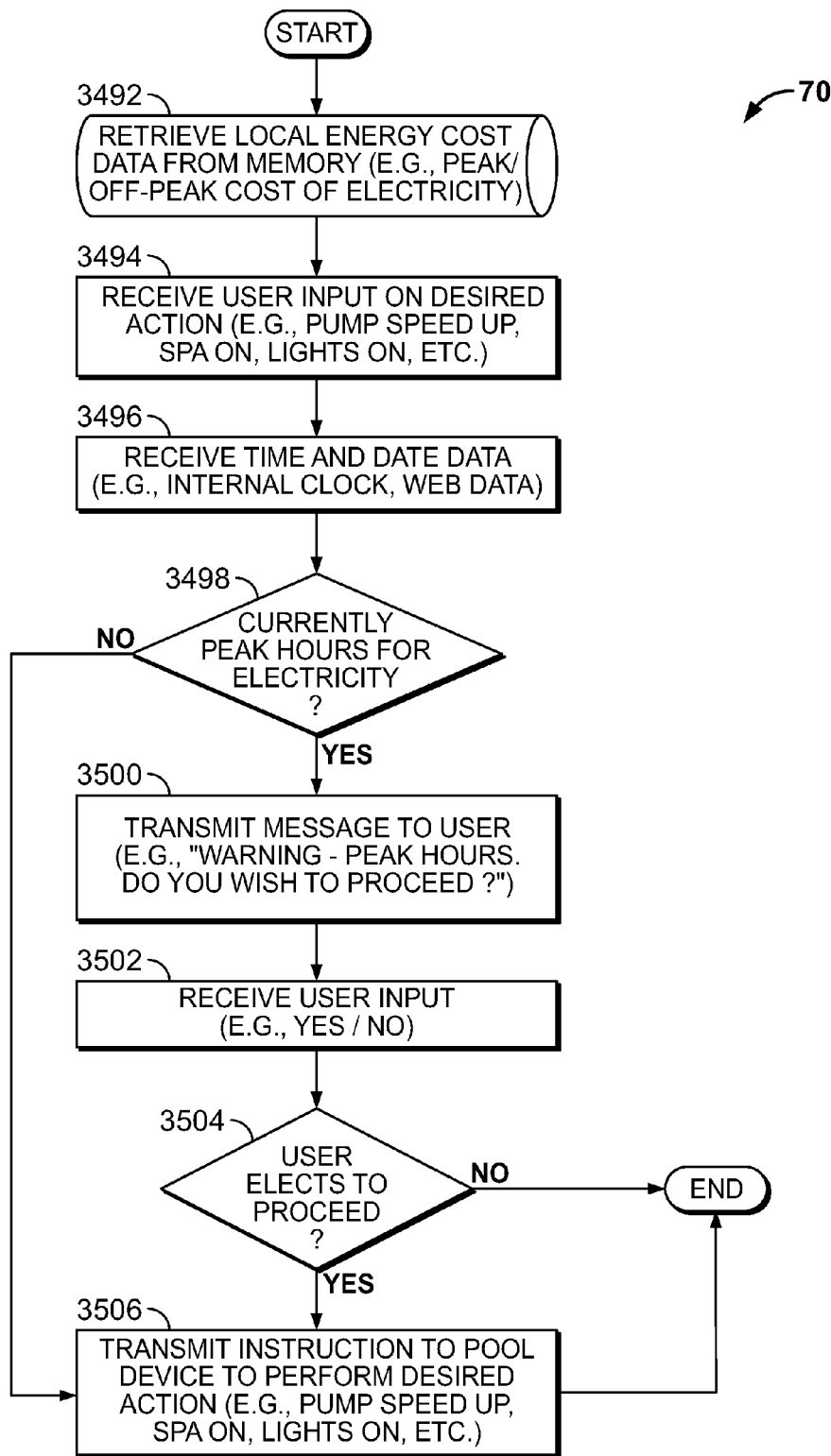


FIG. 33W

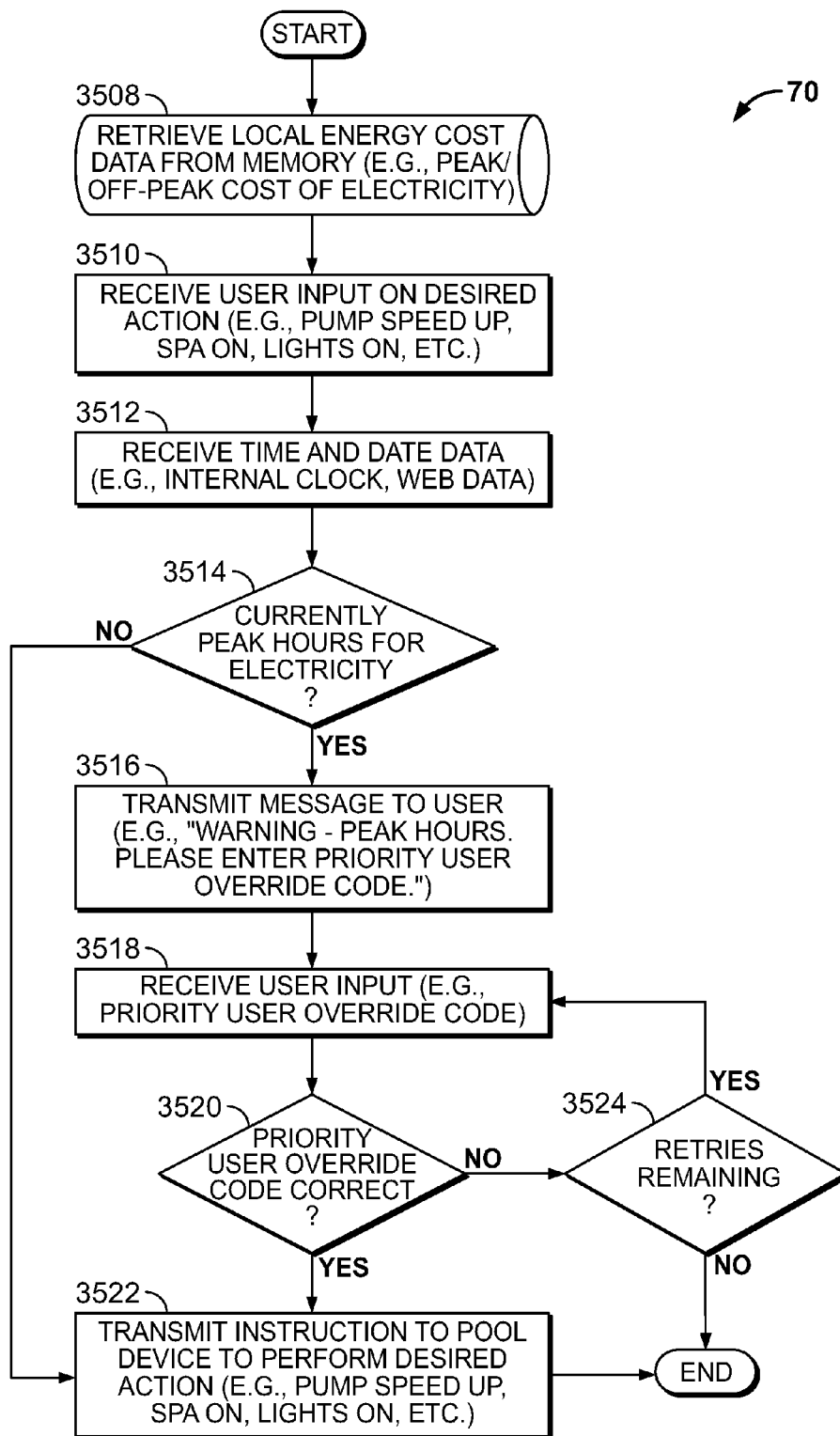


FIG. 33X

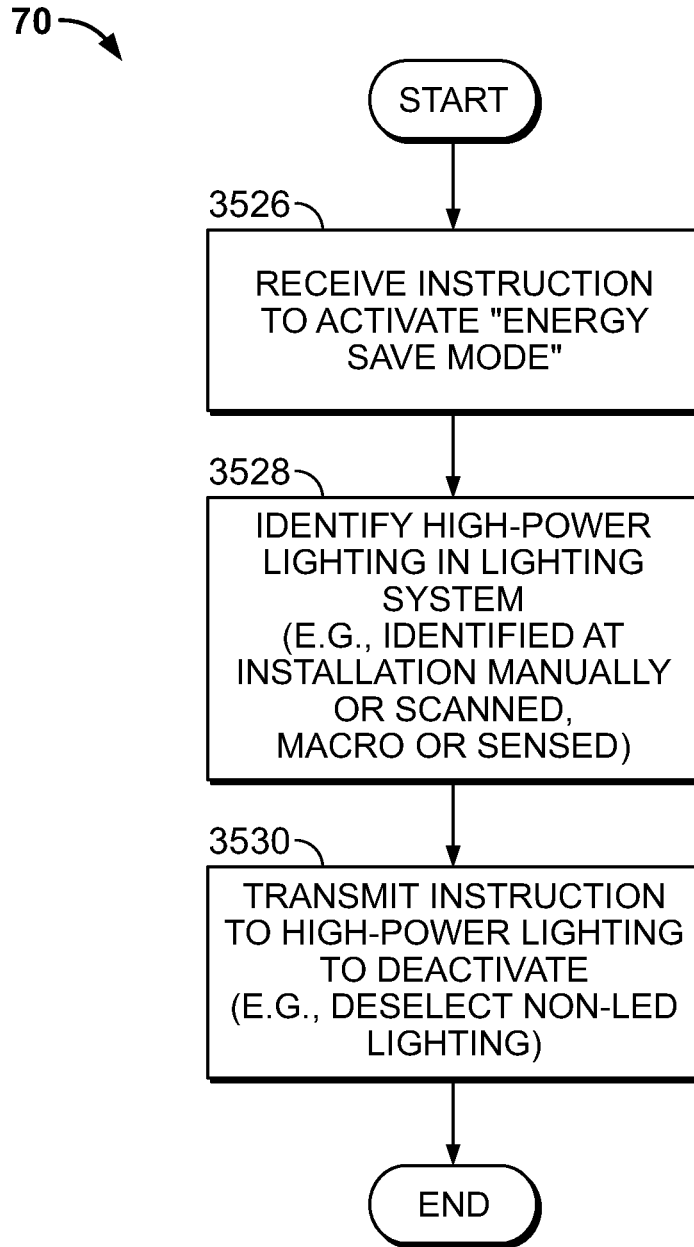


FIG. 33Y

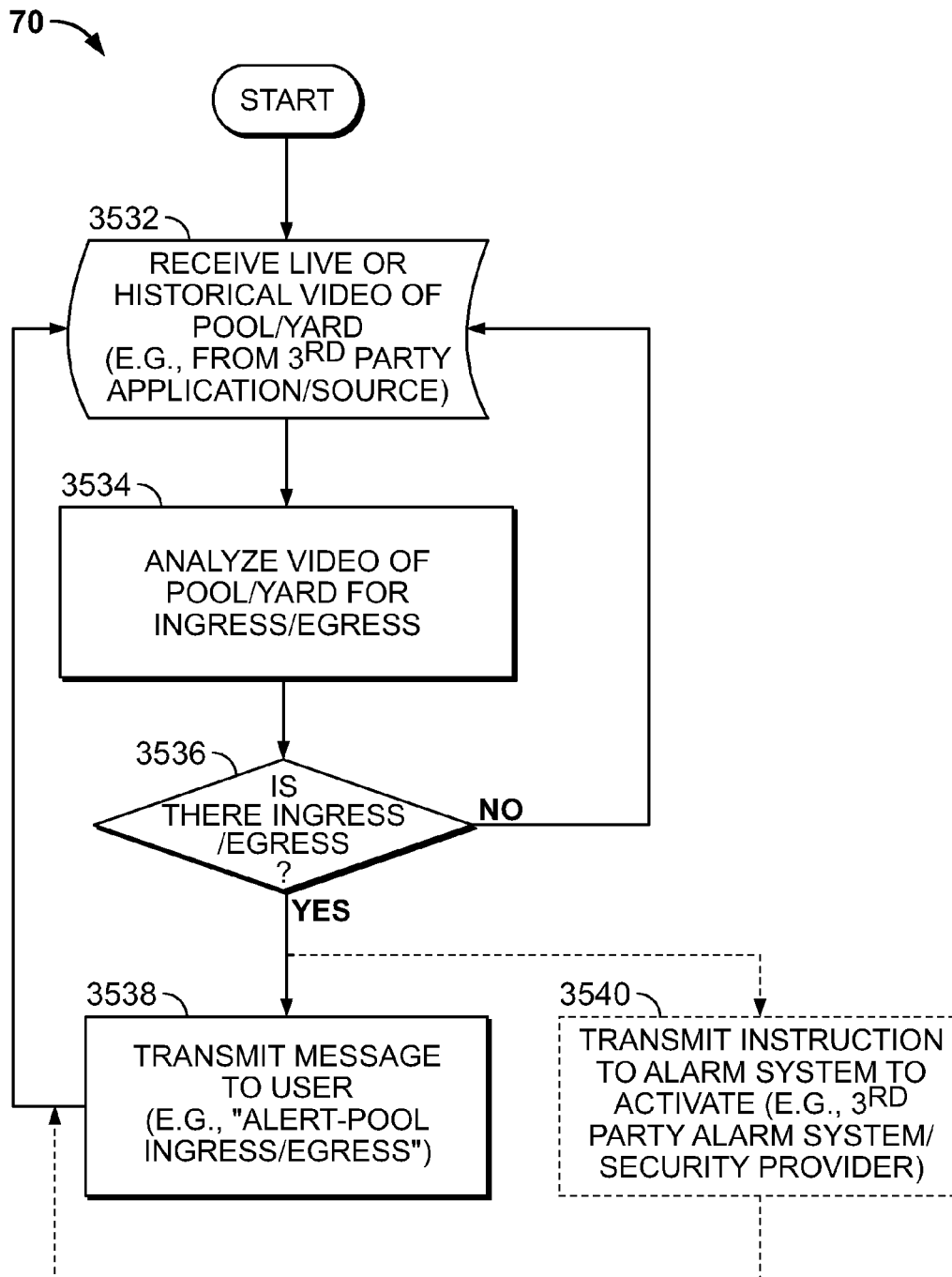


FIG. 33Z

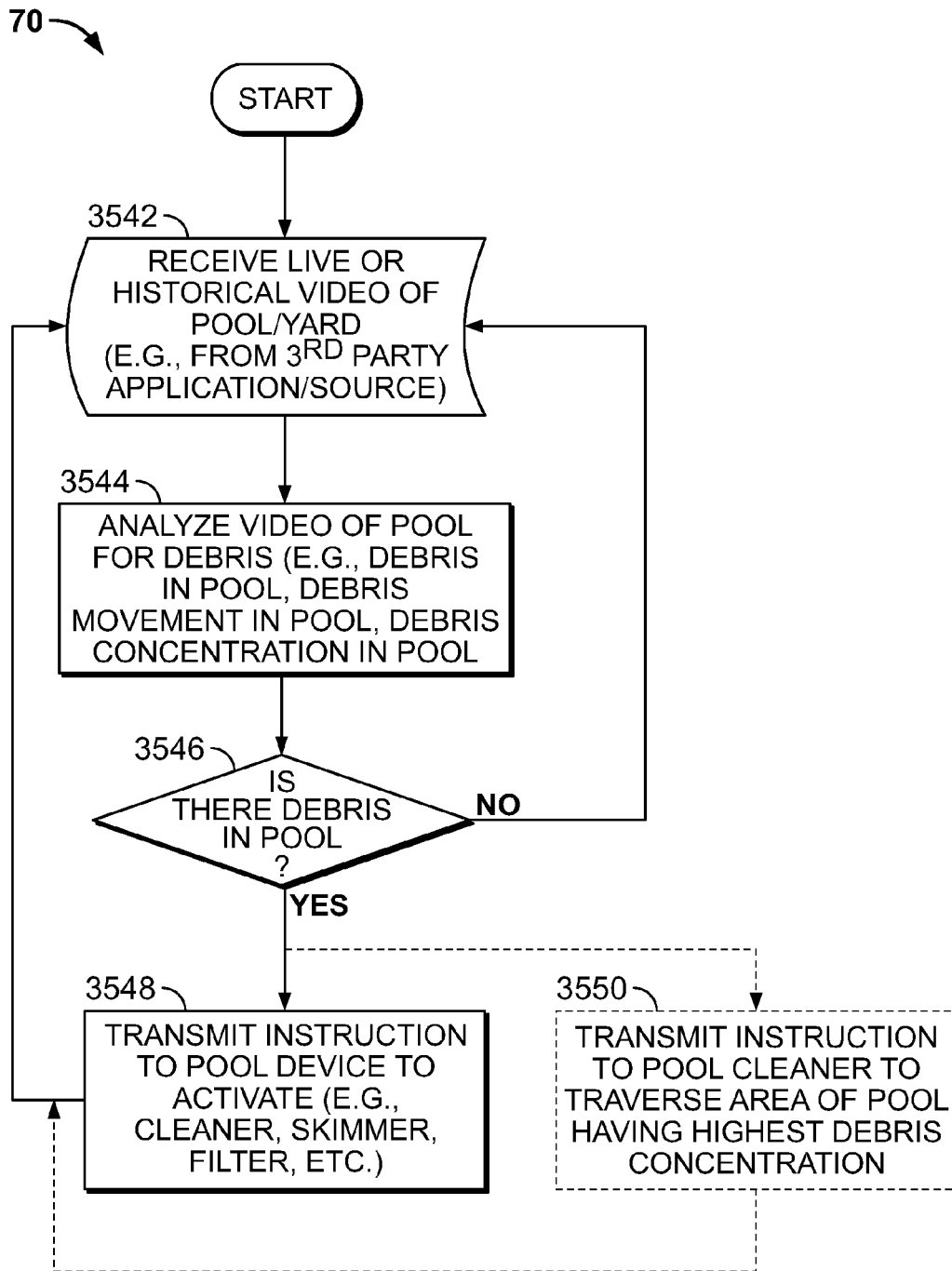


FIG. 33AA

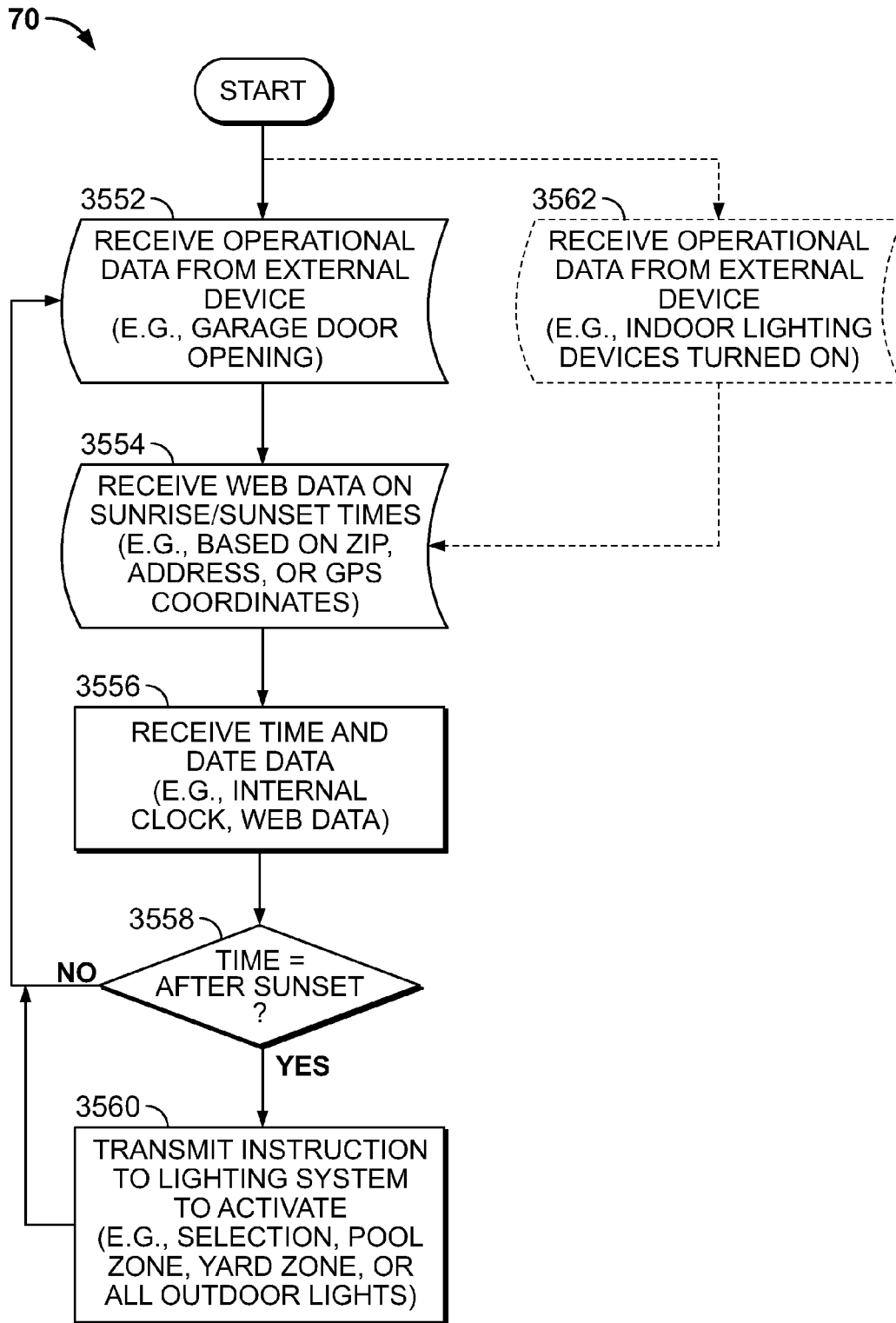


FIG. 33AB

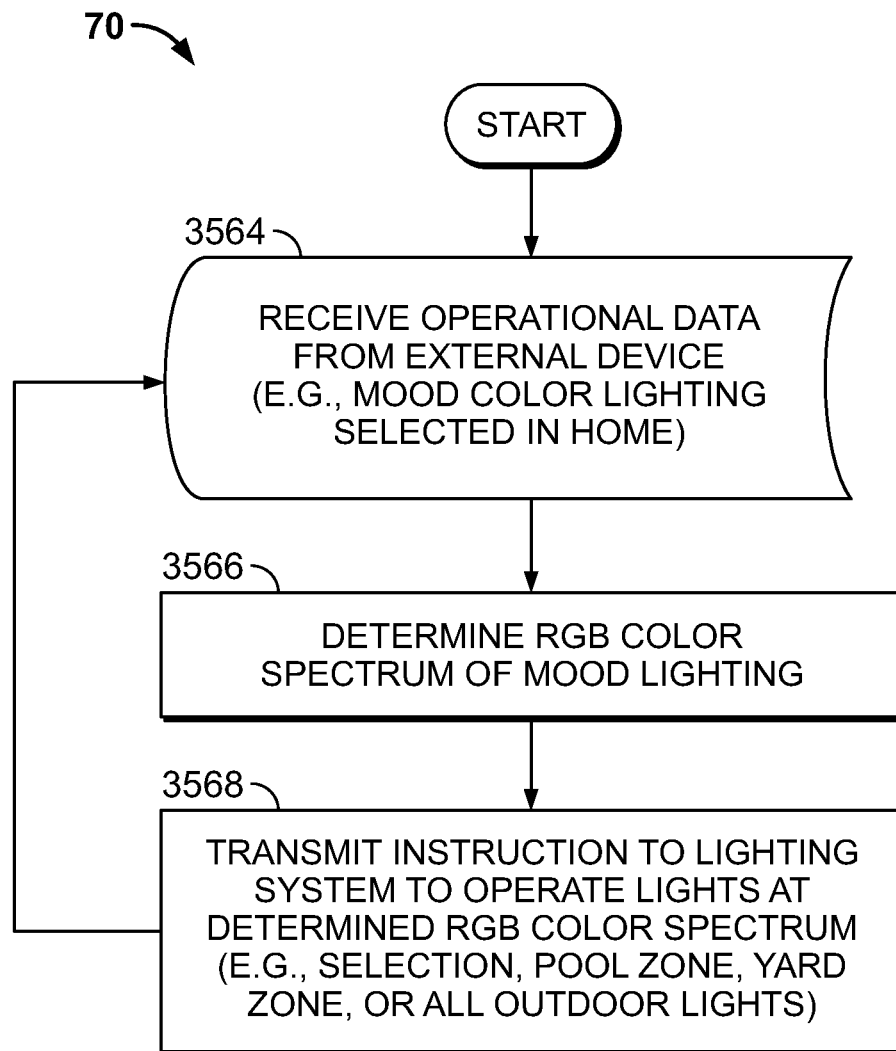


FIG. 33AC

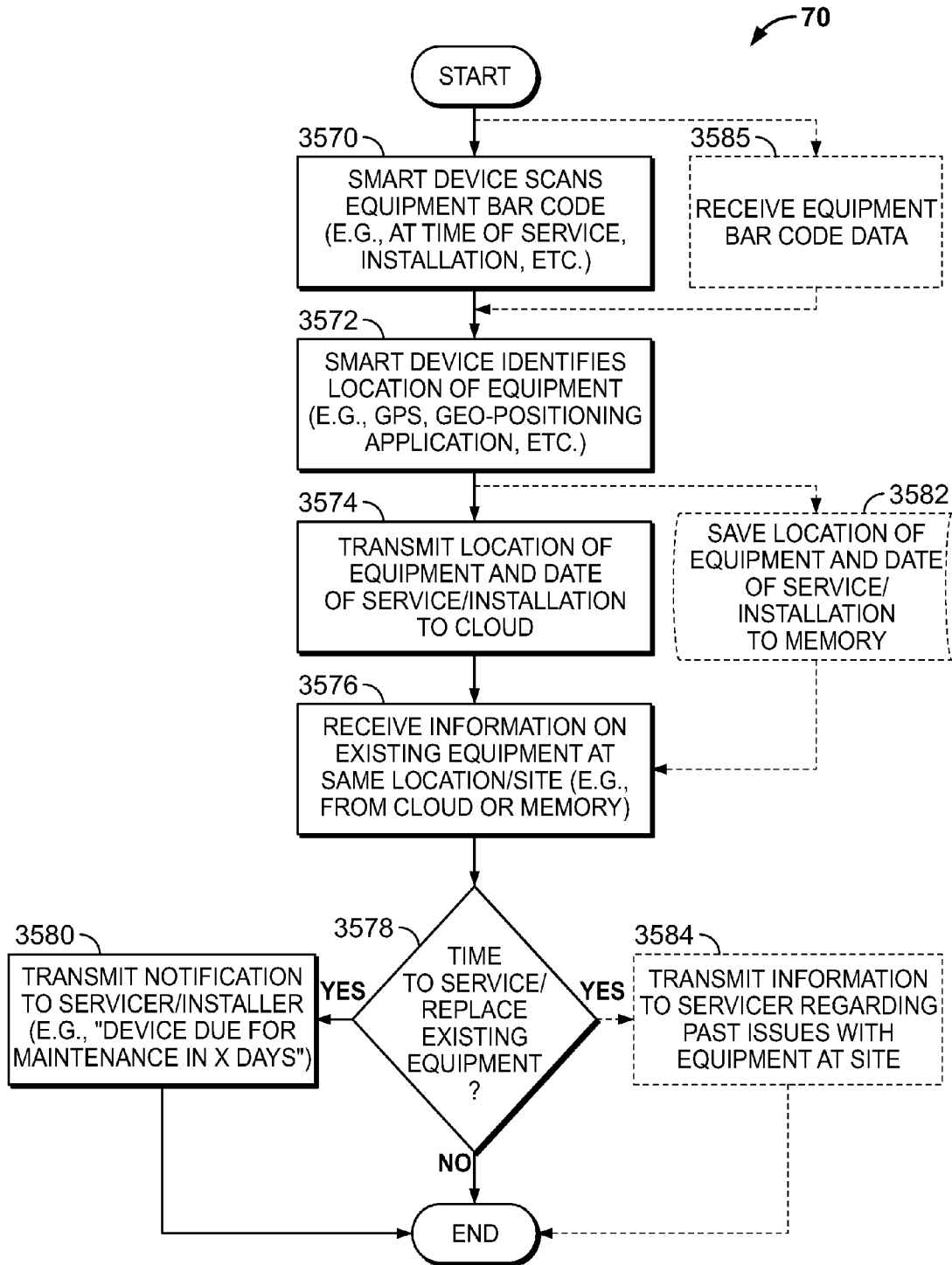


FIG. 33AD

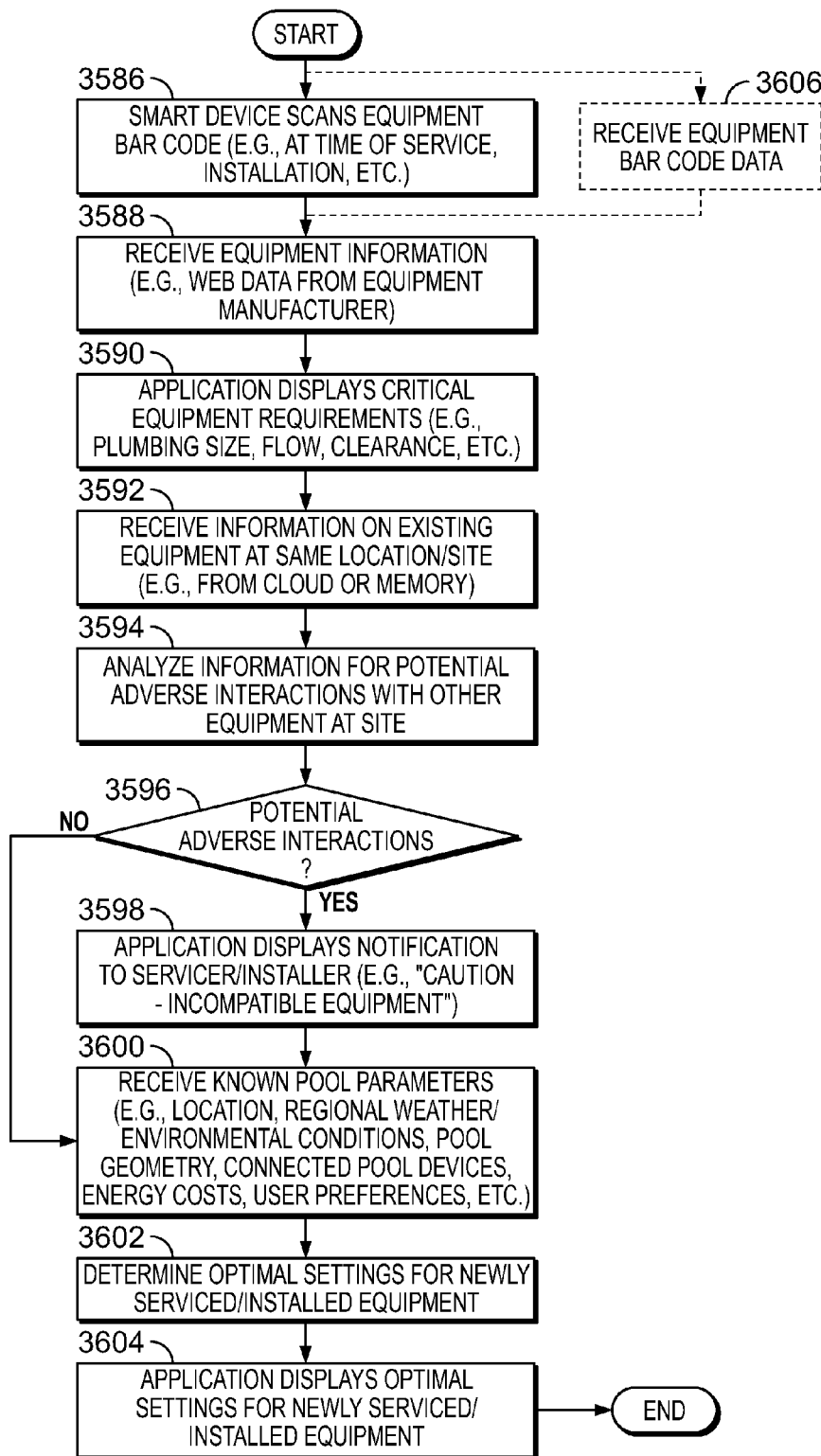


FIG. 33AE

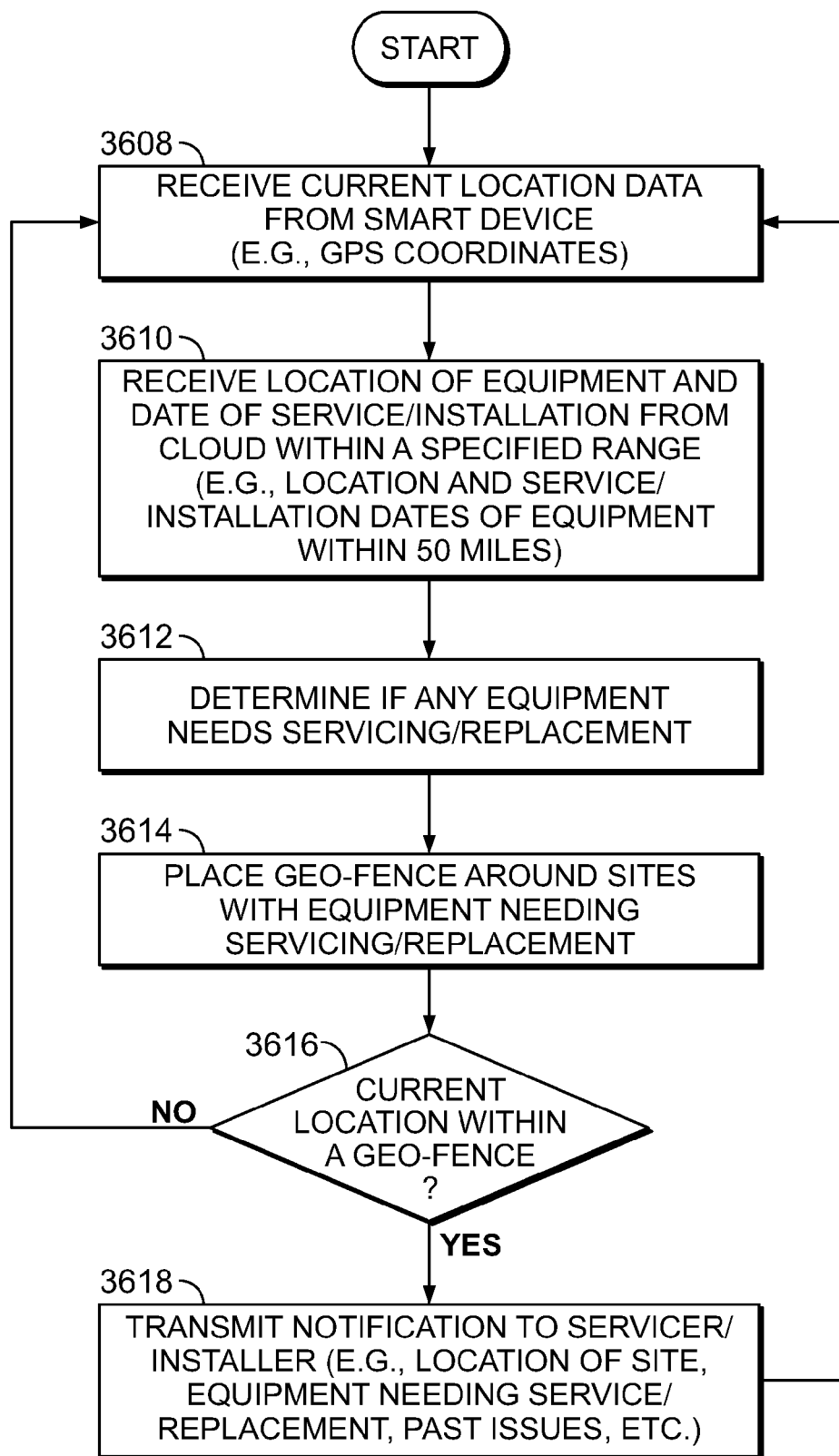


FIG. 33AF

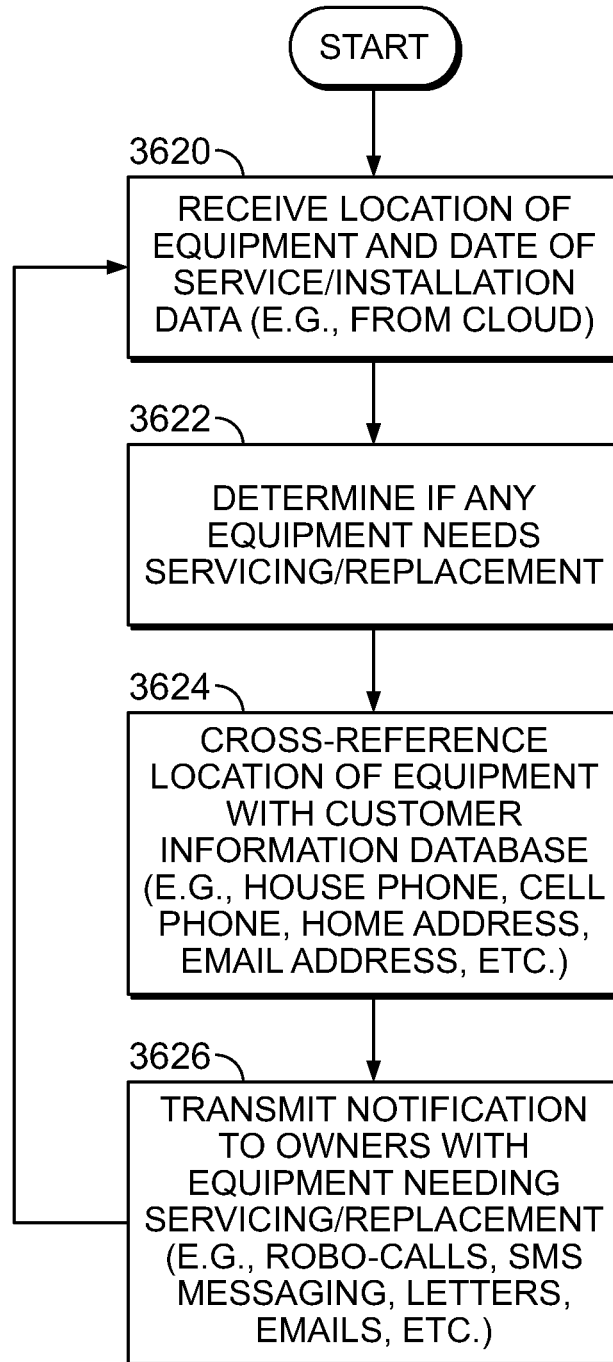


FIG. 33AG

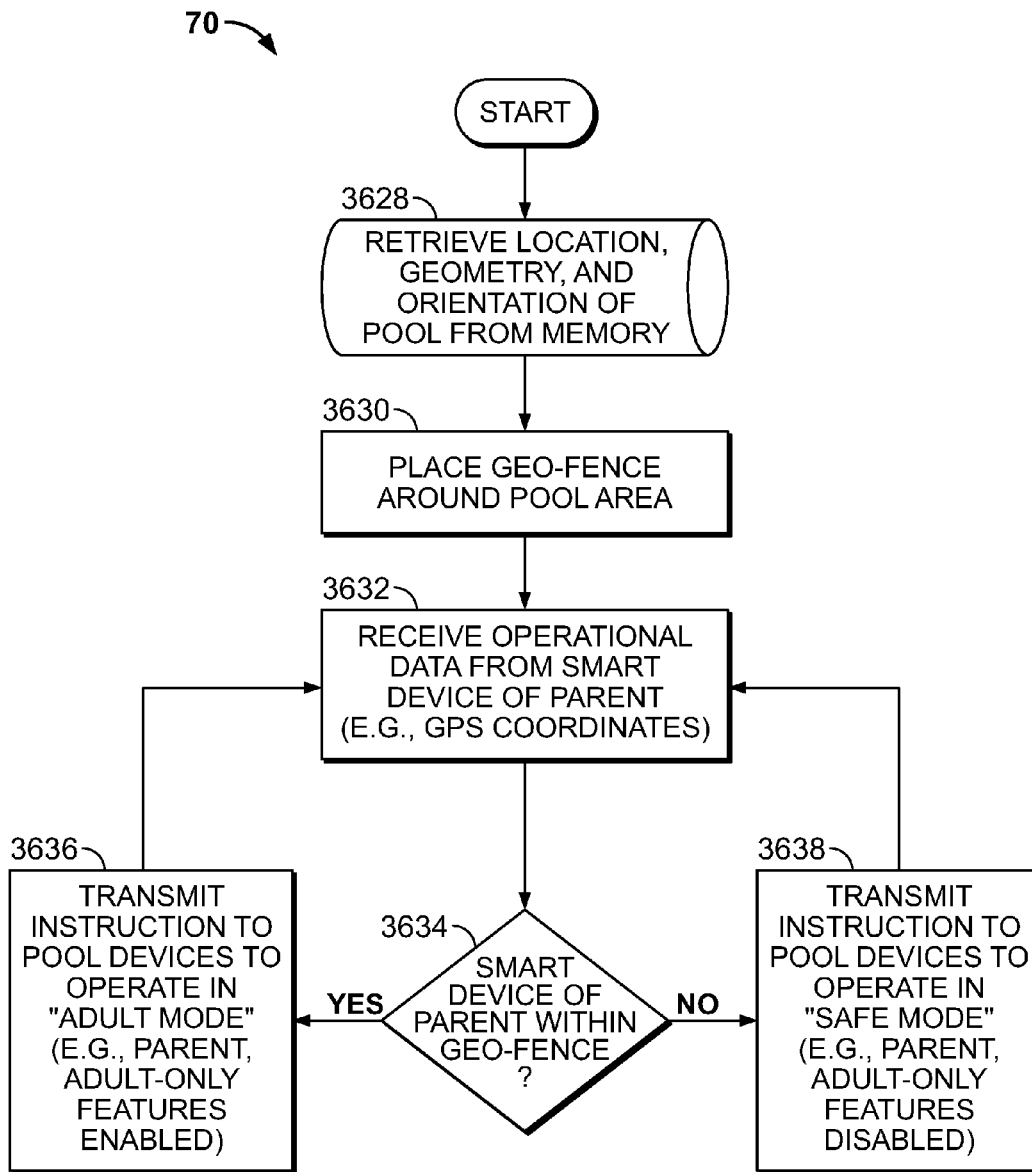


FIG. 33AH

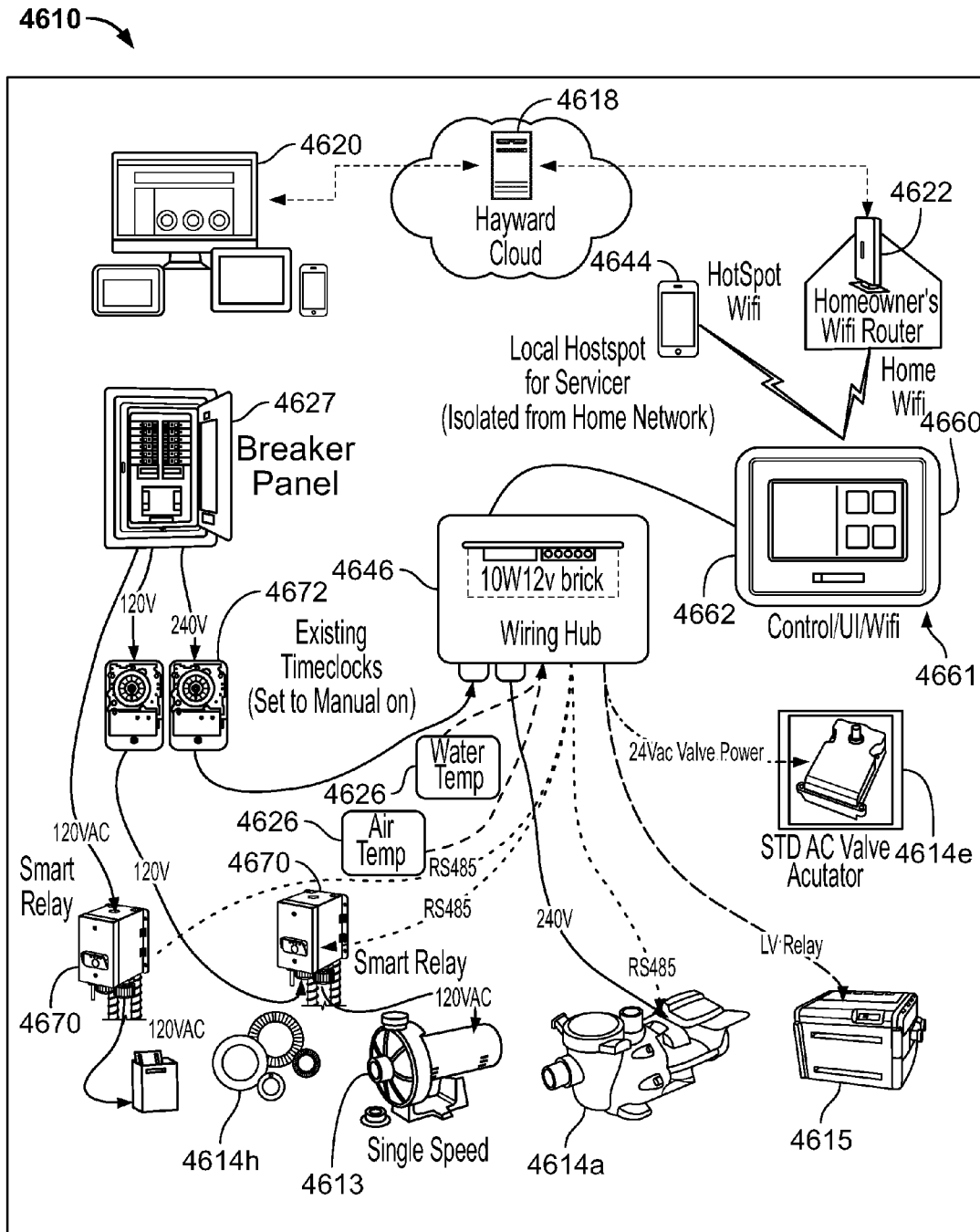


FIG. 34A

4610 ↗

Wiring Hub Taps into Pump Power

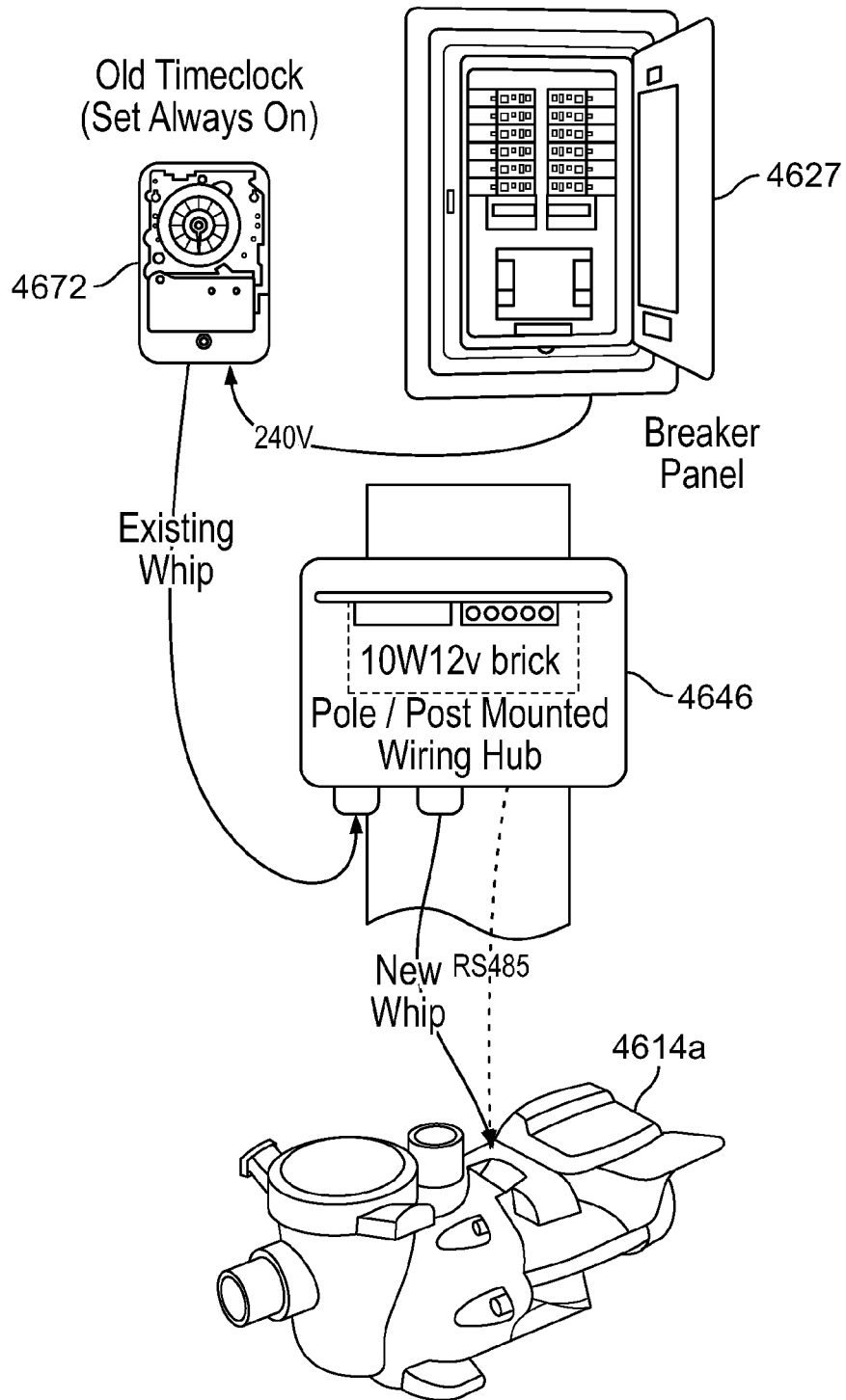


FIG. 34B

Wiring Hub Taps into Heater Power

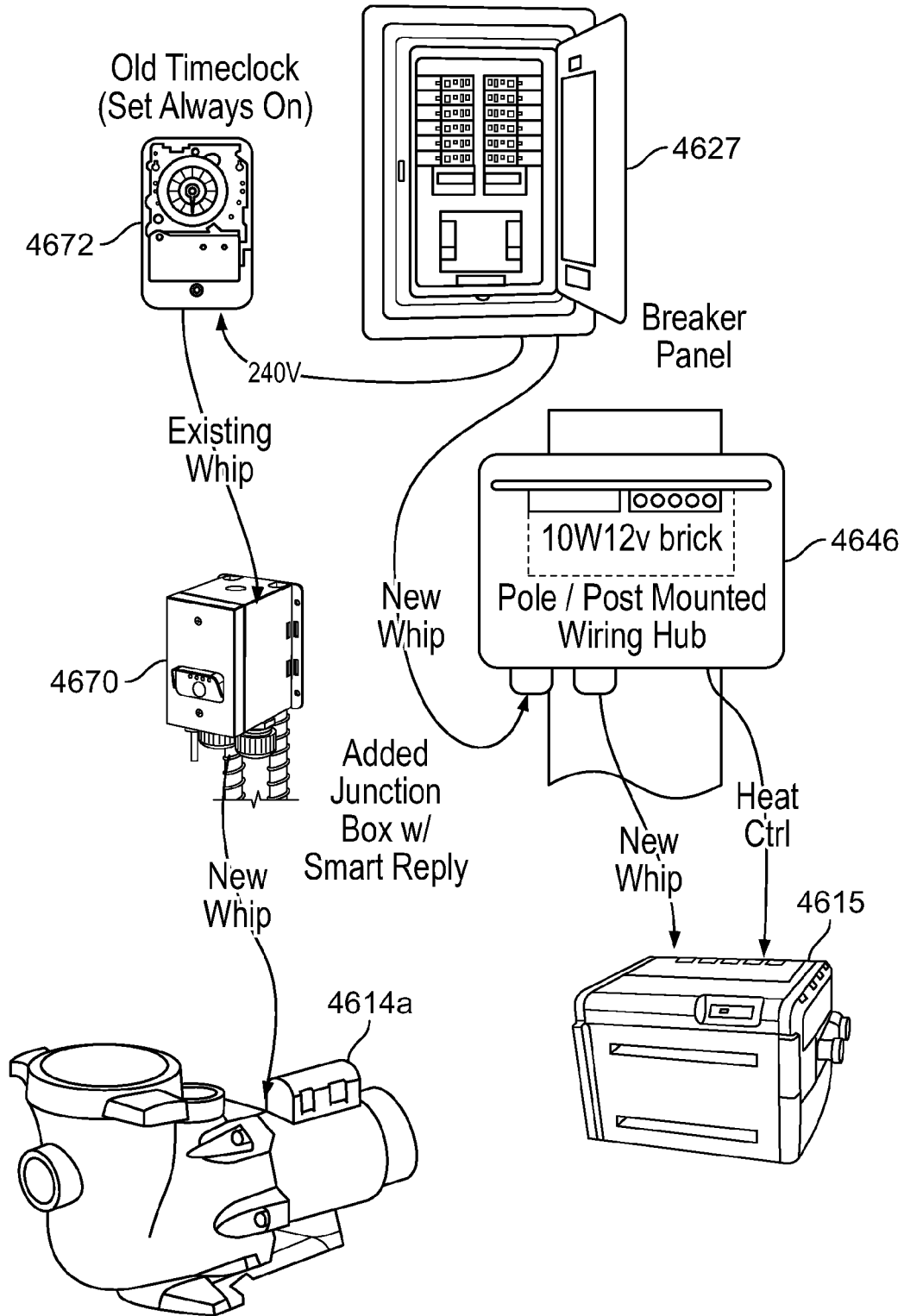


FIG. 34C

Smart Relay or Junction Box Distributes Power

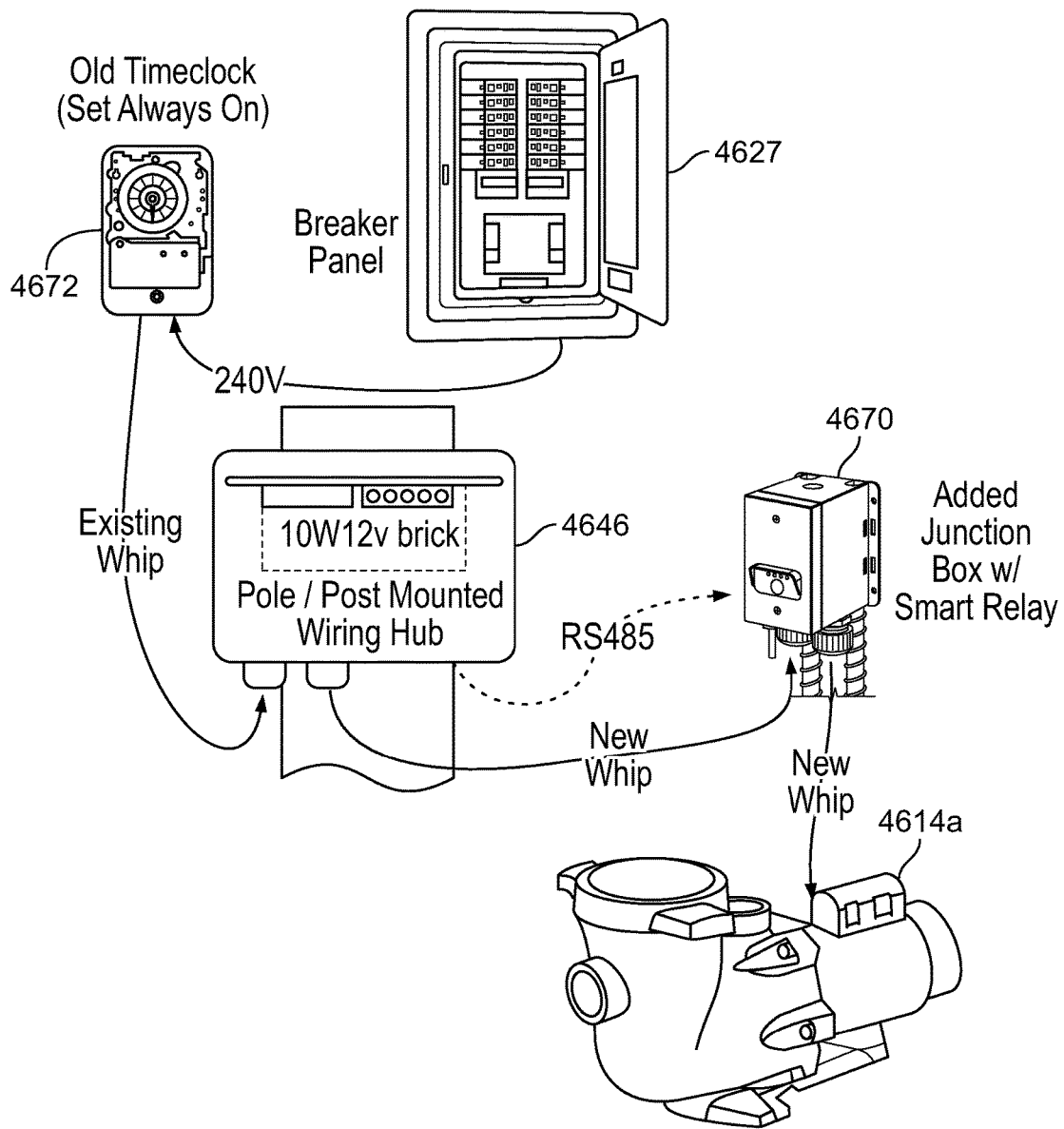


FIG. 34D

Smart Relay or Junction Box Distributes Power

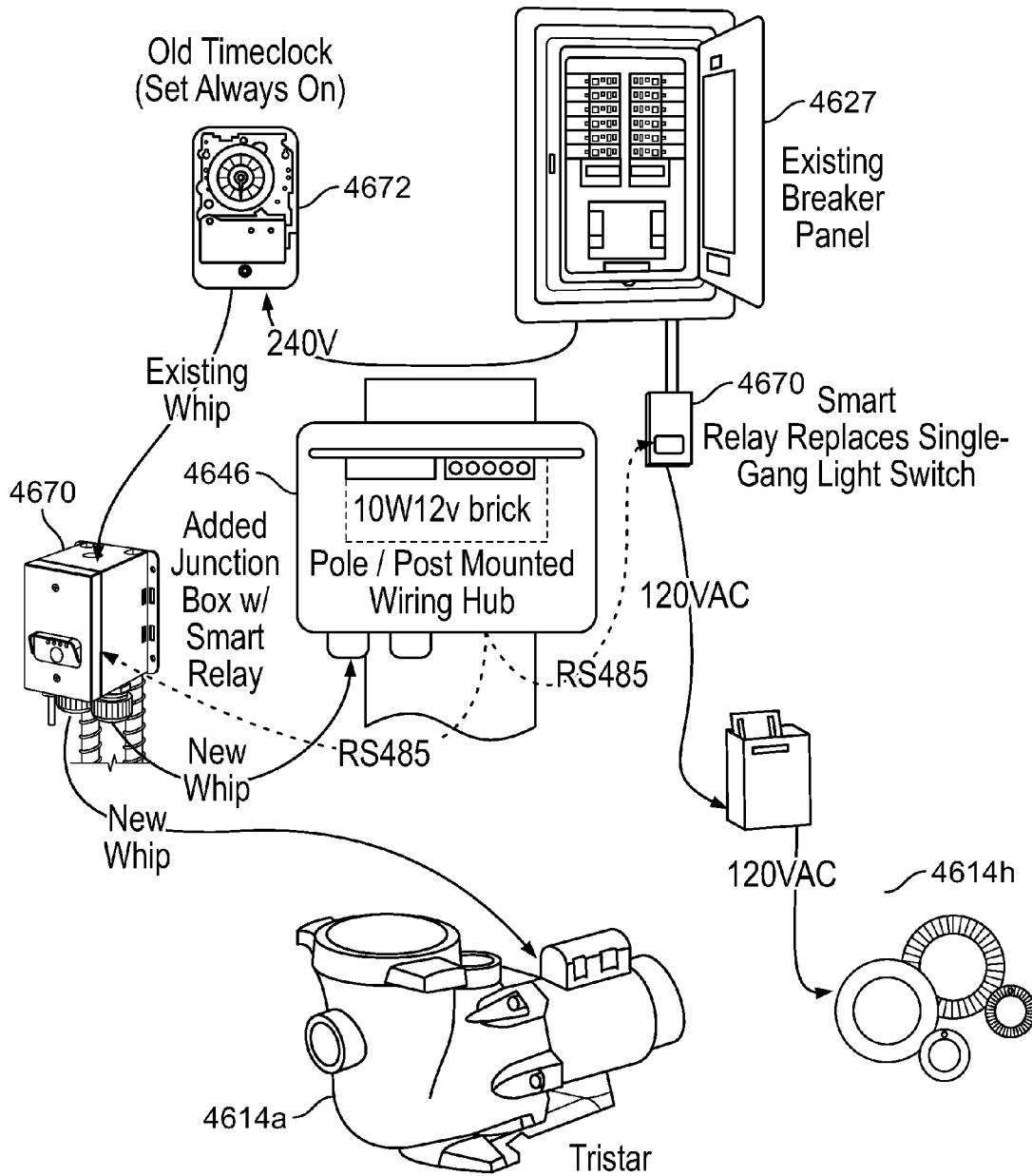


FIG. 34E

Cord Connected Model Allows Pipe Mounting

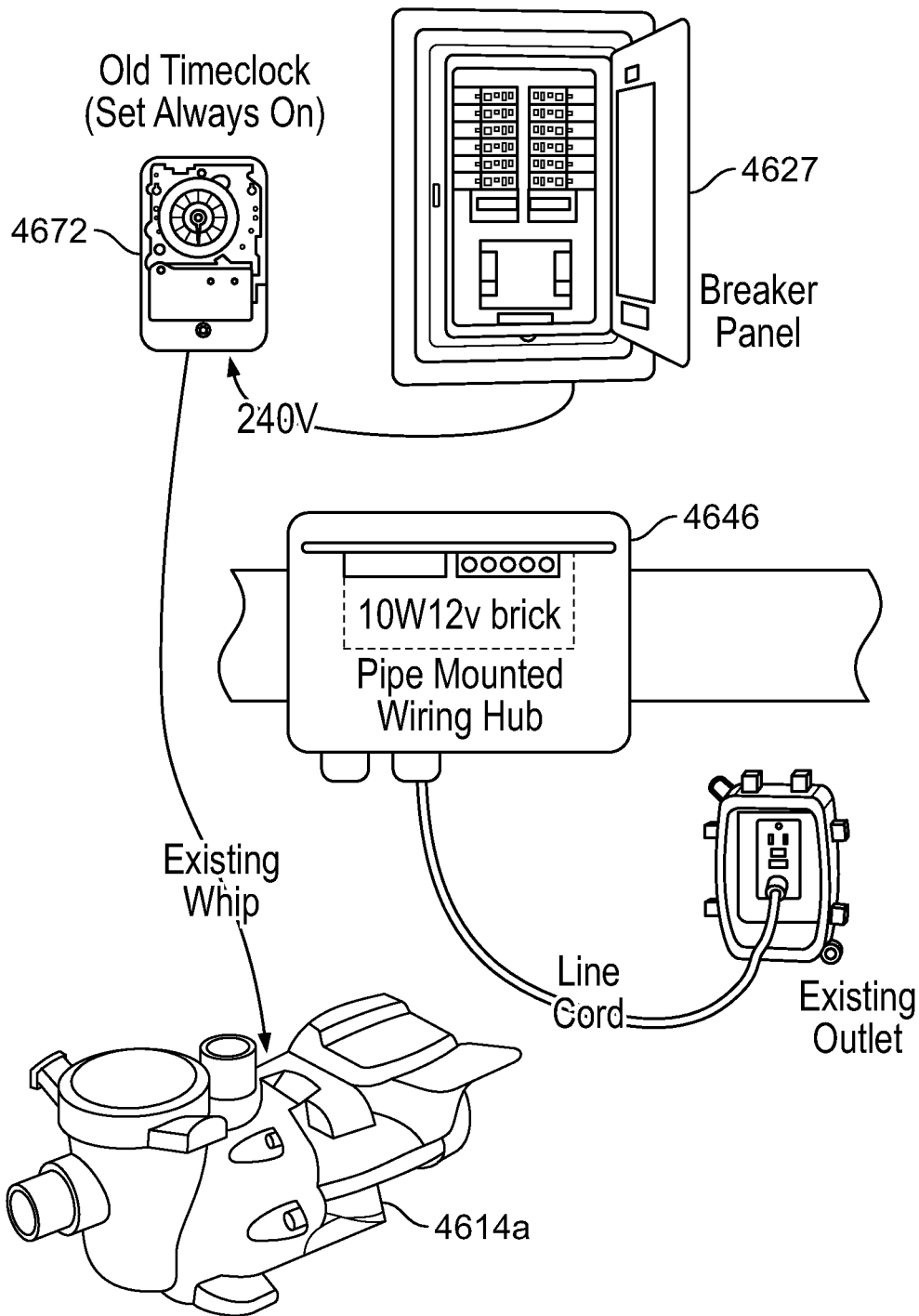


FIG. 34F

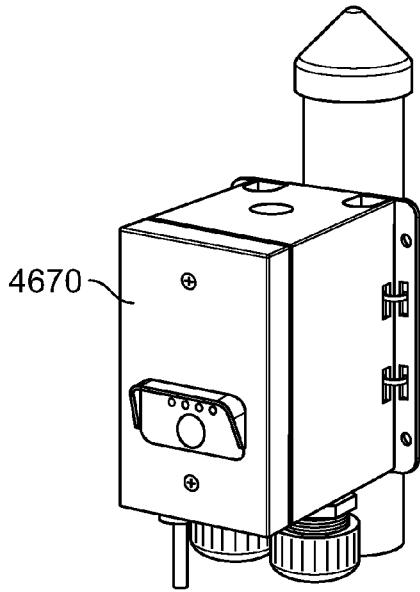


FIG. 34G

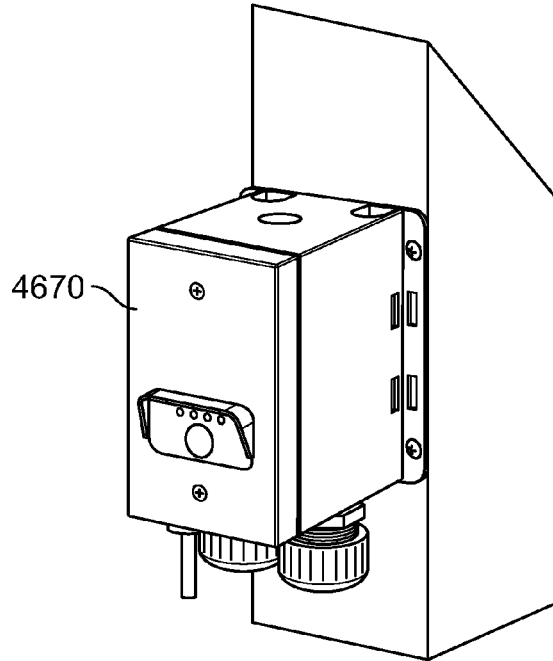


FIG. 34H

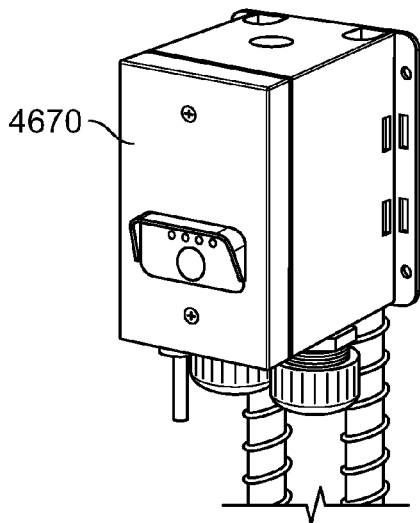


FIG. 34I

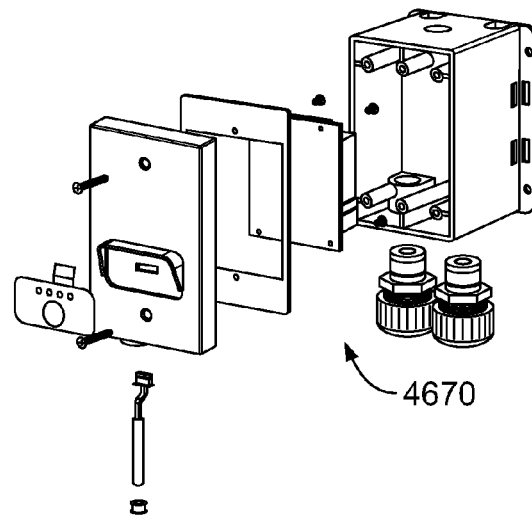


FIG. 34J

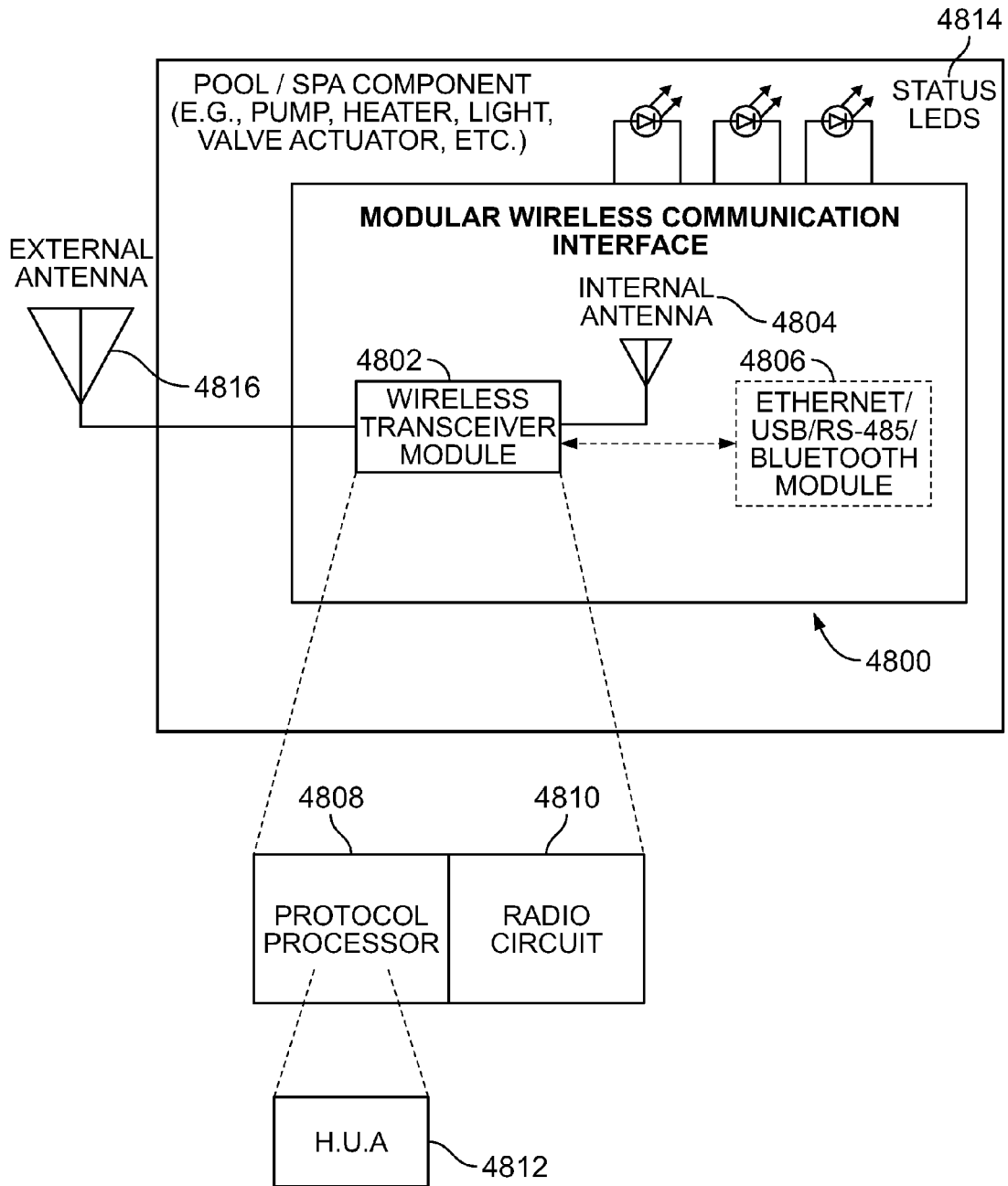


FIG. 35

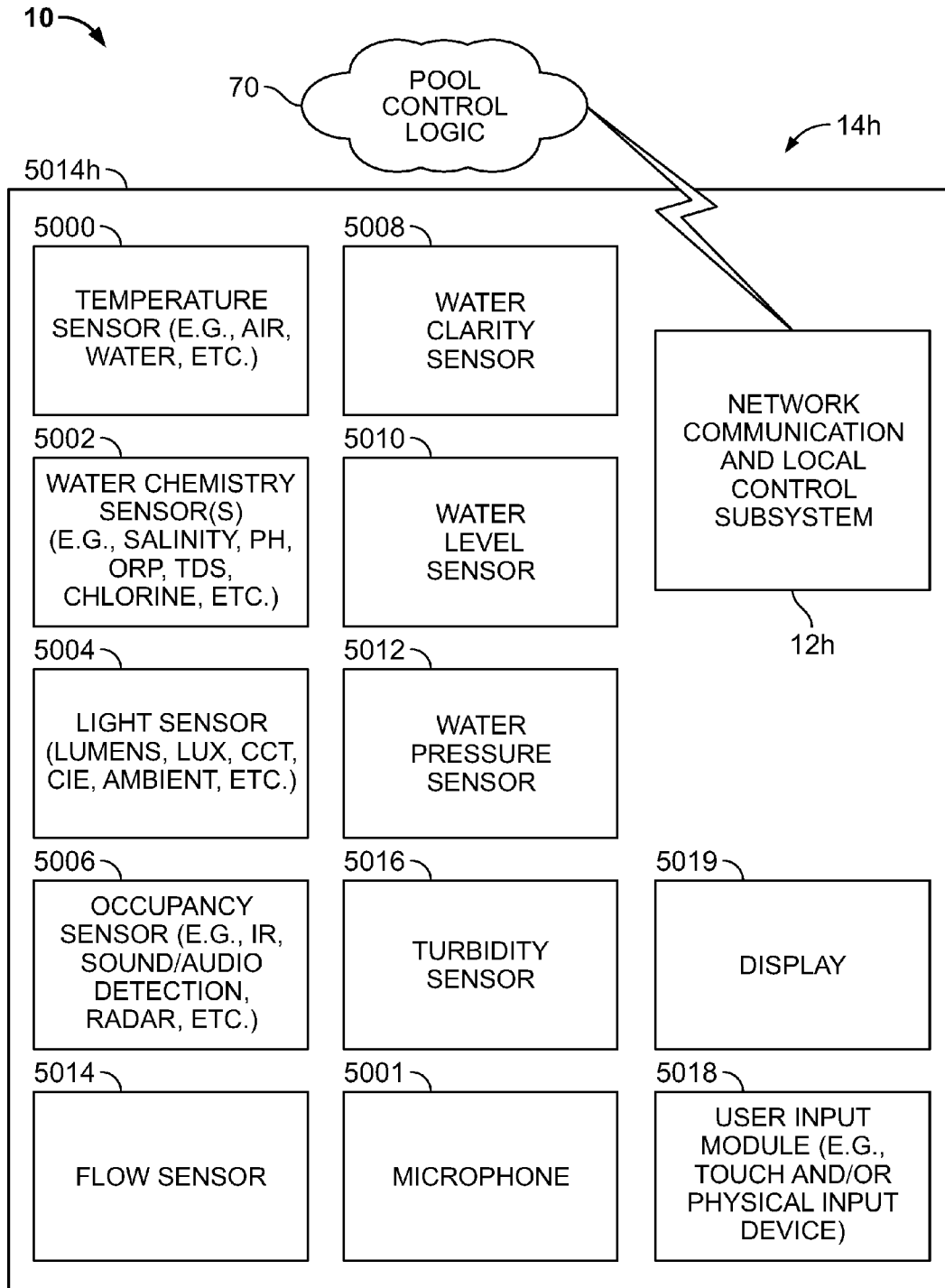


FIG. 36

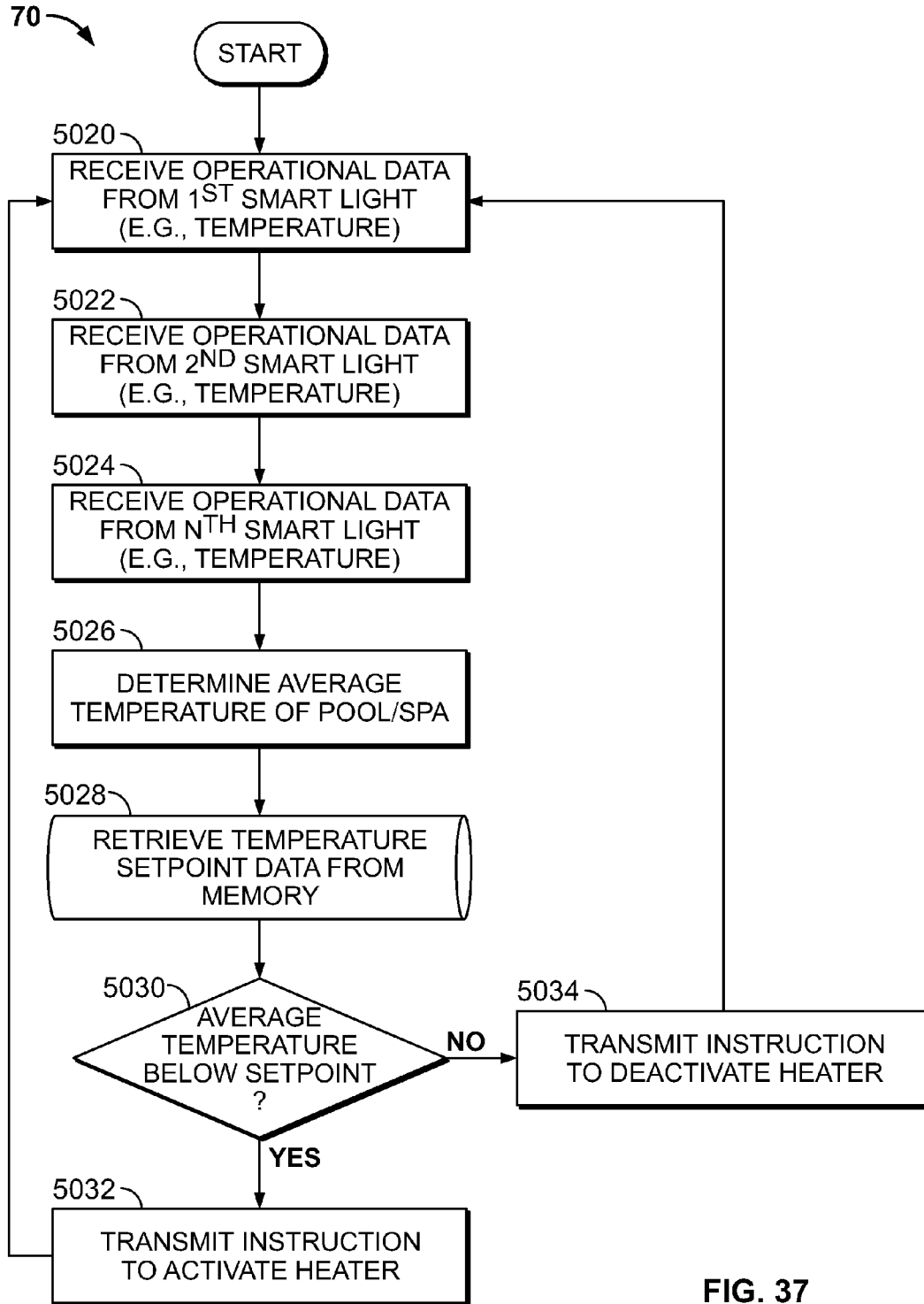


FIG. 37

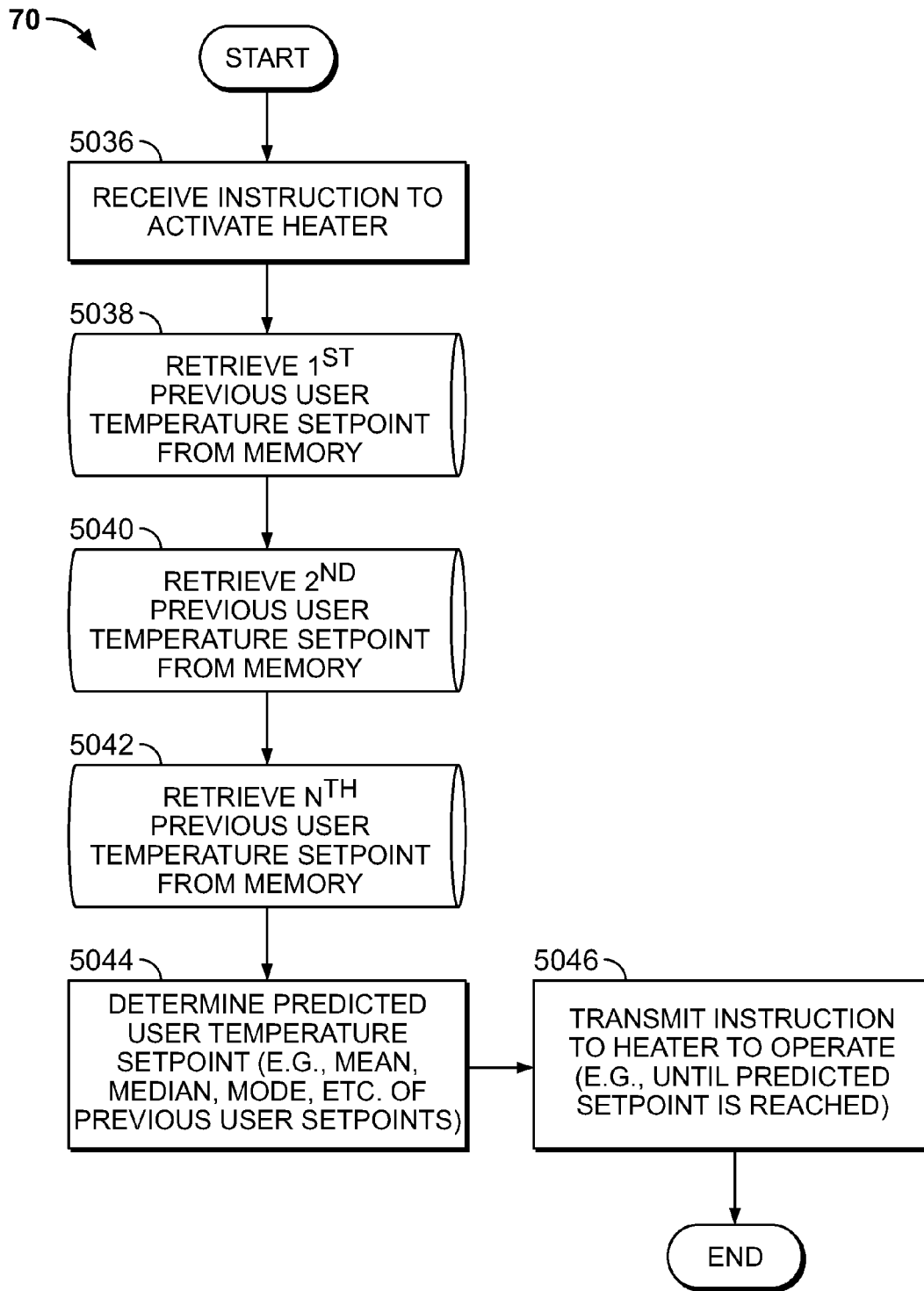


FIG. 38

70

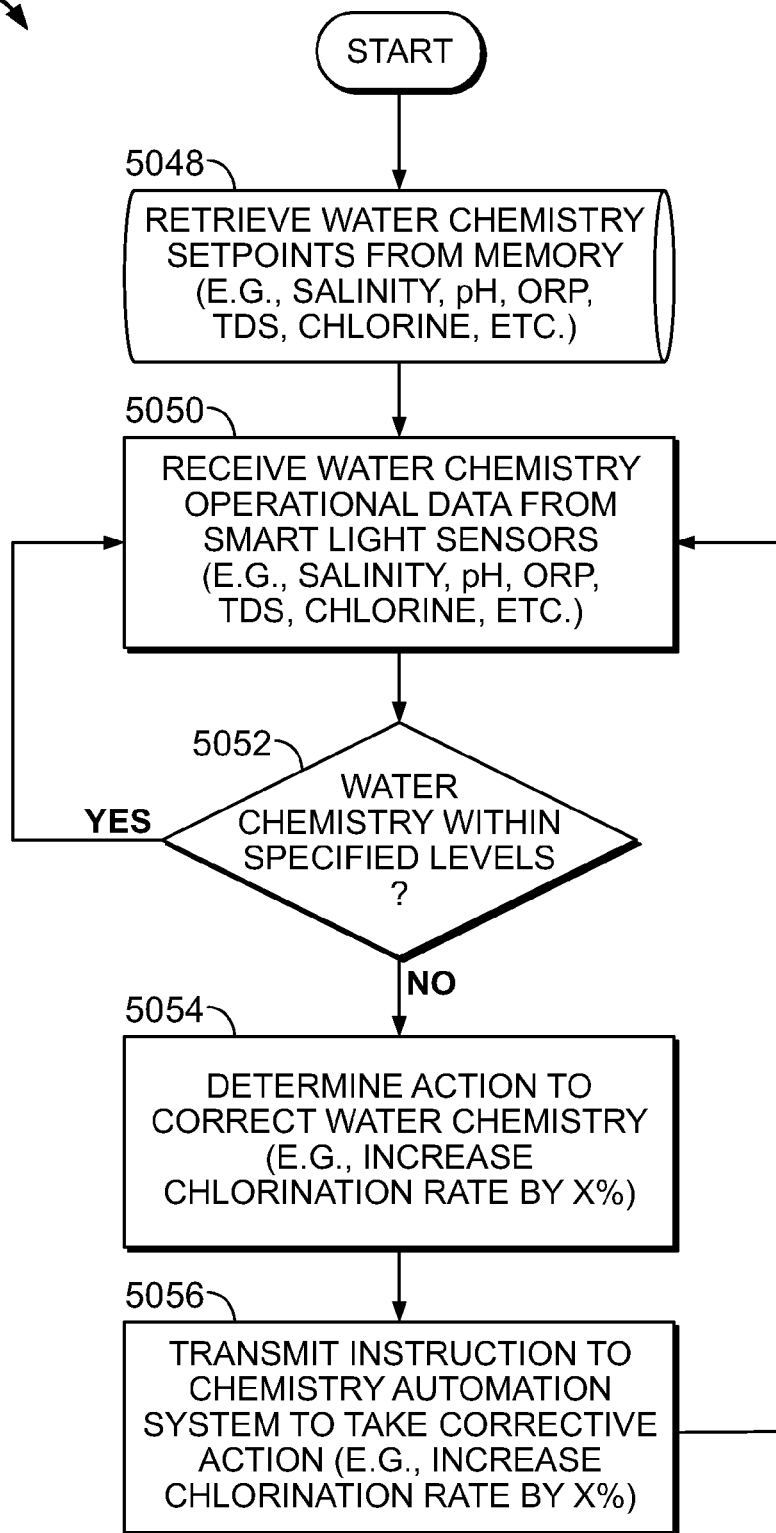


FIG. 39

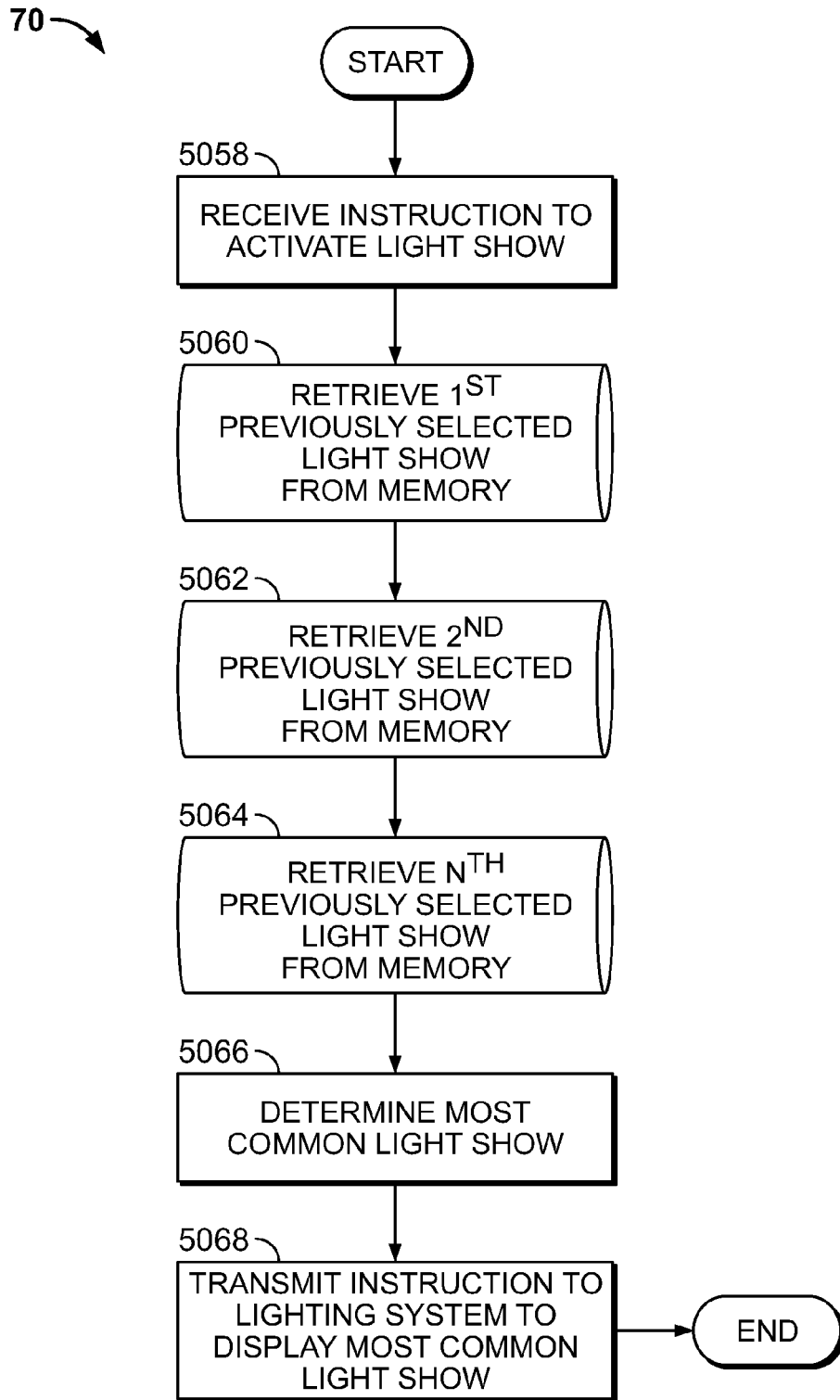


FIG. 40

**SYSTEMS AND METHODS FOR PROVIDING
NETWORK CONNECTIVITY AND REMOTE
MONITORING, OPTIMIZATION, AND
CONTROL OF POOL/SPA EQUIPMENT**

RELATED APPLICATIONS

This application claims priority to U.S. Provisional Patent Application No. 62/286,272 filed on Jan. 22, 2016, U.S. Provisional Patent Application No. 62/310,510 filed on Mar. 18, 2016, U.S. Provisional Patent Application No. 62/381,903 filed on Aug. 31, 2016, U.S. Provisional Patent Application No. 62/412,504 filed on Oct. 25, 2016, and U.S. Provisional Patent Application No. 62/414,545 filed on Oct. 28, 2016, the entire disclosures of these applications hereby expressly incorporated by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

The present disclosure relates to systems and methods for providing network connectivity and remote monitoring, optimization and control of pool/spa equipment.

Related Art

Swimming pool equipment is conventionally controlled by an electronic pool controller at an equipment pad. Power is supplied from the controller and electrical subpanel to the pool equipment through an electrical conduit (e.g., hard-wire). Alternatively, swimming pool equipment can be controlled by electrical circuit breakers in a subpanel at an equipment pad. Power is supplied from the subpanel to the pool equipment through an electrical conduit (e.g., hard-wire). Without an electronic pool controller, any time-based control is typically an electro-mechanical clock wired in series between the subpanel and the pool equipment, thereby breaking one or both legs of the power supply to the pool equipment. To monitor or maintain conditions of pool equipment, the pool, pool water, or the pool environment, sensors or other data collection means typically reside at the equipment pad or the pool.

Remote control of the pool and related equipment typically requires hard-wired communication between the pool controller (at the pad) and pool equipment, as well as wired or wireless communication between the pool controller and user interface. More recent remote control systems feature communication between the controller at the pad and a cloud server (e.g., via a home router), as well as communication between the user interface and the cloud server by cell or wifi router.

Adding control features to an existing pool and equipment pad is typically costly because of the required electrical competence necessary to install new conduits to provide power from the subpanel to the controller, and from the controller to the pool equipment. Further, pool monitoring and maintenance can be confusing and time consuming for pool owners, which often leads to the employment of pool servicers. The lack of connectivity and subsequent lack of understanding of the status and condition of the pool and pool equipment requires costly and sometimes unnecessary visits by pool professionals.

Accordingly, what is needed is a system and method to provide pool owners and pool servicers with enhanced control of, and connectivity between, pool equipment devices, and which reduces hardware and/or installation costs.

SUMMARY OF THE INVENTION

The present disclosure relates to systems and methods for providing network connectivity and remote monitoring,

optimization, and control of pool/spa equipment. "Internet-of-Things" functionality is provided for pool and spa equipment in a flexible and cost-effective manner, in various embodiments. For example, in one embodiment, network connectivity and remote monitoring/control of pool and spa equipment is provided by a network communication and local control subsystem installed in pool/spa equipment. In another embodiment, network connectivity and remote monitoring/control of pool and spa equipment is provided by a pool/spa system controller interconnected with pool/spa equipment operating in conjunction with local and/or remote pool/spa control logic. In another embodiment, network connectivity and remote monitoring and control of pool and spa equipment is provided by way of a pool "hub" interconnected with pool/spa equipment operating in conjunction with remote pool/spa control logic. In yet another embodiment, network connectivity and remote monitoring and control of pool and spa equipment is provided by way of a pool "translator" interconnected with pool/spa equipment operating in conjunction with local and/or remote pool/spa control logic. In still another embodiment, network connectivity and remote monitoring and control of pool and spa equipment is provided by way of a plurality of pool connectivity modules that communicate with pool/spa equipment, operating in conjunction with remote pool/spa control logic. In a further embodiment, network connectivity and remote monitoring and control of pool and spa equipment is provided by way of wireless communications provided directly in the pool/spa equipment and operating in conjunction with remote pool/spa control logic. In yet another embodiment, network connectivity and remote monitoring and control of pool and spa equipment is provided by way of a reduced-size "hub" interconnected with pool/spa equipment operating in conjunction with remote pool/spa control logic. In still another embodiment, network connectivity and remote monitoring and control of pool and spa equipment is provided by way of pool/spa chlorination system and controller that is interconnected with pool/spa equipment operating in conjunction with remote pool/spa control logic. Also disclosed are various control processes ("pool logic") which can be embodied as software code installed in any of the various embodiments of the present disclosure.

Communication between devices, the controller, the router, the cloud, and/or the user interfaces can use a number of technologies, where each technology could provide an advantage in cost or reliability for each communication segment. Data for managing the pool and pool equipment (e.g., relating to wind, time, temperature, humidity to manage heating, water features, skimmer operation, approaching storms, sunrise, sunset, etc.) could be gathered from the cloud, in addition to or instead of data gathered through sensors and datacom cables at the pool or pad. Sensors dedicated to specific pool equipment (e.g., pressure sensors, flow sensors or temp sensors in the heater used to manage pump speed, control valve positions, etc.) could share data with the controller to manage other pool equipment (e.g., to optimize performance), rather than requiring dedicated sensors for each device. Smart switches could be installed between an existing conduit and the subpanel or device by a user (e.g., pool owner or pool professional), because installation of a new hard conduit is unnecessary (reducing the need for an electrician), or smart switches could be integrated into pool or spa equipment. For example, a heater with an integrated smart switch could act as a hub for connectivity to the home router.

In still further embodiments, the system of the present disclosure provides a modular relay, a wiring hub, and/or a

control module that can be conveniently installed near pool/spa equipment, and which provides Internet-enabled remote control and connectivity of pool/spa components without requiring installation of complete (e.g., pad-mounted) pool/spa system controller. Conveniently, the modular relay, wiring hub, and/or control module allow owners of existing pool/spa equipment who do not currently own a pool/spa control system to enjoy the benefits of such a control system without requiring the installation, equipment, and expense associated with conventional pool/spa control systems.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing features of the disclosure will be apparent from the following Detailed Description of the Invention, taken in connection with the accompanying drawings, in which:

FIG. 1 is a diagram illustrating the system of the present disclosure;

FIG. 2 is a block diagram illustrating components of the subsystems of FIG. 1;

FIG. 3 is a diagram illustrating various types of control logic in accordance with the present disclosure;

FIG. 4 is a diagram illustrating processing steps carried out by the system of FIGS. 1-2;

FIG. 5 is a diagram illustrating another embodiment of the present disclosure;

FIG. 6 is a flowchart illustrating processing steps carried out by the system of FIG. 5;

FIG. 7 is a diagram illustrating another embodiment of the system of the present disclosure;

FIG. 8 is a flowchart illustrating processing steps carried out by the system of FIG. 7;

FIG. 9 is a diagram illustrating another embodiment of the system of the present disclosure;

FIG. 10 is a flowchart showing processing steps carried out by the system of FIG. 9;

FIG. 11 is a diagram illustrating another embodiment of the system of the present disclosure;

FIG. 12 is a diagram illustrating processing steps carried out by the system of FIG. 11;

FIG. 13 is a diagram illustrating another embodiment of the system of the present disclosure;

FIG. 14 is a flowchart illustrating processing steps carried out by the system of FIG. 13;

FIG. 15 is a diagram illustrating another embodiment of the system of the present disclosure;

FIGS. 16A-16B are diagram illustrating another embodiment of the system of the present disclosure;

FIG. 17 is a diagram illustrating another embodiment of the system of the present disclosure;

FIG. 18 is a diagram illustrating the pump control logic of FIG. 3;

FIGS. 19A-19AU are flowcharts illustrating processing steps of the pump control logic of FIG. 3;

FIG. 20 is a diagram illustrating chemistry automation control logic of FIG. 3;

FIGS. 21A-21I are flowcharts illustrating processing steps of the chemistry automation control logic of FIG. 3;

FIG. 22 is a diagram illustrating the heater control logic of FIG. 3;

FIGS. 23A-23J are flowcharts illustrating processing steps of the heater control logic of FIG. 3;

FIG. 24 is a diagram illustrating the lighting control logic of FIG. 3;

FIGS. 25A-25AB are flowcharts illustrating processing steps of the lighting control logic of FIG. 3;

FIG. 26 is a diagram illustrating the pool cleaner control logic of FIG. 3;

FIGS. 27A-27O are flowcharts illustrating processing steps of the pool cleaner control logic of FIG. 3;

FIG. 28 is a diagram illustrating the valve actuator control logic of FIG. 3;

FIGS. 29A-29I are flowcharts illustrating processing steps of the valve actuator control logic of FIG. 3;

FIG. 30 is a diagram illustrating water feature control logic of FIG. 3;

FIGS. 31A-31F are flowcharts illustrating processing steps of the water feature control logic of FIG. 3;

FIG. 32 is a diagram illustrating pool control logic of FIG. 3;

FIGS. 33A-33AH are flowcharts illustrating processing steps of the pool control logic of FIG. 3;

FIGS. 34A-34J are diagrams illustrating another embodiment of the system of the present disclosure;

FIG. 35 is a diagram illustrating another embodiment of the system of the present disclosure; and

FIGS. 36-40 are diagrams illustrating further embodiments of the system of the present disclosure.

DETAILED DESCRIPTION OF THE INVENTION

The present disclosure relates to systems and methods for providing network connectivity and remote monitoring, optimization and control of pool/spa equipment, as discussed in detail below in connection with FIGS. 1-40.

FIG. 1 is a diagram illustrating the system 10 of the present disclosure. The system 10 includes, but is not limited to, a plurality of network communication and local control subsystems 12a-12h which could be installed in or connected to a plurality of pool and spa equipment 14a-14h, so as to provide network connectivity and remote monitoring and control of the pool and spa equipment 14a-14h. The subsystems 12a-12h could communicate with each other over a network 16, which could include, but is not limited to, the Internet. Importantly, the subsystems 12a-12h provide "Internet-of-Things" functionality for the plurality of pool and spa equipment 14a-14h. It is noted that subsystems 12a-12h could further include a "big data" subsystem, subsystems for receiving input from manufacturers/factories, subsystems for receiving external data/input (e.g., data from the Internet), and subsystems for receiving input from customers. As will be discussed in greater detail below, the subsystems 12a-12h could include control logic for allowing each of the devices 14a-14h to interact with each other (e.g., to exchange data and commands for controlling each other), as well as to be remotely controlled by another system such as a remote server, a "cloud" based control system, a remote computer system, a smart device (e.g., smart phone, smart speaker, smart chip embedded in the body), etc., and combinations thereof as will be discussed in greater detail below.

As can be seen, the pool and spa equipment 14a-14h could include various types of pool and spa equipment, such as a pump 14a, a heating/cooling system 14b, a sanitization system 14c, a water feature or miscellaneous subsystem 14d, a valve actuator 14e, a pool/spa control system 14f, a pool cleaner 14g, and/or a lighting system 14h. It is noted that, as described herein, the heating/cooling system 14b may also describe, or be described as, a heating system, heater, cooling system, cooler, or any combination thereof. Additionally, as can be seen in FIG. 1, the subsystems 12a-12h

could also communicate with one or more servers **18**, and/or with one or more smart devices **20** (e.g., phone, tablet, computer systems, etc.), via the network **16**. Still further, an on-site control processor **19** could be in communication with the various systems shown in FIG. 1. The on-site control processor **19** could be a pool/spa control system installed at the location of a pool or spa, a reduced-functionality pool/spa control system, or another type of control system. Examples of such systems will be described in detail below.

FIG. 2 is a block diagram illustrating components of the subsystems **12a-12h** in greater detail. As can be seen, a variety of subsystem components could be provided for providing network connectivity for pool and spa equipment via a multitude of wired and wireless means. As noted above, the subsystems **12a-12h** could be installed in pool/spa equipment (e.g., within the physical housings of the equipment **14a-14h**), or connected thereto, to provide network connectivity to each device. Advantageously, the subsystems **12a-12h** can be provided as “after-market” components that provide network connectivity and remote monitoring and control for pool/spa equipment that does not ordinarily include such connectivity. Importantly, the subsystems **12a-12h** allow for a wide variety of wired and wireless connections to the pool/spa equipment. For example, a smart telephone could directly connect with pool or spa equipment via a Bluetooth, WiFi, RF mesh (e.g., ZWave, Zigbee, Thread, Weave, etc.), or satellite connection, via the subsystems **12a-12h**. Moreover, a home computer could connect to pool/spa equipment using a home WiFi network, via the subsystems **12a-12h** or by way of a wired Ethernet connection to the pool/spa equipment. Still further, a remote server or “cloud” platform could connect to the pool/spa equipment via the subsystems **12a-12h**, to allow for remote and/or web-based control.

A processor **22** provides local processing capability for each of the subsystems **12a-12h**. The processor **22** is in communication with a random access memory **24**, and one or more non-volatile memories **28**. The non-volatile memory **28** could store one or more local control programs **30** for providing local control of the pool or spa equipment in which the subsystem is installed. A TCP/IP stack **26** is provided for allowing each of the subsystems to obtain an Internet protocol address, and to provide Internet connectivity for each of the subsystems. The processor **22** could communicate with a wired communication subsystem **36**, a wireless communication subsystem **34**, a sensor interface subsystem **38**, and an actuator interface subsystem **40** via a bus **32**. The wired communication subsystem **36** could include an Ethernet transceiver **42**, and a serial transceiver **44**. The serial transceiver could support one or more suitable serial communication protocols, such as RS-485, RS-232, USB, etc. The wireless communication subsystem **34** could include a Wi-Fi transceiver **46**, a Bluetooth (or Bluetooth LE) transceiver **48**, a cellular data transceiver **50**, a satellite transceiver **52**, and infrared transceiver **54**, and a radiofrequency/RF mesh transceiver **56**. The cellular data transceiver **50** could support one or more cellular data communications protocols, such as 4G, LTE, 5G, etc. The radiofrequency/RF mesh transceiver **56** could support one or more RF mesh network protocols, such as ZWave, Zigbee, Thread, Weave, etc. The sensor interface subsystem **38** could include analog connection interfaces, digital connection interfaces, and one or more analog-to-digital converters **58**. The actuator interface subsystem **40** could include analog connection interfaces, digital connection interfaces, and one or more digital-to-analog converters **60**. The sensor interface subsystem allows the network communication and local

control subsystem to obtain information from a wide variety of sensors associated with pool/spa equipment, as well as other types of sensors. The actuator interface subsystem **40** allows the network communication and local control subsystem to control one or more pieces of pool/spa equipment connected to the subsystem. The wired and wireless communication subsystems **34**, **36** allow the network communication and local control subsystem to connect via various wired and wireless communication means to the Internet. This allows a piece of pool or spa equipment to transmit operational and status information to one or more remote devices, as well as to be remotely controlled by such devices.

FIG. 3 is a diagram illustrating various types of control logic in accordance with the present disclosure, for controlling various types of pool and spa equipment. The control logic, indicated generally as pool control logic **70**, could be embodied as programmed instructions (software code) stored on a non-transitory computer-readable medium, and could include water feature control logic **72**, valve actuator control logic **74**, cleaner control logic **76**, lighting control logic **78**, heater control logic **80**, chemistry automation control logic **82**, and pump control logic **84**. Such logic could be installed locally (e.g., in one or more of the subsystems **12a-12h**), on a remote server or computer system (e.g., in the server **18** or the smart phone/computer system **20**), in the “cloud,” or in any combination of such systems. The functions provided by the logic **70-84** is described in greater detail below. As will be discussed in greater detail below the various logic operations disclosed herein (including the operational instruction disclosed herein) could be triggered by (e.g., receive and a signal from) various sensors and/or inputs to the system, as needed. Such inputs could be periodically monitored by the pool control logic **70** of the system **10**.

FIG. 4 is a diagram illustrating processing steps, indicated generally at **90**, carried out by the system of FIGS. 1-2. It is noted that the term “IoT devices” (shown in the drawings) refers to pool/spa equipment having Internet-of-Things functionality provided in accordance with the present disclosure, such as the equipment **14a-14h** of FIG. 1. Beginning in step **92**, the system monitors IoT devices for incoming operational data. In step **94**, a decision is made as to whether incoming operational data has been received. If a negative determination has been made, control returns to step **92**. Otherwise, step **96** occurs, wherein the system receives incoming operational data. In step **98**, the system processes instructions, operational data, and external data, discussed hereinbelow. Then, in step **100**, the system optimizes operational set points. In step **102**, the system transmits setpoints to one or more devices (one or more of the pool/spa equipment **14a-14h**) for use thereby.

In step **104**, the system also monitors for incoming instructions. A determination is made in step **105** as to whether an incoming instruction has been received. If a negative determination has been made, control returns to step **104**. Otherwise, in step **106**, the system receives one or more incoming instructions. Then, control proceeds to step **98**, discussed above. Additionally, in step **107**, the system also monitors for updated external data (e.g., web data). In step **108**, a decision has been made as to whether updated external data is available. If a negative determination has been made, control returns to step **107**. Otherwise, step **109** occurs, wherein the system receives the updated external data. Then, control proceeds to step **98**, discussed above.

FIG. 5 is a diagram illustrating another embodiment of the present disclosure, indicated generally at **110**. In this

embodiment, network connectivity and remote monitoring/control of pool and spa components is provided by way of a central pool/spa system controller **114f**. The pool/spa system controller **114f** could be the OMNIALOGIC pool/spa system controller manufactured and sold by Hayward Industries Inc. The pool/spa system controller **114f** could communicate with one or more valve actuators **114e**, a single speed pump **113**, a variable speed pump **114a**, pool/spa lighting systems **114h**, a pool/spa heating or cooling system **114b**, and/or a pool/spa chlorination system **114c**, such as a salt chlorinator. Additionally, the pool/spa control system **114f** could receive input from one or more external sensors **126** and could provide “personality” by way of remotely provisioned logic for the devices. The pool/spa control system **114f** communicates with a remote server, such as the server **118**, via a Wi-Fi router **122** and the Internet. The server **118** could communicate with one or more remote control systems **120**, such as a smart device (e.g., smart phone, smart speaker, smart TV, embedded device), a computer system, a tablet computer, etc. The control system **114f** could also receive external web data **131** via the Internet and Wi-Fi router **122** (e.g., time & date, sunrise/sunset data, regional and local weather forecasts, wind, UV, sunlight) for use by pool control logic **170**, described hereinbelow. Additionally, the Wi-Fi router **122** could communicate with a home management system **125** in a peer-to-peer arrangement, if desired. The server **118** could also access big data **127** and perform analytics **129** in connection with various types of information relating to the pool/spa equipment, usage thereof, and status information relating thereto. Further, the server **118** communicate with one or more third-party smart devices **124** via a suitable cloud application programming interface (API). The third-party smart devices **124** could also remotely communicate with and control the pool/spa equipment shown in FIG. 5. Additionally, the pool/spa control system **114f** could include pool logic **170** stored therein for allowing central control and monitoring of pool/spa equipment at the pool/spa site. The pool logic **170** could include any of the various pool control logic described herein. Additionally, such logic **170** could also be stored in the server **118**, or at another location.

FIG. 6 is a flowchart, indicated generally at **130**, illustrating processing steps carried out by the system of FIG. 5. In step **132**, the pool/spa system controller **114f** of FIG. 5 monitors connected devices for incoming operational data. Then, in step **134**, a decision is made as to whether incoming operational data has been received. If not, control returns to step **132**. Otherwise, step **136** occurs, wherein the pool/spa system controller receives incoming operational data. Then, in step **138**, the pool/spa system controller **114f** processes instructions, operational data, and external data, discussed hereinbelow. Then, in step **140**, the pool/spa system controller **114f** optimizes operational set points. In step **142**, the pool/spa system controller transmits set points to the connected devices, such as the pool/spa equipment **113**, **114a**, **114b**, **114h**, and **114c** shown in FIG. 5. In step **144**, the pool/spa system controller **114f** could also transmit such setpoint information to other devices, such as the smart devices **124** illustrated in FIG. 5.

In step **150**, the pool/spa system controller monitors for incoming instructions. In step **152**, a determination is made as to whether an incoming instruction has been received. If not, control returns to step **150**. Otherwise, step **150** occurs, wherein the pool/spa system controller **114f** receives incoming instructions. Then, processing proceeds to step **138**, discussed above. In step **156**, the pool/spa system controller **114f** monitors for updated external data (e.g., web-supplied

data, such as weather information and other information from remote data sources). In step **158**, the system determines whether updated external data is available. If not, control returns to step **156**. Otherwise step **160** occurs, wherein the pool/spa system controller receives the updated external data. Then, control proceeds to step **138**, discussed above.

FIG. 7 is a diagram illustrating another embodiment of the system of the present disclosure, wherein remote connectivity is provided by way of a pool “hub” component **230**. The pool hub component **230** includes a subset of the functional features of the pool/spa system controller **114f** of FIG. 5, such as basic on/off control relays, the ability to select a pump speed, the ability to select heater temperature, the ability to control pool light colors and shows, the ability to set equipment schedules, and the ability to interlock one pool/spa component with another pool/spa component. The pool hub communicates with and controls a number of pool/spa components, such as a single speed pump **213**, a variable speed pump **214a**, pool/spa lighting systems **214h**, a pool/spa heating system **214b**, and a pool/spa chlorination system **214c**. Additionally, the pool hub **230** can control a valve actuator **214e** and can receive various sensor inputs **226** and **228**, such as temperature sensors, wind speed sensors, runtime sensors, current/voltage usage sensors, flow sensors, heater pressure sensors, water temperature sensors, chlorine sensors, pH/ORP sensors, etc. Such sensors could be positioned internally within the hub, external thereto, or a combination thereof. Additionally, the pool hub **230** could be powered by electrical current supplied by a breaker panel **217** or by photovoltaic (e.g., solar) cells and/or systems. Breaker panel **217** could also be a smart circuit breaker (e.g., a circuit breaker that can be controlled via wired or wireless communication) used to provide and/or to interrupt power to the devices disclosed herein. The pool hub **230** could communicate with a remote server **218** via a Wi-Fi router **222** and a network connection such as the Internet. The server to **218** could include pool logic **270** which can be used to remotely monitor and control operation of the devices to **213**, **214a**, **214h**, **214b**, and **214c**. The pool logic **270** could include any of the pool logic discussed herein. Additionally, the server **218** could communicate with one or more remote control devices **220**, such as a smart cellular telephone, a remote computer, a tablet computer, etc. The server **218** could also receive external web data **231** via the Internet (e.g., time & date, sunrise/sunset data, regional and local weather forecasts, wind, UV, sunlight) for use by pool logic **270**. Further, the server **218** could communicate with one or more third-party devices **224** via an appropriate cloud API. Further, the server **218** could process big data **232** and perform analytics **234** on various pool/spa data. Still further, the server **218** could communicate with a home management system **225**, if desired.

FIG. 8 is a flowchart illustrating processing steps, indicated generally at **240**, carried out by the system of FIG. 7. In step **242**, the pool hub **230** monitors connected devices for incoming operational data. In step **244**, a determination is made as to whether an incoming operational data has been received. If not, control returns to step **242**. Otherwise, step **246** occurs, wherein the pool hub **230** receives incoming operational data. Then, in step **248**, the pool **230** transmits incoming instructions and operational data to the server **218**. Then, in step **250**, the server **218** receives the incoming instructions and operational data from the pool hub **230**. In step **252**, the server **218** processes the incoming instructions, operational data, and external data, discussed hereinbelow. In step **254**, the server **218** optimizes operational set points.

Then, in step 256, the server 218 transmits operational setpoints to the pool hub 230. In step 258, the pool hub 230 receives the operational set points. Then, in step 260, the pool hub 230 transmits the operational setpoints to the connected devices. In step 262, the pool hub 230 optionally

transmits the operational setpoints to one or more smart devices, such as the third-party smart devices 224 of FIG. 7. In step 263, the pool hub 230 monitors smart devices for incoming operational data. In step 265, a decision is made as to whether incoming operational data has been received. If not, control returns to step 263. Otherwise, step 246 occurs, where in the incoming operational data is received at the pool hub 230. Then, control passes to step 248, discussed above.

In step 264, the pool hub 230 monitors for incoming instructions. Then, in step 266, a determination is made as to whether an incoming instruction has been received. If a negative determination has been made, control returns to step 264. Otherwise, step 268 occurs, wherein the pool hub 230 receives the incoming instructions. Then, control passes to step 248, discussed above.

In step 272, the server 218 monitors for updated external data, such as web-supplied data including weather data and other data. In step 274, a determination is made as to whether updated external data is available. If not, control returns to step 272. Otherwise, step 276 occurs, wherein the updated external data is received at the server 218. Then, control passes to step 252, discussed above.

FIG. 9 is a diagram illustrating another embodiment of the system of the present disclosure, indicated generally at 310. In this embodiment, a pool command “translator” module 330 is provided, which includes a complete set of pool logic 370. The pool logic 370 could include any of the pool logic discussed herein. The translator 330 could communicate with one or more external relays 329. Additionally, the translator 330 could communicate with a plurality of pool/spa components, including valve actuators 314e, a single speed pump 313, a variable speed pump 314a, pool/spa lighting systems 314h, a pool/spa heating system 314b, and a pool/spa chlorination system 314c. The translator 330 could receive electrical power from a breaker panel 317 or from photovoltaic (e.g., solar) cells and/or systems. Breaker panel 317 could also be a smart circuit breaker (e.g., a circuit breaker that can be controlled via wired or wireless communication) used to provide and/or to interrupt power to the devices disclosed herein. Additionally, the translator 330 could receive information from various sensors such as external sensors 326 and internal sensors 328. Such sensors could include, but are not limited to, temperature sensors, wind speed sensors, runtime sensors, current/voltage usage sensors, flow sensors, heat pressure sensors, water temperature sensors, chlorine sensors, PH/ORP sensors, etc. The translator 330 could also receive external web data 331 via the Internet and Wi-Fi router 322 (e.g., time & date, sunrise/sunset data, regional and local weather forecasts, wind, UV, sunlight) for use by pool logic 370.

The translator 330 could communicate with the remote server 318 via a Wi-Fi router 322 and a network connection such as the Internet. The server 318 could communicate with the remote control system 320, such as a smart cellular telephone, a remote computer, a tablet computer, etc. Additionally, the server 318 could process big data 332 and perform analytics 334 on pool/spa data, using a suitable API. Further, the server 318 could communicate with one or more third-party smart devices 324, using a suitable cloud API. Still further, the server 318 could communicate with a home management system 325, if desired.

FIG. 10 is a flowchart showing processing steps, indicated generally at 340, carried out by the system of FIG. 9. In step 342, the translator 330 monitors connected devices for incoming operational data. In step 334, a decision is made as to whether incoming operational data has been received. If not, control returns to step 342. Otherwise, step 346 occurs, wherein the translator 330 receives the incoming operational data. Then, step 360 occurs, wherein the translator processes instructions, operational data, and external data, discussed hereinbelow. In step 362, the translator optimizes operational set points. Then, in step 364, the translator transmits the setpoints to the connect devices (e.g., to the components 313, 314a, 314e, 314h, 314b, and 314c). Optionally, in step 366, the translator could transmit the setpoints to one or more smart devices, such as the third-party smart devices 324.

In step 348, the translator 330 monitors smart devices for incoming operational data. In step 350, a decision is made as to whether incoming operational data has been received. If not, control returns to step 348. Otherwise, step 352 occurs, wherein the translator 330 receives incoming operational data. Then, control passes to step 360, discussed above.

In step 354, the translator 330 monitors for incoming instructions. In step 356, a decision is made as to whether incoming instructions have been received. If not, control returns to step 354. Otherwise, step 358 occurs, wherein the translator 330 receives incoming instructions. Then, control passes to step 360, discussed above.

In step 368, the translator 330 monitors for updated external data, such as web data. Such data could include, but is not limited to, remote weather data, etc. In step 372, a decision is made as to whether updated external data is available. If not, control returns to step 368. Otherwise, step 374 occurs, wherein the translator 330 receives the updated external data. Then, control passes to step 360, discussed above.

FIG. 11 is a diagram illustrating another embodiment of the system, indicated generally at 410. In this embodiment, remote connectivity is provided by way of a plurality of connectivity modules 430a-430e. Each of these modules could include a combination of high and/or low voltage relays for connection to various pool and spa equipment, such as valve actuators 414e, a single speed pump 413, a variable speed pump 414a, pool/spa lighting systems 414h, pool/spa heating system 414b, and/or pool/spa chlorination system 414c. Connectivity could be provided to the pool/spa equipment additionally using Wi-Fi, Bluetooth, or RF mesh (e.g., ZWave, Zigbee, Thread, Weave, etc.) connectivity. The connectivity modules could provide Wi-Fi for every unit, could adapt for usage with legacy devices, could provide “personality” by way of remotely provisioned logic for the devices, could remember limp mode schedules during a Wi-Fi outage, and could also include start/stop buttons and an LS bus gate way, if desired. The modules could be powered by a breaker panel 427 or by photovoltaic (e.g., solar) cells and/or systems. Breaker panel 427 could also be a smart circuit breaker (e.g., a circuit breaker that can be controlled via wired or wireless communication) used to provide and/or to interrupt power to the devices disclosed herein. Additionally, each of the modules could communicate with a remote server 418 by a Wi-Fi router 422 and a network connection, such as the Internet. The pool/spa control logic 470 could be provided in the server 418 for remotely controlling and monitoring the pool/spa equipment. The pool logic 470 could include any of the pool logic discussed herein. The server 418 could also receive external web data 431 via the Internet (e.g., time & date, sunrise/

sunset data, regional and local weather forecasts, wind, UV, sunlight) for use by pool logic 470. Additionally, the server 418 could communicate with one or more remote control devices 420, such as a smart phone, a remote computer, a tablet computer, etc. The server 418 could access big data 432 and perform analytics 434 on pool/spa data, if desired. Additionally, the server 418 could also communicate with one or more third-party smart devices 424, via a suitable cloud API. Still further, the server 418 could communicate with a home management system 425, if desired.

FIG. 12 is a diagram illustrating processing steps, indicated generally at 440, carried out by the system of FIG. 11. In step 442, the pool connectivity modules 430a-430e monitor smart devices for incoming operational data. In step 444, a determination is made as to whether incoming operational data has been received. If not, control returns to step 442. Otherwise, step 446 occurs, wherein the pool connectivity modules each receive the incoming operational data. Then, and step 448, the pool conductivity modules 430a-430e transmit operational data to the server 418. In step 450, the operational data is received at the server 418. In step 452, the server 418 processes the incoming instructions, operational data, and external data, discussed hereinbelow. Then, in step 454, the server 418 optimizes operational support. In step 456, the server 418 transmits the operational set points to the connected devices (e.g., to the devices 413, 414a, 414e, 414h, 414b, and 414c). In step 458, the server transmits operational set points for the smart devices to the pool connectivity modules 430a-430e. In step 460, the pool conductivity modules 430a-430e receive the operational setpoints for the smart devices. Then, in step 462, the modules transmit the operational set points to the smart devices.

In step 464, the server for 18 monitors connected devices for incoming operational data. In step 466, a determination is made as to whether incoming operational data has been received. If not, control returns to step 464. Otherwise, step 450 occurs, wherein the server 418 receives the operational data. Control then passes to step 452, discussed above.

In step 468, the server 418 monitors for incoming instructions. In step 470, a determination is made as to whether the incoming instructions have been received. If not, control returns to step 468. Otherwise, step 472 occurs, wherein the server 418 receives the incoming instructions. Then, control passes to step 452, discussed above.

In step 474, the server 418 monitors for updated external data, such as web data including, but not limited to, remote weather information, etc. Then, in step 476, a determination is made as to whether updated external data is available. If not, control passes to step 474. Otherwise, step 478 occurs, wherein the updated external data is received at the server 418. Then, control passes to step 452, discussed above.

FIG. 13 is a diagram illustrating another embodiment of the system of the present disclosure, indicated generally at 510. In this embodiment, wireless connectivity is provided directly within pool/spa equipment, allowing such equipment to communicate directly to the Internet. As shown, pool spa equipment, such as a single speed pump 513, a variable speed pump 514a, pool/spa lighting system 514b, heater 514c, and/or chlorinator 514d, in addition to valve actuators 514e, each have built-in wireless communications subsystems, such as Wi-Fi, Bluetooth, radiofrequency/RF mesh (e.g., ZWave, Zigbee, Thread, Weave, etc.), and or cellular wireless communication subsystems. Each of these devices can communicate directly with the Internet via a Wi-Fi router 522. Additionally, external sensors 526 could also communicate with the Wi-Fi router 522, and could also

include built-in wireless communications such as Wi-Fi, Bluetooth, radiofrequency/RF mesh (e.g., ZWave, Zigbee, Thread, Weave, etc.), and cellular communications. The sensors 526 could include, but are not limited to, heater pressure sensors, water temperature sensors, chlorine sensors, pH/aware pressure sensors, etc. It is noted that each of the pool/spa components could include the ability to remember schedules during a Wi-Fi outage (limp mode) as provisioned by remote pool logic. Additionally, each of these devices could include start/stop buttons, if desired, for stand-alone operation. A breaker panel 527 could provide electrical power to each of the pool/spa components. Breaker panel 527 could also be a smart circuit breaker (e.g., a circuit breaker that can be controlled via wired or wireless communication) used to provide and/or to interrupt power to the devices disclosed herein. In some embodiments, photovoltaic (e.g., solar) cells and/or systems could provide electrical power to one or more of the pool/spa components.

Each of the pool/spa components discussed above, including the sensors 526, could communicate with a remote server 518. The server 518 could include pool logic 570 for remotely controlling and/or monitoring the pool/spa equipment. The pool logic 570 could be any of the pool logic discussed herein. The server 518 could receive external web data 531 via the Internet (e.g., time & date, sunrise/sunset data, regional and local weather forecasts, wind, UV, sunlight) for use by pool logic 570. The server 518 could also communicate with one or more remote control devices 520, such as smart telephones, remote computer systems, tablet computers, etc. The server 518 could also access big data 532 and perform analytics 534 on pool/spa data, if desired. Additionally, the server 518 could communicate with one or more third-party smart devices 524, via a suitable cloud API. Still further, the server 518 could communicate with a home management system 525, if desired.

FIG. 14 is a flowchart illustrating processing steps, indicated generally at 540, carried out by the system of FIG. 13. In step 542, the server 518 monitors connected devices for incoming operational data. Then, in step 544, a determination is made as to whether incoming operational data has been received. If not, control returns to step 542. Otherwise, step 546 occurs, wherein the server 518 receives incoming operational data. Then, in step 548, the server 518 processes the instructions, the operational data, and external data, discussed hereinbelow. In step 550, the server 518 optimizes operational set points. Then, in step 552, the server transmits the setpoints to the connected pool/spa devices, such as those devices shown in FIG. 13.

In step 554, the server 518 monitors for incoming instructions. Then, in step 556, a determination is made as to whether incoming instructions have been received. If not, control returns to step 554. Otherwise, step 558 occurs, wherein the server 518 receives incoming instructions. Then, step 548, discussed above, is invoked.

In step 560, the server 518 monitors for updated external data, such as web data including, but not limited to remote weather data, etc. In step 562, a decision is made as to whether updated external data is available. If not, control returns to step 560. Otherwise, step 564 occurs, wherein the server 518 receives the updated external data. Then, control passes to step 548, discussed above.

FIG. 15 is a diagram illustrating another embodiment of the system of the present disclosure, indicated generally at 610. In this embodiment, network connectivity and remote monitoring/control is provided by way of a reduced-size hub 646 which can be easily wall-mounted. The hub 646 provides wired and wireless connections for various pool and

spa equipment, such as a variable speed pump **614a**, a single-speed pump **613**, a smart heater **614b**, a legacy heater **615**, a chlorination system **617**, any other type of chlorinator **614c**, a booster pump **619**, and a third-party pump **621**. Various relays **648**, **650**, **652**, and **654** could also be provided for controlling the pumps, if desired. Also, the hub **646** could communicate with and control a smart valve actuator **614e**, and/or lighting system **614h**. Optional control relays **656** and power supplies **658** could also be in communication with the hub **646**.

As can be seen, the hub **646** could provide a WiFi hotspot for allowing a homeowner's cellular telephone, tablet computer, or personal computer **644** to communicate with the hub **646**, and to control the pool/spa equipment shown in FIG. 15. A breaker panel **627** provides electrical power to the various devices shown in FIG. 15. Breaker panel **627** could also be a smart circuit breaker (e.g., a circuit breaker that can be controlled via wired or wireless communication) used to provide and/or to interrupt power to the devices disclosed herein. In some embodiments, photovoltaic (e.g., solar) cells and/or systems could provide electrical power to one or more of the various devices shown in FIG. 15. A wall-mounted light controller **640** could communicate by Bluetooth and/or RF mesh (e.g., ZWave, Zigbee, Thread, Weave, etc.) to the hub **646** for remotely controlling the lights **614h**. Additionally, a third-party Bluetooth and/or RF mesh-enabled switch **642** could also communicate with the hub **646**. The hub **646** could also communicate with the homeowner's WiFi router **622** for providing an Internet connection to the pool/spa components. A remote pool/spa server **618** could communicate with the router **622** via the Internet, to provide remote monitoring and control of the pool/spa equipment, if desired. Additionally, the server **618** could communicate with one or more remote computer systems **620** such as a smart phone, a tablet computer, a remote computer system, etc., if desired. The pool/spa control logic discussed herein could be installed in the server **618**, in the remote computer **620**, and/or in the smart phone **644** (e.g., by way of a pool control "app"), if desired. Further, the server **618** could communicate with one or more third-party smart devices **624** by a suitable cloud API, and the server **618** could access big data **632** and perform analytics **634** on pool/spa data, if desired. The server **618** could also communicate with a home management system **638**, if desired.

FIG. 16A is a diagram illustrating another embodiment of the system of the present disclosure, indicated generally at **710**. In this embodiment, network connectivity and remote monitoring/control is provided by way of a Wi-Fi-enabled pool/spa chlorination system and controller **717**. The controller **717** provides connections for various pool and spa equipment, such as a variable speed pump **714a**, a single-speed pump **713**, a smart heater **714b**, a legacy heater **715**, a chlorination system **717c**, a booster pump **719**, and a third-party pump **721**. Various relays **749**, **750**, and **754** could also be provided for controlling the pumps, if desired. Also, the controller **717** could communicate with and control a smart valve actuator **714e**, and/or lighting system **714h**. Optional control relays **756** and power supplies **758** could also be in communication with the controller **717**.

A breaker panel **727** provides electrical power to the various devices shown in FIG. 16A. Breaker panel **727** could also be a smart circuit breaker (e.g., a circuit breaker that can be controlled via wired or wireless communication) used to provide and/or to interrupt power to the devices disclosed herein. In some embodiments, photovoltaic (e.g., solar) cells and/or systems could provide electrical power to

one or more of the various devices shown in FIG. 16A. The controller **717** could also communicate with the homeowner's WiFi router **722** for providing an Internet connection to the pool/spa components. A remote pool/spa server **718** could communicate with the router **722** via the Internet, to provide remote monitoring and control of the pool/spa equipment, if desired. Additionally, the server **718** could communicate with one or more remote computer systems **720** such as a smart phone, a tablet computer, a remote computer system, etc., if desired. The pool/spa control logic discussed herein could be installed in the server **718**, in the remote computer **720**, or elsewhere, if desired. Further, the server **718** could communicate with one or more third-party smart devices **724** by a suitable cloud API, and the server **718** could access big data **732** and perform analytics **734** on pool/spa data, if desired. Still further, the server **718** could communicate with a home management system **738** if desired.

FIG. 16B is a diagram illustrating another embodiment of the system of the present disclosure, indicated generally at **4510**. In this embodiment, network connectivity and remote monitoring/control is provided by way of a Wi-Fi-enabled pool/spa variable speed pumping system and controller (also referred to herein in connection with FIG. 16B as "variable speed pumping system," "pumping system," or "controller"), indicated generally at **4514a**. As referred to herein, a variable speed pumping system can include a variable speed pump, a possessor/controller, memory, communications interface(s), and an input device, so that the variable speed pumping system can communicate with and/or control additional installed pool/spa equipment. Accordingly, pump control logic **84**, as described hereinbelow, could be installed/reside in variable speed pumping system **4514a**. For example, any of the various processes in the embodiments described herein in connection with FIGS. 19A-19AU could be incorporated into pump control logic **84** and installed in variable speed pumping system **4514a**, either alone or in any combination. Further, any additional processes disclosed herein in connection with pool control logic **70** (e.g., water feature control logic **72**, valve actuator control logic **74**, cleaner control logic **76**, lighting control logic **78**, heater control logic **80**, chemistry automation control logic **82**) could also be incorporated into pump control logic **84** and installed in variable speed pumping system **4514a**, either alone or in any combination.

The controller **4514a** provides connections for various pool and spa equipment, such as a pool/spa chlorination system **4517**, a single-speed pump **4513**, a smart heater **4514b**, a legacy heater **4515**, a chlorination system **4514c**, a booster pump **4519**, and a third-party pump **4521**. Various relays **4549**, **4550**, and **4554** could also be provided for controlling the pumps, if desired. Variable speed pumping system and controller **4514a** could include on-board or modularly upgradeable pool control components (e.g., communication modules, relays, temperature sensors, pressure sensors, flow sensors, etc.). For example, the variable speed pumping system **4514a** could control existing heaters (or heat pumps) using on-board or modularly upgradeable relays and temperature sensors. Pump control logic **84**, discussed in greater detail hereinbelow, could also utilize multiple sensors for parallel plumbing circuits (e.g., branch plumbing). Also, the controller **4514a** could communicate with and control a smart valve actuator **4514e**, and/or lighting system **4514h**. Optional control relays **4556** and power supplies **4558** could also be in communication with the controller **4514a**. Accordingly, variable speed pumping system and controller **4514a** could use the modularly

upgradeable smart relays to control a variety of existing installed pool/spa equipment including single speed pumps, pressure cleaner booster pumps, LED and incandescent pool lights, and landscape lights. The modularly upgradeable control components can be used by pump control logic **84** to provide pump or system performance reporting and diagnostic functions (present and historical) including, but not limited to, phase current, torque, speed, horsepower, run time, and ramp rate. Pump control logic **84** could provide the system performance and diagnostic information to the cloud, or to a smart to a smart device via a Bluetooth or any of the other communication protocols disclosed herein.

A breaker panel **4527** provides electrical power to the various devices shown in FIG. 16B. Breaker panel **4527** could include one or more smart circuit breakers (e.g., a circuit breaker that can be controlled via wired or wireless communication) used to provide and/or to interrupt power to the devices disclosed herein, and/or conventional circuit breakers. In some embodiments, photovoltaic (e.g., solar) cells and/or systems could provide electrical power to one or more of the various devices shown in FIG. 16B. The controller **4514a** could also communicate with the homeowner's WiFi router **4522** for providing an Internet connection to the pool/spa components. A remote pool/spa server **4518** could communicate with the router **4522** via the Internet, to provide remote monitoring and control of the pool/spa equipment, if desired. Additionally, the server **4518** could communicate with one or more remote computer systems **4520** such as a smart phone, a tablet computer, a remote computer system, etc., if desired. The pool/spa control logic discussed herein could be installed in the variable speed pumping system and controller **4514a**, in the server **4518**, in the remote computer **4520**, or elsewhere, if desired. Further, the server **4518** could communicate with one or more third-party smart devices **4524** by a suitable cloud API, and the server **4518** could access big data **4532** and perform analytics **4534** on pool/spa data, if desired. Still further, the server **4518** could communicate with a home management system **4538** if desired. It is also further complicated that any of the functions described herein could also be performed by the variable speed pumping system and controller **4514a**.

As illustrated in FIG. 16B, the pumping system and controller **4514a** can be provided with a human machine interface or user interface device, indicated generally at **4560**. The user interface could include physical keys, a digital display, and/or a touchscreen **4562**, as shown in FIG. 16B, any other suitable input technologies, or any combination thereof. It is also contemplated that any of the pool/spa equipment described herein could be provided with a similar user interface device. Providing a user interface device **4562** on pumping system and controller **4514a** enables the delivery of existing or enhanced features of local pool/spa equipment control and control of remote devices (e.g., beyond the pool area) to the pool owner via the pool pump, while also reducing costs to the pool owner (e.g., reducing hardware costs, installation expenses, etc.). Because every pool/spa must include at least one pump, providing control of and communication with additional equipment, connectivity, and monitoring (e.g., status and condition of pool and equipment) functionality of the pool environment via the pool pump can further reduce pool owner cost and significantly improve usability. By leveraging information obtained at the equipment pad, from remote/external devices, and/or via a connection to the internet, operation of the pumping system **4514a** and other devices can be further optimized.

FIG. 17 is a diagram illustrating another embodiment of the system of the present disclosure, indicated generally at **810**. In this embodiment, network connectivity and remote monitoring/control is provided by way of a reduced-size hub **860** which can be easily wall-mounted. The hub **860** provides wired and wireless connections for various pool and spa equipment, such as a variable speed pump **814a**, a single-speed pump **813**, a smart heater **814b**, a legacy heater **815**, a chlorination system **817c**, and other equipment (e.g., lighting equipment).

As can be seen, the hub **860** could provide a WiFi hotspot for allowing a homeowner's cellular telephone, tablet computer, or personal computer **844** to communicate with the hub **846**, and to control the pool/spa equipment shown in FIG. 17. A breaker panel **827** provides electrical power to the various devices shown in FIG. 17. Breaker panel **827** could also be a smart circuit breaker (e.g., a circuit breaker that can be controlled via wired or wireless communication) used to provide and/or to interrupt power to the devices disclosed herein. In some embodiments, photovoltaic (e.g., solar) cells and/or systems could provide electrical power to one or more of the various devices shown in FIG. 17. A wall-mounted light controller **840** could communicate by Bluetooth and/or RF mesh (e.g., ZWave, Zigbee, Thread, Weave, etc.) to the hub **860** for remotely controlling lights. Additionally, a third-party Bluetooth and/or RF mesh-enabled switch **842** could also communicate with the hub **860**. The hub **860** could also communicate with the homeowner's WiFi router **822** for providing an Internet connection to the pool/spa components. A remote pool/spa server **818** could communicate with the router **822** via the Internet, to provide remote monitoring and control of the pool/spa equipment, if desired. Additionally, the server **818** could communicate with one or more remote computer systems **820** such as a smart phone, a tablet computer, a remote computer system, etc., if desired. In this embodiment, the server **818** is a cloud-based, virtual server, and the pool/spa control logic discussed herein is installed in the server **818**. The pool logic could be any of the pool logic discussed herein. Further, the server **818** could communicate with one or more third-party smart devices **824** by a suitable cloud API, and the server **818** could access big data **832** and perform analytics **834** on pool/spa data, if desired. The server **818** could also communicate with a home management system **838**, if desired.

FIG. 18 is a diagram illustrating pump control logic **84**. Pump control logic **84** could incorporate and/or be in communication with a variety of types of data and/or data sources. More specifically, pump control logic **84** can communicate with, or receive, user input data **902**, pump operational data **904**, pump factory specifications **906**, pump configuration parameters **908**, web data **910**, pool configuration parameters **912**, data from related devices **914**, health monitoring data **916** and/or external sensor data **918**.

Pump control logic **84** can control variable speed pumps, designed for residential and commercial pool applications (as well as additional installed pool/spa equipment), providing flow and pressure for water circulation and operation of pool equipment. Variable speed pumps, as described herein, could include a pump wet end, a motor, a variable frequency/speed drive, and a user interface (see FIG. 16B). The variable speed pump is used anytime a pool is in operation, which may be year-round and/or all-day based on a particular application (e.g. residential vs. commercial) or location. The pump control logic **84** can control the variable speed drive to operate in stand-alone mode, relay control mode, or via communication with Hayward automation, described hereinbelow.

In stand-alone mode, the pump operates independently of the pool control logic **70**. Stand-alone mode is programmable with respect to functions such as timers and preset speeds. In relay control mode, the pump operates according to inputs received from third party systems and devices using low voltage digital inputs. For example, the digital inputs could be used to select discrete timer speeds set in the pump user interface. When communicating with Hayward automation, the pump is controlled by a variety of Hayward automation systems such as, but not limited to: Omni-Logic®, ProLogic®, and OnCommand®. The pump could communicate with Hayward automation systems using RS485 and associated Hayward automation communication protocols, or any other suitable communication protocol disclosed herein.

In addition to operating in the modes described previously, the pump can also serve as a pool control system. The user interface could utilize a color LCD touch screen with resistive and/or capacitive touch capability, or any other suitable input technology. The user interface could provide a user with information such as ambient air and pool water temperatures, providing true freeze protection capability, as well as thermostat control of a pool heater or heat pump. The user interface could also be used to communicate with and to control one or more smart relays and smart actuators, allowing the pump to coordinate operation of other pieces of pool equipment. For example, the user interface can be used for interlock control of other installed pool/spa equipment. The pump could also be provided with a communication module (e.g., Wi-Fi, ethernet, Bluetooth, ZWave, Zigbee, Thread, Weave, etc.) allowing remote application control of the pump and/or pool pad equipment, and to allow remote data collection of site specific information.

Pump control logic **84** can be controlled remotely with a personal computer, smart phone, tablet, or other device via wired or wireless communication, including but not limited to, Bluetooth, Wi-Fi, powerline transmission, etc. Accordingly, the pump can have a full-featured local interface (see FIG. **16B**), minimal local user interface, or no local user interface at all. Nevertheless, all aspects of the pump operational data and pump control logic **84** can be available for review and adjustment if necessary. The pump control logic **84** can report multiple pieces of information to a user, the system, or a central server for data collection, storage and analysis. The information can include, but is not limited to, date of installation, warranty registration, warranty possible claims, feedback of problems daily operating conditions, usage statistics, feedback of power supply conditions or quality, detailed profiles of pool pad setups, and information related to other equipment the pump may be controlling. The pump control logic **84** can also automatically register warranties and submit warranty claims should there be an issue with any piece of equipment in the system.

User input data **902** could include timers, schedules (e.g., on/off, speed, duration of operation, how much flow should be provided), turnover goals, turbidity/water clarity goals, etc. Pump operational data **904** could include power consumption, current draw, input voltage, flow (rate), flow (yes/no), temperature, water pressure, air cavitation, water detection, debris sensor, etc. Pump factory specifications **906** could include power consumption current draw, input voltage, life expectancy, etc. Pump configuration parameters **908** could include IP address, GPS coordinates, zip code, time and date, etc. Web data **910** could include location (based on IP address), time and date, sunrise/sunset data, regional and local weather forecast data, ambient temperature, ambient light, humidity, season, elevation, dew point,

etc. For example, the pump control logic **84** could shift the pump timers based on weather input. Pool configuration parameters **912** could include pool surface area, pool geometry, pool liner color, pool cover (yes/no), pool volume, etc. Data from related devices **914** could include data relating to at least the following: strainer(s), pool cover(s), filter(s), chlorinator(s), skimmer(s), pool cleaner(s), water features (e.g., laminar, bubbler, sheer fall, deck jet, fountains, scuppers, waterfall, etc.), heater(s) (gas/heat pump), heat (solar), chemical dispenser(s), disinfectant system(s) (ultraviolet ozone), secondary pump(s), tablet/liquid chlorine feeder(s), valves, controller(s), spa(s), water slide(s), etc. For example, the pump control logic **84** could receive input from an external device to identify an operating profile. In another example, the pump control logic **84** could determine the most efficient turn-over rate based on the volume of the body of water. In yet another example the pump control logic could lower the speed of the pump to prevent a water feature from flooding a closed pool cover. Health monitoring data **916** could include line-to-line balance, grounding, bonding, leak current, runtime, operating temperature, power consumption, predictive failure, operating noise, power cycles, airflow sensor, temperature of cooling, efficiency, settings, troubleshooting data, etc. External sensor data **918**, could include water level, water temperature, water flow speed, suction/vacuum pressure, strainer basket load, airflow sensor or temperature of cooling, pool cover detection, turbidity, valve position, etc. Additionally, the pump control logic can receive heater and pump data trends, learning data, time and speeds used per month, time and duration that a pool cover is open, and various characteristics of pump use. While it may be desirable for external sensors to monitor/provide data on as many system parameters as possible (thereby providing greater optimization, automation, and user/operator comfort), it is contemplated that some systems need not utilize an external sensor to monitor every system parameter. For example, if a temperature sensor has not been installed in a particular system, the user/operator can provide this information by first determining the temperature (e.g., by checking a thermometer, a thermocouple, a weather forecast, the Internet, etc.) and then entering the temperature into the system via a user interface. Using this data, the pump control logic **84** could optimize the operation of the pump by, for example, running based on whether conditions (e.g., windy conditions produce more leaves and thus a need for more skimming), maximizing energy factor (or best efficiency point), communicating errors to the user/dealer/manufacturer, communicating performance to the manufacturer (e.g., usage stats) to calculate system curve to profile pools, providing feedback (e.g., basket is full, bearings going bad, seal starting to leak, etc.), and responding to needs of other equipment (e.g., pump/pump control logic could control actuators or other devices for pool pads with limited equipment (Low voltage control), lighting system, cleaner, high voltage control for booster pump, and hub through direct control or bridge to cloud for pool pad).

The pump could include a software application (accessible via user interface **4562** or on a remote device having a similar user interface), described in greater detail hereinbelow, that delivers enhanced features to the user. For example, the application could define a pool owner's usage and target modes for the user to select from including but not limited to efficiency mode, spa mode, or party mode. Selecting a mode will automatically adjust pump speed or flow accordingly. The application can also allow for seasonal adjustability which will adjust operation of the pump based on the time of year. The application can also monitor the pump and

send a signal or message if the pump has been inoperative for a defined period of time. Sending this message can remind a user to resume operation of a pump if he/she manually stopped it. The application can also report the energy consumption of the pump instantly or in monthly or yearly reports. The application can also provide a single push for pre-loaded programs for the pump. The application can also allow for quick access dynamic language translation. The application can also monitor pump usage, and display a number of “favorite” speeds by the user. The amount of speeds shown can be dependent on the user and does not have to show the maximum number of possible preset speeds. The application can also allow for the quick and easy ability to switch to the last selected program or “last known good” program which is the last program that ran without any errors. The application can send notifications of all activities within the system via Wi-Fi, Bluetooth or similar means. The notifications can include but is not limited to a blocked filter, increase in RPM of the pump, or reporting of loss of prime-protects system. The application can include a page for frequently asked questions for service and troubleshooting of all components in the system 10. The application can further include links to service and troubleshooting videos.

The pumping system or application can also certify that installation is correct and reliable. The application can provide a “certification checklist” and wizard that guides the installer to verify the entire pool pad after configuration. Some items on the checklist can include, but is not limited to, checking whether the correct pump is on the correct relay, verify simulated schedule execution, confirm all equipment is working, confirm user preferences, etc. Once the checklist is completed, the pool is “certified” to be configured and tested and is now ready for use.

FIGS. 19A-19G are flowcharts illustrating processing steps of the pump control logic 84. FIG. 19A is a flowchart illustrating processing logic of the pump control logic 84 communicating with a pump. In step 1000, the pump control logic 84 receives an instruction to activate the pump. In step 1002, the pump logic 84 retrieves data pertaining to factory specified power parameters from memory, e.g., parameters relating to power consumption, current draw, and line voltage. In step 1004, the pump logic 84 receives line power operational data. In step 1006, the pump logic 84 determines whether the line power operational data is within factory specified operation parameters. If a positive determination is made, the process proceeds to step 1012. If a negative determination is made, the process proceeds to step 1008. In step 1012, the pump control logic 84 transmits an instruction to the pump to activate, and the process ends. As referenced above, if a negative determination is made at step 1006, then the process proceeds to step 1008. In step 1008, the pump control logic 84 determines if there are any retries remaining. If a positive determination is made, then the pump control logic 84 proceeds to step 1004 and continues the process from that step. If a negative determination is made, then the pump control logic 84 proceeds to step 1010 and transmits an error condition signal, and then returns to step 1004 to continue the process from that step. For example, in step 1002, the line voltage can be measured, including but not limited to, L1-L2, L1-GND, L2-GND, and in step 1010, pump control logic 84 can report associated issues to the user. In another example, pump control logic 84 can measure the line current in step 1002, and in step 1010, pump control logic 84 can report associated issues to the user. In yet another example, pump control logic 84 can measure the ground leakage current in step 1002, monitor for proper

grounding in steps 1006 and 1008, and report associated issues to the user in step 1010. The pump control logic 84 can also check and verify proper bonding connection (e.g., checking for electrical continuity between the pump and a known good bonding point using a voltage measurement circuit or other known means) in the aforementioned steps.

FIG. 19B is another flowchart illustrating processing logic of the pump control logic 84 communicating with a pump in connection with priming. In step 1020, the pump control logic 84 receives an instruction to activate the pump. In step 1022, the pump logic 84 receives operational data from a pump water detection sensor. In step 1024, the pump logic 84 determines whether water is detected. If a positive determination is made, the process proceeds to step 1029. If a negative determination is made, the process proceeds to step 1025. In step 1029, the pump control logic 84 clears the priming period timer, and the process ends. As referenced above, if a negative determination is made at step 1024, then the process proceeds to step 1025. In step 1025, the pump control logic 84 starts or continues the priming period timer and then proceeds to step 1026 where it determines if there is any time remaining. If a positive determination is made, then the pump control logic 84 proceeds to step 1027 where it decrements the priming timer and then continues to step 1022 to continue the process from that step. If a negative determination is made, then the pump control logic 84 proceeds to step 1028 and transmits an error condition signal indicating that prime has failed, and the process ends.

FIG. 19C is another flowchart illustrating processing logic of the pump control logic 84 communicating with a pump. In step 1030, the pump control logic 84 receives an instruction to activate the pump. In step 1032, the pump logic 84 receives operational data from a debris sensor in a strainer basket. In steps 1034 and 1036, the pump logic 84 determines whether the strainer basket is full. If a positive determination is made, the process proceeds to step 1038 where the pump control logic 84 transmits a message to the user to clean the strainer basket and then returns to step 1032. If a negative determination is made in step 1036, then the pump control logic 84 proceeds to step 1039 and transmits an instruction to the pump to activate, and the process ends.

FIG. 19D is a flowchart illustrating processing logic of the pump control logic 84 determining alert conditions of a pump and subsequently notifying a user or pool professional (e.g., service technician, builders, installers, etc.) of the alert condition. The pump control logic 84 proceeds with four parallel routine sequences that respectively begin with steps 1040, 1050, 1060, and 1070. Each routine sequence is discussed sequentially, though it should be understood that the routine loops could operate in parallel, or alternatively, in series with each other. The sequence beginning with step 1040 monitors the health of the pump (as well as other installed pool equipment, discussed hereinbelow) by monitoring the runtime of the pump and comparing the runtime of the pump with life expectancy data. In step 1040 the pump control logic 84 retrieves factory specified life expectancy data from memory. The factory specified life expectancy data could be provided by the manufacturer as a specified number of hour, days, years, etc. for which the entire pump unit is expected to maintain optimal performance. Alternatively, factory specified life expectancy data could be provided for individual components of the pump unit (e.g., motor bearings, other motor components, etc.) in addition to, or in place of, the entire pump unit, thereby providing users and service providers greater granularity and predictability for maintenance protocols. In step 1042, the pump control

logic 84 determines an alert threshold, e.g., less than 90% of pump life expectancy remaining or runtime value. Alternatively, the alert threshold could be provided by the user, by a pool professional (e.g., service technician, builders, installers, etc.), or by the manufacturer. In step 1044, the pump control logic 84 receives operational data on pump runtime and proceeds to step 1045 where it displays an odometer indicating pump runtime. It is noted that the odometer could also be configured to display the remaining life expectancy of the pump and/or individual components. In step 1046, the pump control logic 84 determines if the pump runtime is greater than the threshold. If a negative determination is made, then the process returns to step 1044 and continues to receive operational data on pump runtime. If a positive determination is made, then the process proceeds to step 1048 where an alert is transmitted to a user, and the process ends. The alert could be a visual and/or audio notification that could be displayed on a user's smart device (e.g., phone, text, or email based). For example, if a user's smartphone is in communication with pump control logic 84, the alerts could be delivered via pop-up notification, text, etc. In addition to describing the problem, the alerts could also suggest possible remedies (e.g., "Excessive Motor Heating—Reduce Speed").

The second sequence begins in step 1050 where the pump control logic 84 retrieves factory specified operating temperature data from memory. The process then proceeds to step 1051 and step 1052. In step 1051, the pump control logic 84 stores the temperature rise (ambient to equipment) in the histogram counters, and proceeds to step 1053. The histogram counters can be bands that indicate temperature rise values, e.g., a first counter band can be a temperature rise of 0-10 degrees, a second counter band can be a temperature rise of 10-20 degrees, a third counter band can be a temperature rise of 20-30 degrees, and a fourth counter band can be a temperature rise of greater than 30 degrees. In step 1053, the pump control logic 84 determines if the temperature rise is too high. If a negative determination is made, then the process returns to step 1051 and continues to store the temperature rise in the histogram counters. If a positive determination is made, then the process proceeds to step 1055 where an alert indicating "excessive motor heating" is transmitted to a user, and the process ends. In step 1052, the pump control logic 84 determines an alert threshold, e.g., a temperature value that is 10% above or below operating temperature. In step 1054, the pump control logic 84 receives operational data on pump operating temperature. In step 1056, the pump control logic 84 determines if the pump operating temperature exceeds the threshold, or is outside of a threshold range. If a negative determination is made, then the process returns to step 1054 and continues to receive operational data on pump operating temperature. If a positive determination is made, then the process proceeds to step 1058 where an alert is transmitted to a user, and the process ends.

The third sequence begins in step 1060 where the pump control logic 84 retrieves factory specified power consumption data from memory. In step 1062, the pump control logic 84 determines an alert threshold, e.g., a power value that is 110% of specified power consumption. In step 1064, the pump control logic 84 receives operational data on pump power consumption. In step 1066, the pump control logic 84 determines if the pump power consumption is greater than the threshold. If a negative determination is made, then the process returns to step 1064 and continues to receive operational data on pump power consumption. If a positive

determination is made, then the process proceeds to step 1068 where an alert is transmitted to a user, and the process ends.

The fourth sequence begins in step 1070 where the pump control logic 84 retrieves factory warranty data from memory, e.g., a warranty expiration date. In step 1072, the pump control logic 84 determines an alert threshold, e.g., days left on factory warranty. In step 1074, the pump control logic 84 receives current date information. In step 1075, the pump control logic 84 determines if the current date is beyond the threshold date or the number of days remaining is below the threshold date. If a negative determination is made, then the process returns to step 1074 and continues to receive current date information. If a positive determination is made, then the process proceeds to step 1076 where an alert is transmitted to a user, and the process ends. In addition to the foregoing, it is contemplated that the pump control logic 84 could also report additional information to the user, pool professional (e.g., service technician, builders, installers, etc.), or manufacturer including runtime, operating temperatures/profile, power consumption, operating noise, number of power cycles, temperature of cooling air (from a pump cooling fan), and degradation of efficiency.

FIG. 19E is another flowchart illustrating processing logic of the pump control logic 84 communicating with a pump. In step 1080, the pump control logic 84 receives an instruction to activate the pump. In step 1082, the pump logic 84 retrieves maximum power consumption setpoint data from pool devices from memory, e.g., maximum combined power consumption for all active devices. In step 1084, the pump logic 84 receives operational data on power consumption from all active devices. In step 1086, the pump logic 84 determines the combined power consumption for active devices. In step 1088, the pump logic 84 determines whether the combined power consumption is below a setpoint. If a positive determination is made, the process proceeds to step 1094. If a negative determination is made, the process proceeds to step 1090. In step 1094, the pump control logic 84 transmits an instruction to the pump to activate, and the process ends. As referenced above, if a negative determination is made at step 1088, then the process proceeds to step 1090. In step 1090, the pump control logic 84 determines if there are any retries remaining. If a positive determination is made, then the pump control logic 84 proceeds to step 1084 and continues the process from that step. If a negative determination is made, then the pump control logic 84 proceeds to step 1092 and transmits a power save notification, and the process ends.

FIG. 19F is another flowchart illustrating processing logic of the pump control logic 84 communicating with a pump. In step 1100, the pump control logic 84 receives an instruction to activate the pump. In step 1102, the pump control logic 84 receives date and time information. In step 1104, the pump control logic 84 determines the current season, e.g., summer. In step 1106, the pump control logic 84 retrieves operational setpoint data for the current season from memory, e.g., schedule, pump power, etc. In step 1108, the pump control logic 84 transmits an instruction to the pump to operate at seasonal operational setpoints.

FIG. 19G is another flowchart illustrating processing logic of the pump control logic 84 communicating with the pump. In step 1110, the pump control logic 84 retrieves setpoint data on the desired pool turnover rate from the memory (e.g., the desired turnovers in a twenty-four hour period). While the desired pool turnover rate can be specified by the user and stored in the memory, it is noted that the turnover rate setpoint data it could also be retrieved from the

web based on the size, geometry, location of the pool, or any combination thereof. In step 1112, the pump control logic 84 retrieves pool configuration data on the volume of the pool from the memory. The pump control logic 84 then, in step 1114, receives operational data on flow rate from external sensors. In step 1116, the pump control logic 84, using the turnover rate setpoint data, the pool configuration data, and the external sensor data, calculates the minimum flow rate to achieve the desired pool turnover rate. In step 1118, the pump control logic 84 transmits an instruction to the pump to operate at a minimum speed to achieve the desired turnover rate, and the process then returns to step 1114. It is noted that by this process, the pump control logic 84 could continuously adjust the speed of the pump throughout the twenty-four hour period based on repeated minimum flow rate calculations.

FIG. 19H is another flowchart illustrating processing logic of the pump control logic 84 communicating with the pump. In step 3700, the pump control logic 84 receives an instruction to activate the pump. In step 3702, the pump control logic 84 retrieves data on factory specified power parameters from memory. Some examples of power parameters include, but is not limited to, power consumption, current draw, line voltage, line current, ground leakage current, proper bonding, etc. In step 3704, the pump control logic 84 received operational data of the pump, including but not limited to, L1-L2, L1-GND, and L2-GND. In step 3706, the pump control logic 84 compares whether the operational data is within the specified operating parameters of the pump. If a positive determination is made, the pump control logic 84 proceeds to step 3708 where the pump control logic 84 transmits an instruction to activate the pump and the process ends. If a negative determination is made, the pump control logic 84 proceeds to step 3710 where it decides whether retries are remaining. If a positive determination is made, the pump control logic 84 proceeds back to step 3704 where it receives operational data on the pump. If a negative determination is made, the pump control logic 84 proceeds to step 3712 where an error condition is transmitted and the process proceeds back to step 3704. The above process can measure all parameters related to electrical power of the pump and can indicate any type of issue to the user.

FIG. 19I is another flowchart illustrating processing logic of the pump control logic 84. In step 3714, the pump control logic 84 receives an instruction to monitor or measure the water level in a pump. In step 3716, the pump control logic 84 retrieves data on factory specified parameters from memory for the water level in a pump. In step 3718, the pump control logic 84 receives operational water level data in the pump and in the strainer housing. In step 3720, the pump control logic 84 decides whether the water level data is within the factory specified operating parameters. If a positive determination is made, the pump control logic 84 proceeds to step 3722. If a negative determination is made, the pump control logic 84 proceeds to step 3728. In step 3722, the pump control logic 84 determines whether the water level has been an issue for a set amount of time. If a negative determination is made, the pump control logic 84 will proceed to step 3724 where the speed of the pump is increased periodically. If a positive determination is made, the pump control logic 84 will proceed to step 3726 where it will indicate to the user that there is an air leak in the suction side plumbing. In step 3728, the pump control logic 84 will transmit a message to the user or system that the water level data is within the factory specified parameters.

FIG. 19J is another flowchart illustrating processing logic of the pump control logic 84. In step 3730, the pump control

logic 84 receives an instruction to monitor or measure water flow in the pump. In step 3732, the pump control logic 84 retrieves data on the factory specified parameters from memory for the water flow in the pump. In step 3740, the pump control logic 84 receives operational flow data in the pump. In step 3742, the pump control logic 84 determines whether the flow data is within the range for the factory specified operational parameters. Step 3742 can further be associated with cavitation detection. If a negative determination is made, the pump control logic 84 proceeds to steps 3744, and if a positive determination is made, the pump control logic 84 proceeds to step 3746. In step 3744, the pump control logic 84 determines whether retries are remaining. If there are no retries remaining, the pump control logic 84 proceeds to step 3748 to transmit an error condition and if there are retries remaining, the pump control logic 84 proceeds back to step 3740. In step 3746, the pump control logic 84 transmits a message to the user or the system that the flow data is within the factory specified parameters.

FIG. 19K is another flowchart illustrating processing logic of the pump control logic 84. In step 3750, the pump control logic 84 receives an instruction to monitor or measure the water temperature. In step 3752, the pump control logic 84 retrieves data on the factory specified parameters from memory for the water temperature. In step 3754, the pump control logic 84 receives operational data of water temperature and set point temperature data. In step 3756, the pump control logic 84 determines whether the water temperature is within the set point and/or factory parameters. If a positive determination is made, the pump control logic 84 proceeds to step 3758 where the pump control logic 84 transmits a message to the user that the water temperature is within the factory specified or set point parameters and the process would end thereafter. If a negative determination is made, the pump control logic 84 proceeds to step 3760 where the pump control logic 84 performs a function or changes the pump operation to maintain a factory or set point water temperature. In step 3762, the pump control logic 84 transmits a message to the user or the system that the pump control logic 84 has performed some function or changed the pump operation to maintain a factory or set point water temperature.

FIG. 19L is another flowchart illustrating the processing logic of the pump control logic 84. In step 3764, the pump control logic 84 receives an instruction to monitor or measure the water chemistry. In step 3766, the pump control logic 84 retrieves data on factory specified parameters from memory for the water chemistry. In step 3768, the pump control logic 84 receives operation data regarding the water chemistry. In step 3770, the pump control logic 84 determines whether the water chemistry is within factory specified operating parameters. If a positive determination is made, the pump control logic 84 proceeds to step 3772 where the pump control logic 84 transmits a message to the user that the water chemistry is within the specified operating parameters. If a negative determination is made, the pump control logic 84 proceeds to step 3774 where the pump control logic 84 determines whether the pool chemistry is maintained by a separate device. If a positive determination is made, the pump control logic 84 proceeds to step 3776 where the pump control logic 84 communicates with the other device to determine what the device needs for proper operation. If a negative determination is made, the pump control logic 84 proceeds to step 3778 directly or after step 3776. In step 3778, the pump control logic 84 performs a function or changes operation of the pump to maintain the

proper water chemistry based on the step 3776 or the set point parameters retrieved from memory. In step 3780, the pump control logic 84 transmits a message to the user or the system that attention may be needed regarding the water chemistry.

FIG. 19M is another flowchart illustrating the processing logic of the pump control logic 84. In step 3782, the pump control logic 84 receives an instruction to detect a gasket leak or a shaft seal leak. In step 3784, the pump control logic 84 receives operational data from a sensor in the gasket or shaft seal. In step 3786, the pump control logic 84 determines if there is a gasket or shaft seal leak. In step 3788, the determination is made whether there is in fact a gasket or shaft seal leak. If a negative determination is made, the pump control logic 84 proceeds to step 3790 and will transmit a message to the user or system that there is no leak. If a positive determination is made, the pump control logic 84 will transmit a message in step 3792 that the user should fix the leak.

FIG. 19N is another flowchart illustrating the processing logic of the pump control logic 84. In step 3794, the pump control logic 84 retrieves factory specified life expectancy data of the shaft seal from memory. In step 3796, the pump control logic 84 determines the alert threshold for the life expectancy of the shaft seal. For example, a 90% threshold will alert the user when 90% of the life expectancy of the shaft seal is reached. In step 3798, the pump control logic 84 will receive operational data on the shaft seal runtime. In step 3880, the pump control logic 84 will determine whether the runtime is greater than the threshold with regard to the life expectancy data. If a negative determination is made, the pump control logic 84 will go back to step 3798. If a positive determination is made, the pump control logic 84 will proceed to step 3882 and transmit a message to the user regarding the remaining shaft seal shelf life so that the user can proactively address the shaft seal before a leak occurs.

FIG. 19O is another flowchart illustrating the processing logic of the pump control logic 84. In step 3884, the pump control logic 84 receives an instruction to determine the cleanliness of the filter. In step 3886, the pump control logic 84 retrieves data on the factory specified parameters from memory for debris in the filter and energy consumption of the pump. In step 3888, the pump control logic 84 receives operational data from the sensors in the filter and energy consumption in the pump. In step 3890, the pump control logic 84 determines the cleanliness of the filter based on the debris in the filter. In step 3892, the pump control logic 84 makes a determination as to whether the filter needs to be serviced. If a negative determination is made, the pump control logic 84 in step 3894 will determine if the energy consumption of the pump exceeds a factory or user set threshold, and if it does, the process ends and if it does not, then in step 3896, the pump control logic 84 can adjust the flow to maintain a flow rate based on the amount of debris in the filter. If a positive determination is made in step 3892, the pump control logic 84 in step 3898 will transmit a message to the user or system to service the filter (e.g., clean the cartridge). In step 3900, the pump control logic 84 will determine whether the user took action to service the filter. If a negative determination is made, the pump control logic 84 will proceed to step 3902 to adjust the pump operation to maintain a flow rate needed by the rest of the system 10. If a positive determination is made, the pump control logic 84 will skip step 3902 and will proceed directly back to step 3888.

FIG. 19P is a flowchart illustrating processing steps carried out by the pump control logic 84 for periodically

testing and advising the user of the variance from a “clean filter” state. For example, pump control logic 84 can periodically enter a “test” filter system state where the pool/spa equipment go to predetermined positions/states/speeds for testing the filter. In step 3904, pump control logic 84 monitors for a “clean filter” condition (e.g., operational data from filter or input from a user, servicer, or installer, etc.). For example, a skimmer could communicate (using and of the data communication protocols disclosed herein) to pump control logic 84 that the filter has been cleaned or replaced, or the user could utilize an input device to indicate to pump control logic 84 that the filter has been cleaned or replaced. In step 3906, pump control logic 84 determines if a “clean filter” condition has been received. If a negative determination is made in step 3906, pump control logic 84 returns to step 3904. If a positive determination is made in step 3906, pump control logic 84 proceeds to step 3908, where pump control logic 84 retrieves “test” filter system state setpoints (e.g., valve position, pump speed, etc.) from the memory. In step 3910, pump control logic 84 transmits an instruction to the installed pool/spa equipment to operate at the “test” setpoints. In step 3912, pump control logic 84 receives current operational data from the filter. In step 3914, pump control logic 84 determines if there are (1) retries remaining. If a positive determination is made in step 3914, pump control logic 84 proceeds to step 3916 and saved the “clean filter” operational data to the memory. Thus, after pump control logic 84 receives a “clean filter” condition, the pool/spa equipment enters a “test” system state and records the current operational data from the filter to the memory as a baseline measurement for future comparison. If a negative determination is made in step 3914, pump control logic 84 proceeds to step 3918, where pump control logic 84 computes the variance from the “clean filter” operational data. Optionally, in step 3920, pump control logic 84 could transmit a message to (e.g., advise) the user (e.g., “Filter Health ## %”). In step 3922, pump control logic 84 transmits instructions to the installed pool/spa equipment to resume normal operation. In step 3924, the logic is delayed for X seconds, wherein X is any suitable integer (e.g., 5, 10, 3600, etc.), and the process then reverts to step 3908.

FIG. 19Q is a flowchart illustrating processing steps carried out by the pump control logic 84 for determining if debris is interfering with operation of the pump. For example, in step 3926, pump control logic 84 retrieves setpoint data on the acceptable debris level at a pump component(s) from memory. This setpoint data could be provided by the pump manufacturer, or alternatively, could be set by the user. In step 3928, pump control logic 84 receives operational data on debris at the pump component(s). It is noted that the pump control logic could monitor one or more individual components (e.g., the impeller, shaft seal, and motor shaft) of the pump and could further monitor one or more parameters associated with each component (e.g., the level of debris in the impeller and/or rotational speed of the impeller). For example, pump control logic 84 could determine if there is debris trapped in the impeller by monitoring motor current, motor power consumption, or by using an accelerometer to determine an increase in motor vibration. In step 3930, pump control logic 84 determines if the level of debris at the pump component(s) is below the setpoint. If a positive determination is made in step 3930, pump control logic 84 returns to step 3928. If a negative determination is made in step 3930, pump control logic 84 proceeds to step 3932, where pump control logic 84 determines if there are retries remaining. If a positive determination is made in step 3932, pump

control logic **84** returns to step **3928**. If a negative determination is made in step **3932**, pump control logic **84** proceeds to step **3934**, where pump control logic **84** transmits an instruction to the user (e.g., “Clean Impeller”). While the foregoing process has been discussed in terms of monitoring debris, it is also contemplated that pump control logic **84** can monitor additional parameters and alert the user when these parameters have exceeded their respective setpoints using similar processing steps. For example, in addition to monitoring the level of debris trapped in the impeller, discussed above, pump control logic **84** could also monitor rotational speeds of the components, determine whether debris is causing physical interference with the rotation of the impeller, shaft seal, or motor shaft, and then transmit an instruction to the user to address the issue (e.g., “Binding in Impeller—Clear Debris”). For example, pump control logic **84** could monitor motor current, power consumption, and receive operational data from an accelerometer to determine an increase in motor vibration (thereby indicating physical interference/binding of the impeller). Further still, instead of alerting the user when an operational parameter has exceeded its respective operational setpoint, pump control logic **84** could alter the operation of the pump to restore normal operation. For example, in the case of a variable speed drive, pump control logic **84** could monitor the humidity of the air inside the variable speed drive enclosure and adjust its operating condition to minimize humidity, thereby increasing reliability. For example, pump control logic **84** could receive operational data from a humidity sensor located within the variable speed drive enclosure. If pump control logic **84** determines that the humidity within the variable speed drive enclosure is above a maximum setpoint value, pump control logic **84** could transmit an instruction to the variable speed drive to increase the speed of operation, thereby drying out the air within the enclosure (due to increased temperature of certain electrical components within the enclosure precipitated by the increase in operating speed).

FIGS. **19R** and **19S** are flowcharts illustrating processing steps carried out by the pump control logic **84** for assisting the user in determining the pump setpoints that should be used based on the user’s installed equipment and preferences. It is contemplated that pump control logic **84** could include a wizard-based application that is accessible by the user via a human machine interface installed on the pump, centralized pool/spa control system, smartphone/device, web browser, or any other means for communicating with the system, disclosed herein. For example, in step **3936**, pump control logic **84** prompts the user to specify installed pool/spa equipment and operational parameters therefore (e.g., minimum skimmer speed/flow, number of skimmers, minimum heater speed/flow, has heater, heat pump, solar, etc.). Alternatively, the application could utilize widely-known bar scanning technology (e.g., utilizing/in combination with a camera of smart device), enabling the user to simply scan the barcode of each piece of installed equipment thereby avoiding the necessity of manual entry. Pump control logic **84** could then retrieve additional information (e.g., specifications, setpoints, warranty information, etc.) on the scanned equipment from a remote location (e.g., a remote server) using any suitable communication protocol described herein (e.g., accessing the internet vial a home Wi-Fi router). In step **3938**, pump control logic **84** prompts the user to specify the desired pool/spa activities (e.g., bathing, swimming, water sports, etc.). For example, pump control logic **84** could present the user with a list of pre-programmed activities from which to choose, the user

could search a database of pre-programmed activities, or the user could program custom activities and save the same to memory for later retrieval and use. In step **3940**, pump control logic **84** determines an acceptable range of speed setpoints for the pump (e.g., speed/flow for all pump related features). In step **3942**, pump control logic **84** presents the acceptable speed presets to the user and then prompts the user to select desired/optimal setpoints for the pump and in step **3944**, pump control logic **84** stores the user selected pump setpoints to memory and the process then ends. Optionally, as shown in steps **3950-3954**, the wizard could assist the user in selecting the desired/optimal pump setpoints by stepping through multiple actual pump speeds/flows so that the user can “choose” a desired speed/flow while observing the effect of the different speeds/flows on the actual pool/spa environment. For example, after determining the acceptable speed setpoints for the pump in step **3940**, pump control logic **84** could then proceed to step **3950**, where an instruction is transmitted to the pump to operate at an (acceptable) first (1st) speed. In step **3952**, pump control logic **84** transmits an instruction to the pump to operate at an (acceptable) second (2nd) speed. In step **3954**, pump control logic **84** transmits an instruction to operate the pump at another (acceptable) speed. Pump control logic **84** then proceeds to step **3942**, described hereinabove. It is noted that any number of acceptable speeds can be presented to the user. Accordingly, because the application could be run, viewed, or accessed on a mobile device (e.g., not tethered to a specific location) the wizard/application enables the user to stand poolside, watching features as speeds/flows are automatically displayed by pump control logic **84** or selected by the user/installer for each prompt. The wizard/application also enables the user/installer to stand at the equipment pad, watching equipment function (e.g., heater ignition) as the pump steps through various speeds/flows. Optionally, as shown in steps **3946** and **3948**, pump control logic **84** could sense and/or advise of a maximum speed/flow beyond which the pump cavitates or reaches an undesirable inflection point in energy consumption/efficiency. For example, pump control logic **84** could determine the maximum speed/flow beyond which the pump cavitates using operational data received from an accelerometer, optical sensor, or other means. In step **3946**, pump control logic **84** determines if the user selected setpoints are causing pump cavitation. If a negative determination is made in step **3946**, pump control logic **84** proceeds to step **3944**, discussed hereinabove. If a positive determination is made in step **3946**, pump control logic **84** proceeds to step **3948**, where an alert is transmitted to the user. Alternatively, the system could determine speeds at which the pump cavitates beforehand and remove the speeds at which the pump cavitates from the acceptable setpoints that are presented to the user in step **3942**. Also optionally, pump control logic **84** could suggest to the user alternative modes of operation (e.g., other than that selected by the user) that either improve the reliability of one or more pieces of installed pool/spa equipment, or improve the efficiency of one or more pieces of installed pool/spa equipment, individually, or as a whole system. For example, other pieces of installed pool/spa equipment could communicate with the pump control logic **84** and advise of optimum performance criteria. This logic could reside in other installed pool/spa equipment and be communicated to the pump, or the logic could be contained within the pump itself.

FIG. **19S** is a flowchart illustrating processing steps carried out by the pump control logic **84** for automatically determining the pump setpoints that should be used based on

the user's installed equipment and preferences. According to this embodiment, pump control logic **84** is able to "auto detect" equipment that is installed and automatically determine how the system should be run based on a variety of optimization choices (e.g., energy consumption, water feature performance, heating preferences, etc.). In step **3956**, pump control logic **84** prompts the user to specify desired pool/spa activities (e.g., bathing, swimming, water sports, etc.). As described above, pump control logic **84** could present the user with a list of pre-programmed activities from which to choose, the user could search a database of pre-programmed activities, or the user could program custom activities and save the same to memory for later retrieval and use. In step **3958**, pump control logic **84** receives operational data from pool/spa equipment. In step **3960**, pump control logic **84** determines what pool/equipment has been installed, using the received operational data therefrom. In step **3962**, pump control logic **84** retrieves the installed equipment setpoints (e.g., minimum flow and/or pressure for heater operation) from memory. Using the equipment setpoints, in step **3964**, pump control logic **84** then determines the optimal speed setpoints for the pump based on all of the installed equipment. For example, pump control logic **84** could estimate the necessary pump speed. Alternatively, pump control logic **84** could step through various speeds/flows and receive operational data from the installed equipment (e.g., heaters, water features, valves, etc.) when there is sufficient flow and/or pressure for operation. Pump control logic **84** then proceeds to step **3966**, where pump control logic **84** stores the pump setpoint data to memory, and then the process ends. It is also contemplated that, in addition to pump speed, pump control logic **84** could capture the correct valve positions for delivering the required flow and/or pressure. Pump control logic **84** could also search for signals from any smart utility, radio frequency, Wi-Fi, cellular, Bluetooth, geo-positioning, etc. that provides data for energy costs, energy discount periods, peak demand, etc. (see FIG. **33T**). Pump control logic **84** could then use this data to optimize performance and/or energy costs.

In addition to the foregoing, the application/wizard could walk the user through multiple steps for different installation modes, such as relay control or connection to pool/spa automation controllers (e.g., Hayward automation), and could indicate supported software levels of the pool/spa automation controllers. The application could also access dealer-defined programs/schedules via the cloud and then download the programs/scheduled to the pump for local installation. Although pump control logic **84** could operate according to a dealer-defined or user-defined schedule, pump control logic **84** is capable of determining when pool/spa equipment requires a flow that deviates from the normal schedule (e.g., due to user interaction, weather patterns, addition of pool/spa equipment, etc.) and automatically adjusting the pump flow/speed therefore. The application could further provide the user/installer with answers to frequently asked questions (i.e., FAQs) for the installation process as well as for individual pieces of pool/spa equipment, installation videos (either stored locally or as links accessible through communication protocols discussed herein), and can serve as a dynamic "quick start guide." Pump control logic **84** could also serve as an Automated Engineered pool system solution for areas having regulations, such as in Florida (e.g., reports and/or calculates total dynamic head and/or flow). As described herein, an "Automated Engineered" pool system solution is one that automatically derives Total Dynamic Head ("TDH") by measur-

ing key metrics. For example, it could measure suction head (negative pressure) on the vacuum side of the pump and measure the pressure head on the pressure side of pump, both measurement devices being integral or adjacent to the pump, to derive Total Dynamic Head. Further, an overall System Curve (TDH vs. flow) could be estimated or calculated from a single point or generated when measured at multiple speeds when using a multi-speed pump.

FIG. **19T** is a flowchart illustrating processing steps carried out by the pump control logic **84** for recording baseline performance data for future reference. More specifically, once the initial installation of the pool equipment is complete (see FIGS. **19R** and **19S**), pump control logic **84** can record initial operational data from the installed equipment. For example, in step **3968**, pump control logic **84** determines if the user has completed the installation wizard (see FIGS. **19R** and **19S**). If a negative determination is made in step **3968**, pump control logic **84** repeats step **3968**. If a positive determination is made in step **3968**, pump control logic **84** proceeds to step **3970**, where pump control logic **84** receives operational data from installed pool/spa equipment (e.g., pump performance, motor performance, sound levels, etc.). In step **3972**, pump control logic **84** saves the operational data to the memory as baseline performance data. This baseline performance data could be used, for example, in combination with the health monitoring pump control logic **84** processing steps shown in FIG. **19D** or as illustrated in FIG. **19U**, discussed hereinbelow.

FIG. **19U** is a flowchart illustrating processing steps carried out by the pump control logic **84** for determining pump health by comparing baseline performance data and current operational data. In step **3974**, pump control logic **84** retrieves baseline performance data (e.g., pump performance, motor performance, sound levels, etc.) from the memory. In step **3976**, pump control logic **84** determines an alert threshold (e.g., performance down 10%, sound level increase 10%, etc.). In step **3978**, pump control logic **84** receives current operational data from the installed pool/spa equipment and/or other connected devices (e.g., sound level from microphone located at the pump). In step **3980**, pump control logic **84** calculates the change (e.g., delta) from the baseline performance data. In step **3982**, pump control logic **84** determines if the change from baseline performance is greater than the threshold. If a negative determination is made in step **3982**, pump control logic **84** returns to step **3978**. If a positive determination is made in step **3982**, pump control logic **84** proceeds to step **3984**, where pump control logic **84** determines if there are retries remaining. If a positive determination is made in step **3984**, pump control logic **84** returns to step **3978**. If a negative determination is made in step **3984**, pump control logic **84** proceeds to step **3986**, where an alert is transmitted to the user (e.g., "Service Pump"). The process then ends.

FIG. **19V** is a flowchart illustrating processing steps carried out by the pump control logic **84** for determining current weather conditions. In step **3988**, pump control logic **84** receives an IP address from a smart device on a local network. In step **3990**, pump control logic **84** receives location data based on the IP address (e.g., web data/geolocation provider). In step **3992**, pump control logic **84** receives web data on current weather conditions (based on ZIP code, location/address, or GPS coordinates, discussed hereinbelow). It is noted that pump control logic **84** can receive web data through any wired and/or wireless communication protocols disclosed herein. Current weather conditions can include, for example, temperature, precipitation, wind speed, wind direction, etc. Web data on current weather

conditions could also include live 3rd party data, for example, live weather maps of precipitation and cloud cover. In step 3994, pool pump control logic 84 saves the current weather conditions to the memory for later retrieval. In step 3996, pump control logic 84 is delayed by X seconds, wherein X is any suitable integer (e.g., 5, 10, 3600, etc.) and then the process returns to step 3988. Optionally, in step 3998, pump control logic 84 could transmit an instruction to the user to enter a ZIP code via a user interface device and in step 4000, pump control logic 84 could receive the ZIP code data from the user interface device. In step 4002, pump control logic 84 could also/alternatively receive GPS data from a smart device on the local network (e.g., smart phone connected to home Wi-Fi). While the foregoing is discussed in connection with pump control logic 84 obtaining current weather information from a remote source (e.g., the internet), it is contemplated that pump control logic 84 could obtain current weather information from local sources as well (e.g., receive operational data from local temperature sensors/thermocouples, wind meters/anemometers, rain gauges/ombrometers, etc.).

Pump control logic 84 can receive web data on future/forecasted weather conditions (e.g., 7-day forecasts, almanacs, etc.), in addition to current weather forecasts. FIG. 19W is a flowchart illustrating processing steps carried out by the pump control logic 84 for determining forecasted weather conditions. Although the processing steps shown in FIGS. 19V and 19W are discussed sequentially, it should be understood that the processing steps carried out by pump control logic 84 in FIGS. 19V and 19W could operate in parallel, or alternatively, in series with each other. In step 4004, pump control logic 84 receives an IP address from a smart device on a local network. In step 4006, pump control logic 84 receives location data based on the IP address (e.g., web data/geolocation provider). In step 4008, pump control logic 84 receives web data on forecasted weather conditions (based on ZIP code, location/address, or GPS coordinates, discussed hereinbelow). It is noted that pump control logic 84 can access receive web data through any wired and/or wireless communication protocols disclosed herein. Forecasted weather conditions can include, for example, temperature, precipitation, wind speed, wind direction, etc. Web data on forecasted weather conditions could also include live 3rd party data, for example, live weather maps of precipitation and cloud cover. In step 4010, pool pump control logic 84 saves the forecasted weather conditions to the memory for later retrieval. In step 4012, pump control logic 84 is delayed by X seconds, wherein X is any suitable integer (e.g., 5, 10, 3600, etc.) and then the process returns to step 4004. Optionally, in step 4014, pump control logic 84 could transmit an instruction to the user to enter a ZIP code via a user interface device and in step 4016, pump control logic 84 could receive the ZIP code data from the user interface device. In step 4018, pump control logic 84 could also/alternatively receive GPS data from a smart device on the local network (e.g., smart phone connected to home Wi-Fi).

FIG. 19X is a flowchart illustrating processing steps carried out by pump control logic 84 for instructing the pump to run higher load operating modes during cooler times of the day if higher than normal temperatures are expected. In step 4020, pump control logic 84 receives current date and time data (e.g., from internal clock, as web data, etc.). In step 4022, pump control logic 84 retrieves forecasted weather conditions (e.g., hourly forecast) for the current date. The forecasted weather conditions can be obtained by way of the process described herein, in connection with FIG. 19W. In step 4024, pump control logic 84

retrieves the pump schedule for the current date from the memory. In step 4026, pump control logic 84 identifies periods (e.g., times of day) of high load operating conditions in the pump schedule. In step 4028, pump control logic 84 identifies periods of forecasted high temperatures (e.g., times of day above 80° F.). In step 4030, pump control logic 84 determines if the periods of forecasted high temperatures and high load conditions coincide. If a negative determination is made (e.g., the pump will not be running at a high-load during periods of high temperature) in step 4030, pump control logic 84 returns to step 4020. If a positive determination is made (e.g., the pump will be running at a high-load during periods of high temperature) in step 4030, pump control logic 84 proceeds to step 4032, where periods of forecasted low temperatures (e.g., times of day below 70° F.) are identified. Pump control logic 84 then proceeds to step 4034, where the pump schedule is modified so that the higher load operating modes run during periods of forecasted low temperatures. In step 4036, pump control logic 84 saves the modified pump schedule to the memory. Pump control logic 84 then returns to step 4020.

FIG. 19Y is a flowchart illustrating processing steps carried out by pump control logic 84 for automated operation of pool devices based on current weather conditions (e.g., periods of heavy rain). In step 4038, pump control logic 84 retrieves current weather conditions (e.g., precipitation, wind speed, etc.) data from the memory. The current weather conditions can be obtained by way of the process described herein, in connection with FIG. 19V. In step 4040, pump control logic 84 retrieves maximum precipitation setpoint data from memory. In step 4042, pump control logic 84 determines if the current amount of precipitation is above the maximum precipitation setpoint. If a positive determination is made, the process proceeds to step 4044, where pump control logic 84 transmits an instruction to the pump to suspend operation (e.g., preventing damage due to water ingress). Optionally, in step 4046, pump control logic 84 could transmit an instruction to disconnect power to high voltage circuits. The process then reverts to step 4038. If a negative determination is made in step 4042, the process proceeds to step 4048, where pump control logic 84 determines if the operation of any pool devices (e.g., pump, smart relays, smart circuit breaker, etc.) has been altered due to the weather condition (e.g., heavy precipitation). If a negative determination is made, the process reverts to step 4038. If a positive determination is made, the process proceeds to step 4050, where pump control logic 84 transmits an instruction to revert to regular operation of the pool device(s). Optionally, in step 4052, pump control logic 84 could transmit a message to the user (e.g., "precipitation subsided"). The process then reverts to step 4038. In addition to the foregoing, it is also contemplated that pump control logic 84 could suspend operation in advance of periods of heavy precipitation by monitoring the forecasted weather conditions and suspending operation before the precipitation begins.

FIG. 19Z is a flowchart illustrating processing steps carried out by the pump control logic 84 for automated operation of pool devices based on current weather conditions (e.g., high winds). In step 4054, pump control logic 84 retrieves current weather conditions (e.g., wind speed) data from the memory. The current weather conditions can be obtained by way of the process described herein, in connection with FIG. 19V. In step 4056, pump control logic 84 retrieves maximum wind speed setpoint data from memory. In step 4058, pump control logic 84 determines if the current wind speed is above the maximum wind speed setpoint. If a positive determination is made, the process proceeds to step

4060, where pump control logic 84 transmits an instruction to the pump to increase circulation, thereby providing better skimmer performance. Optionally, in step 4062, pump control logic 84 could transmit an instruction to actuate a smart valve(s). As referred to herein, smart valves (or smart valve actuators) include an actuator which rotates valves in response to a control signal from pool control logic 70 (e.g., water feature control logic 72, valve actuator control logic 74, cleaner control logic 76, lighting control logic 78, heater control logic 80, chemistry automation control logic 82). Accordingly, smart valves could be utilized in any application that requires the automated operation of valves in a pool/spa environment. For example, actuation of smart valves by pump control logic 84 could thereby automatically engage pool/spa operation, solar heating, pool cleaners, water features, provide additional flow to the skimmer(s), and/or decrease flow from the suction outlets during periods of high winds. Also optionally, in step 4064, pump control logic 84 could further detect accumulated debris at pool/spa equipment (e.g., motor fan inlet) and in step 4066, pump control logic 84 could transmit an alert to the user (e.g., "Remove Debris from Motor Fan Inlet"). The process then reverts to step 4054. If a negative determination is made in step 4058, the process proceeds to step 4068, where pump control logic 84 determines if the operation of any pool devices has been altered due to the weather condition (e.g., high winds). If a negative determination is made, the process reverts to step 4054. If a positive determination is made, the process proceeds to step 4070, where pump control logic 84 transmits an instruction to revert to regular operation of the pool device(s). Optionally, in step 4072, pump control logic 84 could transmit a message to the user (e.g., "Wind Has Subsided"). The process then reverts to step 4054.

FIG. 19AA is a flowchart illustrating processing steps carried out by pump control logic 84 for automatically adjusting pump speed/flow for cleaning a pool/spa in response to a weather condition (e.g., high winds). More specifically, pump control logic 84 can manage and/or respond to heavy debris/particulate sources (e.g., trees, vegetation, dust, etc.) up-wind of the pool/spa area by adjusting the pump speed or flow, based on wind speed and/or direction. For example, in step 4074, pump control logic 84 retrieves current weather conditions (e.g., wind speed, direction) data from the memory. The current weather conditions can be obtained by way of the process described herein, in connection with FIG. 19V. In step 4076, pump control logic 84 retrieves maximum wind speed setpoint data from memory. In step 4078, pump control logic 84 determines if the current wind speed is above the maximum wind speed setpoint. If a positive determination is made, the process proceeds to step 4080, where pump control logic 84 retrieves skimmer location data from the memory. The skimmer location data can be obtained by way of the process described herein, in connection with FIG. 33A. In step 4082, pump control logic 84 determines the most downwind skimmer(s). In step 4084, pump control logic 84 transmits an instruction to increase the flow to the downwind skimmer(s) and the process then reverts to step 4074. The flow to the downwind skimmer(s) can be increased in various ways, including, but not limited to, transmitting an instruction to the pump to increase the pump speed, and transmitting an instruction to a smart valve to actuate, thereby adjusting to a position that optimizes flow to the skimmer. Optionally, in step 4086, pump control logic 84 could transmit an instruction to deactivate or reduce water features (e.g., decrease pump speed, adjust valve positions to reduce flow, etc.), thereby preventing splash-out. If a nega-

5 tive determination is made in step 4078, the process proceeds to step 4088, where pump control logic 84 determines if the operation of any pool devices (e.g., pump, smart valves, etc.) have been altered due to the weather condition (e.g., high winds). If a negative determination is made in step 4088, the process reverts to step 4074. If a positive determination is made in step 4088, pump control logic 84 proceeds to step 4090, where pump control logic 84 transmits an instruction to revert to regular operation of the pool device(s). Optionally, in step 4092, pump control logic 84 could transmit a message to the user (e.g., "Wind Has Subsided"). The process then reverts to step 4074.

FIG. 19AB is a flowchart illustrating processing steps carried out by pump control logic 84 for automatically adjusting operation of the pump in response to weather conditions (e.g., ambient temperature, wind speed, and/or wind chill) to provide freeze protection. This enables pump control logic 84 to provide a lower, more energy efficient setpoint (e.g., minimum speed and temperature). In step 4094, pump control logic 84 retrieves current weather conditions data from memory (e.g., ambient temperature, wind speed, and/or wind chill). The current weather conditions can be obtained by way of the process described herein, in connection with FIG. 19V. In step 4096, pump control logic 84 receives operational data from the pump (e.g., pump speed/flow). In step 4098, pump control logic 84 determines if there is a freeze risk based on the current weather conditions and the speed/flow of the pump. If a negative determination is made (e.g., there is no freeze risk) in step 4098, pump control logic 84 returns to step 4094. If a positive determination is made (e.g., there is a freeze risk) in step 4098, pump control logic 84 transmits an instruction to the pump to increase speed/flow. Pump control logic 84 then reverts to step 4094.

FIG. 19AC is a flowchart illustrating processing steps carried out by pump control logic 84 for adjusting the operation of the pump to meet the needs of other pool/spa equipment. For example, pump control logic 84 could increase the speed/flow of the pump in response to an increase in the output of the heater, necessitated by a drop in ambient temperature (e.g., heater output increased to maintain desired pool/spa temperature). In step 4102, the heater output is increased (e.g., due to a drop in ambient temperature). In step 4104, pump control logic 84 receives operational data from the heater (e.g., current or requested BTU output). In step 4106, pump control logic 84 determines if an increase in pump speed/flow is required based on the operational data received from the heater. If a negative determination is made in step 4106, pump control logic 84 returns to step 4104. If a positive determination is made in step 4106, pump control logic 84 proceeds to step 4108, where an instruction is transmitted to the pump to increase speed/flow. Pump control logic 84 then returns to step 4104. While the foregoing process steps are discussed in connection with the pump control logic 84 adjusting the operation of the pump in response to the needs of the heater during a drop in ambient temperature, it is contemplated that pump control logic 84 can adjust the operation of the pump in response to the needs of any of the installed pool/spa equipment disclosed herein.

FIG. 19AD is a flowchart illustrating processing steps carried out by the pump control logic 84 for determining and running a mode of operation based on the time of day (e.g., daytime or evening) or time of year (e.g., season). In step 4110, pump control logic 84 receives an IP address from a smart device on a local network. In step 4112, pump control logic 84 receives location data based on the IP address (e.g.,

web data/geolocation provider). In step 4114, pump control logic 84 receives web data on sunrise/sunset times (based on ZIP code, location/address, or GPS coordinates, discussed hereinbelow). It is noted that pump control logic 84 can receive web data through any wired and/or wireless communication protocols disclosed herein. In step 4116, pump control logic 84 saves the sunrise/sunset data to the memory for later retrieval. In step 4118, pump control logic 84 receives current time and date data (e.g., from web or internal clock). In step 4120, pump control logic 84 determines if the current time is between sunrise and sunset (e.g., daytime). If a positive determination is made in step 4120, pump control logic 84 proceeds to step 4122, where pump control logic 84 retrieves equipment setpoints for a daytime operation mode (e.g., pump speed/flow during the day). In step 4124, pump control logic 84 transmits instructions to installed pool/spa equipment to operate at the retrieved setpoints and then pump control logic 84 returns to step 4118. If a negative determination is made in step 4120, pump control logic 84 proceeds to step 4126, where pump control logic 84 retrieves equipment setpoints for an evening operation mode (e.g., pump speed/flow during the evening) and then pump control logic 84 proceeds to step 4124, discussed hereinabove. While the foregoing process steps have been discussed in terms of selecting a mode of operation based on the time of day, it is also contemplated that pump control logic 84 could select the mode of operation based on the time of year (e.g., season). Furthermore the modes of operation could be pre-programmed (e.g., default seasonal modes of operation/programming provided by the manufacturer, pool professional (e.g., service technician, builders, installers, etc.)) or user-defined (e.g., customized modes of operation based on the time of day or season). Optionally, in step 4128, pump control logic 84 could transmit an instruction to the user to enter a ZIP code via a user interface device and in step 4130, pump control logic 84 could receive the ZIP code data from the user interface device. In step 4132, pump control logic 84 could also/alternatively receive GPS data from a smart device on the local network (e.g., smart phone connected to home Wi-Fi).

FIG. 19AE is a flowchart illustrating processing steps carried out by the pump control logic 84 for determining and running a mode of operation based on the amount of sun exposure. In step 4134, pump control logic 84 receives operational data from an ambient light sensor (e.g., sun exposure). In step 4136, pump control logic 84 retrieves ambient light setpoints (e.g., minimum and/or maximum sun exposure for modes of operation) from the memory. In step 4138, pump control logic 84 determines if the current ambient light is above the minimum setpoint. Conversely, pump control logic 84 could also determine if the current ambient light is below the minimum setpoint or above or below the maximum setpoint, thereby determining high or low sun exposure. If a positive determination is made in step 4138, pump control logic 84 proceeds to step 4140, where pump control logic 84 retrieves equipment setpoints (e.g., pump speed/flow) for a high sun exposure operation mode. If a negative determination is made in step 4138, pump control logic 84 proceeds to step 4144, where pump control logic 84 retrieves equipment setpoints (e.g., pump speed/flow) for a low sun exposure operation mode. In step 4142, pump control logic 84 transmits an instruction(s) to installed pool/spa equipment to operate at the retrieved setpoints for the current operation mode and then the process reverts to step 4134.

FIG. 19AF is a flowchart illustrating processing steps carried out by pump control logic 84 for minimizing sound

pressure when pool occupants are in close proximity to a pumping system. In step 4146, pump control logic 84 receives operational data from a proximity sensor. In step 4148, pump control logic 84 determines if there are pool occupants in close proximity. If a positive determination is made in step 4148, pump control logic 84 proceeds to step 4150, where pump control logic 84 retrieves maximum ambient noise setpoint data for pump operation from the memory (e.g., maximum allowable decibels when occupants are in close proximity to the pump). In step 4152, pump control logic 84 receives ambient noise operational data (e.g., measured decibels from a microphone positioned at or near the pump). In step 4154, pump control logic 84 determines if the measured ambient noise is above the maximum ambient noise setpoint. If a positive determination is made at step 4154, pump control logic 84 proceeds to step 4156, where pump control logic 84 transmits an instruction to the pump to decrease output (e.g., reduce speed by 5%), thereby reducing the decibels generated by the pump. Pump control logic 84 then reverts to step 4152. If a negative determination is made at step 4154, pump control logic 84 reverts to step 4152. If a negative determination is made at step 4148, pump control logic 84 proceeds to step 4158, where pump control logic 84 determines if the operation of the pumping system has been altered (e.g., the output of the pump was previously reduced from normal operating levels). If a negative determination is made in step 4158, pump control logic 84 reverts to step 4146. If a positive determination is made in step 4158, pump control logic 84 proceeds to step 4160, where pump control logic 84 transmits an instruction to the pump system equipment to resume normal operation. Thus, pump control logic 84 could reduce the output of the pumping system to reduce decibel levels when pool occupants are detected, but resume normal operation when pool occupants are no longer present.

FIG. 19AG is a flowchart illustrating processing steps carried out by pump control logic 84 for addressing alert conditions. More specifically, pump control logic 84 could ask the user if it should automatically address the issue and if it should automatically address the issue in the future. In step 4162, pump control logic 84 transmits an alert and recommendation to the user (e.g., “Excessive Motor Heating—Reduce Speed”). The alert and recommendation can be generated as described herein, in connection with FIG. 19D. In step 4164, pump control logic 84 prompts the user for automatic system implementation of the recommendation (e.g., “Reduce Motor Speed?—Y/N”). In step 4166, pump control logic 84 determines if the user elects automatic implementation of the recommendation. If a negative determination is made in step 4166, the process ends. If a positive determination is made in step 4166, pump control logic 84 proceeds to step 4168, where pump control logic 84 prompts the user for automatic implementation of the recommendation for subsequent similar alerts (e.g., “Automatically Address This Alert From Now On?”). In step 4170, pump control logic 84 determines if the user elects automatic implementation for subsequent alerts. If a positive determination is made in step 4170, pump control logic 84 saves the user preference to memory. In step 4174, pump control logic 84 transmits an instruction to the installed pool/spa equipment to implement the recommendation (e.g., reduce motor speed). If a negative determination is made in step 4170, pump control logic 84 proceeds to step 7174 and the process then ends.

FIG. 19AH is a flowchart illustrating processing steps carried out by pump control logic 84 for automatically advising the user of nearby pool service companies when the

pumping system, or any other installed pool/spa equipment, needs attention. It is contemplated that pump control logic **84** could notify the user by way of an on-board indicator provided on the pumping system and/or by way of a notification “pushed” out to other devices (e.g., smart devices) via any of the communication protocols disclosed herein. Pump control logic **84** could also automatically notify a user’s preferred pool service provider when the pumping system, or any other installed pool/spa equipment, needs attention. In step **4176**, pump control logic **84** receives operational data from the installed pool/spa equipment (e.g., temperature of pump motor). In step **4178**, pump control logic **84** determines if any of the installed pool/spa equipment is in need of service. Pump control logic **84** can determine if any of the pool/spa equipment is in need of service by way of a similar process as described herein, in connection with FIG. **19D**. If a negative determination is made in step **4178**, pump control logic **84** returns to step **4176**. If a positive determination is made in step **4178**, pump control logic **84** proceeds to step **4186**, where pump control logic **84** determines the location of the pool/spa. The location of the pool/spa can be determined by way of a similar process as described herein, in connection with FIG. **19V**. In step **4188**, pump control logic **84** receives web data on local pool service providers (e.g., pool service providers in close proximity to the pool/spa location). In step **4190**, pump control logic **84** prompts the user to select a preferred service provider (e.g., from a list of the local pool service providers). In step **4192**, pump control logic **84** stores the selected service provider to memory. In step **4194**, pump control logic **84** transmits an alert to the selected service provider (e.g., skimmer filter at [address] requires replacement). Optionally, pump control logic **84** could automatically notify a previously selected preferred service provider when any of the pool/spa equipment needs attention. For example, in step **4180**, pump control logic **84** could determine if a pool service provider was previously selected. If a negative determination is made in step **4180**, pump control logic **84** proceeds to step **4186**. If a positive determination is made in step **4180**, pump control logic **84** proceeds to step **4182**, where pump control logic **84** retrieves the previously selected service provider data from the memory. In step **4184**, pump control logic **84** transmits an alert to the previously selected service provider (e.g., skimmer filter at [address] requires replacement). Pump control logic **84** then returns to step **4176**. FIG. **19AI** is another flowchart illustrating the processing logic of the pump control logic **84**. In step **4300**, the pump control logic **84** receives an instruction to monitor the status of the filter. In step **4302**, the pump control logic **84** retrieves data on the factory specified parameters from memory for flow and/or pressure drop in the pump. In step **4304**, the pump control logic **84** receives operational data from a sensor regarding the flow and/or pressure drop in the pump. In step **4306**, the pump control logic **84** determines the pressure drop and/or flow rate in the pump. In step **4308**, the pump control logic **84** determines whether the pressure and/or flow rate is within the factory specified parameters. If a positive determination is made, the process ends, and if a negative determination is made, the pump control logic **84** proceeds to step **4310** where the appropriate valves are actuated to initiate backwash filtering.

FIG. **19AJ** is another flowchart illustrating the processing logic of the pump control logic **84**. In step **4312**, the pump control logic **84** receives an instruction to monitor the debris on the surface of the pool. In step **4314**, the pump control logic **84** receives operational data from the vision system which provides the location and amount of debris in loca-

tions of the pool surface. In step **4316**, the pump control logic **84** determines the location of high debris area on the pool surface. In step **4318**, the pump control logic **84** alters the position of return fittings and the skimmers to remove debris from the pool surface in an efficient and effective manner.

FIG. **19AK** is another flowchart illustrating the processing logic of the pump control logic **84**. For example, pump control logic **84** could determine the correct water flow for water features by communicating with other pieces of installed pool/spa equipment which advise pump control logic **84** of optimum performance criteria. This logic could reside in other installed pool/spa equipment and be communicated to the pump, or the logic could be contained within the pump itself. In step **4320**, the pump control logic **84** receives an instruction to determine the correct flow for a water feature. In step **4322**, the pump control logic **84** retrieves data for the water features from memory. The data retrieved can include, but is not limited to, type of water feature, size, capacity, water flow capacity, water flow levels, etc. In step **4324**, the pump control logic **84** receives user input, if any, for water feature customization to achieve a custom appearance. For example, a manual mode could be provided to allow the user to specify the desired water feature performance. If there is no user input, then the pump control logic **84** can use the data retrieved in step **4322**. In step **4326**, the pump control logic **84** can calculate the optimal flow rate based on the characteristics of the water feature. Such characteristics, include but is not limited to, water feature, size, capacity, water flow capacity, water flow levels, etc. In step **4328**, the pump control logic **84** receives a schedule for the water features, if any. In step **4330**, the pump control logic **84** adjusts the valves of the water feature so that their operation can be schedule based. In step **4332**, the pump control logic **84** transmits the flow rate needed for the water feature. The type of water features can include, but is not limited to, laminars, bubblers, waterfalls, deck jets, fountains, and skippers.

FIG. **19AL** is another flowchart illustrating the processing logic of the pump control logic **84**. In step **4334**, the pump control logic **84** receives an instruction to provide flow to a heater. In step **4336**, the pump control logic **84** retrieves water temperature set point data for heater operation from memory. This data could include minimum and maximum water temperatures set by a user or set by factory specified operating parameters. In step **4338**, the pump control logic **84** receives operational temperature data. In step **4340**, the pump control logic **84** determines whether the water temperature is below a minimum set point. If a positive determination is made, the pump control logic **84** proceeds to step **4342** to transmit an instruction to provide flow to the heater. If a negative determination is made, the pump control logic **84** proceeds to step **4344** to determine whether the water temperature is above a maximum set point. If a negative determination is made, the process ends. If a positive determination is made, the pump control logic **84** actuates valves to bypass the heater to improve hydraulic efficiency in step **4346**.

FIG. **19AM** is another flowchart illustrating the processing logic of the pump control logic **84**. In step **4348**, the pump control logic **84** receives an instruction to activate a heater or monitor or address heating controls. In step **4350**, the pump control logic **84** retrieves an optimum flow rate set point data for heater operation from memory. In step **4352**, the pump control logic **84** receives operational flow rate and/or valve position data. In this step, the pump control logic **84** receives data from the heat source identifying when

the heat source has adequate flow and/or pressure to operate. In step 4354, the pump control logic 84 determines whether the operational data is within the optimal set point range. If a positive determination is made, the pump control logic 84 proceeds to step 4356 to store and/or update current optimal flow rate for each heater device. The pump control logic 84 can store a history of this data. If a negative determination is made, the pump control logic 84 proceeds to step 4358 where a determination is made regarding whether retries are remaining. If a positive determination is made, the pump control logic 84 proceeds to step 4360, to transmit an instruction to increase flow to the heater by five percent. Any other percentage increase could be used. If a negative determination is made, the pump control logic 84 proceeds to step 4362 to transmit an error condition and the process would then end.

FIG. 19AN is another flowchart illustrating the processing logic of the pump control logic 84. In step 4364, the pump control logic 84 receives an instruction to manage a pump. In step 4366, the pump control logic 84 receives operational data from a pool cover. In step 4368, the pump control logic 84 determines whether the pool cover is closed. If a negative determination is made, the pump control logic 84 reverts back to step 4366. If a positive determination is made, the pump control logic 84 proceeds to step 4370 where it retrieves pool configuration parameters from memory such as pool surface area, volume, geometry, water features, etc. In step 4372, the pump control logic 84 determines proper operation of the pump when the pool cover is closed based on the factors retrieved above. In step 4374, the pump control logic 84 determines proper pump speed to ensure the pool cover is not damaged by flooding. In step 4376, the pump control logic 84 can determine the decreased rate of chlorine reduction due to lack of direct sunlight or less solar loading. In step 4378, the pump control logic 84 transmits instructions to pump of the foregoing calculations such as proper pump speed.

FIG. 19AO is another flowchart illustrating the processing logic of the pump control logic 84. In step 4380, the pump control logic 84 receives an instruction to manage the water level in the pool. In step 4382, the pump control logic 84 retrieves pool water level settings from memory. This setting can be user set or set by factory default parameters. In step 4384, the pump control logic 84 receives operational data from a sensor monitoring the water level in a pool. In step 4386, the pump control logic 84 determines whether the water level is within the set point parameters. If a positive determination is made, the pump control logic 84 proceeds to step 4388 to transmit an appropriate message to the user or the system. If a negative determination is made, the pump control logic 84 proceeds to step 4390 to adjust the operation of the pump to allow the water level in the pool to reach the set point parameters. In step 4392, the pump control logic 84 transmit an appropriate message to the user or the system that the water level is not in set point range and that the pump operation has been adjusted to remedy the water level situation.

FIG. 19AP is another flowchart illustrating the processing logic of the pump control logic 84. In step 4394, the pump control logic 84 receives an instruction to manage the operation of the pump based on the number of bathers in the pool. In step 4396, the pump control logic 84 receives operational data from motion sensors. In step 4398, the pump control logic 84 determines the number of bathers in the pool based on the data from the motion sensors. In step 4400, the pump control logic 84 retrieves pool configuration parameters from memory. Such parameters could include,

but is not limited to, pool surface area, volume, geometry, etc. The parameters will assist the pump control logic 84 in step 4402 to determine proper pump speed based on the number of bathers in the pool. The pump in step 4402 can adjust its operation based on the number of bathers. Furthermore, the pump control logic 84 could also control other equipment that needs to be deactivated or activated based on the presence and/or number of bathers in the pool. For example, in step 4404, the pump control logic 84 determines whether to activate or deactivate other pool equipment based on the number of bathers in the pool. In step 4406, the pump control logic 84 transmits the deactivation or activation signal to the other equipment.

FIG. 19AQ is another flowchart illustrating the processing logic of the pump control logic 84. In step 4408, the pump control logic 84 receives an instruction to monitor system curve of the pump which is the summation of the dynamic head. In step 4410, the pump control logic 84 retrieves data regarding the pump from memory. In step 4412, the pump control logic 84 receives operational data from sensors monitoring the pump. In step 4414, the pump control logic 84 estimates or calculates the system curve based on the multiple speeds of the pump. Alternatively, pump control logic 84 could estimate or calculate the overall system curve based on a single point. In step 4416, the pump control logic 84 provides an indication of system efficiency rating and alerts trade and/or consumers based on factory defined or selectable changes. In step 4418, the pump control logic 84 provides an indication of system efficiency such as "efficiency mode," "performance mode" etc. and assigns a push button to go to a selected mode with one push of a button. In step 4420, the pump control logic 84 calculates periods of hydraulic inefficiencies and in step 4422, it recommends ways to improve hydraulic efficiency. In step 4424, the pump control logic 84 auto-delivers the correct flow or speed to make the equipment more efficient. For example, pump control logic 84 could measure suction head (negative pressure) on the vacuum side of the pump and measure pressure head on the pressure side of pump, both measurement devices being integral or adjacent to the pump, to derive Total Dynamic Head ("TDH"). An overall System Curve (TDH vs. flow) could also be estimated or calculated from a single point, or generated when measured at multiple speeds when using a multi-speed pump. Further pump control logic 84 could compare the calculated system curve to known industry system curves (e.g., "Curve A", "Curve C", etc.) and determine a hydraulic efficiency "score." Pump control logic 84 could then determine how to improve the efficiency score and then either provide general suggestions to the user to improve said score, or automatically implement the suggestions. In one example, pump control logic 84 could monitor the typical operating flow of the pool/pump and suggest alternate schedules that would achieve the same number of turnovers in a day with lower power consumption.

FIG. 19AR is another flowchart illustrating the processing logic of the pump control logic 84. In step 4426, the pump control logic 84 receives an instruction to monitor demand based operation from local utility companies. In step 4428, the pump control logic 84 retrieves data on factory specified parameters from memory for the utility company. In step 4430, the pump control logic 84 receives operation data of the pump flow. In step 4432, the pump control logic 84 determines whether the pump operational data is within the set point parameters set by the utility company. If a positive determination is made, the pump control logic 84 proceeds to step 4434 where a message is transmitted to the user

regarding the pump operational data being within the set point parameters of the utility company and the process ends. If a negative determination is made, the pump control logic 84 proceeds to step 4436 where the pump control logic 84 performs a function or changes the pump operation to conform to the utility company set point parameters. Then in step 4438, the pump control logic 84 transmits a message that the pump operation has changed to conform to the utility company standards.

FIG. 19AS is another flowchart illustrating the processing logic of the pump control logic 84. In step 4440, the pump control logic 84 receives an instruction to provide flow to a selected pool equipment. In step 4442, the pump control logic 84 retrieves data on factory specified parameters from memory for the pumping needs of a selected pool equipment. In step 4444, the pump control logic 84 determines whether the flow data is being defined by the selected pool equipment. If a negative determination is made, the pump control logic 84 proceeds to step 4446 where the pump itself defines the flow parameters for the selected pool equipment based on the flow provided by the pump. If a positive determination is made and after step 4446, the pump control logic 84 proceeds to step 4448 where it receives operational data for the flow of the pool equipment. In step 4450, the pump control logic 84 determines whether the flow data is within the set point parameters either defined by the equipment or the pump. If a positive determination is made, a message is transmitted to the user or the system that the flow data is within operating parameters. If a negative determination is made, the pump control logic 84 proceeds to step 4454 where the speed of the pump is increased periodically to meet the demand of the pool equipment and the process again reverts to step 4448 to receive operational data and make the same determination in step 4450.

FIG. 19AT is another flowchart illustrating the processing logic of the pump control logic 84. In step 4456, the pump control logic 84 receives an instruction to measure the turbidity of the water. In step 4458, the pump control logic 84 retrieves data on factory specified parameters from memory regarding the turbidity of the water. In step 4460, the pump control logic 84 receives operational turbidity data. In step 4462, the pump control logic 84 determines whether the turbidity data is within the specified operating parameters. If a positive determination is made, the pump control logic 84 proceeds to step 4464 where a message is transmitted regarding the turbidity data being within the operating range. If a negative determination is made, the pump control logic 84 proceeds to step 4466 where a determination is made as to whether the user wants to set a blackout time instead of a filter time. If a negative determination is made, the pump control logic 84 proceeds to step 4468 where the pump control logic 84 automatically sets the filter schedule based on turbidity level. If a positive determination is made, the pump control logic 84 sets a blackout time period based on the user input in step 4470. Then in step 4472, the pump control logic 84 adjusts the pump to pump only what is needed to save energy and meet turbidity levels.

FIG. 19AU is another flowchart illustrating the processing logic of the pump control logic 84. In step 4473, the pump control logic 84 receives an instruction to prime the pump. In step 4474, the pump control logic 84 can start the pump at the desired speed, not the prime speed. In step 4476, the pump control logic 84 receives operation data from the pump regarding water detection. In step 4478, the pump control logic 84 determines whether water is detected. If a positive determination is made, the pump control logic 84

proceeds to step 4480 where the priming period timer is cleared and the process ends. If a negative determination is made, the pump control logic 84 proceeds to step 4482 where a timer is started or continued. In step 4484, the pump control logic 84 make a determination as to whether there is time remaining in the timer that was started. If a positive determination is made, the pump control logic 84 decrements the timer and proceeds back to step 4476. If a negative determination is made, the pump control logic 84 proceeds to step 4484 where a determination is made as to whether if the current try is a retry. If a positive determination is made, the pump control logic 84 proceeds to step 4490 where an error condition is transmitted alerting the system or user that the priming failed and the process ends. If a negative determination is made and the current try is the first try, then the pump control logic 84 proceeds to step 4492 where the pump is stopped and allowed to cool. Then in step 4494, the pump control logic 84 reprimed at the maximum rotations per minute until flow return, then immediately the pump control logic 84 will return to the user or firmware desired speed.

The above processes for the pump control logic 84 can also be applied to a pumping system that is able to manage auxiliary pumps used at any given site. Some of the management features can include, but is not limited to, turning auxiliary pumps on/off according to specific schedules, as well as changing the pump speed for a variable speed pump. Indeed, all of the processes for the pump control logic 84 as shown with respect to FIGS. 18-19AU can be applied to auxiliary pumps. Auxiliary pumps can include, but are not limited to, pressure cleaner booster pumps, waterfall pumps, and pumps used for water features or spas.

It is contemplated that any of the various processes in the embodiments described herein in connection with FIGS. 19A-19AU could be incorporated into pump control logic 84 either alone or in any combination. Further any additional processes disclosed herein in connection with pool control logic 70 (e.g., water feature control logic 72, valve actuator control logic 74, cleaner control logic 76, lighting control logic 78, heater control logic 80, chemistry automation control logic 82) could also be incorporated into pump control logic 84 either alone or in any combination. For example, the pump could include or be modularly upgradeable to include any of the various processes in the embodiments described herein in connection with FIGS. 19A-19AU. Further still, any of the flowcharts illustrating processing steps disclosed in connection with pump control logic 84 can be applied to pool control logic 70 (e.g., water feature control logic 72, valve actuator control logic 74, cleaner control logic 76, lighting control logic 78, heater control logic 80, chemistry automation control logic 82).

As mentioned briefly above, embodiments may provide smart valves/smart valve actuators that include an actuator which rotates valves in response to a control signal. In one embodiment, the smart valve actuator may function as a stand-alone control for its associated valve or valves. In another embodiment, the smart valve actuator may operate in conjunction with a control automation system as described herein. In a further embodiments, the smart valve actuator can operate according to a preset, preconfigured, and/or modifiable schedule. The smart valve actuator as described further below may provide for an easier installation and use by untrained installers and users. Further, the smart valve actuator may reduce the time and cost required when needing multiple pumps and ball valves to attain a perfect balance of distributed or shared water features. Additionally the smart valve actuator gives the pool owner

control over his water features, the ability to articulate and balance them remotely, and the possibility of providing varied effects on demand.

Traditional (non-smart) valve actuators have been used to electrify a valve to enable remote control. Existing valve actuators have internal or software driven limit switches that the installer can use to program the valve actuator to stop turning the valve at the desired point. This allows a valve to turn to a desired point and deliver a desired effect on a water feature, and prevents the actuator motor from turning the valve to inappropriate positions that may ‘dead-head’ the plumbing, blocking all water flow. However, the installer of such a valve actuator must carefully mount the valve actuator in one of four orientations on top of the valve in order to place the existing 180 degrees of control in the needed orientation with the valve. Then the installer must disassemble the actuator body and carefully re-position two cams so that when the shaft position reaches the desired limit, the cam depresses an internal limit switch and disconnects power to the motor. This installation procedure is time consuming and requires skill.

Traditional (non-smart) valve actuators have also required an AC low-volt power supply to power the actuator’s motor. This power source may require additional circuitry or power transformers to generate this power source dedicated only for use to power the actuator motor. Additionally, traditional valve actuators have only one programmable limit for clockwise and one for counterclockwise actuation. These programmable limits may be set to achieve a particular effect on a water feature, for example causing a pleasing flow on a fountain or a desired height on a deck jet. However, if the water flow or pressure changes at the input port of the valve, the desired effect is lost. Similarly, water flow will change due to pump speed changes, filter media condition, and interaction with the valve position of additional valves in the system or booster pumps that may divert water. Having water features that are influenced by interactions with other equipment and valves results in undesired performance. Installers often add completely isolated plumbing systems only for water features to avoid this undesired behavior. An additional issue with traditional valve actuators is that the cam setting of traditional valves is limited in resolution to the splines present on the actuator drive shaft, and is often too coarse to allow setting for an exact water feature effect. This requires compromise in setting to the nearest setting.

Embodiments provide a smart valve actuator that addresses many of the drawbacks of traditional valve actuators. In one embodiment, a smart valve actuator has the ability to be controlled directly at the device or from the pool automation system in the same manner as one would control a variable speed pump, for example, by providing control of intermediate positions via software control. In one embodiment the smart valve actuator may be addressed automatically from the control. In another embodiment, the control may be given an address of the smart valve actuator that enables the control to transmit fixed and variable commands to the smart valve actuator. Embodiments may provide a number of additional features such as the ability to set minimum and maximum settings for each smart valve actuator to allow for minimum and maximum allowed flow and to set protection limits to prevent the valve from turning to potentially damaging positions. Additional features may enable the configuration/setting of high, medium and low default flow settings and the ability to control positions variably by using, as non-limiting examples, digital or analog + and – buttons, a digital or analog slider, or a rotary knob on the controller or on the actuator to control the flow.

In one embodiment LEDs may be provided that allow the pool owner or servicer to identify settings, set points and flow at a glance. In further embodiments, an added flow, temperature or pressure sensor can monitor the water properties of the output flow and automatically adjust the valve position to seek a programmed setpoint and/or an absolute position sensor can allow manual valve actuation without requiring re-synchronization after the motor is re-connected to the shaft, thereby eliminating the need to mount the smart valve actuator in a particular orientation because the device can manage the valve angle over the entire 360 degree rotation of the valve.

The smart valve actuator can be used manually or through automation. The smart valve actuator may sit on an existing valve, may have a valve integral to it on pool equipment plumbing or may be located at a location in the backyard to control a flow of water between one to many plumbed water ports. In one embodiment, the smart valve actuator is capable of receiving from, or giving to, a pool controller, a unique address that enables communication of specific commands and settings between the actuator and its controlling entity. In some embodiments, when controlled by the pool automation system, the smart valve actuator may communicate by communication protocols, including without limitation, RS485, Ethernet, Wi-Fi, Bluetooth™, zwave, Zig-Bee™, thread, cellular or another communication protocol. Wireless control of the smart valve actuator from a web-enabled device or the pool controller may occur in the following embodiments: when the Wi-Fi chip is on main (intelligence) pcb, is attached/plugged into main pcb, is modularly upgraded on the main pcb or in the pcb enclosure, is modularly upgraded on/external to the main pcb enclosure, or is remote to the main pcb enclosure. An antenna may be mounted with, or located remote to, the Wi-Fi chip for all prescribed locations/methods described above. The smart valve actuator may also allow pool controlling devices to communicate directly with web-enabled devices (e.g.: phone, tablets, phones, thermostats, voice enabled devices, etc. . . .) without the need to go through a home router.

The smart valve actuator can be configured to set specific open and close valve settings, and it can be defaulted or configured with default settings for low flow, medium flow, high flow, or programmable flow at varied angles. These flow rates can be used to dial in settings when a pump is powering the water associated with water features. In some cases these flow rates can be used to achieve the desired outcome at the lowest flow increasing the pool’s energy efficiency. The smart valve actuator’s position may be variably controlled in a number of ways, such as without limitation, by using push and hold digital or analog buttons, digital or analog + and – buttons, a digital or analog slider, and/or a rotary knob on the controller or on the actuator to control the flow.

In one embodiment, the smart valve actuator may be used to automate filter valves and their associated positions such as, for example, filter, backwash, rinse, waste, closed, recirculate, and winterize. An additional benefit of the smart valve actuator is that it may allow filters and valves to be bypassed when not required for certain applications, such as when operating an attached spa, thereby improving flow and energy efficiency. In another embodiment, the smart valve actuator could be used in connection with the addition of chemicals (e.g., ORP, pH, free chlorine, etc.) to the pool/spa. For example, the smart valve actuator could be used to integrate the automation of various positions for tablet feeding automation.

In an embodiment, the smart valve actuator may be used to automatically manage water flow needed for operation of suction and pressure cleaners. When a smart valve actuator is used in conjunction with a variable speed pump, the pump may be able to increase its speed to deliver the flow necessary for proper operation of a suction or pressure cleaner, thereby maximizing energy savings when compared to running the variable speed pump at a higher speed throughout the day. In one embodiment, the smart valve actuator control may set angles via commands. The commands may be stored in the controller or the actuator processor. The change in settings may be done automatically; may be done through power interruption to move to the next setting, may be done through time duration of the power interruption; and may be done with a manual setting on the actuator.

Among its features, the smart valve actuator may have 1 to many increments with increments set at 0.5 degrees for 180 degrees, or other resolution or range. The smart valve actuator may measure the angle set manually and store that position in memory for use as one of its default settings. In one embodiment the smart valve actuator may include sensor capabilities to measure the temperature, flow rates and/or pressure of the input water or output water when the valve is diverted and be able to use the measured parameters to turn the motor to achieve a desired setpoint. The flow sensing or pressure sensing may be built into the smart valve actuator or may be attained by a secondary flow sensor.

In one embodiment, a stored setpoint flow/pressure level may be used by a PID loop (or other control algorithm) to turn the valve to a needed position to achieve the flow and the smart valve actuator may update the position if conditions (pressure, flow, etc.) changes.

As noted, the smart valve actuator provides a number of improvements over traditional (non-smart) valve actuators. For example, the smart valve actuator may manage a fluid level in a spa with a sensor or may manage return valves from a spa to prevent the spa from emptying or overflowing via level sensing. The smart valve actuator may block a water feature flow if ambient temperatures are too low thus providing a valve-controlled freeze protection. For example, the smart valve actuator may be operated by a bi-metallic switch as an input that reverses the motor at low temperatures (no circuit board needed). The smart valve actuator may communicate with a pool cover sensor input that prevents activation of a water feature if the pool cover is closed. Additionally, in some embodiments, the smart valve actuator may open a solar panel return if the solar panel temperature has reached a desired setpoint. In one embodiment, the smart valve actuator may include a wind sensor and block a water feature flow if forecasted wind (retrieved from the web) is too high. For example, the smart valve actuator may reverse the motor at higher wind speeds to stop water features from dumping water out of the pool. The smart valve actuator may also block a water feature if flooding is sensed by float or conductivity sensing. In one embodiment, the smart valve actuator may include a dual input power capability that can accept either AC power inputs or DC power input to power the motor. Further, in some embodiments, the smart valve actuator can include a handle, or the like, to provide for manual operation of the smart valve actuator, if necessary, during loss of power (e.g., power cable being cut) or loss of communication (e.g., communications cable being cut, electronics failure, etc.) to the smart valve actuator.

Among the improvements made possible through the use of the smart valve actuator as described herein are increased

efficiency in the pool system. For example, in one embodiment, the smart valve actuator may monitor energy saving interactions with a pump to support a minimum required speed to achieve requested flows in all of the active water features. This approach may enable all water to go through the water features and none through the return jets because of 100% efficiency. Similarly, the smart valve actuator may request a higher RPM if the desired flow cannot be achieved (a pump runs only at filtration speed, but if a water feature is turned on, the smart valve actuator controller can request increased speed if the flow setpoint cannot be achieved). The smart valve actuator position may also be adjusted to see if a desired flow rate can be achieved at the filtration flow rate. Calculations may be performed to determine the most efficient pump speed to achieve the desired results by algorithm or by communication from the pump of the power draw. The use of the smart valve actuator may facilitate measuring and reporting excess flow by comparing the controlled quantity to the valve position and computing the margin available; i.e. determining if the pump speed is higher than needed to achieve the requested water feature flow. The computation may indicate what reduction in pump speed may be implemented.

Embodiments may perform flow sensing and pressure sensing. For example, flow may be measured with a paddle wheel or a turbine and interpreted by a co-located processor or remotely located processor. Flow may also be measured with ultrasonic doppler methods, thermal mass/dispersion methods, magnetic/induction methods, optical methods, etc. Pressure sensing may be performed with a flow sensor mounted on a pipe, or a tube run from the pipe to a sensor mounted on the circuit board. Methods for pressure sensing include strain gage piezoresistive methods, capacitive methods, magnetic diaphragm displacement methods, optical methods, resonant frequency methods, etc. The smart valve actuator may also utilize a temperature sensor. For example, temperature sensing can determine ambient temperature, remote solar panel temperature, or water temperature at the input or output ports.

In some embodiments, the smart valve actuator may include protection features for the pool system. The protection features may include stored limits of damaging valve positions and undesired valve positions along with software to automatically restore permitted valve positions after manual actuation of the valve or understand its position upon power-up to assure that the valve is in the correct position. Additionally, the smart valve actuator may facilitate motor current monitoring and input voltage monitoring to initiate scale-back or shutdown to protect life and prevent internal damage to pool system components.

In one embodiment, the pool system may have a 'legacy' mode that can accept travel limit settings via pushbutton or power interrupt signaling from the controller. This legacy mode can be implemented by disconnecting the motor from the drive shaft and signaling the software by timed direction reversals, wireless communication, or a physical or magnetic pushbutton. In some embodiments, software can learn the relationship between valve angle and measured parameters and predict if a requested setting is possible based on a simulation of what valve angle will be needed to achieve the desired effect. In one embodiment the software may contain methods to prevent 'hunting' or needless motor activation for minor fluctuations of the measured parameters. Further, the motor drive software may generate stepper motor signals to drive the motor faster or slower than current products based on synchronous motors.

FIG. 20 is a diagram 1200 illustrating chemistry automation control logic 82. Chemistry automation control logic 82 could incorporate and/or be in communication with a variety of types of data and/or data sources. More specifically, chemistry automation control logic 82 can communicate with, or receive, user input data 1202, chemistry automation operational data 1204, chemistry automation factory specifications 1206, chemistry automation configuration parameters 1208, web data 1210, pool configuration parameters 1212, data from related devices 124, health monitoring data 1216, and/or external sensor data 1218.

User input data 1202 could include timers, schedules (e.g., on/off, what speed, operation duration, etc.), chlorination levels, alternative sanitizers (e.g., liquid, chlorine, tablets, etc.), etc. Chemistry automation operational data 1204 could include water chemistry, water temperature, air temperature, water detection, water flow (rate), water flow (yes/no), water pressure, air cavitation, salt concentration, chemistry dispense rate, power consumption, current draw, water conductivity, salinity, applied voltage, water hardness, etc. Chemistry automation factory specifications 1206 could include power consumption, current draw, input voltage, etc. Chemistry automation configuration parameters 1208 could include IP address, GPS coordinates, zip code, time and date, etc. Web data 1210 could include location (based on IP address), time and date, sunrise/sunset data, regional and local weather forecast data, temperature, ambient light, solar radiation, humidity, season, elevation, dew point, etc. In one example the chemistry automation logic 82 could shift operation based on weather input. Pool configuration parameters 1212 could include pool surface area, pool geometry, pool liner color, pool cover (yes/no), volume, etc. Data from related devices 1214 could include data relating to at least the following: pump(s), heater(s) (gas/heat pump), heat (solar), pool covers, controller(s), spa(s), water feature(s), secondary pump(s), valves/actuators/bypasses, alternative sanitizers (agent, fill level, weight, feed rate, etc.), etc. In one example, the chemistry automation control logic 82 could receive input from an external device to identify an operating profile. Health monitoring data 1216 could include power consumption, current monitoring, line-to-line balance, grounding, bonding, leak current, runtime, operating temperatures, number of power cycles, efficiency, pressure drop of scaling cell (chlorinator), presence of gas pockets (chlorinator), ultraviolet output (UV sanitizer), ozone suction (UV sanitizer), lamp temperature (UV sanitizer), time to clean (chemistry dispenser), age of dispense medium (chemistry dispenser), born on date (chemistry dispenser), etc. External sensor data 1218, could include water temperature, water flow rate, air temperature, suction/vacuum pressure, water chemistry, turnover rate of pool, ambient light, pool cover detection, motion sensors, bather detection, salt concentration, pH, water hardness, cyanuric acid levels, turbidity, ozone concentrations, algae, microbial populations, phosphate levels, nitrate levels, water level, bather load, etc. It is noted that, the chemistry automation control logic 82 could sample the water from various locations, including ports, as well as offline sensing equipment. It is further noted that the external sensor data 1218 (as well as external sensor data received by any and/or all of the control logic systems 72-83) can be received from sensors in a plurality of locations, including but not limited to, the pool pad, in the pool itself, or remote from the pool. Additionally, the chemistry automation control logic 82 can receive learned information and a pool cover schedule. While it may be desirable for external sensors to monitor/provide data on as many system parameters as possible (thereby providing

greater optimization, automation, and user/operator comfort), it is contemplated that some systems need not utilize an external sensor to monitor every system parameter. For example, if a particular pool chemistry sensor has not been installed in a particular system, the user/operator can provide this information by first determining the pool chemistry (e.g., by manually testing the pool chemistry by conventional means that are well known to the art) and then entering the pool chemistry information into the system via a user interface.

FIGS. 21A-21I are flowcharts illustrating processing steps of the chemistry automation control logic 82. FIG. 21A is a flowchart illustrating processing logic of the chemistry automation control logic 82 communicating with a chemistry automation system. In step 1300, the chemistry automation control logic 82 receives an instruction to activate the chemistry automation system. In step 1302, the chemistry automation control logic 82 receives operational data from the chemistry automation system water detection sensor. The chemistry automation system water detection sensor can be, for example, a flow switch, flow meter, current flow ("gas sensor"), etc. In step 1304, the chemistry automation control logic 82 determines if water is detected. If a positive determination is made, then the chemistry automation control logic 82 proceeds to step 1306 where it transmits an instruction to the chemistry automation system to activate, and the process ends. If a negative determination is made, then the chemistry automation control logic 82 proceeds to step 1308 where it determines if there are any retries remaining. For example, in step 1308 the chemistry automation control logic 82 could determine if there are any retries remaining for a timer (e.g., 1 hour, 6 hours, 24 hours, or any other suitable time interval), or if there has been no flow detected over the same period of time. If a positive determination is made, e.g., the twenty-four hour timer has not expired, then the process returns to step 1302 and continues from there. If a negative determination is made, e.g., the twenty-four hour timer has expired indicating that there has been no flow over a twenty-four hour period, then the process proceeds to step 1310 where an error condition is transmitted, and the process ends.

FIG. 21B is another flowchart illustrating processing logic of the chemistry automation control logic 82 communicating with a chemistry automation system. In step 1312, the chemistry automation control logic 82 receives an instruction to activate the chemistry automation system. In step 1314, the chemistry automation control logic 82 retrieves data on factory specified power parameters from memory (e.g., power consumption, current draw, and line voltage). In step 1316, the chemistry automation control logic 82 receives line power operational data. In step 1318, the chemistry automation control logic 82 determines if the line power is within factory specifications. If a positive determination is made, then the chemistry automation control logic 82 proceeds to step 1320 where it transmits an instruction to the chemistry automation system to activate, and the process ends. If a negative determination is made, then the chemistry automation control logic 82 proceeds to step 1322 where it determines if there are any retries remaining. If a positive determination is made, then the process returns to step 1316 and continues from there. If a negative determination is made, then the process proceeds to step 1324 where an error condition is transmitted, and the process ends.

FIG. 21C is another flowchart illustrating processing logic of the chemistry automation control logic 82 communicating with a chemistry automation system. In step 1326, the chemistry automation control logic 82 retrieves user-speci-

fied chlorination levels from memory. In step 1328, the chemistry automation control logic 82 retrieves pool configuration parameters from memory, e.g., pool surface area, volume, geometry, etc. In step 1330, the chemistry automation control logic 82 receives operational data from the chemistry automation system, e.g., chlorination rate. In step 1332, chemistry automation control logic 82 determines the length of chlorination time to reach the user-specified level. In step 1334, chemistry automation control logic 82 transmits an instruction to the chemistry automation system to run for the determined length of time, and then returns to step 1330.

FIG. 21D is another flowchart illustrating processing logic of the chemistry automation control logic 82 communicating with a chemistry automation system. In step 1336, the chemistry automation control logic 82 retrieves user-specified chlorination levels from memory. In step 1338, the chemistry automation control logic 82 receives pump operational data, e.g., turnover rate. In step 1340, the chemistry automation control logic 82 receives water chemistry operational data from external sensors. In step 1342, chemistry automation control logic 82 transmits pump and water chemistry operational data to memory. In step 1344, the chemistry automation control logic 82 determines if the chlorine level is below the user-specified level. If a negative determination is made, then the chemistry automation control logic 82 returns to step 1338 and continues from there. If a positive determination is made, then the chemistry automation control logic 82 proceeds to step 1346 where it determines the length of chlorination time required to reach the user-specified chlorine level. In step 1348, the chemistry automation control logic 82 transmits the determined chlorination time to memory. In step 1350, the chemistry automation control logic 82 transmits an instruction to the chemistry automation system to run for the determined length of time, and then returns to step 1338.

FIG. 21E is another flowchart illustrating processing logic of the chemistry automation control logic 82 communicating with a chemistry automation system. In step 1352, the chemistry automation control logic 82 receives operational data from ambient light sensors. In step 1354, the chemistry automation control logic 82 determines the amount of direct sunlight to a body of water. In step 1356, the chemistry automation control logic 82 retrieves pool configuration parameters from memory, e.g., pool surface area, volume, geometry, etc. In step 1358, the chemistry automation control logic 82 determines the rate of chlorine reduction due to direct sunlight. In step 1360, the chemistry automation control logic 82 transmits an instruction to the chemistry automation system to increase dispensing rate of chlorine by rate of chlorine reduction due to direct sunlight, and then returns to step 1352.

FIG. 21F is another flowchart illustrating processing logic of the chemistry automation control logic 82 communicating with a chemistry automation system. In step 1362, the chemistry automation control logic 82 receives an instruction to activate the chemistry automation system. In step 1364, the chemistry automation control logic 82 receives operational data from the pool cover. In step 1366, the chemistry automation control logic 82 determines if the pool cover is closed. If a negative determination is made, then the chemistry automation control logic 82 returns to step 1364 and continues from there. If a positive determination is made, then the chemistry automation control logic 82 proceeds to step 1368 where it retrieves pool configuration parameters from memory, e.g., pool surface area, volume, geometry, etc. In step 1370, the chemistry automation con-

trol logic 82 determines the decreased rate of chlorine reduction due to lack of direct sunlight. In step 1372, the chemistry automation control logic 82 transmits an instruction to the chemistry automation system to decrease the dispensing rate of chlorine by the decreased rate of chlorine reduction due to lack of direct sunlight, and then returns to step 1364.

FIG. 21G is another flowchart illustrating processing logic of the chemistry automation control logic 82 communicating with a chemistry automation system. In step 1374, the chemistry automation control logic 82 receives an instruction to activate the chemistry automation system. In step 1376, the chemistry automation control logic 82 receives operational data from the motion sensors. In step 1378, the chemistry automation control logic 82 determines the number of bathers in the pool. In step 1380, the chemistry automation control logic 82 retrieves pool configuration parameters from memory, e.g., pool surface area, volume, geometry, etc. In step 1382, the chemistry automation control logic 82 determines an increased chlorine demand based on the number of bathers. In step 1384, the chemistry automation control logic 82 transmits an instruction to the chemistry automation system to increase the dispensing rate of chlorine by the increased chlorine demand based on the number of bathers, and then returns to step 1376.

FIG. 21H is a flowchart illustrating processing logic of the chemistry automation control logic 82 determining alert conditions of a chemistry automation system. The chemistry automation control logic 82 proceeds with four parallel routine sequences that respectively begin with steps 1386, 1396, 1406, 1416. Each routine sequence is discussed sequentially, though it should be understood that the routine loops could operate in parallel, or alternatively, in series with each other. The first sequence begins in step 1386 where the chemistry automation control logic 82 retrieves factory specified life expectancy data from memory. In step 1388, the chemistry automation control logic 82 determines an alert threshold, e.g., less than 90% of chemistry automation life expectancy remaining or runtime value. In step 1390, the chemistry automation control logic 82 receives operational data on chemistry automation runtime. In step 1392, the chemistry automation control logic 82 determines if the chemistry automation runtime is greater than the threshold. If a negative determination is made, then the process returns to step 1390 and continues to receive operational data on chemistry automation runtime. If a positive determination is made, then the process proceeds to step 1394 where an alert is transmitted to a user, and the process ends.

The second sequence begins in step 1396 where the chemistry automation control logic 82 retrieves factory specified operating temperature data from memory. In step 1398, the chemistry automation control logic 82 determines an alert threshold, e.g., a temperature value that is 10% above or below operating temperature. In step 1400, the chemistry automation control logic 82 receives operational data on chemistry automation system operating temperature. In step 1402, the chemistry automation control logic 82 determines if the chemistry automation system operating temperature exceeds the threshold, or is outside of a threshold range. If a negative determination is made, then the process returns to step 1400 and continues to receive operational data on chemistry automation system operating temperature. If a positive determination is made, then the process proceeds to step 1404 where the chemistry automation control logic 82 reduces the output of the chemistry automation system.

The third sequence begins in step 1406 where the chemistry automation control logic 82 retrieves factory specified power consumption data from memory. In step 1408, the chemistry automation control logic 82 determines an alert threshold, e.g., power value that is 110% of specified power consumption. In step 1410, the chemistry automation control logic 82 receives operational data on chemistry automation system power consumption. In step 1412, the chemistry automation control logic 82 determines if the chemistry automation system power consumption is greater than the threshold. If a negative determination is made, then the process returns to step 1410 and continues to receive operational data on chemistry automation system power consumption. If a positive determination is made, then the process proceeds to step 1414 where the chemistry automation control logic 82 reduces the output of the chemistry automation system.

The fourth sequence begins in step 1416 where the chemistry automation control logic 82 retrieves factory warranty data from memory, e.g., a warranty expiration date. In step 1418, the chemistry automation control logic 82 determines an alert threshold, e.g., days left on factory warranty. In step 1420, the chemistry automation control logic 82 receives current date information. In step 1422, the chemistry automation control logic 82 determines if the current date is beyond the threshold date or the number of days remaining is below the threshold date. If a negative determination is made, then the process returns to step 1420 and continues to receive current date information. If a positive determination is made, then the process proceeds to step 1424 where an alert is transmitted to a user, and the process ends.

FIG. 21I is another flowchart illustrating processing logic of the chemistry automation control logic 82 communicating with a chemistry automation system. In step 1426, the chemistry automation control logic 82 retrieves factory specified servicing data from memory, e.g., service intervals. In step 1428, the chemistry automation control logic 82 retrieves date of previous service from memory. In step 1430, the chemistry automation control logic 82 determines the time to the next service and then proceeds to steps 1432 and 1438. In step 1438, the chemistry automation control logic 82 transmits an instruction to the human-machine interface device to display the time to the next service. In step 1432, the chemistry automation control logic 82 determines the alert threshold, e.g., 30 days to next service. In step 1434, the chemistry automation control logic 82 determines if the time to the next service is less than the threshold. If a negative determination is made, then the process returns to step 1428 and continues to receive the date of previous service from memory. If a positive determination is made, then the process proceeds to step 1436 where the chemistry automation control logic 82 transmits an alert to the user.

FIG. 22 is a diagram 1500 illustrating heater control logic 80. Heater control logic 80 could incorporate and/or be in communication with a variety of types of data and/or data sources. More specifically, heater control logic 80 can communicate with, or receive, user input data 1502, heater operational data 1504, heater factory specifications 1506, heater configuration parameters 1508, web data 1510, pool configuration parameters 1512, data from related devices 1514, health monitoring data 1516, and/or external sensor data 1518.

User input data 1502 could include heating and/or cooling temperature set points, heating or cooling mode, pool/spa mode, heater x or cooler x, where "x" is an index referring

to one or more heating and/or cooling devices, countdown to heat, etc. Heater operational data 1504 could include line voltage, power consumption, gas pressure, air pressure or vacuum, air temperature, humidity, other environmental conditions, flow rate, water level, state (e.g., on/off), temperature setpoint, duration setpoint, operating noise, etc. Heater factory specifications 1506 could include gas heater input rating, gas heater thermal efficiency, heat pump output & COP (coefficient of performance) at T1 (reference test temperature 1), RH1 (reference test relative humidity 1), heat pump output & COP at T1, RH2 (reference test relative humidity 2), heat pump output & COP at T2 (reference test temperature 2), RH1, heat pump output & COP at T2, RH2, power consumption, current draw, input voltage, etc. Heater configuration parameters 1508 could include IP address, GPS coordinates, zip code, etc. Web data 1510 could include regional solar irradiance data, regional weather forecast data, regional fuel cost data, direct solar irradiance—modeled clear-sky, diffuse solar irradiance—modeled clear-sky, air temperature, relative humidity, wind speed, cloud cover, cost of natural gas, cost of propane gas, cost of electricity, etc. Pool configuration parameters 1512 could include pool surface area, pool volume, emissivity of pool, absorptivity of pool, pool solar exposure, fraction of weather station wind speed at pool surface, desired water temperature, pump schedule, type of pool cover (solar transmittance, thermal conductivity, emissivity, absorptivity), pool cover use schedule, etc. Data from related devices 1514 could include data relating to at least the following: pump(s), secondary pump(s), filter bypass, water feature(s), chemical dispensers, valves/actuators/bypass, pool cover(s), controller(s), spa(s), etc. The following relationships could exist between the heater control logic 80 the related devices: water features (used to assist loss of heat/coolers), chemical dispensers (logic 80 could open bypass to prevent off balance chemistry from entering the heater), secondary pump (affects overall system flow), tablet/liquid chlorine feeder (if present in system should not be used on the same loop as the heater), and external sensors (could have shared flow switch and water temperature sensors). Health monitoring data 1516 could include runtime, operating temperatures/profile, power consumption, predictive failure, number of cycles, degradation of efficiency, pool chemistry, fuel gas pressure, refrigerant pressures, refrigerant temperatures, exhaust temperature, carbon monoxide, freeze and condensation warnings, motor speed (RPM), other operating conditions, settings, troubleshooting data, etc. External sensor data 1518, could include air temperature, humidity, ambient noise, pool chemistry, fuel gas pressure, exhaust temperature, carbon monoxide, carbon dioxide, oxygen, vibration, bather detection, etc. Additionally, the heater control logic 80 can receive information pertaining to time limits on setting block heater schedules, maximum allowable temperatures, password protection, scheduled heating, and setback schedules. While it may be desirable for external sensors to monitor/provide data on as many system parameters as possible (thereby providing greater optimization, automation, and user/operator comfort), it is contemplated that some systems need not utilize an external sensor to monitor every system parameter. For example, if a temperature sensor has not been installed in a particular system, the user/operator can provide this information by first determining the temperature (e.g., by checking a thermometer, a thermocouple, a weather forecast, the internet, etc.) and then entering the temperature into the system via a user interface.

FIGS. 23A-23J are flowcharts illustrating processing steps of the heater control logic 80. FIG. 23A is a flowchart

illustrating processing logic of the heater control logic 80 communicating with a heater. In step 1520, the heater control logic 80 receives an instruction to activate the heater. In step 1522, the heater logic 80 retrieves data pertaining to factory specified power parameters from memory, e.g., parameters relating to power consumption, current draw, and line voltage. In step 1524, the heater logic 80 receives line power operational data. In step 1526, the heater logic 80 determines whether the line power operational data is within factory specifications. If a positive determination is made, the process proceeds to step 1528. If a negative determination is made, the process proceeds to step 1530. In step 1528, the heater control logic 80 transmits an instruction to the heater to activate, and the process ends. As referenced above, if a negative determination is made at step 1526, then the process proceeds to step 1530. In step 1530, the heater control logic 80 determines if there are any retries remaining. If a positive determination is made, then the heater control logic 80 proceeds to step 1524 and continues the process from that step. If a negative determination is made, then the heater control logic 80 proceeds to step 1532 and transmits an error condition signal, and then ends the process.

FIG. 23B is another flowchart illustrating processing logic of the heater control logic 80 communicating with a heater. In step 1534, the heater control logic 80 receives an instruction to activate the heater. In step 1536, the heater logic 80 retrieves minimum fuel setpoint data for heater operation from memory, e.g., minimum gas pressure. In step 1538, the heater logic 80 receives operational data on fuel, e.g., current gas pressure. In step 1540, the heater logic 80 determines whether the gas pressure is above a minimum setpoint. If a positive determination is made, the process proceeds to step 1542. If a negative determination is made, the process proceeds to step 1541. In step 1542, the heater control logic 80 transmits an instruction to the heater to activate, and the process ends. As referenced above, if a negative determination is made at step 1540, then the process proceeds to step 1541. In step 1541, the heater control logic 80 logs the error timestamp. In step 1543, the heater control logic 80 determines if the number of error logs for the week exceeds the allowable amount. If a positive determination is made, the process proceeds to step 1545. If a negative determination is made, the process proceeds to step 1544. In step 1545, the heater control logic 80 transmits an alert to the user, and the process ends. As referenced above, if a negative determination is made at step 1543, then the process proceeds to step 1544 where the heater control logic 80 determines if there are any retries remaining. If a positive determination is made, then the heater control logic 80 proceeds to step 1538 and continues the process from that step. If a negative determination is made, then the heater control logic 80 proceeds to step 1546 and transmits an error condition signal, and then ends the process.

FIG. 23C is another flowchart illustrating processing logic of the heater control logic 80 communicating with a heater. In step 1548, the heater control logic 80 receives an instruction to activate the heater. In step 1550, the heater logic 80 retrieves blower setpoint data for heater operation from memory, e.g., minimum air pressure. In step 1552, the heater logic 80 receives blower operational data, e.g., air pressure. In step 1554, the heater logic 80 determines whether the air pressure is above the minimum setpoint. If a positive determination is made, the process proceeds to step 1556. If a negative determination is made, the process proceeds to step 1558. In step 1556, the heater control logic 80 transmits an instruction to the heater to activate, and the process ends. As

referenced above, if a negative determination is made at step 1554, then the process proceeds to step 1558. In step 1558, the heater control logic 80 determines if there are any retries remaining. If a positive determination is made, then the heater control logic 80 proceeds to step 1560 and transmits an instruction to the blower to increase the air pressure by 5%, and proceeds to step 1552 and continues the process from that step. It is noted that while the blower could increase air pressure in 5% increments it is contemplated that any satisfactory incremental value could be chosen for optimization of the system (e.g., 1%, 2%, 5%, 10%, etc.). If a negative determination is made, then the heater control logic 80 proceeds to step 1562 and transmits an error condition signal, and then ends the process.

FIG. 23D is another flowchart illustrating processing logic of the heater control logic 80 communicating with a heater. In step 1564, the heater control logic 80 receives an instruction to activate the heater. In step 1566, the heater logic 80 retrieves water temperature setpoint data for heater operation from memory, e.g., minimum and maximum water temperatures. In step 1568, the heater logic 80 receives operational temperature data, e.g., water temperature read by a sensor. In step 1570, the heater logic 80 determines whether the water temperature is below the minimum setpoint. If a positive determination is made, the process proceeds to step 1572. If a negative determination is made, the process returns to step 1568. In step 1572, the heater control logic 80 transmits an instruction to the heater to activate. In step 1574, the heater control logic 80 receives operational temperature data. In step 1576, the heater control logic 80 determines if the water temperature is above a maximum setpoint. If a positive determination is made, then the heater control logic 80 proceeds to step 1578 and transmits an instruction to the heater to switch to standby mode, and the process ends. If a negative determination is made, then the heater control logic 80 returns to step 1574.

FIG. 23E is another flowchart illustrating processing logic of the heater control logic 80 communicating with a heater. In step 1582, the heater control logic 80 receives an instruction to activate the heater. In step 1584, the heater logic 80 retrieves minimum flow rate setpoint data for heater operation from memory, e.g., gallons per minute. In step 1586, the heater logic 80 receives operational flow rate data. In step 1588, the heater logic 80 determines whether the flow rate is above the minimum setpoint. If a positive determination is made, the process proceeds to step 1590. If a negative determination is made, the process proceeds to step 1592. In step 1590, the heater control logic 80 transmits an instruction to the heater to activate, and the process ends. As referenced above, if a negative determination is made at step 1588, then the process proceeds to step 1592. In step 1592, the heater control logic 80 determines if there are any retries remaining. If a positive determination is made, then the heater control logic 80 proceeds to step 1594 and transmits an instruction to the pump to increase the flow by 5%, and proceeds to step 1586 and continues the process from that step. It is noted that while the pump could increase flow in 5% increments it is contemplated that any satisfactory incremental value could be chosen for optimization of the system (e.g., 1%, 2%, 5%, 10%, etc.). If a negative determination is made, then the heater control logic 80 proceeds to step 1596 and transmits an error condition signal, and then ends the process.

FIG. 23F is another flowchart illustrating processing logic of the heater control logic 80 communicating with a heater. In step 1598, the heater control logic 80 receives an instruction to activate the heater. In step 1600, the heater logic 80

retrieves runtime setpoint data for heater operation from memory, e.g., duration of operation. In step **1602**, the heater logic **80** transmits an instruction to the heater to activate. In step **1604**, the heater logic **80** sets a countdown timer for a predefined number (“x”) of seconds, where “x” is the desired runtime of the heater, and activates the timer. In step **1606**, the heater logic **80** determines if the timer has reached “0.” If a positive determination is made, the process proceeds to step **1608**. If a negative determination is made, the process returns to step **1604**. In step **1608**, the heater control logic **80** transmits an instruction to deactivate the heater, and the process ends.

FIG. **23G** is another flowchart illustrating processing logic of the heater control logic **80** communicating with a heater. In step **1610**, the heater control logic **80** retrieves maximum ambient noise setpoint data for heater operation from memory. In step **1612**, the heater logic **80** receives ambient noise operational data. In step **1614**, determines if the ambient noise is above the maximum allowed value. If a positive determination is made, the process proceeds to step **1616**. If a negative determination is made, the process returns to step **1612**. In step **1616**, the heater control logic **80** determines if there are any retries remaining. If a positive determination is made, then the heater control logic **80** proceeds to step **1618** and transmits an instruction to the heater to decrease the output by 5%, and proceeds to step **1612** and continues the process from that step. It is noted that while the heater could decrease output in 5% increments it is contemplated that any satisfactory incremental value could be chosen for optimization of the system (e.g., 1%, 2%, 5%, 10%, etc.). If a negative determination is made, then the heater control logic **80** proceeds to step **1620** and transmits an error condition signal, and then ends the process.

FIG. **23H** is another flowchart illustrating processing logic of the heater control logic **80** communicating with a heater. In step **1622**, the heater logic **80** receives operational data from ambient noise sensors. In step **1624**, the heater logic **80** transmits operational data from ambient noise sensors to memory. In step **1626**, the heater logic **80** determines the average ambient noise setpoint based on operational data from the sensors. In step **1628**, the heater logic **80** receives operational data from heater noise sensors. In step **1630**, the heater logic **80** determines if the decibel level is above the average ambient setpoint. If a positive determination is made, the process proceeds to step **1632**. If a negative determination is made, the process returns to step **1628**. In step **1632**, the heater control logic **80** determines if there are any retries remaining. If a positive determination is made, then the heater control logic **80** proceeds to step **1634** and transmits an instruction to the heater to decrease performance by 5%, and proceeds to step **1628** and continues the process from that step. It is noted that while the heater could decrease performance in 5% increments it is contemplated that any satisfactory incremental value could be chosen for optimization of the system (e.g., 1%, 2%, 5%, 10%, etc.). If a negative determination is made, then the heater control logic **80** proceeds to step **1636** and transmits an error condition signal, and then ends the process.

It is noted that the processing logic of the heater control logic **80** shown in FIGS. **23G** and **23H** could be combined into a process that determines the average ambient noise level over a given period of time and then saves the average ambient noise level to the memory for later retrieval as the maximum ambient noise setpoint data for heater operation,

illustrated in step **1610** of FIG. **23G**. The process could then proceed according to the steps as illustrated in FIG. **23G** as described above.

FIG. **23I** is a flowchart illustrating processing logic of the heater control logic **80** determining alert conditions of a heater. The heater control logic **80** proceeds with four parallel routine sequences that respectively begin with steps **1638**, **1648**, **1658**, and **1668**. Each routine sequence is discussed sequentially, though it should be understood that the routine loops could operate in parallel, or alternatively, in series with each other. The first sequence begins in step **1638** where the heater control logic **80** retrieves factory specified life expectancy data from memory. In step **1640**, the heater control logic **80** determines an alert threshold, e.g., less than 90% of heater life expectancy remaining or runtime value. In step **1642**, the heater control logic **80** receives operational data on heater runtime. In step **1642**, the heater control logic **80** determines if the heater runtime is greater than the threshold. If a negative determination is made, then the process returns to step **1642** and continues to receive operational data on heater runtime. If a positive determination is made, then the process proceeds to step **1646** where an alert is transmitted to a user, and the process ends.

The second sequence begins in step **1648** where the heater control logic **80** retrieves factory specified operating temperature data from memory. In step **1650**, the heater control logic **80** determines an alert threshold, e.g., a temperature value that is 10% above or below operating temperature. In step **1652**, the heater control logic **80** receives operational data on heater system operating temperature. In step **1654**, the heater control logic **80** determines if the heater system operating temperature exceeds the threshold, or is outside of a threshold range. If a negative determination is made, then the process returns to step **1652** and continues to receive operational data on heater system operating temperature. If a positive determination is made, then the process proceeds to step **1656** where an alert is transmitted to a user, and the process ends.

The third sequence begins in step **1658** where the heater control logic **80** retrieves factory specified power consumption data from memory. In step **1660**, the heater control logic **80** determines an alert threshold, e.g., power value that is 110% of specified power consumption. In step **1662**, the heater control logic **80** receives operational data on heater system power consumption. In step **1664**, the heater control logic **80** determines if the heater system power consumption is greater than the threshold. If a negative determination is made, then the process returns to step **1662** and continues to receive operational data on heater system power consumption. If a positive determination is made, then the process proceeds to step **1666** where an alert is transmitted to a user, and the process ends.

The fourth sequence begins in step **1668** where the heater control logic **80** retrieves maximum carbon monoxide output setpoint from memory, e.g., the maximum permitted carbon monoxide output for the heater. In step **1670**, the heater control logic **80** determines an alert threshold, e.g., 905 of maximum carbon monoxide output. In step **1672**, the heater control logic **80** receives operational data on heater system carbon monoxide output. In step **1674**, the heater control logic **80** determines if the heater system carbon monoxide output is greater than the threshold. If a negative determination is made, then the process returns to step **1672** and continues to receive operational data on heater system carbon monoxide output. If a positive determination is made, then the process proceeds to step **1676** where it

transmits an instruction to the heater to deactivate. The process then proceeds to step 1678 and transmits an alert to a user, and the process ends.

FIG. 23J is a flowchart illustrating the procedure implemented when heat is being requested by a user. In step 1680, the heater control logic 80 receives an instruction that heat is called for. In step 1682, the heater control logic 80 proceeds to check if the heater has power. In step 1684, the heater control logic 80 determines if the heater has power. If a negative determination is made, then the process proceeds to step 1714. If a positive determination is made, then the process proceeds to step 1686. In step 1714, the heater control logic 80 determines if there are any retries remaining. If a positive determination is made then the process returns to step 1682, but if a negative determination is made then the process proceeds to step 1716 where the heater control logic 80 indicates an error condition and the process ends. As referenced above, if a positive determination is made in step 1684, then the process proceeds to step 1686. In step 1686, the heater control logic 80 checks the gas pressure. In step 1688, the heater control logic 80 determines if the pressure is within the specified range. If a positive determination is made, then the process proceeds to step 1690. If a negative determination is made, then the process proceeds to step 1718. In step 1718, the heater control logic 80 determines if there are any retries remaining. If a positive determination is made then the process returns to step 1686. If a negative determination is made then the process proceeds to step 1720 where the heater control logic 80 indicates an error condition and the process ends. As referenced above if a positive determination is made in step 1688, then the process proceeds to step 1690. In step 1690, the heater control logic 80 checks the blower operation. In step 1692, the heater control logic 80 determines if the air pressure is within the specified range. If a positive determination is made, then the process proceeds to step 1694. If a negative determination is made, then the process proceeds to step 1722. In step 1722, the heater control logic 80 determines if there are any retries remaining. If a positive determination is made then the process returns to step 1690. If a negative determination is made then the process proceeds to step 1724 where the heater control logic 80 indicates an error condition and the process ends. As referenced above if a positive determination is made in step 1692, then the process proceeds to step 1694. In step 1694, the heater control logic 80 checks the water flow. In step 1696, the heater control logic 80 determines if the flow rate (GPM) is within the specified range. If a positive determination is made, then the process proceeds to step 1698. If a negative determination is made, then the process proceeds to step 1726. In step 1726, the heater control logic 80 determines if there are any retries remaining. If a positive determination is made then the process proceeds to step 1728 where it sends an electronic signal to the pump to increase or decrease the flow by 5%, and then returns to step 1694. It is noted that while the pump could increase or decrease flow in 5% increments it is contemplated that any satisfactory incremental value could be chosen for optimization of the system (e.g., 1%, 2%, 5%, 10%, etc.). If a negative determination is made in step 1726 then the process proceeds to step 1730 where the heater control logic 80 indicates an error condition and the process ends. As referenced above if a positive determination is made in step 1696, then the process proceeds to step 1698. In step 1698, the heater control logic 80 queries for an operation temperature setpoint. In step 1700, the heater control logic 80 determines if the operation temperature setpoint has been received. If a positive determination is

made, then the process proceeds to step 1702. If a negative determination is made, then the process proceeds to step 1732. In step 1732, the heater control logic 80 determines if there are any retries remaining. If a positive determination is made then the process proceeds to step 1734 where it prompts the heater for a desired water temperature, and then returns to step 1698. If a negative determination is made in step 1732 then the process proceeds to step 1736 where the heater control logic 80 indicates an error condition and the process ends. As referenced above if a positive determination is made in step 1700, then the process proceeds to step 1702. In step 1702, the heater control logic 80 electronically receives data relating to the water temperature. In step 1704, the heater control logic 80 determines if the operation temperature setpoint is greater than the water temperature. If a positive determination is made, then the process proceeds to step 1706. If a negative determination is made, then the process proceeds to step 1740. In step 1740, the heater control logic 80 places the heater in standby and returns to step 1702. As referenced above if a positive determination is made in step 1704, then the process proceeds to step 1706. In step 1706, the heater control logic 80 engages the heater. In step 1708, the heater control logic 80 starts a timer. In step 1710, the heater control logic 80 determines if the temperature setpoint is lower than the water temperature. If a positive determination is made, then the process proceeds to step 1712 where it deactivates the heater and the process ends. If a negative determination is made, then the process proceeds to step 1742. In step 1742, the heater control logic 80 determines if the operation duration has exceeded the threshold. If a positive determination is made, then the process proceeds to step 1712 where it deactivates the heater and the process ends. If a negative determination is made then the process returns to step 1706.

FIG. 24 is a diagram 1800 illustrating lighting control logic 78. Lighting control logic 78 could incorporate and/or be in communication with a variety of types of data and/or data sources. More specifically, lighting control logic 78 can communicate with, or receive, user input data 1802, lighting operational data 1804, lighting factory specifications 1806, lighting configuration parameters 1808, web data 1810, pool configuration parameters 1812, data from related devices 1814, health monitoring data 1816 and/or external sensor data 1818.

User input data 1802 could include lighting color, lighting intensity, lighting duration, timers, schedule, default program(s), pool temperature setpoint(s), etc. Lighting operational data 1804 could include status (on/off), cycles (on/off), line voltage, current draw, power consumption, environment (water/air), temperature (lights), ambient light, light color, light intensity, etc. Lighting factory specifications 1806 could include lumen output, life expectancy, current draw, input voltage, power consumption, operating environment, etc. Lighting configuration parameters 1808 could include IP address, GPS coordinates, zip code, time and date, etc. Web data 1810 could include location (based on IP address), time and date, sunrise/sunset data, local lighting code, regional and local weather forecast data, etc. Pool configuration parameters 1812 could include pool surface area, pool geometry, pool liner color, pool cover (yes/no), pool cover schedule, etc. Data from related devices 1814 could include data relating to at least the following: additional lights/systems, chlorinator(s), pump(s), cleaner(s), water feature(s), heater (gas), heater (solar), chemical dispenser, valve(s), pool cover (various), controller, spa, water slide, etc. For example, the following relationships could exist between the lighting control logic 78

the related devices: valves (activate water features, solenoid, dancing waters, etc.), and water slide (shows path, auto-on). Health monitoring data **1816** could include errors, runtime, estimated lumen output, average power consumption, line voltage, line current, percent of light output, operating environment, warranty countdown, water pressure, etc. External sensor data **1818**, could include ambient light, lighting output, motion/occupancy, bather detection, temperature (pool), moisture, chlorine content, pH level, etc. While it may be desirable for external sensors to monitor/ provide data on as many system parameters as possible (thereby providing greater optimization, automation, and user/operator comfort), it is contemplated that some systems need not utilize an external sensor to monitor every system parameter. For example, if a pool temperature sensor has not been installed in a particular system, the user/operator can provide this information by first determining the pool temperature (e.g., by checking a thermometer, thermocouple, etc.) and then entering the pool temperature into the system via a user interface. FIGS. **25A-25AB** are flowcharts illustrating processing steps of the lighting control logic **78**. FIG. **25A** is a flowchart illustrating processing logic of the lighting control logic **78** communicating with a lighting system. In step **1820**, the lighting control logic **78** receives an instruction to activate the lighting system. In step **1822**, the lighting control logic **78** retrieves data pertaining to factory specified power parameters from memory, e.g., parameters relating to power consumption, current draw, and line voltage. In step **1824**, the lighting control logic **78** receives line power operational data. In step **1826**, the lighting logic **78** determines whether the line power operational data is within factory specifications. If a positive determination is made, the process proceeds to step **1828**. If a negative determination is made, the process proceeds to step **1830**. In step **1828**, the lighting control logic **78** transmits an instruction to the lighting system to activate, and the process ends. As referenced above, if a negative determination is made at step **1826**, then the process proceeds to step **1830**. In step **1830**, the lighting control logic **78** determines if there are any retries remaining. If a positive determination is made, then the lighting control logic **78** proceeds to step **1824** and continues the process from that step. If a negative determination is made, then the lighting control logic **78** proceeds to step **1832** and transmits an error condition signal, and the process ends.

FIG. **25B** is another flowchart illustrating processing logic of the lighting control logic **78** communicating with a lighting system. In step **1832**, the lighting control logic **78** receives an instruction to activate the lighting system. In step **1834**, the lighting control logic **78** retrieves factory specified operating environment data from memory, e.g., is the light in air or water. In step **1836**, the lighting control logic **78** receives data from lighting fixture moisture sensor. In step **1838**, the lighting control logic **78** determines the environment of the lighting fixture, e.g., is the fixture in air or water. In step **1840**, the lighting control logic **78** determines if the lighting fixture is in the environment specified by the factory specified operating environment. If a positive determination is made, the process proceeds to step **1842**. If a negative determination is made, the process proceeds to step **1844**. In step **1842**, the lighting control logic **78** transmits an instruction to the lighting system to activate, and the process ends. As referenced above, if a negative determination is made at step **1840**, then the process proceeds to step **1844**. In step **1844**, the lighting control logic **78** determines if there are any retries remaining. If a positive determination is made, then the lighting control logic **78** proceeds to step **1836** and

continues the process from that step. If a negative determination is made, then the lighting control logic **78** proceeds to step **1846** and transmits an error condition signal, and the process ends.

FIG. **25C** is a flowchart illustrating a process for a user to define a light show. In step **1848**, the lighting control logic **78** prompts the user for a desired lighting color. In step **1850**, the lighting control logic **78** receives the desired lighting color data from the user. In step **1852**, the lighting control logic **78** prompts the user for a desired lighting speed. In step **1854**, the lighting control logic **78** receives the desired lighting speed data from the user. In step **1856**, the lighting control logic **78** prompts the user for a desired lighting motion profile. In step **1858**, the lighting control logic **78** receives desired lighting motion profile data from the user. In step **1860**, the lighting control logic **78** retrieves pool geometry data from memory. In step **1862**, the lighting control logic **78** processes the data received from the user and the pool geometry data. In step **1864**, the lighting control logic **78** generates a virtual preview of a light show from the user data and pool geometry data. In step **1866**, the lighting control logic **78** transmits the virtual preview of the light show to the user. In step **1868**, the lighting control logic **78** prompts the user to save virtual preview parameters to the memory. In step **1870**, the lighting control logic **78** determines if the user has saved the parameters. If a positive determination is made then the process proceeds to step **1872** where the lighting control logic **78** transmits the parameters to memory as a stored light show, and the process ends. If a negative determination is made, then the process proceeds to step **1874** where the lighting control logic **78** prompts the user to enter new parameters, and then proceeds to step **1876**. In step **1876**, the lighting control logic **78** determines if the user has elected to enter new parameters. If a positive determination is made then the process returns to step **1848**. If a negative determination is made then the process ends.

FIG. **25D** is another flowchart illustrating processing logic of the lighting control logic **78** communicating with a lighting system. In step **1878**, the lighting control logic **78** determines the geographic location of the pool, e.g., based on IP address or configuration parameters. In step **1880**, the lighting control logic **78** receives sunrise/sunset data from the web based on the geographic location. In step **1882**, the lighting control logic **78** receives current time data. In step **1886**, the lighting control logic **78** determines if the current time is after sunset. If a positive determination is made, the process proceeds to step **1888**. If a negative determination is made, the process proceeds to step **1884** where the lighting control logic **78** delays operation for a predetermined period of time, and after the expiration of the predetermined period of time returns to step **1882**. As referenced above, if a positive determination is made at step **1886**, then the process proceeds to step **1888**. In step **1888**, the lighting control logic **78** determines if the current time is before sunrise. If a positive determination is made, then the lighting control logic **78** proceeds to step **1890** where it transmits an instruction to activate the lighting system, and the process ends. If a negative determination is made, then the lighting control logic **78** proceeds to step **1892** where it delays operation for a predetermined period of time, and after the expiration of the predetermined period of time returns to step **1882**.

FIG. **25E** is another flowchart illustrating processing logic of the lighting control logic **78** communicating with a lighting system. In step **1894**, the lighting control logic **78** determines the geographic location of the pool, e.g., based on IP address or configuration parameters. In step **1896**, the

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lighting control logic 78 receives sunrise/sunset data from the web based on the geographic location. In step 1898, the lighting control logic 78 receives current time data. In step 1900, the lighting control logic 78 determines if the current time is after sunset. If a positive determination is made, the process proceeds to step 1902. If a negative determination is made, the process proceeds to step 1910 where the lighting control logic 78 delays operation for a predetermined period of time, and after the expiration of the predetermined period of time returns to step 1898. As referenced above, if a positive determination is made at step 1900, then the process proceeds to step 1902. In step 1902, the lighting control logic 78 determines if the current time is before sunrise. If a positive determination is made, then the lighting control logic 78 proceeds to step 1904. If a negative determination is made, then the lighting control logic 78 proceeds to step 1892 where it delays operation for a predetermined period of time, and after the expiration of the predetermined period of time returns to step 1898. As referenced above, if a positive determination is made at step 1902, then the process proceeds to step 1904. In step 1904, the lighting control logic 78 receives operational data from a pool cleaner. In step 1906, the lighting control logic 78 determines if the pool cleaner is running. If a negative determination is made, then the process returns to step 1898. If a positive determination is made, then the process proceeds to step 1908 where the lighting control logic 78 transmits an instruction to activate the lighting system.

FIG. 25F is another flowchart illustrating processing logic of the lighting control logic 78 communicating with a lighting system. In step 1914, the lighting control logic 78 receives operational data from a water feature. In step 1916, the lighting control logic 78 determines the operational status of the water feature. In step 1918, the lighting control logic 78 determines if the water feature is running. If a negative determination is made, then the process returns to step 1914. If a positive determination is made, then the process proceeds to step 1920 where the lighting control logic 78 interlocks with the water feature. In step 1922, the lighting control logic 78 transmits an instruction to the lighting system to activate.

FIG. 25G is another flowchart illustrating processing logic of the lighting control logic 78 communicating with a lighting system. In step 1924, the lighting control logic 78 receives operational data from a pool cover. In step 1926, the lighting control logic 78 determines the operational status of the pool cover, e.g., is the pool cover open or closed. In step 1928, the lighting control logic 78 determines if the pool cover is open. If a positive determination is made, then the process returns to step 1924. If a negative determination is made, then the process proceeds to step 1930 where the lighting control logic 78 transmits an instruction to the lighting system to deactivate, and then returns to step 1924.

FIG. 25H is another flowchart illustrating processing logic of the lighting control logic 78 communicating with a lighting system. In step 1932, the lighting control logic 78 receives an instruction to activate the lighting system. In step 1934, the lighting control logic 78 receives operational data from a pool cover. In step 1936, the lighting control logic 78 determines the operational state of the pool cover, e.g., is the pool cover open or closed. In step 1938, the lighting control logic 78 determines if the pool cover is open. If a positive determination is made, then the process proceeds to step 1940 where the lighting control logic 78 transmits an instruction to the lighting system to activate and then returns to step 1934. If a negative determination is made, then the process proceeds to step 1942 where the lighting control

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logic 78 determines if there are any retries remaining. If a positive determination is made, then the process returns to step 1934. If a negative determination is made, then the process proceeds to step 1944 where an error condition is transmitted, and the process ends.

FIG. 25I is another flowchart illustrating processing logic of the lighting control logic 78 communicating with a lighting system. In step 1946, the lighting control logic 78 receives an instruction to activate the lighting system. In step 1948, the lighting control logic 78 receives operational data from a pool cover. In step 1950, the lighting control logic 78 determines the operational state of the pool cover, e.g., is the pool cover open or closed. In step 1952, the lighting control logic 78 determines if the pool cover is open. If a positive determination is made, then the process proceeds to step 1960 where the lighting control logic 78 transmits an instruction to the lighting system to activate, and the process ends. If a negative determination is made, then the process proceeds to step 1954 where the lighting control logic 78 prompts a user to open the pool cover. In step 1956, the lighting control logic 78 determines if the user has issued an instruction to open the pool cover. If a negative determination is made, then the process returns to step 1948. If a positive determination is made, then the process proceeds to step 1958 where the lighting control logic 78 transmits an instruction to the pool cover to open, and the process ends.

FIG. 25J is another flowchart illustrating processing logic of the lighting control logic 78 communicating with a lighting system. In step 1962, the lighting control logic 78 receives a minimum ambient light setpoint value. In step 1964, the lighting control logic 78 receives a maximum ambient light setpoint value. In step 1966, the lighting control logic 78 receives a current ambient light value from an external sensor. In step 1968, the lighting control logic 78 determines if the current ambient light value is below the minimum ambient light setpoint. If a negative determination is made, then the process returns to step 1966. If a positive determination is made, then the process proceeds to step 1970 where the lighting control logic 78 transmits an instruction to the lighting system to activate the lights. In step 1972, the lighting control logic 78 receives a current ambient light value from an external sensor. In step 1974, the lighting control logic 78 determines if the current ambient light value is below a minimum ambient light setpoint. If a positive determination is made, then the process proceeds to step 1980 where the lighting control logic 78 transmits an instruction to the lighting system to increase the lumen output by 5% and then returns to step 1972. It is noted that while the lighting system could increase lumen output in 5% increments it is contemplated that any satisfactory incremental value could be chosen for optimization of the system (e.g., 1%, 2%, 5%, 10%, etc.). If a negative determination is made, then the process proceeds to step 1976. In step 1976, the lighting control logic 78 determines if the current ambient light value is above the maximum ambient light setpoint. If a negative determination is made (e.g., the ambient light is in the acceptable range—above the minimum setpoint and below the maximum setpoint), then the process proceeds to step 1978 where it delays for a predetermined time period and then returns to step 1972. If a positive determination is made, then the process proceeds to step 1984 where the lighting control logic 78 determines if there are any retries remaining. If a negative determination is made, then the process proceeds to step 1986 where the lighting control logic 78 transmits an instruction to the lighting system to deactivate the lights and then returns to step 1966. If a positive determination is made, then the

process proceeds to step 1982 where the lighting control logic 78 transmits an instruction to the lighting system to decrease lumen output by 5% and then returns to step 1972. It is noted that while the lighting system could increase lumen output in 5% increments it is contemplated that any satisfactory incremental value could be chosen for optimization of the system (e.g., 1%, 2%, 5%, 10%, etc.).

FIG. 23K is a flowchart illustrating processing logic of the lighting control logic 78 determining an error condition and preventative maintenance reminders for a lighting system. The lighting control logic 78 proceeds with six parallel routine sequences that respectively begin with steps 1988, 1994, 2004, 2014, 2024, 2034. Each routine sequence is discussed sequentially, though it should be understood that the routine loops could operate in parallel, or alternatively, in series with each other. The first sequence begins in step 1988 where the lighting control logic 78 monitors for an error condition. In step 1990, the lighting control logic 78 determines if there is an error condition. If a negative determination is made, then the process returns to step 1988. If a positive determination is made, then the process proceeds to step 1992 where the lighting control logic 78 transmits an error condition. In step 1993, the lighting control logic 78 determines if the user has snoozed the error condition. If a negative determination is made, then the process ends. If a positive determination is made, then the process proceeds to step 1995 where it delays for a predetermined period of time and then returns to step 1992.

The second sequence begins at step 1994, where the lighting control logic 78 retrieves factory specified life expectancy data from memory. In step 1996, the lighting control logic 78 determines a preventative maintenance threshold, e.g., less than 90% of light life expectancy remaining or runtime value. In step 1998, the lighting control logic 78 receives operational data on lighting system runtime. In step 2000, the lighting control logic 78 determines if the lighting system runtime is greater than the threshold. If a negative determination is made, then the process returns to step 1998 and continues to receive operational data on lighting system runtime. If a positive determination is made, then the process proceeds to step 2002 where a preventative maintenance reminder is transmitted to a user, and the process ends.

The third sequence begins in step 2004 where the lighting control logic 78 retrieves factory specified lumen output data from memory. In step 2006, the lighting control logic 78 determines a maintenance threshold, e.g., a lumen output value that is 90% of a specified lumen output. In step 2008, the lighting control logic 78 receives operational data on lighting system lumen output. In step 2010, the lighting control logic 78 determines if the lighting system operating lumen output is less than the threshold. If a negative determination is made, then the process returns to step 2008 and continues to receive operational lumen output data for the lighting system. If a positive determination is made, then the process proceeds to step 2012 where a preventative maintenance reminder is transmitted to a user, and the process ends.

The fourth sequence begins in step 2014 where the lighting control logic 78 retrieves factory specified power consumption data from memory. In step 2016, the lighting control logic 78 determines a maintenance threshold, e.g., power value that is 110% of specified power consumption. In step 2018, the lighting control logic 78 receives operational data on lighting system power consumption. In step 2020, the lighting control logic 78 determines if the lighting system power consumption is greater than the threshold. If

a negative determination is made, then the process returns to step 2018 and continues to receive operational data on lighting system power consumption. If a positive determination is made, then the process proceeds to step 2022 where a preventative maintenance reminder is transmitted to a user, and the process ends.

The fifth sequence begins in step 2024 where the lighting control logic 78 retrieves factory specified input voltage data from memory. In step 2026, the lighting control logic 78 determines a maintenance threshold, e.g., an input voltage value that is +/-10% of specified line voltage. In step 2028, the lighting control logic 78 receives operational data on lighting system line voltage. In step 2030, the lighting control logic 78 determines if the lighting system line voltage is greater than the threshold. If a negative determination is made, then the process returns to step 2028 and continues to receive operational data on lighting system line voltage. If a positive determination is made, then the process proceeds to step 2032 where a preventative maintenance reminder is transmitted to a user, and the process ends.

The sixth sequence begins in step 2034 where the lighting control logic 78 retrieves factory warranty data from memory. In step 2036, the lighting control logic 78 determines a maintenance threshold, e.g., 90% of the time period of the factory warranty has expired. In step 2038, the lighting control logic 78 receives operational data on lighting system runtime. In step 2040, the lighting control logic 78 determines if the lighting system runtime is greater than the threshold. If a negative determination is made, then the process returns to step 2038 and continues to receive operational data on lighting system runtime. If a positive determination is made, then the process proceeds to step 2042 where a preventative maintenance reminder is transmitted to a user, and the process ends.

FIG. 25L is another flowchart illustrating processing logic of the lighting control logic 78 communicating with a lighting system. In step 2044, the lighting control logic 78 receives lighting system temperature operational data. In step 2046, the lighting control logic 78 determines if the lighting system needs to scale back lumen output due to temperature. If a negative determination is made, then the process returns to step 2044. If a positive determination is made, then the process proceeds to step 2048 where the lighting control logic 78 receives pool temperature operational data. In step 2050, the lighting control logic 78 determines the required reduction in pool temperature to return the lighting system to full lumen output. In step 2052, the lighting control logic 78 transmits an instruction to the heater to reduce the temperature by the required amount, and then returns to step 2044.

FIG. 25M is another flowchart illustrating processing logic of the lighting control logic 78 communicating with a lighting system. In step 2054, the lighting control logic 78 receives lighting system temperature operational data. In step 2056, the lighting control logic 78 determines if the lighting system needs to scale back lumen output due to temperature. If a negative determination is made, then the process returns to step 2054. If a positive determination is made, then the process proceeds to step 2058 where the lighting control logic 78 transmits an instruction to the heater instructing it to decrease output by 5%, and then returns to step 2054. It is noted that while the heater could decrease output in 5% increments it is contemplated that any satisfactory incremental value could be chosen for optimization of the system (e.g., 1%, 2%, 5%, 10%, etc.).

FIG. 25N is another flowchart illustrating processing logic of the lighting control logic 78 communicating with a

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lighting system. In step 2060, the lighting control logic 78 retrieves pool temperature setpoint data from memory. In step 2062, the lighting control logic 78 receives pool temperature operational data. In step 2064, the lighting control logic 78 determines the range between temperature setpoint and temperature operational data. In step 2066, the lighting control logic 78 retrieves RGB color table from memory. In step 2068, the lighting control logic 78 generates a lookup table including desired RGB color spectrum and associated temperature range (e.g., from blue at measured temperature to white at setpoint). In step 2070, the lighting control logic 78 receives pool temperature operational data. In step 2072, the lighting control logic 78 determines the RGB color associated with temperature operational data. In step 2074, the lighting control logic 78 transmits an instruction to the lighting system to display the RGB color associated with the pool temperature, and then returns to step 2070.

FIG. 25O is another flowchart illustrating processing logic of the lighting control logic 78 communicating with a lighting system. In step 2076, the lighting control logic 78 retrieves chlorine level setpoint data from memory. In step 2078, the lighting control logic 78 receives chlorine level operational data. In step 2080, the lighting control logic 78 determines the range between chlorine level setpoint and chlorine level operational data. In step 2082, the lighting control logic 78 retrieves RGB color table from memory. In step 2084, the lighting control logic 78 generates a lookup table including desired RGB color spectrum and associated chlorine level range (e.g., from green at measured temperature to purple at setpoint). In step 2086, the lighting control logic 78 receives chlorine level operational data. In step 2088, the lighting control logic 78 determines the RGB color associated with chlorine level operational data. In step 2090, the lighting control logic 78 transmits an instruction to the lighting system to display the RGB color associated with the chlorine level. In step 2092, the lighting control logic 78 determines if the chlorine level operational data is equal to the chlorine level setpoint. If a positive determination is made, then the process proceeds to step 2094 where the lighting control logic 78 transmits a message stating that the pool chemistry is "OK," and the process ends. If a negative determination is made, then the process proceeds to step 2096 where the lighting control logic 78 transmits a message stating that chlorine should be added to the pool. The process then proceeds to step 2098 where it delays for a predetermined period of time before returning to step 2086.

FIG. 25P is another flowchart illustrating processing logic of the lighting control logic 78 communicating with a lighting system. In step 2100, the lighting control logic 78 retrieves chlorine level setpoint data from memory. In step 2102, the lighting control logic 78 receives chlorine level operational data. In step 2104, the lighting control logic 78 determines if the chlorine level operational data is equal to the chlorine level setpoint. If a positive determination is made, then the process returns to step 2102. If a negative determination is made then the process proceeds to step 2106 where it retrieves a lighting program associated with a chlorine imbalance from memory, e.g., activate yellow or flashing yellow light to alert a user to a chlorine imbalance. In step 2108, the lighting control logic 78 transmits an instruction to the lighting system to display the program associated with a chlorine imbalance, and then returns to step 2102.

FIG. 25Q is another flowchart illustrating processing logic of the lighting control logic 78 communicating with a lighting system. In step 2110, the lighting control logic 78 monitors for user-selected light shows and colors. In step

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2112, the lighting control logic 78 determines if the user has selected a light show or colors. If a negative determination is made, then the process returns to step 2110. If a positive determination is made, then the process proceeds to step 2114 where the lighting control logic 78 receives parameters of the user-selected light show or color. In step 2116, the lighting control logic 78 receives a timestamp for the user-selected light show or colors. In step 2118, the lighting control logic 78 transmits the parameters and timestamp to memory. In step 2120, the lighting control logic 78 determines the most commonly selected light show or colors. In step 2122, the lighting control logic 78 saves the most commonly selected light show or colors to memory as a default lighting program, and then returns to step 2110.

FIG. 25R is another flowchart illustrating processing logic of the lighting control logic 78 communicating with a lighting system. This process includes two parallel branches for defining a lighting program for pool features and displaying a lighting program for a specific pool features. The process begins at steps 2124 and 2144. In step 2124, the lighting control logic 78 monitors for user-selected light shows and colors. In step 2126, the lighting control logic 78 determines if the user has selected a light show or colors. If a negative determination is made, then the process returns to step 2124. If a positive determination is made, then the process proceeds to step 2128 where the lighting control logic 78 determines if additional pool features are currently active, e.g., pool/spa spillover features. If a negative determination is made, then the process proceeds to step 2142 where the lighting control logic 78 displays the user-selected light show or colors, and the process ends. If a positive determination is made, then the process proceeds to step 2130 where it receives operational data of the currently active pool features. In step 2132, the lighting control logic 78 receives parameters of the user-selected light show or color. In step 2134, the lighting control logic 78 receives a timestamp for the currently active pool features and light-show. In step 2136, the lighting control logic 78 transmits the pool feature operational data, light show parameters, and timestamp to memory. In step 2138, the lighting control logic 78 determines the most commonly selected light show or colors associated with the additional pool feature. In step 2140, the lighting control logic 78 saves the most commonly selected light show or colors to memory as a default lighting program for the additional pool features, and then returns to step 2124.

In step 2144, the lighting control logic 78 monitors for currently active pool features. In step 2146, the lighting control logic 78 determines if there are any currently active pool features. If a negative determination is made, then the process returns to step 2144. If a positive determination is made, then the process proceeds to step 2148 where the lighting control logic 78 determines if there is a stored default lighting program for the pool feature. If a negative determination is made, then the process proceeds to step 2124, where it goes through the process of having a user define a light show for that pool feature. If a positive determination is made, then the process proceeds to step 2150, where the lighting control logic 78 retrieves the stored default program for the pool feature from memory. In step 2152, the lighting control logic 78 transmits an instruction to the lighting system to display the default program for the pool feature, and the process ends.

FIG. 25S is another flowchart illustrating processing logic of the lighting control logic 78 communicating with a lighting system. In step 2154, the lighting control logic 78 receives operational data from a motion sensor. In step 2156,

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the lighting control logic 78 determines if the motion sensor has been triggered. If a negative determination is made, then the process returns to step 2154. If a positive determination is made, then the process proceeds to step 2158 where the lighting control logic 78 receives sunrise/sunset data from the Internet. In step 2160, the lighting control logic 78 receives the current time data. In step 2162, the lighting control logic 78 determines if the current time is after sunset. If a negative determination is made, then the process returns to step 2154. If a positive determination is made, then the process proceeds to step 2164. In step 2164, the lighting control logic 78 determines if the current time is before sunrise. If a negative determination is made, then the process returns to step 2154. If a positive determination is made then the process proceeds to steps 2166 and 2168, where the lighting control logic 78 transmits a signal to activate the lighting system, transmits an alert to the user, and then ends the process.

FIG. 25T is another flowchart illustrating processing logic of the lighting control logic 78 communicating with a lighting system. In step 2170, the lighting control logic 78 receives operational data from a motion sensor. In step 2172, the lighting control logic 78 determines if the motion sensor has been triggered. If a negative determination is made, then the process returns to step 2170. If a positive determination is made, then the process proceeds to step 2174 where the lighting control logic 78 retrieves a minimum ambient light setpoint value from memory. In step 2176, the lighting control logic 78 receives ambient light operational data. In step 2178, the lighting control logic 78 determines if the ambient light operational data is below the minimum setpoint. If a negative determination is made, then the process returns to step 2170. If a positive determination is made, then the process proceeds to steps 2180 and 2182, where the lighting control logic 78 transmits a signal to activate the lighting system, transmits an alert to the user, and then ends the process.

FIG. 25U is another flowchart illustrating processing logic of the lighting control logic 78 communicating with a lighting system. In step 2184, the lighting control logic 78 receives operational data from a motion sensor. In step 2186, the lighting control logic 78 determines if the motion sensor has been triggered. If a negative determination is made, then the process returns to step 2184. If a positive determination is made, then the process proceeds to step 2188 where the lighting control logic 78 retrieves a minimum ambient light setpoint value from memory. In step 2190, the lighting control logic 78 receives ambient light operational data. In step 2192, the lighting control logic 78 determines if the ambient light operational data is below the minimum setpoint. If a negative determination is made, then the process returns to step 2184. If a positive determination is made, then the process proceeds to step 2194 where it determines if a light show is in progress. If a negative determination is made, then the process proceeds to step 2202. If a positive determination is made then the process proceeds to step 2196. In step 2196, the lighting control logic 78 transmits an instruction to the lighting system to discontinue showing the current show. As referenced above, if a negative determination is made in step 2194, then the process proceeds to step 2202. In step 2202, the lighting control logic 78 transmits an instruction to activate the lighting system. Step 2196 and 2202 both proceed to step 2198 where the lighting control logic 78 transmits an instruction to the lighting system to display white light at the maximum lumen value. In step 2200, the lighting control logic 78 transmits an alert to the user, and the process ends.

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FIG. 25V is another flowchart illustrating processing logic of the lighting control logic 78 communicating with a lighting system. In step 2204, the lighting control logic 78 receives operational data from light sensors. In step 2206, the lighting control logic 78 saves operational data from the light sensors to memory. In step 2208, the lighting control logic 78 determines the average setpoint based on operational data from the light sensors. In step 2210, the lighting control logic 78 determines if there is remaining time to establish the setpoint. If a positive determination is made, then the process returns to step 2204 and the setpoint continues to be established. If a negative determination is made, then the process proceeds to step 2212 where the lighting control logic 78 determines the acceptable deviation from the setpoint, e.g., 90% of the setpoint. In step 2214, the lighting control logic 78 receives operational data from the light sensors. In step 2216 the lighting control logic 78 determines if the operational data from the light sensors is within the acceptable deviation. If a positive determination is made, then the process returns to step 2214. If a negative determination is made, then the process proceeds to step 2218 where the lighting control logic 78 transmits an instruction to the pump to activate. In step 2220, the lighting control logic 78 transmits an instruction to the chlorinator to activate and then proceeds to step 2222 where it delays for a predetermined period of time before returning to step 2204.

FIG. 25W is another flowchart illustrating processing logic of the lighting control logic 78 communicating with a lighting system. In step 2224, the lighting control logic 78 determines the geographic location of the pool, e.g., based on IP address or configuration parameters. In step 2226, the lighting control logic 78 receives local weather forecast data from the Internet/Web. In step 2228, the lighting control logic 78 processes the weather forecast and identifies impending inclement weather. In step 2230, the lighting control logic 78 determines if there is any impending inclement weather. If a negative determination is made, then the process returns to step 2226. If a positive determination is made, then the process proceeds to step 2232 where the lighting control logic 78 retrieves a weather alert lighting program from memory and then proceeds to steps 2234 and 2236. In step 2234, the lighting control logic 78 transmits an instruction to the lighting system to display the weather alert program, e.g., a flashing white light at maximum lumen output. In step 2236, the lighting control logic 78 transmits an instruction to the pool devices to shield against lightning strike.

FIG. 25X is another flowchart illustrating processing logic of the lighting control logic 78 communicating with a lighting system. In step 2238, the lighting control logic 78 receives operational data from external moisture sensors. In step 2240, the lighting control logic 78 determines the presence of precipitation, e.g., versus a splash of water, for example. In step 2242, the lighting control logic 78 determines if there is precipitation. If a negative determination is made, then the process proceeds to step 2246. If a positive determination is made, then the process proceeds to step 2244 where the lighting control logic 78 transmits an instruction to the lighting system to activate, and then returns to step 2238. In step 2246, the lighting control logic 78 receives operational data from the lighting system. In step 2248, the lighting control logic 78 determines if the lighting system is active. If a negative determination is made, then the process returns to step 2238. If a positive determination is made, then the process proceeds to step 2250 where the

lighting control logic 78 transmits an instruction to the lighting system to deactivate, and returns to step 2238.

FIG. 25Y is another flowchart illustrating processing logic of the lighting control logic 78 communicating with a lighting system. In step 2252, the lighting control logic 78 monitors safety alarms for incoming operational data. In step 2254, the lighting control logic 78 receives incoming operational data from the safety alarms. In step 2256, the lighting control logic 78 determines if a safety alarm has been triggered. If a negative determination is made, then the process returns to step 2252. If a positive determination is made, then the process proceeds to step 2258 where the lighting control logic 78 receives parameters of the user-selected light show or color. In step 2116, the lighting control logic 78 retrieves a safety alarm lighting program from the memory. In step 2260, the lighting control logic 78 transmits an instruction to the lighting system to display the safety alarm program, e.g., a flashing red light at maximum lumen output, and the process ends.

FIG. 25Z is another flowchart illustrating processing logic of the lighting control logic 78 communicating with a lighting system. In step 2262, the lighting control logic 78 determines the geographic location of the pool, e.g., based on IP address or configuration parameters. In step 2264, the lighting control logic 78 receives regional sea turtle migratory and nesting data from the Internet/Web. In step 2266, the lighting control logic 78 determines the proximity of the pool to sea turtle nesting areas. In step 2268, the lighting control logic 78 determines if the pool is located in a sea turtle nesting area. If a negative determination is made, then the process returns to step 2264. If a positive determination is made, then the process proceeds to step 2270 where the lighting control logic 78 receives the current data. In steps 2272 and 2274, the lighting control logic 78 determines if the current date is during the sea turtle nesting season. If a negative determination is made then the process returns to step 2270. If a positive determination is made, then the process proceeds to step 2276 where the lighting control logic 78 transmits an instruction to the lighting system to lock out all colors other than amber, and the process ends.

FIG. 25AA is a flowchart illustrating processing logic of the lighting control logic 78 for controlling multiple light sources. The lighting control logic 78 proceeds with four parallel routine sequences that respectively begin with steps 2278, 2288, 2298, 2308. Each routine sequence is discussed sequentially, though it should be understood that the routine loops could operate in parallel, or alternatively, in series with each other. The first sequence begins in step 2278 where the lighting control logic 78 transmits an instruction to a first light source to display a color. In step 2280, the lighting control logic 78 monitors a first motion sensor for incoming operational data. In step 2282, the lighting control logic 78 receives incoming operational data from the first motion sensor. In step 2284, the lighting control logic 78 determines if motion has been detected. If a negative determination is made then the process returns to step 2280. If a positive determination is made then the process proceeds to step 2286 where the lighting control logic 78 transmits an instruction to the first light source to change the color, and then returns to step 2284.

The second sequence begins in step 2288 where the lighting control logic 78 transmits an instruction to a second light source to display a color. In step 2290, the lighting control logic 78 monitors a second motion sensor for incoming operational data. In step 2292, the lighting control logic 78 receives incoming operational data from the second motion sensor. In step 2294, the lighting control logic 78

determines if motion has been detected. If a negative determination is made then the process returns to step 2290. If a positive determination is made then the process proceeds to step 2296 where the lighting control logic 78 transmits an instruction to the second light source to change the color, and then returns to step 2294.

The third sequence begins in step 2298 where the lighting control logic 78 transmits an instruction to a third light source to display a color. In step 2300, the lighting control logic 78 monitors a third motion sensor for incoming operational data. In step 2302, the lighting control logic 78 receives incoming operational data from the third motion sensor. In step 2304, the lighting control logic 78 determines if motion has been detected. If a negative determination is made then the process returns to step 2300. If a positive determination is made then the process proceeds to step 2306 where the lighting control logic 78 transmits an instruction to the third light source to change the color, and then returns to step 2304.

The n^{th} sequence begins in step 2308 where the lighting control logic 78 transmits an instruction to an n^{th} light source to display a color. In step 2310, the lighting control logic 78 monitors an n^{th} motion sensor for incoming operational data. In step 2312, the lighting control logic 78 receives incoming operational data from the n^{th} motion sensor. In step 2314, the lighting control logic 78 determines if motion has been detected. If a negative determination is made then the process returns to step 2310. If a positive determination is made then the process proceeds to step 2316 where the lighting control logic 78 transmits an instruction to the n^{th} light source to change the color, and then returns to step 2314.

FIG. 25AB is another flowchart illustrating processing steps of the lighting control logic 78 communicating with the lighting system 14h. In step 2318, the lighting control logic 78 receives water pressure operational data from external sensor(s) at a first time. In step 2320, the lighting control logic 78 delays for x seconds, where "x" refers to any suitable integral value (e.g., 30, 60, 3600, 7200, etc.). In step 2322, the lighting control logic 78 receives water pressure operational data from external sensor(s) at a second time. In step 2324, the lighting control logic 78 determines the change (e.g., delta (A)) in water pressure. In step 2326, the lighting control logic 78 retrieves setpoint data for the acceptable drop, or increase, in water pressure from the memory. In step 2328, the lighting control logic 78 determines if the change in water pressure is acceptable (e.g., by comparing the actual change in water pressure to the acceptable change in water pressure). If a positive determination is made, then the process returns to step 2318. If a negative determination is made, then the process proceeds to step 2230 where the lighting control logic 78 retrieves a lighting program associated with a drop, or increase, in water pressure from the memory (e.g., red lights, red flashing lights, fast pulsing lights for pressure increase, slow pulsing lights for pressure decrease, etc.). In step 2332, the lighting control logic 78 transmits instructions the lighting system 14h to display the lighting program associated with the drop, or increase, in pressure. Optionally, in step 2334, the lighting control system 78 could also for example, transmit a "Backwash" message to the user/operator. The processing control logic 78 then returns to step 2318.

The lighting control logic 78 can also manage and/or control the brightness of a plurality of lights in response to noise or sound. An ambient noise or sound sensor can be used to detect a plurality of bathers ingress and egress from the swimming pool and even the bathers voices. For

example, the ambient noise sensor can detect voice commands and/or noise levels and control the lights based such voice commands and noise levels. Furthermore, the lighting control logic 78 can modulate the plurality of lights color, tempo, etc. if the control logic senses music, games, voices, etc. Further, the noise sensor could also sense for games being played by bathers, for example, "Marco Polo," and adjust output of the lights accordingly.

The lighting control logic 78 can also receive input from a pressure sensor for effectively determining depth of the water above the sensor. This sensor can be located in a light or any other suitable location in a pool or spa environment. The lighting control logic 78 can trigger an automatic water fill routine or draining routine to adjust the water level based on any set level in the system.

FIG. 26 is a diagram 2400 illustrating pool cleaner control logic 76. Pool cleaner control logic 76 could incorporate a variety of types of data and/or data sources. More specifically, pool cleaner control logic 76 could incorporate user input data 2402, pool cleaner operational data 2404, pool cleaner factory specifications 2406, pool cleaner configuration parameters 2408, web data 2410, pool configuration parameters 2412, data from related devices 2414, health monitoring data 2416, and/or external sensor data 2418. While it may be desirable for external sensors to monitor/provide data on as many system parameters as possible (thereby providing greater optimization, automation, and user/operator comfort), it is contemplated that some systems need not utilize an external sensor to monitor every system parameter. For example, if a pool cover detection sensor has not been installed in a particular system, the user/operator can provide this information by first determining if the pool cover has been deployed (e.g., by visual inspection) and then entering the pool cover deployment status into the system via a user interface.

User input data 2402 could include timers, schedules (e.g., on/off and what speed), cleaning patterns (e.g., orientation of cleaner), etc. Pool cleaner operational data 2404 could include submersion (e.g., float switch and/or moisture sensor), debris level (e.g., collection bag), debris weight, power consumption, current draw, speed of motor (RPM), speed of turbine (RPM), speed of cleaner, orientation of cleaner, etc. In one example, the pool cleaner control logic 76 could make a determination as to whether energy can be supplied to the cleaner via an integral turbine. Pool cleaner factor specifications 2406 could include motor speed, power consumption, current draw, input voltage, life expectancy, etc. Pool cleaner configuration parameters 2408 could include IP address, GPS coordinates, zipcode, time and date, etc. Web data 2410 could include location (e.g., based on IP address), time and date, sunrise/sunset data, ambient light, season, etc. Pool configuration parameters 2412 could include connected pool devices, pool surface area, pool geometry, pool liner color, pool cover (e.g., yes or no), pool cover schedule, etc. Data from related devices 2414 could include the pump, booster pump, changeover valve, valve actuator, vision system, pool cover, controller, power supply, etc. Health monitoring data 2416 could include line-to-line balance, grounding, bonding, leak current, runtime, operating temperature, power consumption, etc. External sensor data 2418 could include water circulation, water flow rate, water pressure water turbidity, power consumption, current draw, line voltage, valve actuation, ambient light, debris location, pool cover detection, etc. Using this data, the pool cleaner control logic 76 could optimize the operation of the pool cleaner. Examples include, anti-kink/hose un-tangle, adjust performance based on internal sensors, cleaner and/or

cleaner circuit pressure sensing, time of day sensing, and send cleaner to dirty/high debris area of the pool.

FIGS. 27A-27O are flowcharts illustrating processing steps of the pool cleaner control logic 76. FIG. 27A is a flowchart illustrating processing logic of the pool cleaner control logic 76 communicating with a pump. In step 2420, the pool cleaner control logic 76 receives instruction to activate a pool cleaner. In step 2422, the pool cleaner control logic 76 receives operation data from a pump. In step 2424, the pool cleaner control logic 76 determines whether the pump is on. If a positive determination is made, the process proceeds to step 2426. If a negative determination is made, then in step 2425 the pool cleaner control logic 76 transmits instructions to the pump to activate, and then proceeds to step 2426. In step 2426, the pool cleaner control logic 76 retrieves minimum flow rate setpoint data for the pool cleaner operation from a memory (e.g., gallons per minute). In step 2428, the pool cleaner control logic 76 receives operational flow rate data 2428. In step 2430, the pool cleaner control logic 76 determines whether the flow rate is above a minimum setpoint. If a positive determination is made, then the process proceeds to step 2432, where the pool cleaner control logic 76 transmits instructions to the pool cleaner to activate, and then the process ends. If a negative determination is made in step 2430, then the process proceeds to step 2434, where the pool cleaner control logic 76 determines whether there are retries remaining. If a positive determination is made, then in step 2436, the pool cleaner control logic 76 transmits instructions to the pump to increase the flow rate (e.g., by 5%), and the process reverts back to step 2428. If instead, a negative determination is made in step 2434, then in step 2438, the pool cleaner control logic 76 transmits an error condition, and the process ends.

FIG. 27B is a flowchart illustrating processing steps of the pool cleaner control logic 76 communicating with a booster pump. In step 2440, the pool cleaner control logic 76 receives instructions to activate the pool cleaner. In step 2442, the pool cleaner control logic 76 retrieves pool configuration data from memory (e.g., connected pool devices). In step 2444, the pool cleaner control logic 76 receives operational data from a pump. In step 2446, the pool cleaner control logic 76 determines whether the pump is on. If a positive determination is made, the process proceeds to step 2448. If a negative determination is made, in step 2456, the pool cleaner control logic 76 transmits instructions to the pump to activate, and the proceeds to step 2448. In step 2448, the pool cleaner control logic 76 determines whether there is a booster pump. If a positive determination is made, then in step 2450 the pool cleaner control logic 76 receives operational data from the booster pump. In step 2452, the pool cleaner control logic 76 determines whether the booster pump is on. If a positive determination is made in step 2452, then in step 2454, the pool cleaner control logic 76 transmits instructions to the pool cleaner to activate. If a negative determination is made in step 2452, then in step 2458 the pool cleaner control logic 76 transmits instructions to the booster pump to activate, and then proceeds to step 2454. If a negative determination is made in step 2448, then the process proceeds to step 2454 (as discussed above).

FIG. 27C is a flowchart illustrating processing steps of the pool cleaner control logic 76 communicating with a valve actuator. In step 2460, the pool cleaner control logic 76 receives instructions to activate a pool cleaner. In step 2462, the pool cleaner control logic 76 receives operational data from a changeover valve actuator (e.g., orientation). In step 2464, the pool cleaner control logic 76 determines whether

the valve actuator is in the correct orientation (e.g., valve is open). If a positive determination is made, then the process proceeds to step 2466, where the pool cleaner control logic 76 transmits instructions to the pool cleaner to activate, and then the process ends. If a negative determination is made in step 2464, then the process proceeds to step 2468, where the pool cleaner control logic 76 determines whether there are retries remaining. If a positive determination is made, then in step 2470, the pool cleaner control logic 76 transmits instructions to the valve actuator to move to the correct orientation (e.g., open), and the process reverts to step 2462. If instead, a negative determination is made in step 2468, then in step 2472, the pool cleaner control logic 76 transmits an error condition (e.g., valve seized), and the process ends.

FIG. 27D is a flowchart illustrating processing steps of the pool cleaner control logic 76 communicating with a pressure sensor. In step 2474, the pool cleaner control logic 76 receives instructions to activate a pool cleaner. In step 2476, the pool cleaner control logic 76 retrieves pressure setpoint data for pool cleaner operation from memory (e.g., minimum pressure). In step 2478, the pool cleaner control logic 76 receives operational data from a pressure sensor. In step 2480, the pool cleaner control logic 76 determines whether the pressure is sufficient. If a negative determination is made in step 2480, then in step 2490, the pool cleaner control logic 76 determines whether there are any retries remaining. If a positive determination is made in step 2490, then in step 2492, the pool cleaner control logic 76 transmits instructions to the pump to increase output (e.g., by 5%), and the process reverts back to step 2478. If a negative determination is made in step 2490, then in step 2494, the pool cleaner control logic 76 transmits an error condition (e.g., leak), and the process ends. If a positive determination is made in step 2480, then in step 2482, the pool cleaner control logic 76 retrieves flow rate setpoint data for pool cleaner operation from a memory (e.g., minimum flow rate). In step 2484, the pool cleaner control logic 76 receives operational data from a flow sensor. In step 2486, the pool cleaner control logic 76 determines whether the flow rate is sufficient. If a positive determination is made in step 2486, then in step 2488, the pool cleaner control logic 76 transmits instructions to the pool cleaner to activate, and then the process ends. If a negative determination is made in step 2486, then in step 2496, the pool cleaner control logic 76 determines whether there are any retries remaining. If a positive determination is made, then in step 2498, the pool cleaner control logic 76 transmits instructions to the pump to increase output (e.g., by 5%), and the process reverts to step 2484. If instead, a negative determination is made in step 2496, then in step 2500, the pool cleaner control logic 76 transmits an error condition (e.g., blockage), and the process ends. It should be noted that the above process can apply to actuate valves to control the pool cleaner. The valve actuation algorithms are explained in greater detail below.

FIG. 27E is a flowchart illustrating processing steps of the pool cleaner control logic 76 communicating with a valve. In step 2502, the pool cleaner control logic 76 receives instructions to activate a pool cleaner. In step 2504, the pool cleaner control logic 76 retrieves pressure setpoint data for a pool cleaner operation from a memory (e.g., minimum circuit pressure). In step 2506, the pool cleaner control logic 76 receives operational data from a pressure sensor. In step 2508, the pool cleaner control logic 76 determines whether the circuit pressure is sufficient. If a positive determination is made, then in step 2510, the pool cleaner control logic 76 transmits instructions to the pool cleaner to activate, and the process ends. If a negative determination is made in step

2508, then in step 2512, the pool cleaner control logic 76 determines whether there are any retries remaining. If a positive determination is made, then in step 2514, the pool cleaner control logic 76 receives operational data from an input valve (e.g., valve position). In step 2516, the pool cleaner control logic 76 determines required valve actuation to achieve pressure setpoint (e.g., open 90%). In step 2518, the pool cleaner control logic 76 transmits instructions to the valve to actuate by a determined amount. If a negative determination is made in step 2512, then in step 2520, the pool cleaner control logic 76 transmits an error condition (e.g., valve seized), and the process ends.

FIG. 27F is a flowchart illustrating processing steps of the pool cleaner control logic 76 communicating with a pool cleaner submersion sensor. In step 2522, the pool cleaner control logic 76 receives instruction to activate a pool cleaner. In step 2524, the pool cleaner control logic 76 receives operational data from the pool cleaner submersion sensor (e.g., float switch or moisture sensor). In step 2526, the pool cleaner control logic 76 determines whether the pool cleaner is submerged. If a positive determination is made, then in step 2528, the pool cleaner control logic 76 transmits instructions to the pool cleaner to activate. If a negative determination is made in step 2526, then in step 2530, the pool cleaner control logic 76 determines whether there are any retries remaining. If a positive determination is made, then the process reverts to step 2524. If a negative determination is made, then the process proceeds to step 2532, where the pool cleaner control logic 76 transmits an error condition, and the process ends.

FIG. 27G is a flowchart illustrating processing steps of the pool cleaner control logic 76 communicating with a debris sensor of the pool cleaner collection bag. In step 2534, the pool cleaner control logic 76 receives instructions to activate a pool cleaner. In step 2536, the pool cleaner control logic 76 receives operational data from a debris sensor for a collection bag. In step 2538, the pool cleaner control logic 76 determines the debris level of the collection bag. In step 2546, the pool cleaner control logic 76 could optionally transmit instruction to an HMI device to display the debris level of the collection bag. In step 2540, the pool cleaner control logic 76 determines whether the collection bag is full. If a positive determination is made, then in step 2544, the pool cleaner control logic 76 transmits a message to the user to empty the collection bag, and the process reverts to step 2536. Optionally, in step 2541 the pool cleaner logic 76 could transmit an instruction to the pool cleaner to swim to a pool skimmer and purge the collection bag so that the debris from the collection bag is emptied without user intervention and quickly removed from the pool via the skimmer. If a negative determination is made in step 2540, then in step 2542, the pool cleaner control logic 76 transmits instructions to the pool cleaner to activate, and the process ends.

FIG. 27H is a flowchart illustrating processing steps of the pool cleaner control logic 76 communicating with a pool cleaner regarding a motor speed threshold. In step 2548, the pool cleaner control logic 76 retrieves factory specified pool cleaner motor speed data from memory. In step 2550, the pool cleaner control logic 76 determines the motor speed threshold for a full collection bag (e.g., 95% of factory specified speed). In step 2552, the pool cleaner control logic 76 receives operational data from the pool cleaner (e.g., motor speed). In step 2554, the pool cleaner control logic 76 determines whether the motor speed is below a threshold. If a negative determination is made, the process reverts to step 2552. If a positive determination is made, the process

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proceeds to step 2556, where the pool cleaner control logic 76 transmits a message to the user to empty the collection bag, and the process reverts to step 2552.

FIG. 27I is a flowchart illustrating processing steps of the pool cleaner control logic 76 communicating regarding line power operational data. In step 2558, the pool cleaner control logic 76 receives instructions to activate a pool cleaner. In step 2560, the pool cleaner control logic 76 retrieves data on factory specified power parameters from a memory (e.g., power consumption, current draw, and/or line voltage). In step 2562, the pool cleaner control logic 76 receives line power operational data. In step 2564, the pool cleaner control logic 76 determines whether the line power is within factory specifications. If a positive determination is made, then in step 2566, the pool cleaner control logic 76 transmits instructions to the pool cleaner to activate. If a negative determination is made in step 2564, then in step 2568, the pool cleaner control logic 76 determines whether there are any retries remaining. If a positive determination is made in step 2568, then the process reverts to step 2562. If a negative determination is made in step 2570, then in step 2570, the pool cleaner control logic 76 transmits an error condition, and the process ends.

FIG. 27J is a flowchart illustrating processing steps of the pool cleaner control logic 76 communicating with an internal tachometer. In step 2572, the pool cleaner control logic 76 receives instructions to activate a pool cleaner. In step 2580, the pool cleaner control logic 76 transmits instructions to the pool cleaner to activate. In step 2574, the pool cleaner control logic 76 retrieves turbine setpoint data for a pool cleaner operation from memory (e.g., minimum RPMs). In step 2576, the pool cleaner control logic 76 receives operational data from an internal tachometer. In step 2578, the pool cleaner control logic 76 determines whether the speed of the turbine is sufficient. If a positive determination is made in step 2578, the process reverts to step 2576. If a negative determination is made in step 2578, then in step 2582, the pool cleaner control logic 76 determines whether there are any retries remaining. If a positive determination is made in step 2582, then in step 2584, the pool cleaner control logic 76 transmits instructions to the pump to increase output (e.g., by 5%), and the process reverts to step 2576. If a negative determination is made in step 2582, then in step 2586, the pool cleaner control logic 76 transmits an error condition (e.g., obstruction), and the process ends.

FIG. 27K is a flowchart illustrating processing steps of the pool cleaner control logic 76 communicating with an internal tachometer. In step 2588, the pool cleaner control logic 76 receives instructions to activate a pool cleaner. In step 2596, the pool cleaner control logic 76 transmits instructions to the pool cleaner to activate. In step 2590, the pool cleaner control logic 76 retrieves turbine setpoint data for a pool cleaner operation from a memory (e.g., minimum RPMs). In step 2592, the pool cleaner control logic 76 receives operational data from an internal tachometer. In step 2594, the pool cleaner control logic 76 determines whether the speed of the turbine is sufficient. If a positive determination is made, the process reverts to step 2592. If in step 2594, a negative determination is made, then in step 2598, the pool cleaner control logic 76 determines whether there are any retries remaining. If a positive determination is made in step 2598, then in step 2600, the pool cleaner control logic 76 receives operational data from a flow rate sensor. In step 2602, the pool cleaner control logic 76 determines the required increase in flow rate to achieve the turbine speed setpoint. In step 2604, the pool cleaner control logic 76 determines the required increase in pump speed to achieve

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a required flow rate. In step 2606, the pool cleaner control logic 76 transmits the instruction to the pump to increase output by the determined amount, and the process reverts to step 2592. If a negative determination is made in step 2598, then in step 2608, the pool cleaner control logic 76 transmits an error condition (e.g., obstruction), and the process ends.

FIG. 27L is a flowchart illustrating processing steps of the pool cleaner control logic 76 communicating with a pump. In step 2610, the pool cleaner control logic 76 retrieves scheduling data for a pool cleaner operation from a memory (e.g., operating hours, duration, schedule, weather conditions, upcoming events at the site, etc.). In step 2612, the pool cleaner control logic 76 receives time data from a clock (e.g., current time). In step 2614, the pool cleaner control logic 76 determines whether the current time is within hours of operation. If a negative determination is made, then the process reverts to step 2612. If a positive determination is made, then in step 2616, the pool cleaner control logic 76 receives operational data from a pump. In step 2618, the pool cleaner control logic 76 determines whether the pump is on. If a positive determination is made in step 2618, then in step 2620, the pool cleaner control logic 76 transmits instructions to the pool cleaner to activate. If a negative determination is made in step 2618, then in step 2622, the pool cleaner control logic 76 transmits instructions to the pump to activate, and the process proceeds to step 2620.

FIG. 27M is a flowchart illustrating processing steps of the pool cleaner control logic 76 communicating with an ambient light sensor. In step 2624, the pool cleaner control logic 76 receives operational data from an ambient light sensor. In step 2626, the pool cleaner control logic 76 determines the time of day (e.g., day, night, etc.). In step 2628, the pool cleaner control logic 76 determines whether it is nighttime. If a negative determination is made, the process reverts to step 2624. If a positive determination is made, then in step 2630, the pool cleaner control logic 76 receives operational data from a pump. In step 2632, the pool cleaner control logic 76 determines whether the pump is on. If a positive determination is made in step 2632, then in step 2634, the pool cleaner control logic 76 transmits instructions to the pool cleaner to activate, and the process ends. If a negative determination is made in step 2632, then in step 2636, the pool cleaner control logic 76 transmits instructions to the pump to activate, and the process proceeds to step 2634.

FIG. 27N is a flowchart illustrating processing steps of the pool cleaner control logic 76 communicating with a vision system. In step 2638, the pool cleaner control logic 76 receives instructions to activate a pool cleaner. In step 2640, the pool cleaner control logic 76 receives operational data from a vision system (e.g., location of debris). In step 2642, the pool cleaner control logic 76 determines the location of a high debris area. In step 2644, the pool cleaner control logic 76 determines the location and orientation of the pool cleaner. In step 2646, the pool cleaner control logic 76 transmits instructions to the pool cleaner to traverse the high debris area. The process then reverts to step 2640.

FIG. 27O is a flowchart illustrating processing steps of the pool cleaner control logic 76 communicating with a software application. In step 2639 the application displays a graphical representation or image of the pool on the device on which the software application is installed. While step 2639 shows the software application installed on a smartphone, it is to be appreciated that the software application can be installed on various devices of the system 10, including but not limited to the computer system 20 or the pool/spa control system 14f. In step 2641, the user indicates (e.g., by touching the

smartphone screen in the appropriate location) where debris is observed in the pool. In step 2643 the software application marks each spot that the user has indicated with a graphical overlay (e.g., a box is placed around each indicated debris area). In step 2645 the software application transmits an instruction to the cleaner 14g to navigate to the debris areas indicated by the user and clean the same. The process then ends.

It is noted that the pool cleaner control logic illustrated in FIGS. 27A-27O and discussed above could be used to control a pool/spa cleaner that does not have on-board electronic controls, such as, for example, a conventional suction or pressure cleaner. In such instances, control of the cleaner could be implemented by way of a valve actuator that has an associated processor and network connectivity, such as the valve actuator discussed herein in connection with FIGS. 28-29I. The valve actuator would be in fluid communication with the cleaner, and the control logic discussed in connection with FIGS. 27A-27O would be applied to control the valve actuator to correspondingly control operation of the cleaner.

FIG. 28 is a diagram 2700 illustrating valve actuator control logic 74. Valve actuator control logic 74 could incorporate a variety of types of data and/or data sources. More specifically, valve actuator control logic 76 could incorporate user input data 2702, valve actuator operational data 2704, valve actuator factory specifications 2706, valve actuator configuration parameters 2708, web data 2710, pool configuration parameters 2712, data from related devices 2714, health monitoring data 2716, and/or external sensor data 2718.

User input data 2702 could include schedule information (e.g., on/off and what orientation, duration of power on/off for specific orientation, open/close), etc. Valve actuator operational data 2704 could include line voltage, operation (e.g., on, off, etc.), orientation (e.g., open, close, etc.), power duration, etc. Valve actuator factor specification 2706 could include source voltage, power consumption, current draw, etc. Valve actuator configuration parameters 2708 could include IP address, GPS coordinates, zipcode, time and date, etc. Web data 2710 could include location (e.g., based on IP address), time and date, sunrise/sunset data, temperature, ambient light, season, etc. Pool configuration parameters 2712 could include pool surface area, pool geometry, pool line color, pool cover (e.g., yes, no, etc.), pool cover schedule, etc. Data from related devices 2714 could include additional valves, pump, heater (e.g., gas, heat pump, etc.), heat (e.g., solar), spa, UV ozone, cleaner, controller, chlorinator, water features, water slide, skimmer, filter, etc. Health monitoring data 2716 could include power consumption, current monitoring, source voltage, etc. External sensor data 2718 could include water flow rate, water pressure, etc. While it may be desirable for external sensors to monitor/provide data on as many system parameters as possible (thereby providing greater optimization, automation, and user/operator comfort), it is contemplated that some systems need not utilize an external sensor to monitor every system parameter. For example, if a water pressure sensor has not been installed in a particular system, the user/operator can provide this information by first determining the water pressure (e.g., by visually inspecting an analog water pressure gauge) and then entering the water pressure information into the system via a user interface.

FIGS. 29A-29I are flowcharts illustrating processing steps of the valve actuator control logic 74. FIG. 29A is a flowchart illustrating processing steps of the valve actuator control logic 74 communicating with a valve actuator. In

step 2720, the valve actuator control logic 74 receives instructions to actuate a valve. In step 2722, the valve actuator control logic 74 retrieves data on factory specified power parameters from a memory (e.g., line voltage). In step 2724, the valve actuator control logic 74 receives line voltage operational data. In step 2726, the valve actuator control logic 74 determines whether the line voltage is within the factory specifications. If a positive determination is made, then in step 2728, the valve actuator control logic 74 transmits instructions to the valve actuator to actuate. If a negative determination is made in step 2726, then in step 2730, the valve actuator control logic 74 determines whether there are any retries remaining. If a positive determination is made in step 2730, then the process reverts to step 2724. If a negative determination is made in step 2730, then in step 2732, the valve actuator control logic 74 transmits an error condition (e.g., undervoltage, overvoltage, etc.), and the process ends.

FIG. 29B is a flowchart illustrating processing steps of the valve actuator control logic 74 communicating with a heater. In step 2734, the valve actuator control logic 74 receives instructions to activate a heater. In step 2736, the valve actuator control logic 74 receives operational data from a pump. In step 2740, the valve actuator control logic 74 receives operational data from a heater valve actuator (e.g., orientation) 14e. In step 2742, the valve actuator control logic 74 determines whether the heater valve actuator 14e is in the correct orientation (e.g., valve is open). If a positive determination is made in step 2742, then in step 2750 a determination is made as to whether the pump 14a is on. If a positive determination is made in step 2750, in step 2744, the valve actuator control logic 74 transmits instructions to the heater 14b to activate, and the process ends. If a negative determination is made in step 2750 the valve actuator control logic 74 transmits an instruction to the pump 14a to activate and the process then proceeds to step 2744. If a negative determination is made in step 2742, then in step 2738, a determination is made as to whether the pump 14a is on. If a positive determination is made in step 2738, the valve actuator control logic 74 transmits an instruction to the pump 14a to deactivate. If a negative determination is made in step 2738, the process proceeds to step 2754. In step 2752, the valve actuator control logic 74 determines whether there are any retries remaining. If a positive determination is made in step 2752, then in step 2754, the valve actuator control logic 74 transmits instructions to the heater valve actuator 14e to move to the correct orientation (e.g., open) and the process then reverts to step 2736. If a negative determination is made in step 2752, then in step 2756, the valve actuator control logic 74 transmits an error condition (e.g., valve seized), and the process ends.

FIG. 29C is a flowchart illustrating processing steps of the valve actuator control logic 74 communicating with a heater. In step 2758, the valve actuator control logic 74 receives instructions to activate a heater. In step 2760, the valve actuator control logic 74 receives operational data from a pump. In step 2762, the valve actuator control logic 74 determines whether the pump is active. If a negative determination is made in step 2762, then in step 2776, the valve actuator control logic 74 determines whether there are any retries remaining. If a positive determination is made in step 2776, then the process reverts to step 2760. If a negative determination is made in step 2776, then in step 2778, the valve actuator control logic 74 transmits an error condition (e.g., interlock), and the process ends. If a positive determination is made in step 2762, then in step 2764, the valve actuator control logic 74 receives operational data from a

heater valve actuator (e.g., orientation). In step 2766, the valve actuator control logic 74 determines whether the heater valve actuator is in the correct orientation (e.g., valve is open). If a positive determination is made in step 2766, then in step 2768, the valve actuator control logic 74 transmits instructions to the heater to activate, and the process ends. If a negative determination is made in step 2766, then in step 2770, the valve actuator control logic 74 determines whether there are any retries remaining. If a positive determination is made in step 2770, then in step 2772, the valve actuator control logic 74 transmits instructions to the heater valve actuator to move to the correct orientation (e.g., open). If a negative determination is made in step 2770, then in step 2774, the valve actuator control logic 74 transmits an error condition (e.g., valve seized), and the process ends.

FIG. 29D is a flowchart illustrating processing steps of the valve actuator control logic 74 communicating with a water feature valve actuator. In step 2780, the valve actuator control logic 74 receives instructions to increase the output of the water stream feature (e.g., new flow rate setpoint). In step 2782, the valve actuator control logic 74 receives operational data from a water feature (e.g., flow rate). In step 2784, the valve actuator control logic 74 determines whether the water feature is active. If a positive determination is made in step 2784, then in step 2786, the valve actuator control logic 74 determines whether the flow rate is sufficient. If a positive determination is made in step 2786, then the process ends. If a negative determination is made in step 2786, then in step 2794, the valve actuator control logic 74 determines whether there are any retries remaining. If a positive determination is made in step 2794, then in step 2796, the valve actuator control logic 74 transmits instructions to the water feature valve actuator to increase throughput (e.g., by 5%), and the process reverts to step 2782. If a negative determination is made in step 2794, then in step 2798, the valve actuator control logic 74 transmits an error condition (e.g., blockage), and the process ends. If a negative determination is made in step 2784, then in step 2788, the valve actuator control logic 74 determines whether there are any retries remaining. If a positive determination is made in step 2788, then in step 2790, the valve actuator control logic 74 transmits instructions to the water feature valve actuator to open, and the process reverts to step 2782. If a negative determination is made in step 2788, then in step 2792, the valve actuator control logic 74 transmits an error condition (e.g., blockage), and the process ends. It is to be appreciated that while flow rate operational data is received from the water feature in the process described above, similar process steps could be followed should pressure, or other, operational data be received from the water feature.

FIG. 29E is a flowchart illustrating processing steps of the valve actuator control logic 74 communicating with a water feature valve actuator. In step 2800, the valve actuator control logic 74 receives instructions to activate a water feature. In step 2802, the valve actuator control logic 74 retrieves flow rate setpoint data for water feature operation from a memory (e.g., minimum flow rate). In step 2804, the valve actuator control logic 74 receives operational data from a water feature (e.g., flow rate). In step 2806, the valve actuator control logic 74 determines whether the water feature is active. If a positive determination is made in step 2806, then in step 2808, the valve actuator control logic 74 determines whether the flow rate is sufficient. If a positive determination is made in step 2808, then the process ends. If a negative determination is made in step 2808, then in step 2816, the valve actuator control logic 74 determines whether

there are any retries remaining. If a positive determination is made in step 2816, then in step 2818, the valve actuator control logic 74 transmits instructions to the water feature valve actuator to increase throughput (e.g., by 5%), and the process reverts to step 2804. If a negative determination is made in step 2816, then in step 2820 the valve actuator control logic 74 transmits an error condition (e.g., blockage), and the process ends. If a negative determination is made in step 2806, then in step 2810, the valve actuator control logic 74 determines whether there are any retries remaining. If a positive determination is made in step 2810, then in step 2812, the valve actuator control logic 74 transmits instructions to the water feature valve actuator to open, and the process reverts to step 2802. If a negative determination is made in step 2810, then in step 2814, the valve actuator control logic 74 transmits an error condition (e.g., blockage), and the process ends.

FIG. 29F is a flowchart illustrating processing steps of the valve actuator control logic 74 communicating with a heater valve actuator. In step 2822, the valve actuator control logic 74 receives instructions to activate the heater. In step 2824, the valve actuator control logic 74 receives operational data from a heater valve actuator (e.g., orientation). In step 2826, the valve actuator control logic 74 determines whether the heater valve actuator is in the correct orientation (e.g., valve is open). If a negative determination is made in step 2826, then in step 2834, the valve actuator control logic 74 determines whether there are any retries remaining. If a positive determination is made in step 2834, then in step 2836, the valve actuator control logic 74 transmits instructions to the heater valve actuator to move to the correct orientation (e.g., open), and the process reverts to step 2824. If a negative determination is made in step 2834, then in step 2838, the valve actuator control logic 74 transmits an error condition (e.g., valve seized), and the process ends. If a positive determination is made in step 2826, then in step 2828, the valve actuator control logic 74 receives operational data from a pump valve actuator (e.g., orientation). In step 2830, the valve actuator control logic 74 determines whether the pump valve actuator is in the correct orientation (e.g., valve is open). If a positive determination is made in step 2830, then in step 2832, the valve actuator control logic 74 transmits instructions to the heater to activate. If a negative determination is made in step 2830, then in step 2840, the valve actuator control logic 74 determines whether there are any retries remaining. If a positive determination is made in step 2840, then in step 2842, the valve actuator control logic 74 transmits instructions to the pump valve actuator to move to the correct orientation (e.g., open), and the process reverts to step 2828. If a negative determination is made in step 2840, then in step 2844, the valve actuator control logic 74 transmits an error condition (e.g., valve seized), and the process ends.

FIG. 29G is a flowchart illustrating processing steps of the valve actuator control logic 74. In step 2846, the heater valve actuator receives instructions to open. In step 2848, the heater valve actuator sends instructions to the pump valve actuator to open. In step 2850, the heater valve actuator receives operating data from the pump valve actuator. In step 2852, the heater valve actuator determines if the pump valve actuator is open. In step 2854, the heater valve actuator moves to the open orientation.

FIG. 29H is a flowchart illustrating processing steps of the valve actuator control logic 74. In step 2856, the valve actuator control logic 74 receives instructions to actuate a valve. In step 2858, the valve actuator control logic 74 receives an input from a timer for x seconds. In step 2860,

the valve actuator control logic 74 transmits instructions to the valve actuator to move to a desired orientation.

FIG. 29I is a flowchart illustrating processing steps of the valve actuator control logic 74 communicating with a pump. In step 2862, the valve actuator control logic 74 retrieves operational setpoint data on valve actuator orientation for a given pump speed (e.g., actuate valve at a given speed). In step 2864, the valve actuator control logic 74 receives operational data from a pump (e.g., RPMs). In step 2866, the valve actuator control logic 74 determines the correct valve actuator orientation for a speed of the pump. In step 2868, the valve actuator control logic 74 receives operational data from a valve actuator (e.g., orientation). In step 2870, the valve actuator control logic 74 determines whether the valve actuator is in the correct orientation. If a positive determination is made in step 2870, then the process reverts to step 2864. If a negative determination is made in step 2870, then in step 2872, the valve actuator control logic 74 determines whether there are any retries remaining. If a positive determination is made in step 2872, then in step 2874, the valve actuator control logic 74 transmits instructions to the valve actuator to move to the correct orientation, and the process reverts to step 2868. If a negative determination is made in step 2872, then in step 2876, the valve actuator control logic 74 transmits an error condition (e.g., valve seized), and the process ends.

FIG. 30 is a diagram 2900 illustrating water feature control logic 72. Water feature control logic 72 could incorporate a variety of types of data and/or data sources. More specifically, water feature control logic 72 could incorporate user input data 2902, water feature operational data 2904, water feature factory specifications 2906, water feature configuration parameters 2908, web data 2910, pool configuration parameters 2912, data from related devices 2914, health monitoring data 2916, and/or external sensor data 2918.

User input data 2902, could include timers, schedules, feature parameters (e.g., how high, how much flow for effect), etc. Water feature operational data 2904 could include pressure, water flow rate, debris sensing, actuator position, etc. Water feature configuration parameters 2908 could include IP address, GPS coordinates, zipcode, time and date, etc. Web data 2910 could include location (e.g., based on IP address), time and date, sunrise/sunset data, regional/local weather forecast, wind speed, wind direction, etc. Pool configuration parameters 2912 could include connected pool devices, pool surface area, pool geometry, pool line color, pool cover (e.g., yes, no, etc.), pool cover schedule, etc. Data from related devices 2914 could include additional water features, pump, chemistry dispenser, heater (e.g., gas pump, heat pump, etc.), heat (e.g., solar), chiller, spa, UV sanitizer, pool cleaner, controller, chlorinator, water slide, skimmer, filter, voice recognition/activation system, etc. External sensor data 2918 could include debris sensor, water temperature, motion sensor, ambient noise, etc. While it may be desirable for external sensors to monitor/provide data on as many system parameters as possible (thereby providing greater optimization, automation, and user/operator comfort), it is contemplated that some systems need not utilize an external sensor to monitor every system parameter. For example, if a water temperature sensor has not been installed in a particular system, the user/operator can provide this information by first determining the water temperature (e.g., by checking a thermometer, thermocouple, etc.) and then entering the water temperature into the system via a user interface. Using this data, the water feature control logic 76 could optimize the operation of the water features

by, for example, determining if the feature has been degraded due to debris by receiving data from a pressure sensor in the unit, determining appropriate operation by receiving weather data (e.g., wind location, direction, and speed) and modifying operating parameters, not running the water feature or altering the operation thereof if users are present (e.g., auto-home, or auto-away), enhance turn-over and make pH adjustments, varying the height of water from a water feature by using a variable position actuator, self-leveling the water feature using an actuator and level sensor.

FIGS. 31A-31F are flowcharts illustrating processing steps of the water feature control logic 72. FIG. 31A is a flowchart illustrating processing steps of the water feature control logic 72. In step 2920, the water feature control logic 72 receives instructions to activate a water feature. In step 2922, the water feature control logic 72 retrieves minimum flow rate setpoint data for water feature operation from a memory (e.g., gallons per minute). In step 2924, the water feature control logic 72 receives operational flow rate data. In step 2926, the water feature control logic 72 determines whether the flow rate is above a minimum setpoint. If a positive determination is made in step 2926, then in step 2928, the water feature control logic 72 transmits instructions to the water feature actuator valve to move to an open orientation, and the process ends. If a negative determination is made in step 2926, then in step 2930, the water feature control logic 72 determines whether there are any retries remaining. If a positive determination is made in step 2930, then in step 2932, the water feature control logic 72 transmits instructions to the pump to increase flow (e.g., by 5%), and the process reverts to step 2924. If a negative determination is made in step 2930, then in step 2934, the water feature control logic 72 transmits an error condition, and the process ends.

FIG. 31B is a flowchart illustrating processing steps of the water feature control logic 72. In step 2936, the water feature control logic 72 receives instructions to activate a water feature. In step 2938, the water feature control logic 72 receives operational data from connected pool devices (e.g., additional water features). In step 2940, the water feature control logic 72 determines whether there are additional water features. If a positive determination is made in step 2940, then in step 2942, the water feature control logic 72 determines whether additional water features are active. If a positive determination is made in step 2942, then in step 2944, the water feature control logic 72 transmits instructions to the water feature actuator valve to move to an open orientation, and the process ends. If a negative determination is made in step 2942, then in step 2946, the water feature control logic 72 transmits instruction to additional water feature actuator valves to move to the open orientation, and the process ends. If a negative determination is made in step 2940, then the process proceeds to step 2944 (as discussed above).

FIG. 31C is a flowchart illustrating processing steps of the water feature control logic 72. In step 2948, the water feature control logic 72 receives operational data from chemistry automation system. In step 2950, the water feature control logic 72 determines if the chemistry automation system is active. If a negative determination is made in step 2950, then the process reverts to step 2948. If a positive determination is made in step 2950, then in step 2952, the water feature control logic 72 transmits instructions to the water feature actuation valve to move to the open orientation.

FIG. 31D is a flowchart illustrating processing steps of the water feature control logic 72. In step 2954, the water feature control logic 72 retrieves water temperature setpoint data

from memory (e.g., desired pool temperature). In step 2956, the water feature control logic 72 receives operational data from a temperature sensor. In step 2958, the water feature control logic 72 determines whether the temperature is above a setpoint. If a positive determination is made in step 2958, then in step 2960, the water feature control logic 72 transmits instructions to the chiller to activate. In step 2962, the water feature control logic 72 transmits instructions to the water feature actuation valve to move to the open orientation, and the process reverts to step 2956. If a negative determination is made in step 2958, then in step 2964, the water feature control logic 72 receives operational data from chiller and water feature. In step 2966, the water feature control logic 72 determines whether the chiller and water feature are active. If a negative determination is made in step 2966, then the process reverts to step 2956. If a positive determination is made in step 2966, then in step 2968, the water feature control logic 72 transmits instruction to deactivate the chiller and water feature.

FIG. 31E is a flowchart illustrating processing steps of the water feature control logic 72. In step 2970, the water feature control logic 72 receives operational data from a motion sensor. In step 2972, the water feature control logic 72 determines whether the motion sensor is triggered. If a positive determination is made in step 2972, then in step 2980, the water feature control logic 72 transmits instruction to the water feature valve actuator to move to the open position, and the process reverts to step 2970. If a negative determination is made in step 2972, then in step 2974, the water feature control logic 72 receives operational data from a water feature valve actuator (e.g., orientation). In step 2976, the water feature control logic 72 determines whether the valve actuator is in the open orientation. If a negative determination is made in step 2976, the process reverts to step 2970. If a positive determination is made in step 2976, then in step 2978, the water feature control logic 72 transmits instruction to the water feature valve actuator to move to the closed position, and the process reverts to step 2970.

FIG. 31F is a flowchart illustrating processing steps of the water feature control logic 72. In step 2982, the water feature control logic 72 retrieves ambient noise setpoint data from memory (e.g., maximum ambient noise value). In step 2984, the water feature control logic 72 receives operational data from an ambient noise sensor. In step 2986, the water feature control logic 72 determines whether the ambient noise is above a maximum setpoint. If a positive determination is made in step 2986, then in step 2988, the water feature control logic 72 transmits instruction to water feature valve actuator to decrease throughput (e.g., by 5%), and the process reverts to step 2984. If a negative determination is made in step 2986, then in step 2990, the water feature control logic 72 transmits instruction to the water feature valve actuator to increase throughput (e.g., by 5%), and the process reverts to step 2984.

It is noted that the water feature control logic illustrated in FIGS. 31A-31F and discussed above could be used to control a pool/spa water feature that does not have on-board electronic controls, such as, for example, a conventional water feature. In such instances, control of the water feature could be implemented by way of a valve actuator that has an associated processor and network connectivity, such as the valve actuator discussed herein in connection with FIGS. 28-29I. The valve actuator would be in fluid communication with the water feature, and the control logic discussed in connection with FIGS. 27A-27O would be applied to control the valve actuator to correspondingly control operation of the water feature.

FIG. 32 is a diagram 3000 illustrating another embodiment of pool control logic 70. Pool control logic 70 could incorporate a variety of types of data and/or data sources in addition to those discussed hereinabove. More specifically, pool control logic 70 could process user input data 3002, operational data 3004, equipment factory specifications 3006, equipment configuration parameters 3008, web data 3010, pool configuration parameters 3012, data from related devices 3014, health monitoring data 3016, and/or external sensor data 3018.

User input data 3002, could include maximum sun exposure (e.g., UV, intensity, etc.), minimum sun exposure, device operation setpoints, preferred pool/spa area, contact means (e.g., SMS/text), user profiles, zip code, maximum wind speed setpoint, lighting programs, mode selection, override code, and desired actions (e.g., pump speed up, spa on, lights on, etc.). Operational data 3004 could include GPS coordinates, compass bearing, accelerometer information, image data, IP address, timers, energy usage, and video monitoring data. Equipment factory specifications 3006 could include device maximum wind speed, device operation setpoints, device power requirements, and device critical requirements (e.g., plumbing size, flow rate, clearance, etc.). Equipment configuration parameters 3008 could include IP address, GPS coordinates, ZIP code, time and date, lighting programs, etc. Web data 3010 could include location (based on IP address), time & date, sun position, maximum sun exposure, sunrise/sunset data, local lighting code, regional & local weather, forecast data, wind speed and direction, historic weather conditions, live weather maps, local noise ordinance, local traffic conditions, local energy providers, local energy costs, energy rebates and discounts, video monitoring data, device/equipment information, etc. Pool configuration parameters 3012 could include, pool surface area, pool geometry, pool cover (e.g., yes, no), etc. Related devices/systems 3014 could include smart devices, user interface devices, shading devices, skimmers, pumps, water features, fire features, pool covers, lighting systems, heaters or coolers, pool cleaners, sanitization systems, chemical dispensing systems, alarm systems, garage doors, interior (home) lights, maintenance system/application, etc. Health monitoring data 3016 could include ambient temperature, water temperature, wind speed, warranty countdown, maintenance schedule, past equipment issues, service history, etc. External sensor data 3018 could include motion sensors (e.g., bather detection), ambient temperature sensors, water temperature sensors, ambient noise sensors, light sensors (home/interior), video (home/interior), bar code scanners, etc. While it may be desirable for external sensors to monitor/provide data on as many system parameters as possible (thereby providing greater optimization, automation, and user/operator comfort), it is contemplated that some systems need not utilize an external sensor to monitor every system parameter. For example, if a temperature sensor has not been installed in a particular system, the user/operator can provide this information by first determining the temperature (e.g., by checking a thermometer, a thermocouple, a weather forecast, the internet, etc.) and then entering the temperature into the system via a user interface.

FIGS. 33A-33AH are flowcharts illustrating additional processing steps of the pool control logic 70 carried out with respect to related devices, systems, and applications. FIG. 33A is a flowchart illustrating processing steps of the pool control logic 70 for determining locations of skimmers and/or the pool/spa to account for wind, sun, or other external factors. In step 3100, the pool control logic 70

transmits an instruction to the user to traverse the perimeter of the pool while holding the smart device. In step 3102, the pool control logic 70 receives positioning data (e.g., GPS coordinates, compass bearing, etc.) from the smart device as the user traverses the pool. In step 3104, the pool control logic 70 transmits an instruction to the user to place the smart device at a skimmer location. In step 3106, the pool control logic 70 receives positioning data (e.g., GPS coordinates, compass bearing, accelerometer information, etc.) from the smart device placed at the skimmer location. Optionally, to enable higher accuracy in locating the skimmer and/or pool/spa, in step 3108, the pool control logic 70 transmits an instruction to the user to photograph the skimmer and pool using the smart device and in step 3110, the pool control logic 70 receives image data from the smart device. In step 3112, the pool control logic 70 determines the location of the skimmer relative to the pool (e.g., using GPS, compass, accelerometer information, and/or image data provided by the smart device). In step 3114, pool control logic 70 saves the location of the skimmer to memory for later retrieval, described hereinbelow in connection with FIG. 33G. Optionally, in step 3116 pool control logic can also determine the location, geometry, and orientation of the pool/spa (e.g., using GPS, compass, accelerometer information, and/or image data from the smart device) and in step 3118, pool control logic 70 could save the location, geometry, and orientation of the pool/spa to memory for later retrieval, described hereinbelow in connection with FIG. 33L.

FIG. 33B is a flowchart illustrating processing steps carried out by the pool control logic 70 for estimating sun exposure and alerting the user to the same. In step 3120, pool control logic 70 transmits an instruction to the user to photograph the pool/spa using a smart device. In step 3122, pool control logic 70 receives data from the smart device (e.g., GPS, compass, image, date and time data, etc.). In step 3124, pool control logic 70 determines if additional photographs are needed (e.g., multiple photographs could be taken at various times during the day). If a positive determination is made, pool control logic 70 proceeds to step 3126, where the logic is delayed for X seconds, wherein X is any suitable integer (e.g., 5, 10, 3600, etc.), and the process then reverts to step 3120. If a negative determination is made, the process proceeds to step 3128, where pool control logic 70 receives data on sun position (e.g., from sun tracking application or web data) based on location data from the smart device. In step 3130, pool control logic 70 receives current date and time data (e.g., from internal clock or as web data). In step 3132, pool control logic estimates the current sun exposure (e.g., ultraviolet “UV” index) based on location, image, sun position, and date and time data. In step 3134, pool control logic 70 retrieves a maximum UV exposure setpoint from the memory. The maximum UV exposure setpoint could be provided by the user, or retrieved as web data provided by a recognized health organization. In step 3136, pool control logic 70 determines if the current sun exposure is above the maximum UV exposure setpoint. If a positive determination is made, the process proceeds to step 3138, where pool control logic 70 transmits an alert to the user (e.g., “Caution—High UV Index”). If a negative determination is made, the process reverts to step 3130.

FIG. 33C is a flowchart illustrating processing steps carried out by the pool control logic 70 for automatically deploying shading devices (e.g., umbrellas, awnings, shades, etc.) based on estimated sun exposure. In step 3140, pool control logic 70 transmits an instruction to the user to photograph the pool/spa using a smart device. In step 3142,

pool control logic 70 receives data from the smart device (e.g., GPS, compass, image, date and time data, etc.). In step 3144, pool control logic 70 determines if additional photographs are needed (e.g., multiple photographs could be taken at various times during the day). If a positive determination is made, pool control logic 70 proceeds to step 3146, where the logic is delayed for X seconds, wherein X is any suitable integer (e.g., 5, 10, 3600, etc.), and the process then reverts to step 3140. If a negative determination is made, the process proceeds to step 3148, where pool control logic 70 receives data on sun position (e.g., from sun tracking application or web data) based on location data from the smart device. In step 3150, pool control logic 70 receives current date and time data (e.g., from internal clock or as web data). In step 3152, pool control logic 70 estimates the current sun exposure (e.g., ultraviolet “UV” index, sun intensity, etc.) based on location, image, sun position, and date and time data. In step 3154, pool control logic 70 retrieves a shading device setpoint from the memory. The shading device setpoint is a sun exposure value for triggering operation of the shading devices, and could be provided by the user, as a configuration parameter, or retrieved as web data. In step 3156, pool control logic 70 determines if the current estimated sun exposure is above the shading device setpoint. If a positive determination is made, the process proceeds to step 3158, where pool control logic 70 transmits an instruction to the shading devices to deploy and then reverts to step 3150. If a negative determination is made, the process proceeds to step 3160, where pool control logic 70 determines if the shading devices are deployed. If a negative determination is made, the process reverts to step 3150. If a positive determination is made, the process proceeds to step 3162, where pool control logic 70 transmits an instruction to the shading devices to retract and then reverts to step 3150.

FIG. 33D is a flowchart illustrating processing steps carried out by the pool control logic 70 for notifying a user of sun conditions at a preferred area of the pool (e.g., lounging area). In step 3164, pool control logic 70 transmits an instruction to the user to photograph the pool/spa using a smart device. In step 3166, pool control logic 70 receives data from the smart device (e.g., GPS, compass, image, date and time data, etc.). In step 3168, pool control logic 70 determines if additional photographs are needed (e.g., multiple photographs could be taken at various times during the day). If a positive determination is made, pool control logic 70 proceeds to step 3170, where the logic is delayed for X seconds, wherein X is any suitable integer (e.g., 5, 10, 3600, etc.), and the process then reverts to step 3164. If a negative determination is made, the process proceeds to step 3172, where pool control logic 70 receives data on sun position (e.g., from sun tracking application or web data) based on location data from the smart device. In step 3174, pool control logic 70 retrieves location data of a preferred area of the pool from the memory. The location data of the preferred area of the pool can be obtained by way of a similar process, as described herein, in connection with FIG. 33A (e.g., process for determining skimmer location). In some embodiments, multiple users could specify one or more preferred areas of the pool/spa area. In step 3176, the pool control logic 70 receives current date and time data (e.g., from internal clock, or as web data). In step 3178, pool control logic 70 estimates the current sun exposure at the preferred area (e.g., using GPS, compass, image, and sun positioning data). In step 3180, pool control logic 70 retrieves a minimum sun exposure setpoint (e.g., minimum UV index or sun intensity) from the memory. In step 3182, pool control logic 70 determines if the current estimated sun exposure is above

the minimum sun exposure setpoint. If a negative determination is made, the process reverts to step 3176. If a positive determination is made, the process proceeds to step 3184, where pool control logic 70 transmits an alert to the user (e.g., "Lounge Area is Sunny"). In some embodiments, multiple users can create profiles containing their preferred areas of the pool and a means for receiving alerts. For example, a user could create a profile with two preferred areas of the pool, name the preferred areas of the pool (e.g., "lounge area," "spa area," etc.) and pool control logic 70 could send the user a SMS/text message when either of the preferred areas are sunny. It is also noted that pool control logic 70 could collect historical usage data for each user and save the data (e.g., to the memory) to individual user profiles for later retrieval and use.

FIG. 33E is a flowchart illustrating processing steps carried out by the pool control logic 70 for planning the optimal placement of a pool/spa prior to installation. In step 3186, pool control logic 70 transmits an instruction to the user to photograph a desired pool/spa location using a smart device. In step 3188, pool control logic 70 receives desired location data from the smart device (e.g., GPS coordinates, compass bearing, image data, etc.). In step 3190, pool control logic 70 receives data on sun position (e.g., data from sun tracking application or as web data), based on the location data from the smart device. In step 3192, pool control logic 70 determines the optimal location and orientation of the pool/spa for ideal sun exposure (e.g., using GPS, compass, and image data from smart device). Optionally, in step 3194, pool control logic 70 receives data on historic weather conditions (e.g., prevailing winds, speed, direction, etc.) based on the location data from the smart device and in step 3196, pool control logic 70 determines the optimal location of a skimmer (e.g., based on historic wind conditions/direction). In step 3197, pool control logic 70 transmits the optimized location and orientation data to the user (e.g., in the form of architectural drawings, renderings, etc.). In step 3198, pool control logic 70 saves the optimized location data to the memory for later retrieval.

FIG. 33F is a flowchart illustrating processing steps carried out by the pool control logic 70 for determining current weather conditions. In step 3200, pool control logic 70 receives an IP address from a smart device on a local network. In step 3202, pool control logic 70 receives location data based on the IP address (e.g., web data/geolocation provider). In step 3204, pool control logic 70 receives web data on current weather conditions (based on ZIP code, location/address, or GPS coordinates, discussed hereinbelow). Current weather conditions can include, for example, temperature, precipitation, wind speed, wind direction, etc. Web data on current weather conditions could also include live 3rd party data, for example, live weather maps of precipitation and cloud cover. In step 3206, pool control logic 70 saves the current weather conditions to the memory for later retrieval. In step 3208, pool control logic 70 is delayed by X seconds, wherein X is any suitable integer (e.g., 5, 10, 3600, etc.) and then the process returns to step 3200. Optionally, in step 3210, pool control logic 70 could transmit an instruction to the user to enter a ZIP code via a user interface device and in step 3212, pool control logic 70 could receive the ZIP code data from the user interface device. In step 3214, pool control logic 70 could also/alternatively receive GPS data from a smart device on the local network (e.g., smart phone connected to home Wi-Fi).

FIG. 33G is a flowchart illustrating processing steps carried out by the pool control logic 70 for selecting a skimmer based on current weather conditions. In step 3216,

pool control logic 70 retrieves current weather conditions (e.g., wind direction) data from the memory. The current weather conditions can be obtained by way of the process described herein, in connection with FIG. 33F. In step 3218, pool control logic 70 retrieves skimmer location data from the memory. The skimmer location data can be obtained by way of the process described herein, in connection with FIG. 33A. In step 3220, pool control logic 70 determines if there are multiple skimmers. If a negative determination is made, the process ends. If a positive determination is made, the process proceeds to step 3222, where pool control logic 70 determines the most downwind skimmer (using the location data). In step 3224, pool control logic 70 transmits an instruction to the most downwind skimmer to activate. Pool control logic 70 could also send an instruction to all other skimmers to deactivate. The process then reverts to step 3216. In some embodiments, pool control logic 70 could transmit an instruction to increase the suction of an upwind skimmer to compensate for the wind conditions or pool control logic 70 could transmit an instruction to decrease the suction of a downwind skimmer to compensate for the increased debris flowing therethrough due to the wind condition. In further embodiments, pool control logic 70 could transmit an instruction to alter the skimmer suction relative to main drain suction.

FIG. 33H is a flowchart illustrating processing steps carried out by the pool control logic 70 for automated operation of pool devices based on current weather conditions. In step 3226, pool control logic 70 retrieves current weather conditions (e.g., wind speed, up-wind debris source direction) data from the memory. The current weather conditions can be obtained by way of the process described herein, in connection with FIG. 33F. In step 3228, pool control logic 70 retrieves maximum wind speed setpoint data from memory. In step 3230, pool control logic 70 determines if the current wind speed is above the maximum wind speed setpoint. If a positive determination is made, the process proceeds to step 3238, where pool control logic 70 transmits an instruction to the pump to increase circulation. Optionally, in step 3240, pool control logic 70 could transmit an instruction to deactivate or reduce water features (e.g., fountains). Optionally, in step 3242, pool control logic 70 could transmit an instruction to deactivate or reduce fire features. Optionally, in step 3224, pool control logic 70 could transmit an instruction to retract shading devices (e.g., umbrellas, awnings, shades, etc.). Alternatively, in the event of pool devices that are not capable of being automated/receiving control signals/are not connected to the system 10, in step 3246, pool control logic 70 could transmit a message to the user (e.g., "Caution—High Winds"). The process then reverts to step 3226. If a negative determination is made in step 3230, the process proceeds to step 3232, where pool control logic 70 determines if the operation of any pool devices has been altered due to the weather condition (e.g., high winds). If a negative determination is made, the process reverts to step 3226. If a positive determination is made, the process proceeds to step 3234, where pool control logic 70 transmits an instruction to revert to regular operation of the pool device(s). Optionally, in step 3236, pool control logic 70 could transmit a message to the user (e.g., "Wind Has Subsided"). The process then reverts to step 3226. The above process can also be used to configure the skimmer locations with respect to the up-wind debris direction.

FIG. 33I is a flowchart illustrating processing steps carried out by the pool control logic 70 for automated operation of a pool cover based on current weather conditions. In step 3248, pool control logic 70 retrieves current weather con-

ditions (e.g., wind speed) data from the memory. The current weather conditions can be obtained by way of the process described herein, in connection with FIG. 33F. In step 3250, pool control logic 70 retrieves maximum wind speed setpoint data from memory. In step 3252, pool control logic 70 determines if the current wind speed is above the maximum wind speed setpoint. If a positive determination is made, the process proceeds to step 3260, where pool control logic 70 receives operational data from a pool motion sensor (e.g., bather detection, as described hereinabove). In step 3262, pool control logic 70 determines if an active bather has been detected. If a positive determination is made, the process could optionally proceed to step 3264, where pool control logic 70 transmits an instruction to the lighting system to display a weather alert program (e.g., flashing white lights) and the process then reverts to step 3248. If a negative determination is made, the process proceeds to step 3266, where pool control logic 70 transmits an instruction to close the pool cover (e.g., 90% closed, allowing for safety egress). If a negative determination is made in step 3252, the process proceeds to step 3254, where pool control logic 70 determines if the operation of any pool devices (e.g., pool cover, lighting system) has been altered due to the weather condition (e.g., high winds). If a negative determination is made, the process reverts to step 3248. If a positive determination is made, the process proceeds to step 3256, where pool control logic 70 transmits an instruction to revert to regular operation of the pool device(s). Optionally, in step 3258, pool control logic 70 could transmit a message to the user (e.g., "Wind Has Subsided"). The process then reverts to step 3248.

FIG. 33J is a flowchart illustrating processing steps carried out by the pool control logic 70 for compensating heat loss due to current weather conditions. In step 3268, pool control logic 70 retrieves current weather conditions (e.g., wind speed) data from the memory. The current weather conditions can be obtained by way of the process described herein, in connection with FIG. 33F. In step 3270, pool control logic 70 retrieves maximum wind speed setpoint data from memory. In step 3272, pool control logic 70 determines if the current wind speed is above the maximum wind speed setpoint. If a positive determination is made, the process proceeds to step 3280, where pool control logic 70 retrieves pool configuration parameters from memory (e.g., pool surface area, geometry, volume, etc.). In step 3282, pool control logic 70 receives data on the ambient temperature (e.g., from sensor or web data). In step 3284, pool control logic 70 receives operational data on water temperature (e.g., from sensor). In step 3286, pool control logic 70 determines heat loss due to the current weather condition (e.g., prevailing winds). In step 3288, pool control logic 70 transmits an instruction to the heater to increase output (e.g., compensating for the heat loss) and the process reverts to step 3268. If a negative determination is made in step 3272, the process proceeds to step 3274, where pool control logic 70 determines if the operation of any pool devices (e.g., heater) has been altered due to the weather condition (e.g., high winds). If a negative determination is made, the process reverts to step 3268. If a positive determination is made, the process proceeds to step 3276, where pool control logic 70 transmits an instruction to revert to regular operation of the pool device(s). Optionally, in step 3278, pool control logic 70 could transmit a message to the user (e.g., "Wind Has Subsided"). The process then reverts to step 3268.

FIG. 33K is a flowchart illustrating processing steps carried out by the pool control logic 70 for determining if a freeze risk exists and if so, taking appropriate action. In step

3290, pool control logic 70 retrieves current weather conditions (e.g., wind speed) data from the memory. The current weather conditions can be obtained by way of the process described herein, in connection with FIG. 33F. In step 3292, pool control logic 70 retrieves maximum wind speed setpoint data from memory. In step 3294, pool control logic 70 determines if the current wind speed is above the maximum wind speed setpoint. If a positive determination is made, the process proceeds to step 3302, where pool control logic 70 receives data on the ambient temperature (e.g., from sensor or web data). In step 3304, pool control logic 70 determines heat loss due to the current weather condition (e.g., prevailing winds). Heat loss due to the weather conditions (e.g., wind) can be obtained by way of the process described herein, in connection with FIG. 33J. In step 3306, pool control logic 70 determines if a freeze risk exists (e.g., due to ambient temperature, heat loss, wind chill, etc.). If a negative determination is made, the process reverts to step 3290. If a positive determination is made, the process proceeds to step 3308, where pool control logic 70 transmits an instruction to the pump to increase speed. Optionally, in step 3310, pool control logic 70 could transmit an instruction to the heater to increase output, in step 3312, pool control logic 70 could transmit an instruction to the lighting system to display a freeze risk program (e.g., flashing blue lights), and in step 3314, pool control logic 70 could transmit a message to the user (e.g., "Freeze Risk"). The process then reverts to step 3290. If a negative determination is made in step 3294, the process proceeds to step 3296, where pool control logic 70 determines if the operation of any pool devices (e.g., pump, heater, lighting system, etc.) has been altered due to the weather condition (e.g., high winds). If a negative determination is made, the process reverts to step 3290. If a positive determination is made, the process proceeds to step 3298, where pool control logic 70 transmits an instruction to revert to regular operation of the pool device(s). Optionally, in step 3300, pool control logic 70 could transmit a message to the user (e.g., "Wind Has Subsided"). The process then reverts to step 3290.

FIG. 33L is a flowchart illustrating processing steps carried out by the pool control logic 70 for cleaning a pool/spa in response to a weather condition (e.g., high winds). In step 3316, pool control logic 70 retrieves current weather conditions (e.g., wind speed, direction) data from the memory. The current weather conditions can be obtained by way of the process described herein, in connection with FIG. 33F. In step 3318, pool control logic 70 retrieves maximum wind speed setpoint data from memory. In step 3320, pool control logic 70 determines if the current wind speed is above the maximum wind speed setpoint. If a positive determination is made, the process proceeds to step 3328, where pool control logic 70 retrieves pool geometry and orientation data from the memory. The pool geometry and orientation data can be obtained by way of the process described herein, in connection with FIG. 33A. In step 3330, pool control logic 70 determines the downwind area of the pool/spa. In step 3332, pool control logic 70 transmits an instruction to a pool cleaner to traverse the downwind area of the pool and the process then reverts to step 3316. If a negative determination is made in step 3320, the process proceeds to step 3322, where pool control logic 70 determines if the operation of any pool devices (e.g., pool cleaner) has been altered due to the weather condition (e.g., high winds). If a negative determination is made, the process reverts to step 3316. If a positive determination is made, the process proceeds to step 3324, where pool control logic 70 transmits an instruction to revert to regular operation of the

pool device(s). Optionally, in step 3326, pool control logic 70 could transmit a message to the user (e.g., “Wind Has Subsidied”). The process then reverts to step 3316.

FIG. 33M is a flowchart illustrating processing steps carried out by the pool control logic 70 for sanitizing a pool/spa in response to a weather condition (e.g., high winds). In step 3334, pool control logic 70 retrieves current weather conditions (e.g., wind speed) data from the memory. The current weather conditions can be obtained by way of the process described herein, in connection with FIG. 33F. In step 3336, pool control logic 70 retrieves maximum wind speed setpoint data from memory. In step 3338, pool control logic 70 determines if the current wind speed is above the maximum wind speed setpoint. If a positive determination is made, the process proceeds to step 3346, where pool control logic 70 retrieves pool configuration parameters (e.g., pool surface area, geometry, volume, etc.) from the memory. In step 3348, pool control logic 70 determines the increased sanitization needs of the pool due to the weather condition (e.g., high winds causing increased debris in pool). In step 3350, pool control logic 70 transmits an instruction to a sanitization system to increase operation by the determined amount and the process then reverts to step 3334. If a negative determination is made in step 3338, the process proceeds to step 3340, where pool control logic 70 determines if the operation of any pool devices (e.g., sanitization system) has been altered due to the weather condition (e.g., high winds). If a negative determination is made, the process reverts to step 3334. If a positive determination is made, the process proceeds to step 3342, where pool control logic 70 transmits an instruction to revert to regular operation of the pool device(s). Optionally, in step 3344, pool control logic 70 could transmit a message to the user (e.g., “Wind Has Subsidied”). The process then reverts to step 3334.

FIG. 33N is a flowchart illustrating processing steps carried out by the pool control logic 70 for operating pool devices based on timers triggered by sunrise/sunset times. In step 3352, pool control logic 70 receives an IP address from a smart device on a local network. In step 3354, pool control logic 70 receives location data based on the IP address (e.g., web data/geolocation provider). In step 3356, pool control logic 70 receives web data on sunrise/sunset times (based on ZIP code, location/address, or GPS coordinates, discussed hereinbelow). In step 3358, pool control logic 70 receives time and date data (e.g., via an internal clock or as web data). In step 3360, pool control logic 70 determines if the current time is the sunrise or sunset time. If a negative determination is made, the process reverts to step 3358. If a positive determination is made, the process proceeds to step 3362, where pool control logic 70 begins a timer for X seconds, wherein X is any suitable integer (e.g., 5, 10, 3600, etc.). In step 3364, pool control logic 70 transmits an instruction to a pool device to activate/alter operation. For example, pool control logic 70 could transmit an instruction to the pump 14a to increase speed upon sunrise, for a specified duration of time, or pool control logic 70 could transmit an instruction to display a countdown to sundown. In step 3366, pool control logic 70 determines if the timer has reached zero (0) seconds. If a negative determination is made, the process repeats step 3366. If a positive determination is made, the process proceeds to step 3368, where pool control logic 70 transmits an instruction to the pool device to deactivate/resume normal operation. The process then reverts to step 3352. Optionally, in step 3370, pool control logic 70 could transmit an instruction to the user to enter a ZIP code via a user interface device and in step 3372, pool control logic 70 could receive the ZIP code data from the user interface

device and then the process could proceed to step 3356. In step 3374, pool control logic 70 could also/alternatively receive GPS data from a smart device on the local network (e.g., smart phone connected to home Wi-Fi) and then the process could proceed to step 3356.

FIG. 33O is a flowchart illustrating processing steps carried out by the pool control logic 70 for operating pool devices based on sunrise/sunset times (e.g., activate at sunrise, deactivate at sunset). For example, the pool control logic 70 could transmit an instruction to the pump 14a to increase speed upon sunrise and decrease speed upon sunset, the pool control logic 70 could transmit an instruction to increase the filtration rate or hours based on sunlight hours, or the pool control logic 70 could transmit an instruction to the lighting system 14b to activate upon sundown and deactivate upon sunrise. In step 3376, pool control logic 70 receives an IP address from a smart device on a local network. In step 3378, pool control logic 70 receives location data based on the IP address (e.g., web data/geolocation provider). In step 3380, pool control logic 70 receives web data on sunrise/sunset times (based on ZIP code, location/address, or GPS coordinates, discussed hereinbelow). In step 3382, pool control logic 70 receives time and date data (e.g., via an internal clock or as web data). In step 3384, pool control logic 70 determines if the current time is the sunrise or sunset time. If a negative determination is made, the process reverts to step 3382. If a positive determination is made, the process proceeds to step 3386, where pool control logic 70 transmits an instruction to a pool device to activate/alter operation. In step 3388, pool control logic 70 receives time and date data (e.g., via an internal clock or as web data). In step 3390, pool control logic 70 determines if the current time is the sunrise or sunset time. If a negative determination is made, the process reverts to step 3388. If a positive determination is made, the process proceeds to step 3392, where pool control logic 70 transmits an instruction to the pool device to deactivate/resume normal operation. The process then reverts to step 3376. Optionally, in step 3394, pool control logic 70 could transmit an instruction to the user to enter a ZIP code via a user interface device and in step 3396, pool control logic 70 could receive the ZIP code data from the user interface device and then the process could proceed to step 3380. In step 3398, pool control logic 70 could also/alternatively receive GPS data from a smart device on the local network (e.g., smart phone connected to home Wi-Fi) and then the process could proceed to step 3380.

FIG. 33P is a flowchart illustrating processing steps carried out by the pool control logic 70 for operating pool devices at different setpoints during the daytime and evening. For example, pool control logic 70 could operate a sanitization system at a first setpoint during the daytime and operate at a second setpoint during the evening. In step 3400, pool control logic 70 receives web data on sunrise/sunset times. The web data on sunrise/sunset times can be obtained by way of the process described herein, in connection with FIG. 33N. In step 3402, pool control logic 70 receives time and date data (e.g., via an internal clock or as web data). In step 3404, pool control logic 70 determines if the current time is the sunrise or sunset time. If a negative determination is made, the process reverts to step 3402. If a positive determination is made, the process proceeds to step 3406, where pool control logic 70 retrieves setpoint data for a daylight sanitization rate from the memory. In step 3408, pool control logic 70 transmits an instruction to a sanitization system to operate at the daylight sanitization rate. In step 3410, pool control logic 70 receives time and date data

(e.g., via an internal clock or as web data). In step 3412, pool control logic 70 determines if the current time is the sunrise or sunset time. If a negative determination is made, the process reverts to step 3410. If a positive determination is made, the process proceeds to step 3414, where pool control logic 70 retrieves setpoint data on an evening sanitization rate from the memory. In step 3416, pool control logic 70 transmits an instruction to the sanitization system to operate at the evening sanitization rate. The process then reverts to step 3400.

FIG. 33Q is a flowchart illustrating processing steps carried out by the pool control logic 70 for operating a sanitization system based on the current weather conditions. In step 3418, pool control logic 70 retrieves current weather conditions data from the memory. Current weather conditions data can be obtained by way of the process described herein, in connection with FIG. 33F. Current weather conditions could include air temperature, humidity, heat/cold index, wind-chill, etc. Optionally, in step 3426, pool control logic 70 could receive water temperature operational data from a sensor. In step 3420, pool control logic 70 retrieves pool configuration parameters from the memory. In step 3422, pool control logic 70 determines the sanitization rate based on the current weather conditions. While the sanitization rate could be determined based on the current weather conditions, other chemical dispensing and/or production rates could be determined as well. Optionally, in step 3428, pool control logic 70 could determine the sanitization rate based on the water temperature. In step 3424, pool control logic 70 transmits an instruction to the sanitization system to operate at the determined rate. The process then reverts to step 3418.

FIG. 33R is a flowchart illustrating processing steps carried out by the pool control logic 70 for operating the system 10 based on maximum ambient noise. In step 3430, pool control logic 70 receives web data on the local noise ordinance (e.g., maximum decibels at specified times allowed by code). The web data on the local noise ordinance can be obtained by way of a similar process as described herein, in connection with FIG. 33N (e.g., by determining the location of the system 10 and then receiving web data based on that location). In step 3432, pool control logic 70 receives time and date data (e.g., internal clock or web data). In step 3434, pool control logic 70 receives operational data from an ambient noise sensor. In step 3436 pool control logic 70 determines if the current ambient noise is above the maximum ambient noise (set by ordinance) at the current time. If a negative determination is made, the process reverts to step 3432. If a positive determination is made, the process proceeds to step 3438, where pool control logic 70 transmits an instruction to a pool device (e.g., water feature, pump, heater, blower, etc.) to reduce operation by X %, wherein X is any suitable integer between one (1) and one hundred (100) (e.g., 1, 2, 5, 10, etc.). The process then reverts to step 3432. The above process can apply based on geo-positioning data.

FIG. 33S is a flowchart illustrating processing steps carried out by the pool control logic 70 for compensating for ambient noise. In step 3440, pool control logic 70 receives web data (e.g., Google maps) on local traffic conditions (e.g., number/density/speed of vehicles surrounding current location). The web data on the local traffic conditions can be obtained by way of a similar process as described herein, in connection with FIG. 33N (e.g., by determining the location of the system 10 and then receiving web data based on that location). In step 3442, pool control logic 70 determines/estimates the noise intensity of the local traffic. Optionally,

in step 3452, pool control logic 70 could receive operational data from an ambient noise sensor that is positioned to sense the noise produced by the local traffic. In step 3444, pool control logic 70 determines the intensity of white noise needed to compensate for the noise intensity of the local traffic. In step 3446, pool control logic 70 transmits an instruction to a pool device (e.g., water feature or other device capable of producing white noise) to increase output by X %, wherein X is any suitable integer (e.g., 5, 10, 50, etc.). In step 3448, pool control logic 70 receives operational data from an ambient noise sensor (e.g., white noise sensor). In step 3450, pool control logic 70 determines if the white noise being produced is sufficient to compensate for the noise being produced by the local traffic. If a negative determination is made, the process reverts to step 3446. If a positive determination is made, the process reverts to step 3440.

FIG. 33T is a flowchart illustrating processing steps carried out by the pool control logic 70 for determining the local cost of energy. In step 3454, pool control logic 70 receives an IP address from a smart device on a local network. In step 3456, pool control logic 70 receives location data based on the IP address (e.g., web data/geolocation provider). In step 3458, pool control logic 70 receives web data (e.g., a listing) of local energy providers (based on ZIP code, location/address, or GPS coordinates, discussed hereinbelow). In step 3460, pool control logic 70 transmits an instruction to the user to select their local energy provider (e.g., from a list of local energy providers). The local energy providers/vendors can also be determined by way of the user entering, scanning, or selecting the vendor from a drop-down menu. In step 3462, pool control logic 70 receives web data on local energy cost (e.g., as provided by the selected energy vendor). The local energy costs could include both current energy costs and/or forecasted energy costs. Optionally, in step 3474, pool control logic 70 could transmit a rebate/discount message to the user (e.g., government and/or power company energy and/or energy-based equipment rebates and discounts). In step 3464, pool control logic 70 saves the local energy cost data to the memory for later retrieval. In step 3466, pool control logic 70 is delayed for X seconds, wherein X is any suitable integer (e.g., 5, 10, 3600, etc.) and the process then reverts to step 3454. Optionally, in step 3468, pool control logic 70 could transmit an instruction to the user to enter a ZIP code via a user interface device and in step 3470, pool control logic 70 could receive the ZIP code data from the user interface device and then the process could proceed to step 3458. In step 3472, pool control logic 70 could also/alternatively receive GPS data from a smart device on the local network (e.g., smart phone connected to home Wi-Fi) and then the process could proceed to step 3458.

FIG. 33U is a flowchart illustrating processing steps carried out by the pool control logic 70 for informing the user of the cost of a desired action. In step 3476, pool control logic 70 retrieves local energy cost data from the memory. The web data on the local energy costs can be obtained by way of the process as described herein, in connection with FIG. 33T (e.g., by determining the location of the system 10 and then receiving web data based on that location). In step 3478, pool control logic 70 receives user input on a desired action (e.g., pump speed up, spa on, lights on, etc.). The desired action could also include bringing a pool feature to a desired state, over time (e.g., bringing the pool water temperature to 80 degrees Fahrenheit by Friday at 5:00 pm and maintaining the temperature for a specified duration of time). In step 3480, pool control logic 70 determines the

predicted cost of the desired action. In step 3482, pool control logic 70 transmits a message to the user (e.g., cost per minute, hour, day, etc.).

FIG. 33V is a flowchart illustrating processing steps carried out by the pool control logic 70 for optimizing the operation of pool devices based on energy cost (peak and off-peak hours). In step 3484, pool control logic 70 retrieves local energy cost data from the memory (e.g., peak/off-peak cost of electricity). The web data on the local energy costs can be obtained by way of the process as described herein, in connection with FIG. 33T (e.g., by determining the location of the system 10 and then receiving web data based on that location). In step 3486, pool control logic 70 receives user input on pool device operating schedules (e.g., filtering, pool cleaning, etc.). In step 3488, pool control logic 70 determines an optimized schedule for the lowest energy cost. For example, normal filtering and pool cleaner operation cycles could be adjusted based on the lowest cost of energy during off-peak hours. In step 3490, pool control logic 70 transmits an instruction to the pool devices to operate according to the optimized schedule. In addition, energy-based commands could be capable of auto-overriding other system commands, and vice-versa, based on weather/environmental demands (e.g., optimized energy settings vs. weather vs. basic pool requirements—clean, sanitized, etc.). The process then returns to step 3484.

FIG. 33W is a flowchart illustrating processing steps carried out by the pool control logic 70 for warning the user of pool device operation during peak energy cost hours. In step 3492, pool control logic 70 retrieves local energy cost data from the memory (e.g., peak/off-peak cost of electricity). The web data on the local energy costs can be obtained by way of the process as described herein, in connection with FIG. 33T (e.g., by determining the location of the system 10 and then receiving web data based on that location). In step 3494, pool control logic 70 retrieves user input on a desired action (e.g., pump speed up, spa on, lights on, etc.). In step 3496, pool control logic 70 receives time and date data (e.g., internal clock, or as web data). In step 3498, pool control logic 70 determines whether the current time corresponds to peak hours for electricity costs. If a positive determination is made, the process proceeds to step 3500, where pool control logic 70 transmits a message to the user (e.g., “Warning—Peak hours. Do you wish to proceed?”). In step 3502, pool control logic 70 receives user input (e.g., yes/no). In step 3504, pool control logic 70 determines if the user wishes to proceed with the desired action. If a negative determination is made, the process ends. If a positive determination is made, the process proceeds to step 3506, where pool control logic 70 transmits an instruction to the pool device to perform the desired action (e.g., pump speed up, spa on, lights on, etc.) and the process ends. If a negative determination is made at step 3498, the process proceeds to step 3506.

FIG. 33X is a flowchart illustrating processing steps carried out by the pool control logic 70 for preventing use of the system 10 during peak electrical cost hours. In step 3508, pool control logic 70 retrieves local energy cost data from the memory (e.g., peak/off-peak cost of electricity). The web data on the local energy costs can be obtained by way of the process as described herein, in connection with FIG. 33T (e.g., by determining the location of the system 10 and then receiving web data based on that location). In step 3510, pool control logic 70 retrieves user input on a desired action (e.g., pump speed up, spa on, lights on, etc.). In step 3512, pool control logic 70 receives time and date data (e.g., internal clock, or as web data). In step 3514, pool control

logic 70 determines if it is currently peak hours for electricity costs. If a positive determination is made, the process proceeds to step 3516, where pool control logic 70 transmits a message to the user (e.g., “Warning—Peak hours. Please enter Priority User override code.”). In step 3518, pool control logic 70 receives user input (e.g., Priority User override code). In step 3520, pool control logic 70 determines if the Priority User override code is correct. If a positive determination is made, the process proceeds to step 3522, where pool control logic 70 transmits an instruction to the pool device to perform the desired action (e.g., pump speed up, spa on, lights on, etc.) and the process ends. If a negative determination is made, the process proceeds to step 3524, where pool control logic 70 determines if there are retries remaining (e.g., remaining attempts to enter the correct code). If a negative determination is made at step 3524, the process ends. If a positive determination is made at step 3524, the process reverts to step 3518. If a negative determination is made at step 3514, the process proceeds to step 3522.

FIG. 33Y is a flowchart illustrating processing steps carried out by the pool control logic 70 for deactivating high-powered systems/devices/components to reduce electrical costs. In step 3526, pool control logic 70 receives an instruction to activate “Energy Save Mode.” In step 3528, pool control logic 70 identifies high-powered lighting devices in the lighting system. The high-powered lighting devices could be identified at the time of installation (e.g., manually or scanned) or by pool control logic 70 (e.g., macro or sensed). In step 3530, pool control logic 70 transmits an instruction to the high-powered lighting to deactivate (e.g., deactivate non-LED lighting devices). While the “Energy Save Mode” has been described herein in connection with lighting devices, “Energy Save Mode” could also identify and deactivate any device using an amount power that exceeds a predefined setpoint. Additionally, pool control logic 70 could transmit an instruction to a device to reduce operation until the device is only consuming power at low, predefined setpoint. In addition to the examples discussed hereinabove, in connection with FIGS. 33T-33Y, web data (e.g., 3rd party Web advised conditions, energy cost, weather, environmental, etc.) could be used to prompt/trigger pool control logic 70 (e.g., pump control, valve control, lighting control, cleaner control, etc.) to adjust speed, flow, position, mode, performance, behavior, etc. of any piece of pool equipment or feature, or any other device in communication with the system 10, to reduce energy costs, or to return to a previous state.

The system of the present disclosure also provides systems for leveraging synergies between the pool control logic 70 and other applications (e.g., connecting to and/or communicating with a common application and sharing a user interface, advising the user of various alerts/conditions, controlling pool functions and/or devices, reaction or synchronization to/with external devices connected through the cloud, etc.). For example, FIG. 33Z is a flowchart illustrating processing steps carried out by the pool control logic 70 for alerting the user to pool/spa area ingress and egress. In step 3532, pool control logic 70 receives live or historical video of the pool/yard (e.g., from 3rd party application/source). In step 3534, pool control logic 70 analyzes the video of the pool/yard for occupant ingress/egress. In step 3536, pool control logic 70 determines if there has been an ingress/egress (e.g., unwanted intrusion, monitoring the whereabouts of children, etc.) in connection with a body of water. If a negative determination is made, the process reverts to step 3532. If a positive determination is made, the process

proceeds to step 3538, where pool control logic 70 transmits a message to the user (e.g., “Alert—pool ingress/egress”). The process then reverts to step 3532. Optionally, in step 3540, pool control logic 70 could transmit instructions to an alarm system to activate (e.g., 3rd party alarm system/security provider) and then revert to step 3532. The pool control logic 70 could also communicate with 3rd party security systems (e.g., front-door systems with video, audio, door unlock/lock, etc.) and in-home lighting systems and receive data from 3rd party live satellite image/video feeds.

FIG. 33AA is a flowchart illustrating processing steps carried out by the pool control logic 70 for leveraging video data from a 3rd party to maintain the cleanliness of a pool/spa. In step 3542, pool control logic 70 receives live or historical video of the pool/yard (e.g., from 3rd party application/source). In step 3544, pool control logic 70 analyzes the video of the pool/yard for debris (e.g., presence of debris in pool, debris movement in pool, debris concentration in pool, etc.). In step 3546, pool control logic 70 determines if there is debris in the pool. If a negative determination is made, the process reverts to step 3542. If a positive determination is made, the process proceeds to step 3548, where pool control logic 70 transmits an instruction to a pool device to activate (e.g., cleaner, skimmer, filter, etc.). The process then reverts to step 3542. Optionally, in step 3550, pool control logic 70 could transmit an instruction to a pool cleaner to traverse the area of the pool having the highest concentration of debris, and then revert to step 3542.

FIG. 33AB is a flowchart illustrating processing steps carried out by the pool control logic 70 for operation of the lighting system 14h based on operational data from an external source. In step 3552, pool control logic 70 receives operational data from an external source (e.g., a signal that the garage door is opening). Optionally, in step 3562, pool control logic 70 could receive operational data from another external device (e.g., a signal that the indoor lighting devices are turned on). In step 3554, pool control logic 70 receives web data on sunrise/sunset times (e.g., based on ZIP code, address, or GPS coordinates). The web data on the sunrise/sunset times can be obtained by way of the process as described herein, in connection with FIG. 33N (e.g., by determining the location of the system 10 and then receiving web data based on that location). In step 3556, pool control logic 70 receives current time and date data (e.g., from an internal clock, or as web data). In step 3558, pool control logic 70 determines if the current time is after sunset. If a negative determination is made, the process reverts to step 3552. If a positive determination is made, the process proceeds to step 3560, where pool control logic 70 transmits an instruction to the lighting system to activate (e.g., a selection, pool zone, yard zone, or all outdoor lights). The process then reverts to step 3552. In addition to the foregoing, pool control logic 70 could also synchronize/trigger the outdoor/pool lighting system to an “all on” command for the indoor lights. This is particularly useful for emergency lighting scenarios. For example, the indoor lights could receive an “all on” command in response to a triggered smoke detector and pool control logic 70 could transmit an instruction to the lighting system 14h to activate all lights at maximum intensity. Pool control logic 70 could determine that an “all on” command has been sent to the indoor lights directly, by receiving the same command (e.g., direct communication or network communication between the indoor lights and/or smoke detector and pool control logic 70), or indirectly, by monitoring the indoor lighting and/or smoke detector (e.g., light sensors or video monitoring for the indoor lighting, noise sensor for the smoke detector, etc.).

FIG. 33AC is a flowchart illustrating processing steps carried out by the pool control logic 70 for matching or synchronizing the operation of the lighting system 14h to interior mood lighting in a home. In step 3564, pool control logic 70 receives operational data from an external device (e.g., mood/color lighting selected in a home). Alternatively, pool control logic 70 could receive operational data from a sensor positioned for sensing the lighting conditions (e.g., intensity or color) in the home, or pool control logic 70 could receive operational data from a third party application or video feed showing the lighting conditions in the house. In step 3566, pool control logic 70 determines the RGB color spectrum of the mood lighting. In step 3568, pool control logic 70 transmits an instruction to the lighting system to operate the lights at the determined RGB color spectrum (e.g., matching the mood lighting to a selection, pool zone, yard zone, or all outdoor lights).

FIG. 33AD is a flowchart illustrating processing steps carried out by the pool control logic 70 for communicating with a smart device in the possession of a servicer/installer. In step 3570 the smart device scans an equipment bar code (e.g., at time of service, installation, etc.). Optionally, in step 3585, pool control logic 70 could receive the equipment bar code data scanned by the smart device. In step 3572, the smart device identifies the location of the scanned equipment (e.g., via GPS, geo-positioning application, etc.). In step 3574, the smart device transmits the location of the equipment and the date of service/installation to the cloud. For example, the location of the equipment and date of service/installation could be used for warranty registration, as well as other purposes, as described hereinbelow. The cloud could be accessed by pool control logic 70, or a third party system (e.g., smart device/maintenance system used by servicer/installer). Optionally, in step 3582, pool control logic 70 could save the location of the equipment and the date of service/installation to the memory for later retrieval. In step 3576, pool control logic 70 receives information on existing equipment installed at the same location/site (e.g., from the cloud or from the memory). In step 3578, pool control logic 70 determines if it is at or near time to service/replace any of the existing installed equipment. If a positive determination is made, the process proceeds to step 3580, where pool control logic 70 transmits a notification to the servicer/installer (e.g., “Device due for maintenance in X days”) and the process ends. Optionally, if a positive determination is made in step 3578, the process could proceed to step 3584, where pool control logic 70 transmits information to the servicer/installer regarding past issues with the equipment at the location/site and the process ends. If a negative determination is made in step 3578, the process ends. This service information could also be accessed through the cloud and viewed by the servicer/installer, original equipment manufacturer, or authorized service center. The service information could also be provided to the servicer/installer before arrival at the site through a smart device and/or application utilizing geo-fencing and global positioning systems (e.g., a geo-fence is placed around the site and the service information is provided to the servicer/installer upon crossing the geo-fence threshold), discussed hereinbelow.

FIG. 33AE is a flowchart illustrating processing steps carried out by the pool control logic 70 for communicating with an application used by a servicer/installer. In step 3586, a smart device scans an equipment bar code (e.g., at the time of service, installation, etc.). Optionally, in step 3606, pool control logic 70 could receive the equipment bar code data scanned by the smart device. In step 3588, an application on the smart device receives equipment information (e.g., web

data from the equipment manufacturer). In step **3590**, the application displays critical equipment requirements (e.g., plumbing size, flow, clearance, etc.). In step **3592**, the application receives information on existing equipment at the same location/site (e.g., from the cloud or from memory). The application can receive information on existing equipment by way of a similar process as to that described herein, in connection with FIG. **33AD**. Alternatively, in addition to scanning the equipment being scanned/installed, any preexisting equipment could be scanned, and data on the preexisting equipment could be received from the cloud or from memory. In step **3594**, the application analyzes the information for any potential adverse interactions with other equipment installed at the same location/site. In step **3596**, the application determines if there are any potential adverse interactions. If a positive determination is made, the process proceeds to step **3598**, where the application displays a notification to the servicer/installer (e.g., "Caution—incompatible equipment"). If a negative determination is made, the process proceeds to step **3600**, where the application receives known pool parameters (e.g., location, regional weather/environmental conditions, pool geometry, connected pool devices, energy costs, user preferences, etc.). In step **3602**, the application determines optimal settings for the newly serviced/installed equipment. The application can recommend programming based on regional preferences, including seasonal programming (summer, winter, etc.). Further, the application can estimate energy costs based on location weather data and other locational factors. The price estimation can take into account local currency. In step **3604**, the application displays the optimal settings for the newly serviced/installed equipment. While the process described hereinabove, in connection with FIG. **33AE**, makes reference to an application that could be used by a servicer/installer, pool control logic **70** could also accomplish these same steps.

It is noted that global positioning and geo-fencing systems could be utilized with the systems of the present disclosure to provide a servicer with service opportunities (e.g., time to service/replace existing equipment). For example, a smart device having a global positioning system could be used to alert the servicer of service opportunities when an application on the smart device recognizes that the current location of the smart device is within a specified range of a geo-fenced area around a site having equipment in need of servicing/replacement. In this regard, FIG. **33AF** is a flowchart illustrating processing steps carried out by notifying a servicer of servicing opportunities around his/her current location. In step **3608**, an application receives current location data (e.g., GPS coordinates) from a smart device. The application could run on the smart device, a laptop, a remote server having a web-accessible user interface, or any other suitable mobile device that can accompany the servicer/installer. In step **3610**, the application receives the location of equipment and date of service/installation from the cloud within a specified range (e.g., location and service/installation dates of equipment within 50 miles). In step **3612**, the application determines if any of the equipment within the specified range needs servicing/replacement. In step **3614**, the application places a geo-fence around sites with equipment needing servicing/replacement. In step **3616**, the application determines if the current location of the smart device (e.g., mobile device running application and carried by the servicer) is within a geo-fenced area. If a negative determination is made, the process reverts to step **3608**. If a positive determination is made, the process proceeds to step **3618**, where the application transmits a notification to the servicer/

installer (e.g., location of site, equipment needing service/replacement, past issues, etc.) and the process reverts to step **3608**. While the process described hereinabove, in connection with FIG. **33AE**, makes reference to an application that could be used by a servicer/installer, pool control logic **70** could also accomplish/be used in connection with these same steps. For example, pool control logic **70** could transmit the location and service date of the equipment to the cloud or same the data to memory, where the data is later accessed by the application, or pool control logic **70** could determine if any of the equipment needs servicing/replacing and transmit a notification to the application regarding same.

FIG. **33AG** is a flowchart illustrating processing steps of a maintenance/targeted marketing system in accordance with the system of the present disclosure for notifying a pool/spa owner that equipment is in need of service. In step **3620**, the maintenance system receives (e.g., from pool control logic, cloud, servicer, etc.) data on the location of equipment and date of service/installation. In step **3622**, the maintenance system determines if any equipment needs servicing/replacement. In step **3624**, the maintenance system cross-references the location of the equipment needing servicing/replacement with a customer information database (e.g., house phone, cellular phone, home address, email address, etc.). In step **3626**, the maintenance system transmits a notifications to owners/users with equipment needing servicing/replacement (e.g., robo-calls, SMS messaging, letters, emails, etc.).

FIG. **33AH** is a flowchart illustrating processing steps carried out by the pool control logic **70** for limiting the operation of pool devices when the an adult is not present. In step **3628**, pool control logic **70** retrieves pool location, geometry, and orientation data from memory. The pool location, geometry, and orientation data can be obtained by way of the process described herein, in connection with FIG. **33A**. In step **3630**, pool control logic **70** places a geo-fence around the pool/spa area. In step **3632**, pool control logic **70** receives operational data from a smart device of an adult/parent (e.g., GPS coordinates). In step **3634**, pool control logic **70** determines if the smart device is within the geo-fenced area. If a positive determination is made, the process proceeds to step **3636**, where pool control logic **70** transmits an instruction to the pool devices to operate in "Adult Mode" (e.g., parent, adult-only, features enabled) and the process reverts to step **3632**. If a negative determination is made, the process proceeds to step **3638**, where pool control logic **70** transmits an instruction to the pool devices to operate in "Safe Mode" (e.g., parent, adult-only, features disabled) and the process reverts to step **3632**.

FIGS. **34A-34J** are diagrams showing additional embodiments of the pool and/or spa control system of the present disclosure, indicated generally at **4610**. More specifically, FIGS. **34A-34J** illustrate modular relays **4670**, a wiring hub **4646**, and a control module **4661** provided in accordance with the present disclosure.

FIG. **34A** is a diagram illustrating another embodiment of the system of the present disclosure, indicated generally at **4610**. In this embodiment, network connectivity and remote monitoring/control is provided by way of a wiring hub **4646** which can be easily mounted to a variety of surfaces (discussed hereinbelow in connection with FIGS. **34F-34I**). The wiring hub **4646** provides connections for various pool and spa equipment, such as a variable speed pump **4614a**, a single-speed pump **4613**, and a legacy heater **4615**, as well as other equipment. For example, the hub **4646** could communicate with and control a smart valve actuator **4614e**, and/or lighting system **4614h**. Optional smart control relays

4670 could also be in communication with the hub **4646**, or could communicate with any other HUA (e.g., a unique addressing system, digital, analog or mechanical switches or dip switches) enabled pool/spa component capable of receiving or assigning a network address.

As can be seen, the hub **4646** could be in communication (e.g., using any of the wired or wireless connections and associated communication protocols discussed hereinabove) with a control module **4661** having a user interface **4660**. The user interface device **4660** could include physical keys, a digital display, and/or a touchscreen **4662**, as shown in FIG. **34A**. Any other suitable input technologies, or any combination thereof, could also be utilized, thereby enabling a user to interact with the pool and/or spa control system **10**. Additionally, the control module **4661** could provide a WiFi hotspot for allowing a service provider's cellular telephone, tablet computer, or other mobile computing device **4644** to communicate with the system **10**, and to control the pool/spa equipment shown in FIG. **34A**. Communication between the service provider's cellular telephone, tablet computer, or other mobile computing device **4644** and the system **10** could be established using the user interface **4660** (e.g., using physical keys, a digital display, and/or by touch) or by proximity to the control module **4661**, described in greater detail hereinbelow. A breaker panel **4627** provides electrical power to the various devices shown in FIG. **34A**. Breaker panel **4627** could also be a smart circuit breaker (e.g., a circuit breaker that can be controlled via wired or wireless communication) used to provide and/or to interrupt power to the devices disclosed herein. In some embodiments, photovoltaic (e.g., solar) cells and/or systems could provide electrical power to one or more of the various devices shown in FIG. **34A**. The hub **4646** could also communicate with the homeowner's WiFi router **4622** via the control module **4661**, thereby providing an Internet connection to the pool/spa components in communication with the wiring hub **4646**. A remote pool/spa server **4618** could communicate with the router **4622** via the Internet, to provide remote monitoring and control of the pool/spa equipment, if desired. Additionally, the server **4618** could communicate with one or more remote computer systems **4620** such as a smart phone, a tablet computer, a remote computer system, home automation, etc., if desired. The pool/spa control logic discussed herein could be installed in the server **4618**, in one or more of the remote computers **4620**, and/or in the control module **4661**, if desired.

As illustrated in FIG. **34A**, the system could include a control/UI/Wifi module **4661** which includes an external controlling unit **4660** having a user interface ("UI") display **4662**, a control board with processor and memory (not shown), and which is able to communicate with a home router **4622** by way of a wired or wireless connection (e.g., integral Wifi/cellular/RF, wired Ethernet, and/or an external wifi/cellular antenna). More specifically, the Control/UI/Wifi module **4661** could include a printed circuit board (not shown), a control module having a processor and memory, a graphical user interface display **4662** (e.g., LCD, LED, buttons, knobs, capacitive plastic, etc.), a wifi module, ethernet jack, USB port, LEDs, a sealed enclosure, a mounting bracket (e.g., for mounting the module **4661** to a wall, post, pole, plumbing, etc.), and a means for communication with a wiring hub **4646**. In other embodiments, the control module **4661** could be mounted on or inside another piece of equipment such as, for example, a pump, heater, chlorinator, control, timeclock, etc.) The control module **4661** could communicate with the wiring hub **4646** by way of either

wired (e.g., RS485, ethernet, USB, serial, etc.) or wireless (e.g., Wifi, Bluetooth, ZigBee, ZWave, cellular, thread, etc.) communication protocols.

The wiring hub **4646** includes an enclosure, provisions for wire routing (meeting or exceeding IPxx ingress protection standards), a printed circuit board, and a power cord "whip" (cable). The wiring hub could be provided with communication interfaces for receiving and transmitting data to one or more devices. For example, the wiring hub could communicate with, temperature sensors, external sensor, flow sensors, pressure sensors, chemical and physical property sensors, valve actuator ports, RS485 bus connections (for smart devices, smart relay(s), smart (firmware assisted) valves, smart sensors, and other smart devices) chlorination connections, lighting connections, power connectors, low voltage relays, etc. Additionally, the communication interfaces could also be used to expand the functionality of the wiring hub such as, for example, by being used to interface with wireless communication chips (e.g., Wifi, Bluetooth, Zigbee, ZWave, cellular, thread, etc.), and additional communication modules.

The Control/UI/Wifi module **4661** is used to monitor, activate, and operate installed pool equipment. The control module **4661** could operate the equipment as needed with people present or absent, in the pool or around the backyard, which may be year-round and/or all-day based on application (e.g. residential vs. commercial) or location. The control module **4661** also monitors, detects, informs, and initiates protective action through a heuristic capability (using one or more algorithms) by accumulating and analyzing raw sensor data and external data to automatically develop 'normal' and 'abnormal' operating ranges, then taking action or alerting operators when the algorithm detects that operation is out of normal or safe operating range. The heuristic algorithms can also learn from operator response to a condition, and therefore account for factors not anticipated or sensed by the equipment. Such algorithms could be implemented in any of the embodiments discussed in the present disclosure, and need not be limited to the control module **4661**.

The control module **4661** provides for distributed (e.g., the control module can be moved throughout the pool/spa environment based on the particular needs of the pool/spa environment and needs/wants of the pool/spa user) control of pool equipment and conditions that can be moved according to the specific needs of a particular pool/spa environment and/or user. For example, the control module **4661** could be moved away from the power switching or pool equipment to a remote location, closer to the wireless network, or closer to the home, or closer to wherever the user is (e.g., poolside). In addition, the control module **4661** could also allow for full pool control capability to be moved, or transferred, to a remote location from the pool pad, such as for example, to a cloud server **4618** or to a remote office.

The connection to the wiring hub can be extended or virtualized via communications protocol over other mediums. The wiring hub **4646** could locally switch power or the wiring hub **4646** could command smart relays **4670** (discussed hereinbelow) to switch power or control signals. The wiring hub **4646** could further be provided with "limp mode" behaviors (discussed in greater detail hereinbelow) if communication to the controller is severed or impaired. These behaviors could include, but are not limited to, maintaining interlocks between relays, schedules, or other special behaviors that are intended to keep the pool system functional at a reduced level until normal operation is restored. The wiring hub **4646** could also integrate safety

control functions needed for heating or other appliances, or the wiring hub **4646** could directly communicate with such safety controls.

The control module **4661** and wiring hub **4646** could be mounted on a wall, on a post, on a stake (e.g., rebar), on a piece of plumbing, inside or on a piece of existing pool/spa equipment (e.g., pump, heater, chlorinator, existing automation, etc.). Further the control module **4661** and wiring hub **4646** may be mounted together in a single location or mounted separately.

The wiring hub **4646** could provide power to the control system by tapping existing power connections at the load end of the conduit coming from a sub panel, timeclock, control, junction box or other electrical connection to the powered equipment. After turning off the power at breaker **4627**, a pool installer or service professional could remove the power whip from the existing equipment, and then reconnect the power whip to the wiring hub, thereby providing power to the wiring hub and control module **4661** without having to access the line voltage compartment of an electrical panel. Further, a new whip could then be connected to the wiring hub **4646** which could, in turn, deliver power from the wiring hub **4646** to additional powered equipment (see FIGS. **34B** and **34C**). For example, an existing power conduit from a variable speed pump **4614a** or a single speed pump **4613** could be disconnected from the variable speed pump **4614a** and then plugged back into, or otherwise connected to, the wiring hub **4646**. A new power whip could then be used to connect the wiring hub **4646** to the variable speed pump **4614a**. Further, a communication cable (e.g., RS485) could be connected between the wiring hub **4646** and the variable speed pump **4614** to provide communication therebetween. In another example, the installed power conduit from a heater **4615** could be disconnected from the heater **4615** and then plugged into, or otherwise connected to, the wiring hub **4646**. A new power conduit could then be used to connect the wiring hub **4646** to the heater **4615** and a communication cable (e.g., RS485) could be connected between the wiring hub **4646** and the heater **4615** to provide communication therebetween. In a further example, the installed power conduit from a powered device (e.g., pump, heater, chlorinator, cleaner, transformer, etc.) is disconnected from the powered device and then reconnected to an input of the wiring hub **4646**. A new power conduit cable is then used to connect the wiring hub **4646** to a smart relay **4670** and an additional power conduit cable is used to connect the smart relay **4670** to the powered device (e.g., pump, heater, chlorinator, cleaner, transformer, etc.). As illustrated in FIG. **34F**, the wiring hub **4646** and/or control/UI/wifi module **4661** could also be powered directly from a 120V/240V NEMA style plug, thereby qualifying as a cord-connected appliance. Because safety codes allow for increased flexibility in the location and mounting of cord-connected appliances, the labor to install or retrofit the devices is reduced, and the accessibility to the user, installer, or site wiring technician is improved. The modular nature of the wiring hub **4646** and control module **4661** provides for configurations thereof that are tailored for integration with the installed pool/spa equipment (e.g., such as a pump, heater, chlorinator, etc.) or that can remain in stand-alone configurations, thereby providing flexible communication to the controlled devices (e.g., via a wired or wireless connection). It is within the scope of the present disclosure that any and all of the pool control logic described herein could be located in and run from the wiring hub **4646** and/or the control module **4661**.

The modular relays of the present disclosure could be used in connection with both residential and some commercial applications. The modular relays provide control (e.g., activation and deactivation) of a piece of pool equipment based on a control signal received from a controller (e.g., control module **4661**) or local manual input (discussed hereinbelow). For example, the modular relay **4670** could be used to control a pump, cleaner booster, spa booster, heater, pool lights, spa lights, landscape lights, post lights, accent lights, other types of lights, fans, chlorinators, water feature pumps, pond pumps, and cleaners, as well as additional pieces of electrically powered/controlled pool/spa equipment and yard equipment/devices. The modular relay **4670** could include a printed circuit board, a processor, an HUA (e.g., a unique addressing system, digital, analog or mechanical switches or dip switches), activation and/or deactivation button, status LEDs, a relay (s), an enclosure with multiple power entries, a power cord whip, and wired (e.g., RS485, USB, ethernet, etc.) and/or wireless communication (e.g., Wi-Fi, Bluetooth, Bluetooth LE, zwave, Zig-Bee, cellular, thread, mesh, etc.) interfaces for communicating with the controlling hardware.

The modular relay **4670** can be controlled by a variety of controlling devices. For example, the relay **4670** could be controlled on schedule (e.g., existing timeclocks **4672**), using an algorithm (e.g., controller/pool control logic **70**), through user input (e.g., a button on the modular relay), from a web enabled device (e.g., through the cloud, the router or direct) or in stand-alone manual mode. The controlling devices could include, but are not limited to, a pump, a heater, a cleaner, a salt chlorinator, a lighting controller, a chemical automation system, a hub or an existing controller, a smart phone, tablet, computer, or smartwatch, or a voice enabled device (e.g., Amazon Echo).

The modular relay of the present disclosure could be capable of detecting when there is no communication from a controlling system/device, if the modular relay has not yet been configured, or if the modular relay has been improperly operated or installed, and in response, placing itself in stand-alone manual or ‘limp’ modes.

In stand-alone mode (as well as service, manual, limp or other modes which are independent from commands from a controller), the relay can operate independently of the pool/spa control system. For example, in the event that communication with the control system could not be established, the modular relay could automatically enter standalone mode. In standalone mode, the modular relay could provide a visual indication (e.g., a flashing or steadily illuminated multicolor LED status indicator) that communication with the control system could not be established, or that communication has been severed. The modular relay could then implement a limp mode for the relay. In limp mode the modular relay could still be activated in response to timed events/schedules. The behaviors of the modular relay when in manual or limp modes could be defined by firmware or set by user preference, thus providing the ability to maintain a schedule, always turn off, always turn on, switch to a special schedule, or other actions intended to maintain the water body while the pool/spa control system is in a state of reduced functionality.

The relay could also enter service mode in response to motion or other proximity detection (e.g., when a service provider is in close proximity to a piece of pool/spa equipment), geofencing (e.g., when a service provider enters the vicinity of the pool/spa area), voice command (e.g., in response to audible request to “enter service mode”) or a button press (e.g., a physical “service” button located on the

relay). Service mode could also allow a technician to temporarily operate the relay and then pass control back (e.g., manually or via a timer) to the controller. The modular relay device could also allow local control (e.g., by touch or voice) at the smart relay without disabling remote control.

In an exemplary embodiment the relay could enter service mode in response to a service provider being in close proximity to the relay. For example, an application running on the service provider's mobile device could communicate with the relay using any of the communication protocols heretofore described and grant the service provider access to configuration parameters for the relay and/or the pool control system 10. In further embodiments, additional security measures could be implemented for preventing unauthorized access to the configuration parameters. For example, a password could be required for access to the configuration parameters. The password could be stored within the application so as to auto-populate and unlock the system parameters when the service provider is in close proximity to the relay. Alternatively, the service provider could be prompted for a password when in close proximity to the relay. Multiple passwords could be set so as to unlock various system parameters associated with individual passwords. For example, a service provider password could be used to unlock all of the system parameters, whereas a pool user password could only unlock a subset of the system parameters.

The modular relay could indicate the status of the modular relay through LEDs (e.g., integrated into the modular relay), text, graphics, or sound (e.g., provided on a user interface device), or directly to web, wifi, Bluetooth, Zigbee enabled devices (e.g., smartphones and other mobile devices). For example the status indications could include, but are not limited to, power, Internet connection, communicating with the system, no communication with the system, wifi connected, no wifi, controlled mode, service mode, enabled or disabled, current, voltage, runtime history, actuation history, etc.

The smart relay can identify itself to a controller (e.g., by providing a physical or network address, or by asking for an address to be provided by the controller automatically), thereby allowing the modular relay to communicate with, and be controlled by the controller. The modular relay could also be manually given a particular network address. The controller could control one or a plurality of relays independently, in a timed sequence, or simultaneously.

As illustrated in FIG. 34A discussed in greater detail hereinbelow, the modular relay device could be provided with its own proprietary/dedicated electrical/junction box ("enclosure") for one (e.g., relay 4670) or a plurality of relays (e.g., wiring hub 4646), but could also be installed in an existing single gang, dual gang, timeclock, or non-traditional electrical/junction box. As shown in FIGS. 34G-34I, the proprietary/dedicated enclosure of the modular relay device could be provided with a multitude of means for mounting the enclosure to the pool pad. For example, the means for mounting the enclosure could include, but are not limited to, hose clamps, screw holes, rebar mounts, zip-tie holes, etc. FIG. 34F illustrates the modular relay 4670 with integral means for mounting to a plumbing pipe (e.g., rounded back). FIG. 34G illustrates the modular relay 4670 with integral means for mounting to a pole (e.g., rounded back). FIG. 34H illustrates the modular relay 4670 with integral means for mounting to a post or wall (e.g., screw bosses). FIG. 34I illustrates the modular relay 4670 with integral means for mounting to rebar inserts (e.g., rebar

holders). A secondary structure could also be provided and could include one or more of the means for mounting the enclosure.

As illustrated in FIG. 34B, the modular relay device could include an incoming (power) whip/connection (including conduit connection hardware) for conducting power from the supply (e.g., breaker panel). The connection could be built in, attached, supplied or purchased separately. According to the embodiment illustrated in FIG. 34B, incoming whip(s) could connect to an existing sub-panel, timeclock enclosure, or junction box with conductors connecting to existing equipment's power connection and the opposite end of the incoming whip(s) could connect to the relay connection in the modular relay system inside the enclosure. It is desirable to utilize the existing whip to connect the breaker panel 4627 to the wiring hub 4646 or another intermediary piece of equipment (e.g., timeclock 4672) so as to avoid entering/accessing the "hot" section of the breaker panel 4627 or subpanel.

Whips can enter and exit the enclosure from the same side (e.g., both entering and exiting the bottom of the enclosure as shown in FIG. 34B) or from opposite sides (e.g., from a side to the top or bottom, from the top or bottom to the side, or from the top to the bottom or bottom to the top, etc.). The whips could be coupled to the enclosure using straight connections, using 45 degree or 90 degree conduit connectors, or low profile connectors. Standard conduit connectors could be used or proprietary connections could be added to improve simplicity of connections. The threading of the conduit connectors could be male or female, or alternatively, the conduit connectors and the enclosure need not use threading at all. Additionally, there can be a conduit entry and/or exit in the cover of the relay or relay enclosure. All of the conduit entries/exits and conduit connectors discussed hereinabove could also have integral liquid tight cord entries for ease of installation. Accordingly, the modular relay device enclosure is designed such that it readily accepts incoming whips from existing equipment (e.g., sub-panel, timeclock or junction box, etc.) and exiting whips to the powered and controlled device.

The enclosure of the modular relay device could have relays that are detachable, that are integral, or that are integral and fully potted. Further, the relays could be permanently installed, mounted by way of screws, or could be mounted by way of a hinged connection (inside or outside) with one or more screws.

The modular relay device could have a ground fault circuit interrupter ("GFCI"), arc fault, or other protective circuit built into the relay. The modular relay device could also measure load power, supply voltage, contact closure, contact resistance, or general contact health. In addition, the modular relay device could measure circuit or ambient temperature, or sense water flow or temperature via an attached sensor. The inclusion of GFCI or other safety functions could satisfy wiring requirements without needing an additional (and expensive) GFCI breaker.

The relay could be encased/over molded into a line cord, thereby allowing a servicer/installer to remove the existing whip from the power supply (e.g., breaker panel) to the piece of equipment and replace it with a new line cord having an integral relay. It is desirable to utilize the existing whip to connect the breaker panel to the wiring hub so as to avoid entering/accessing the "hot" section of the breaker panel or subpanel, and use the new over molded line cord with integral relay to connect the wiring hub and piece of pool/spa equipment. However, the new over molded line cord with integral relay could be used to connect breaker

panel and the wiring hub, and the existing whip could be used to connect the piece of pool/spa equipment and the wiring hub. The new line cord could further include a means to communicate with the controller (e.g., RS485, USB, Ethernet, Bluetooth, Wifi, Zigbee, Cellular, Thread, LE Bluetooth, any mesh type network, etc.).

The relay could also include a number of additional smart relay capabilities that could allow for the addition of other circuitry, inputs, or external communication modules. For example, the modular relay device could accept sensor inputs (e.g., temp, light, wind, etc.) or external data (e.g., storm detection, web servers, GPS inputs for geo fencing, etc.). It is within the scope of the current disclosure that any and all of the pool control logic described herein could be locate in and run from the relay **4670**.

FIG. 35 is a diagram illustrating another embodiment of the system of the present disclosure, wherein a wireless communication device, indicated generally at **4800**, provides communication between pool/spa components or equipment, a home router, and the internet. The wireless communication interface **4800** allows pool controlling devices (e.g., pump, heater, chlorinator, cleaner, hub, automation, etc.) to communicate with the home router and thereby communicate with the Internet. The wireless communication device could be located directly on the main (intelligence) printed circuit board (“PCB”), could be attached/plugged into the main PCB, could be provided as a modular upgrade to the main PCB or PCB enclosure, could be a modular upgrade to/external to the main PCB enclosure, or could be located remotely to the main PCB enclosure. As shown in FIG. 35, an antenna could be mounted with (internal antenna **4804**) or remote to (external antenna **4816**) a wireless transceiver module **4802** in the embodiments described herein. The wireless communication interface **4800** could also allow pool controlling devices to directly communicate with web enabled devices (e.g., smartphones, tablets, thermostats, voice enabled devices, etc.) without the need to go through a home router. Additionally, the wireless communication interface **4800** could provide communication between the pool/spa components or equipment and the web/cloud server, thereby providing tools and indicators to assist a user in solving connectivity problems with the controller through the server/cloud and to the consumer and apps.

As shown in FIG. 35, the wireless communication interface **4800** includes a protocol processor **4808**, a radio circuit **4810**, and an antenna **4804** and could be installed directly on the circuit board of the controlling equipment. In another embodiment, the wireless communication interface **4800** could have a secondary external antenna **4816** that could be installed for better connectivity (e.g., signal strength) or for placement at a location closer to the home router.

The wireless communication interface **4800** could also include a printed circuit board, a protocol processor **4808**, an HUA module **4812** (e.g., for providing a unique hardware address), a radio circuit **4810**, an antenna **4804**, status LEDs **4814**, an ethernet/USB/RS485/Bluetooth connection **4806**, and an enclosure that could be mounted using the enclosure itself or using a secondary mount. For example, a secondary mount could be provided for mounting the wireless communication interface **4800** without (or with) the use of tools (e.g., by snapping the antenna to the mount or other suitable methods). In addition to, or in place of, the ethernet/USB/RS485/Bluetooth connection **4806**, the wireless communication interface **4800** could include any wired or wireless communication protocol disclosed herein for communicating with the controller hardware.

An antenna (internal antenna **4802** or external antenna **4816**) is used to communicate commands from remote web enabled devices (e.g., wireless devices) to a controller unit, which activate equipment as needed with people present or absent, in the pool or around the backyard, which may be year-round and/or all-day based on application (e.g. residential vs. commercial) or location. Additionally, the wireless communication interface **4800** could communicate with the controlling devices by way of RS485, USB, Bluetooth, ethernet, cellular, Wi-Fi, ZigBee or other communication protocols. For example, the antenna **4802** could facilitate communication with the home router through Wi-Fi, Cellular, Bluetooth, ethernet, or other communication protocols.

The wireless communication interface **4800** could also be provided with a button to activate service/troubleshooting indicators (e.g., LEDs **4814**) to provide information relating to the status/connectivity problems of the wireless communication interface **4800**. For example, the wireless communication interface **4800** could be provided with LED indicators **4814** which could be illuminated in various colors (e.g., black, green, orange, red, etc.) and activation patterns (e.g., solid, blinking, etc.) based on the status of the wireless communication interface **4800**. For example, a green LED could indicate normal operation, a yellow LED could indicate an issue that can be addressed by the user, and a red LED could indicate an issue that needs to be addressed by a service provider. The status LEDs could further include a power icon LED (indicating bad cable, no power, power ok, WPS activation), a router icon LED (indicating router not present, incorrect password, no IP address assigned, router DHCP error, incompatible router/black listed firmware or model), a web icon LED (indicating web not present, no UDP connection allowed, no remote server found, connected to web server), an Internet icon LED (indicating no internet/no google, high error rate, connected to the internet), a signal strength LED (indicating not configured, out of range, weak signal, 75% or greater signal), a quality of signal LED (indicating error rates via a bar graph, high error rate, strong connection/low error rate), and a connection speed LED (indicating reduced connection speed/sufficient connection speed). Additionally, the LEDs could indicate the status of the connection as illustrated in Table 1 below.

TABLE 1

LED State	Connection Status
Power: Off	No Power, USB/Wire Corruption
Power: Off	No SSID Password
Router: Blinking	No IP Address
Internet: Off	No Internet Access (No Google)
Router: Blinking	No DHCP Server Response (Static Only)
Router Config: Blinking	No IP Path -> Remote Server (Internet is OK)
Router Config: Blinking	No UDP to Remote Server (Firewall)
Radio Link: Blinking	High Error Rate
(Break Out)	No Network Connection
Internet: Blinking	Frequent Internet Response Delays
Slow Flicker on High Trending Issue	Past Issue Not Currently Happening
Power: Slow Flicker	Firmware Needs Update radio, host, optional, urgent
Power: Slow Flicker	WPS for Unknown Password

The connection status could also be communicated through the controller user interface (e.g., a status page) to help installers/users identify communication problems with the cloud and/or application using similar multicolor status indicators as described above. For example, all faults could be provided in a list with one color (e.g., green) or another

color (e.g., red) indicators to identify a connection problem area. The status page could also provide a solution to a particular connection problem associated with a color. Further, the system could prompt the user to contact the manufacturer in the event that a problem is not known or that the problem is known to not be resolvable through a troubleshooting manual.

The status page could be activated through a service button (e.g., provided on the control device, pool/spa equipment, or in an application) to allow a web-enabled device to obtain the status of the wireless communication interface via an application. For example, the application status page could provide all of the faults in a list with green or red indicators to easily identify problem areas, a description of the solutions to particular problems, a walk-through presentation on how to address/fix the problem, and/or a video illustrating how to address/fix the problem. The application could also provide a configuration walk-through page to instruct a user on how to configure the wireless communication interface. The configuration walk-through page could be activated through a service button. The application could also connect to a service to provide remote customer service via a web-enabled controller which could allow the service provider to remotely troubleshoot and fix the problem with minimum user interaction.

The pool "hub" disclosed herein, as well as the various embodiments disclosed herein, allows for wired and wireless communication (e.g., wireless methods 802.11 protocols, Zigbee, Zwave), with pool pad components. Communication could include product status, product health, energy use (e.g., individual and/or system), errors, preventative maintenance, etc. The hub could incorporate all of the types of communication to the hub and from the hub to the home router. The pool hub could be upgraded through the web, push updates to connected equipment at the pad, etc. The hub could be fully configured (e.g., through an app), which includes schedules, names, temperatures, possible chemical dosage, percentage output, etc. The hub could have web based cloud connectivity to other cloud based devices or systems to allow for enhanced communication and/or enhanced external inputs. The hub could have a communication antenna for RF mesh (e.g., ZWave, Zigbee, Thread, Weave), BlueTooth, etc to connect to pool and non-pool equipment. The connectivity could be done at the pool pad, the processing could be done on the cloud (e.g., with one app built based on activated features). The hub could connect thermal imaging to relay pool, pad, spa, and/or weather information to the hub. The hub could enable virtual interlocks between devices based on predetermined rules and relationships.

The system of the present disclosure is modular and can grow with the addition and/or replacement of equipment. More specifically, the system consolidates all products as they are added (e.g., pump, heater, chemistry automation systems), and could only show the ones currently installed. App updates (e.g., for accessing the system from a local device) could come from new compiled code and/or a profile held in the device and transferred to the app. The system could store the operating profile and/or environment of the devices captured by the hub or in the devices and relayed to the hub (which could support the predictive failure ability as well as supports warranty analysis claims). The system could store standard profiles for heater/pump (e.g., Northeast region by zipcode) and/or heater/pump/lights (e.g., Southwest region by zipcode) for easy configuration (e.g., start with standard configurations based on the geography).

The system could monitor a variety of types of plug in and/or wireless sensors (e.g., air, pool, spa, solar, temperature, etc.) for a variety of types of measurements (e.g., presence of flow, measurement of flow, line pressure, water levels, UV levels, wind speeds, light presence, etc.). Other types of sensors that could be used include turbidity sensors, bacteria sensors, alkalinity sensors, hardness sensors, RF sensors, sound wave sensors, different light spectrum sensors, reflectors, magnetic sensors, radar, infrared, humidity, evaporation, moisture, motion, galvanic corrosion, chemical corrosion, electrolysis, electrical storm sensors, etc. The sensors could analyze and/or process raw data (e.g., locally sensed parameters, from a third party source, etc.) with an integrated processor or communicate the raw data (e.g., locally sensed parameters, from a third party source, etc.) for processing in a co-located or remote processor. The sensor analysis could incorporate trigger points, trend monitoring, manual correlation analysis, automatic correlation analysis, etc. The sensors could be individual or grouped (e.g., for more efficient connection and/or pairing).

The hub could function as a router for data, relay for data, or analyze the data. The hub could have one or many different electrical and protocol data communication interfaces to support connection to legacy and future protocols and devices. The hub could have built in Ethernet (e.g., wired, wifi, cellular, and/or other), as well as communication with home router and/or direct to cloud (e.g., cellular). The hub could connect through wired (e.g., RS485) and/or wireless communication (e.g., wifi, bluetooth, zwave, zigbee, etc.) with a pump (e.g., for full variable speed pump ("VSP") capabilities), heater or heat pump (e.g., for heat control), etc. (i.e., low voltage and/or high voltage applications). The hub could have one or more modular relays or relay banks (e.g., four relays or relay banks). The hub could connect to the relay bank for relay control through wired (e.g., RS485) and/or wireless communication. The relays could be used to control any electrical devices (e.g., high or low voltage), such as pumps, lights, etc. The hub could control wired or wireless valves with transformation at plug or 120V (e.g., to provide power to valve based on hub architecture). The hub could connect to a light controller through wired and/or wireless (e.g., Bluetooth and/or RF mesh such as ZWave, Zigbee, Thread, Weave, etc.) communication, such as to give relay control to a pool, spa, backyard lighting, etc.

The system can perform a variety of types of analytics. For example, the system could analyze electrical, gas, and/or propane usage for one or more pool devices, sites, and/or geographies (e.g., based on data from the hub or device). The system could analyze consolidated site information to facilitate creation of algorithms (e.g., to increase efficiency for all users). The system could use historical data trends to predict future trends, future costs, utility budgets, warnings, efficiency change, as well as to offer preventative maintenance, predictive failure, and/or potential downtime risks. The system could communicate with utilities via a web-based API or some other suitable mechanism. The system could use data trends and/or external data to minimize energy usage and/or facilitate energy consumption decisions. The system could analyze data to predict a budget for requested outcomes to give consumers better visibility in their choices. The system could use external web based data to automate decisions based on learned or imputed data or trends. The system could use historical and/or external data to predict outcomes heating or filtering events to increase autonomy and reduce energy usage for these outcomes. The system could use failures, predictive failures or preventative

maintenance alerts to automatically assign or request service from a customer or partner. The system could use external data from partners to increase the efficiency, potential decisions, functionality of the hub in the IoT world. The system could use data to adjust automated decisions based on sensors, decision information, inputs from other devices, etc. The system could use flow, pool temperature, air temperature, wind data, etc. to automatically adjust the pool turnover and optimize (e.g., fastest, most efficient) the pool pump for amount of turnover, speed, etc., and/or to automatically adjust the chemical dispensing and/or production to maximize life of cells. The system could use data communicated to the hub from a water leveling sensor to predict leaks and/or water bills, and/or to automatically alert leak repair company that customer has an issue with his or her pool. The system could use web based data (e.g., time of year, sunrise and sunset, time, etc.) to predict light availability and automate changes in device schedules. The system could use consolidated site information to help notify the user of a devices operation through the actions of an alternate device. The system could provide an installer with a step by step interface for product installation when a product is selected.

While various forms of web data have been described above in connection with FIGS. 1-33AH, web data can also include, but is not limited to: environmental conditions such as ambient temperature, humidity, wind speed and direction, rain, lightning, snow, cloud coverage, forecasts (e.g., 5 day, 10 day, etc.), pollen, visibility, fog, pollution, smog, road conditions, travel delays, UV index, location, zip code, GPS coordinates, IP address, sunrise, sunset, sun location, wind chill, public water costs, public water availability, public water quality, drought or flood alerts, average chemical costs (e.g., internet costs of chlorine, etc.), tornado/hurricane alerts, etc.; local energy data such as electricity costs, fuel costs, peak hours and cost fluctuation, sun location, available energy rebates, etc.; personal data produced in conjunction with web or web enabled device (e.g., nest, phone, hub, etc.) such as location (e.g., home, away, on the way home, etc.), data usage, amount of web enabled devices used or connected (e.g., five downloaded apps could represent a family of five), energy used (e.g., fuel, electricity, etc.), data speed (e.g., upload/download rate (mbps), ping), etc.; and product data (e.g., in conjunction with registration) such as warranty, age, recalls, tech bulletins, replacement parts, specs, tech support, tutorials (e.g., instructional videos), specials (e.g., coupons, promotions, etc.), local support (e.g., authorized service center), firmware updates, new product releases, pool industry news, safety alerts, safety suggestions, etc.

It is contemplated that all of the systems disclosed herein could interface with one or more dedicated/proprietary or 3rd party voice interaction devices (e.g., Apple's Siri, Amazon Echo, etc.). Pool control logic 70 could interface with the voice interaction devices directly (e.g., Bluetooth), locally (e.g., through network router or mesh network), or via the cloud. The user commands, inputs, actions, etc., described herein, could be provided to pool control logic 70 via the voice interaction device and notifications, messages, alerts, etc., described herein, could be transmitted to the user via the voice interaction device (e.g., verbal notification, messages, alerts, etc.). For example, to activate the lighting system 14h, a user could simply say, "Alexa, turn on the pool lights."

It is contemplated that that the various devices in the embodiments described herein could also communicate by way of power line carrier (e.g., power-line digital subscriber line (PDSL), mains communication, power-line telecommu-

nications, or power-line networking (PLN)) to allow the various interconnected components to communicate with one another via electrical wiring.

It is also contemplated that site data could be replaced with cloud data, or data at the site could be combined with data in the cloud, and the system could intelligently combine disparate data from different cloud servers.

Also contemplated is capturing specific equipment data (e.g., bar codes) by a smartphone camera at the site at the time of installation and connecting to an application. This can, at the same time, capture GPS coordinates for the address and date of installation for warranty registration, and automatically load the location of the pool into the pool control logic with cloud support for sunrise/sunset, real time and forecasted weather data. Similarly, by standing by the pool and taking photo of the pool, one can record North-South-East-West (e.g., phone compass) and load similar data into the pool control logic with cloud support for using wind direction as well. If photos are taken multiple times in the day, compass and date information could be used to extrapolate the pool's sun exposure for pool heating and other calculations.

In addition to receiving operational data from locally installed pool/spa equipment, remote data (e.g., an off-site or cloud server) and web data, described hereinabove, it is also contemplated that pool control logic 70 could receive operational data from one or more pieces of pool equipment having enhanced sensing capabilities. For example, the system 10 could include lighting system 14h (see, e.g., FIG. 1) having a smart light 5014h. More specifically, as shown in FIG. 36, smart light 5014h could include temperature sensor 5000 (e.g., for temperature sensing of air, water, etc.), microphone 5001, chemistry sensor 5002 (e.g., for sensing salinity, pH, ORP, TDS, chlorine, etc.), light output sensor 5004 (e.g. for sensing lumen, lux, CCT, CIE, etc.), occupancy sensor 5006 (e.g., IR, sound/audio detection, radar, etc.), water clarity sensor 5008, water level sensor, 5010, water pressure sensor 5012, flow sensor 5014, turbidity sensor 5016, user input module 5018 (e.g., touch panel, physical buttons, etc.) and network communication and local control subsystem 12h (see, e.g., FIGS. 1-2). The smart light 5014h could further include the ability to measure for stray current. The user input module could include touch-based inputs (e.g., capacitive, inductive, fear field RF, etc.). The smart light 5014h could further include a display 5019 provided as a separate component or integrally provided with user input module 5018. The smart light 5014h could accordingly be used to display an error message for a fault condition or warning message regarding pool chemistry, or could be used to display any other kind of visual media. Although previously discussed, it is noted that the network communication and local control subsystem 12h could communicate with pool control logic 70, located in one or more of the pool/spa components discussed herein, using any of the communication protocols discussed herein, including but not limited to, power line carrier, ethernet, RF, Bluetooth, Wi-Fi, and ZigBee. Smart light 5014h could also record hours of operation, light output, voltage, and current as well as corresponding operating and environmental conditions during use. It is further noted that temperature sensor 5000, microphone 5001, chemistry sensor 5002, light output sensor 5004, occupancy sensor 5006, water clarity sensor 5008, water level sensor, 5010, water pressure sensor 5012, flow sensor 5014, turbidity sensor 5016, user input module 5018, and network communication and local control subsystem 12h could be incorporated into the a lighting device, or could be provided as an additional attachment to the lighting

device body. Further, as discussed above, pool control logic 70 could reside or be run within the smart light 5014h, in another piece of pool/spa equipment, remotely, or distributed amongst one or more of these locations.

FIG. 37 is a flowchart illustrating processing steps of the pool control logic 70 for controlling a heater based on operational data received from the smart lights 5014h described above. More specifically, multiple smart lights provided in and around the pool/spa could act as a mesh array of temperature sensor inputs for determining the average temperature of the pool/spa and controlling the heater accordingly. In step 5020, the pool control logic 70 receives operational data, e.g., temperature, from a first smart light. In step 5022, the pool control logic 70 receives operational data, e.g., temperature, from a second smart light. In step 5024, the pool control logic 70 receives operational data, e.g., temperature, from the nth smart light. That is, the pool control logic 70 receives operational data for all smart lights in addition to the first and second smart lights discussed in connection with steps 5022 and 5024. In step 5026, the pool control logic 70 determines the average temperature off the pool/spa based on the operational data received from the smart lights. In step 5028, the pool control logic 70 retrieves temperature setpoint data from memory. In step 5030, the pool control logic 70 determines if the average temperature (determined in step 5026) is below the temperature setpoint. If a positive determination is made, e.g., the average temperature is below the temperature setpoint, then the process proceeds to step 5032, where the pool control logic 70 transmits an instruction to activate a heater and the process reverts to step 5020. If a negative determination is made, e.g., the average temperature is greater than the temperature setpoint, then the process proceeds to step 5034, where the pool control logic 70 transmits an instruction to deactivate a heater and the process reverts to step 5020. It is also contemplated that instead of determining the average temperature of the pool/spa, pool control logic 70 could determine the warmest or coolest area of the pool/spa and control the heater accordingly (e.g., warming the coolest area of the pool to a temperature setpoint, or cease warming of the pool when the warmest area of the pool reaches a temperature setpoint).

FIG. 38 is a flowchart illustrating processing steps of the pool control logic 70 for controlling a heater by determining a predicted temperature setpoint based on previous user specified temperature setpoints. In step 5036, the pool control logic 70 receives an instruction to activate a heater. In step 5038, the pool control logic 70 retrieves a first previous user temperature setpoint from memory. In step 5040, the pool control logic 70 retrieves a second previous user temperature setpoint from memory. In step 5042, the pool control logic 70 retrieves the nth previous user temperature setpoint from memory. That is, in step 5042 the pool control logic 70 retrieves all other previous user temperature setpoints from memory that are desired. For example, the system can be set-up so that the three (3), four (4), five (5), ten (10), or twenty (20), etc., most recent previous user temperature setpoints are utilized in this process. In step 5044, the pool control logic 70 determines a predicted user temperature setpoint based on the previous user temperature setpoints retrieved from memory in steps 5038, 5040, and 5042. This determination can be based on, for example, the mean, median, mode, etc., of the previous user temperature setpoints retrieved from memory. In step 5046, the pool control logic 70 transmits an instruction to a heater to operate, e.g., until the predicted setpoint determined in step 5044 is reached.

FIG. 39 is a flowchart illustrating processing steps of the pool control logic 70 for controlling the pool/spa water chemistry by operating sanitization equipment based on operational data received from water chemistry sensors in one or more smart lights 5014h. In step 5048, the pool control logic 70 receives water chemistry setpoints, e.g., relating to salinity, pH, ORP, TDS, chlorine levels, etc., from memory. In step 5050, the pool control logic 70 receives water chemistry operational data, e.g., salinity, pH, ORP, TDS, chlorine levels, etc., from smart light sensors. In step 5052, the pool control logic 70 determines if the water chemistry operational data (determined in step 5050) is within specific levels, e.g., which are based on the setpoints retrieved in step 5048. If a positive determination is made, then the process returns to step 5050, where the pool control logic 70 continues to receive water chemistry operational data from the smart light sensors. If a negative determination is made, then the process proceeds to step 5054, where the pool control logic 70 determines an action to correct the water chemistry, e.g., increase chlorination rate by X %. In step 5056, the pool control logic transmits an instruction to the chemistry automation system to take corrective action in accordance with the action determined in step 5054, e.g., increase the chlorination rate by X %, and the process reverts to step 5050.

In accordance with additional embodiments of the present disclosure, using similar processing steps as described in connection with FIG. 39, pool control logic 70 could also use operational data received from the smart light 5014h sensors to control a robotic cleaner based on operational data received from water clarity sensor 5008 or occupancy sensor 5006, activate the pump and/or filter based on operational data received from water clarity sensor 5009, activate water features, actuate valves, or activate the pump based on operational data received from flow sensor 5014, trigger a house alarm (if armed) based on operational data received from occupancy sensor 5006, activate the lighting system based on operational data received from occupancy sensor 5006 (e.g., turn on the lights, increase the intensity of the lights, switch light color based on an unplanned occupancy or turn lights on based on time of day, automatically turn off after a period of time if no occupant detected, "follow the swimmer" by only activating the light when an occupant is detected proximate thereto), adjust the water temperature based on operational data received from occupancy sensor 5006, adjust light output based on operational data received from ambient light sensor 5004, and adjust CCT based on operational data received from ambient air temperature sensor 5000.

FIG. 40 is a flowchart illustrating processing steps of the pool control logic 70 for predicatively displaying the most popular light show based on previously selected light shows. In step 5058, the pool control logic 70 receives an instruction to activate a light show. In step 5060, the pool control logic 70 retrieves a first previously selected light show from memory. In step 5062, the pool control logic 70 retrieves a second previously selected light show from memory. In step 5064, the pool control logic 70 retrieves the nth previously selected light show from memory. That is, in step 5064 the pool control logic 70 retrieves all other previously selected light shows from memory. For example, the system can be set-up so that the three (3), four (4), five (5), ten (10), or twenty (20), etc., most recent previously selected light shows are utilized in this process. In step 5066, the pool control logic 70 determines the most common light show based on the previously selected light shows retrieved from memory in steps 5060, 5062, and 5064. In step 5068, the

pool control logic 70 transmits an instruction to a lighting system to display the most common light show as determined in step 5066. It is further contemplated that rather than receiving all of the previously selected light shows from the memory, pool control logic 70 could instead retrieve a set number of most recent light shows (e.g., most recent 10 light shows), or pool control logic 70 could retrieve light shows that were selected within a specified period of time (e.g., light shows selected within the last year). In addition to displaying light shows, it is also contemplated that the smart light 5014h could communicate with music and speaker systems to provide a coordinated music and lighting show (e.g., lights change color and intensity, pulse, move, etc. based on a particular musical selection).

It is further contemplated smart light 5014h could provide for user interaction with the pool/spa control system 10 and pool control logic 70. As discussed above, the smart light could include a user input module 5018 having touch-based inputs and a display 5019. For example, the user could use the touch-based controls to adjust the water temperature at the smart light 5014h, or to modify or change a light show or light color. Similarly, the touch-based controls and display 5019 could be used to virtually configure custom light shows. Additionally, the user could interact with the pool/spa control system 10 using the microphone 5001 (e.g., using voice commands either above or below water).

In accordance with embodiments of the disclosure, the pool control logic 70 could receive operational data from a plurality of smart lights 5014h disposed about a pool/spa. More specifically, pool control logic 70 could receive operational data from occupancy sensors 5006 in the plurality of smart lights 5014h. Using the plurality of lights 5014h and sensors 5006 as nodes in a mesh array, pool control logic 70 could determine the location of the occupant in the pool/spa.

In accordance with embodiments of the present disclosure, the smart light 5014h could further perform an optical comparison with a camera to identify when the pool is dirty or contains debris or other particulate.

In accordance with embodiments of the present disclosure, a plurality of smart lights 5014h could be used as an array to provide directional input for a robotic cleaner. For example, as discussed above, pool control logic 70 could determine areas of the pool having high concentrations of dirt or debris. Further, a plurality of smart lights 5014h could be disposed about a pool/spa. Pool control logic 70 could then determine the smart light 5014h in closest proximity to the debris and send an instruction to activate the smart light 5014h. The pool cleaner would then detect the light from the smart light 5014, proceed towards the same, and accordingly proceed towards the area having a high concentration of debris. Alternatively, smart lights 5014h could independently illuminate if they determine they are proximate to an area of high debris. The pool cleaner could then proceed to each area of high debris, in turn.

In accordance with embodiments of the present disclosure, smart lights 5014h could be used to provide light catalyzed chemistry for sanitization by adjusting their light output wavelength. For example, pool control logic 70 could receive an instruction to sanitize the pool/spa. Pool control logic 70 could then retrieve light wavelength sanitization setpoint data from the memory (e.g., sanitization wavelength is 254 nm). Pool control logic 70 could then transmit an instruction to the lighting system 14h and/or smart light 5014h to operate at the sanitization setpoint (e.g., 254 nm).

Having thus described the disclosure in detail, it is to be understood that the foregoing description is not intended to limit the spirit or scope thereof.

The invention claimed is:

1. A method for remotely monitoring and controlling a pump for a pool or a spa, comprising the steps of:
 - assigning by a processor of the pump an Internet Protocol (IP) address to the pump;
 - establishing a network connection between the processor of the pump and a remote device;
 - providing for remote monitoring of operational parameters associated with the pump from the remote device over the network connection;
 - providing for remote control of the pump from the remote device over the network connection;
 - retrieving by the processor factory specified life expectancy data from a memory;
 - determining by the processor a life expectancy alert threshold based on the factory specified life expectancy data;
 - receiving at the processor operational data on runtime of the pump;
 - determining by the processor if the runtime of the pump exceeds the life expectancy alert threshold; and
 - controlling, by the processor, the pump based on the determination by the processor of whether the runtime of the pump exceeds the life expectancy alert threshold.
2. The method of claim 1, further comprising transmitting an alert to the remote device if the runtime of the pump exceeds the alert threshold.
3. The method of claim 1, wherein the processor is configured to control the pump and the remote device.
4. The method of claim 1, further comprising establishing a second network connection between the processor of the pump and a second remote device.
5. The method of claim 4, further comprising providing for control of the second remote device from the pump over the second network connection based on data received by the processor.
6. The method of claim 1, wherein the pump includes a housing enclosing (i) the processor and (ii) a network communication subsystem for providing direct communication between the processor and the Internet.
7. The method of claim 6, wherein the network connection between the processor and the remote device is established over the Internet.
8. The method of claim 1, further comprising receiving at the processor web data from the Internet, the web data being specific to the physical location of the pump.
9. The method of claim 8, further comprising controlling operation of the pump in response to the web data.
10. The method of claim 1, wherein the remote device comprises one of a server, a cloud platform, a personal computer, a smartphone, a lighting system, a pool cleaning system, a pool or spa control system, a valve actuator, a water feature, a sanitization system, a heating system, and a cooling system.
11. A method for remotely monitoring and controlling a pump for a pool or a spa, comprising the steps of:
 - assigning by a processor of the pump an Internet Protocol (IP) address to the pump;
 - establishing a network connection between the processor of the pump and a remote device;
 - providing for remote monitoring of operational parameters associated with the pump from the remote device over the network connection;

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providing for remote control of the pump from the remote device over the network connection;
 retrieving by the processor factory specified operating temperature data from the memory;
 determining by the processor a temperature alert threshold based on the factory specified operating temperature data;
 receiving at the processor operational data on operating temperature of the pump;
 determining by the processor if the operating temperature of the pump exceeds the temperature alert threshold; and
 controlling, by the processor, the pump based on the determination by the processor of whether the temperature of the pump exceeds the temperature alert threshold.

12. The method of claim 11, further comprising transmitting an alert to the remote device if the temperature of the pump exceeds the temperature alert threshold.

13. The method of claim 11, wherein the processor is configured to control the pump and the remote device.

14. The method of claim 11, further comprising establishing a second network connection between the processor of the pump and a second remote device.

15. The method of claim 14, further comprising providing for control of the second remote device from the pump over the second network connection based on data received by the processor.

16. The method of claim 11, wherein the pump includes a housing enclosing (i) the processor and (ii) a network communication subsystem for providing direct communication between the processor and the Internet.

17. The method of claim 16, wherein the network connection between the processor and the remote device is established over the Internet.

18. The method of claim 11, further comprising receiving at the processor web data from the Internet, the web data being specific to the physical location of the pump.

19. The method of claim 18, further comprising controlling operation of the pump in response to the web data.

20. The method of claim 11, wherein the remote device comprises one of a server, a cloud platform, a personal computer, a smartphone, a lighting system, a pool cleaning system, a pool or spa control system, a valve actuator, a water feature, a sanitization system, a heating system, and a cooling system.

21. A method for remotely monitoring and controlling a pump for a pool or a spa, comprising the steps of:

assigning by a processor of the pump an Internet Protocol (IP) address to the pump;
 establishing a network connection between the processor of the pump and a remote device;
 providing for remote monitoring of operational parameters associated with the pump from the remote device over the network connection;
 providing for remote control of the pump from the remote device over the network connection;
 storing temperature rise data in histogram counters and determining by the processor if the temperature of the pump is rising at a rate that exceeds a predetermined threshold value; and
 controlling, by the processor, the pump based on the determination.

22. The method of claim 21, further comprising transmitting an alert to the remote device if the temperature of the pump is rising at a rate that exceeds the predetermined threshold value.

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23. The method of claim 21, wherein the processor is configured to control the pump and the remote device.

24. The method of claim 21, further comprising establishing a second network connection between the processor of the pump and a second remote device.

25. The method of claim 24, further comprising providing for control of the second remote device from the pump over the second network connection based on data received by the processor.

26. The method of claim 21, wherein the pump includes a housing enclosing (i) the processor and (ii) a network communication subsystem for providing direct communication between the processor and the Internet.

27. The method of claim 26, wherein the network connection between the processor and the remote device is established over the Internet.

28. The method of claim 21, further comprising receiving at the processor web data from the Internet, the web data being specific to the physical location of the pump.

29. The method of claim 28, further comprising controlling operation of the pump in response to the web data.

30. The method of claim 21, wherein the remote device comprises one of a server, a cloud platform, a personal computer, a smartphone, a lighting system, a pool cleaning system, a pool or spa control system, a valve actuator, a water feature, a sanitization system, a heating system, and a cooling system.

31. A method for remotely monitoring and controlling a pump for a pool or a spa, comprising the steps of:

assigning by a processor of the pump an Internet Protocol (IP) address to the pump;
 establishing a network connection between the processor of the pump and a remote device;
 providing for remote monitoring of operational parameters associated with the pump from the remote device over the network connection;
 providing for remote control of the pump from the remote device over the network connection;
 retrieving by the processor factory specified power consumption data from a memory;
 determining by the processor a power consumption alert threshold based on the factory specified power consumption data;
 receiving at the processor operational data on power consumption of the pump;
 determining by the processor if the power consumption of the pump exceeds the power consumption alert threshold; and
 controlling, by the processor, the pump based on the determination by the processor of whether the power consumption of the pump exceeds the power consumption alert threshold.

32. The method of claim 31, further comprising transmitting an alert to the remote device if the power consumption of the pump exceeds the power consumption alert threshold.

33. The method of claim 31, wherein the processor is configured to control the pump and the remote device.

34. The method of claim 31, further comprising establishing a second network connection between the processor of the pump and a second remote device.

35. The method of claim 34, further comprising providing for control of the second remote device from the pump over the second network connection based on data received by the processor.

36. The method of claim 31, wherein the pump includes a housing enclosing (i) the processor and (ii) a network

communication subsystem for providing direct communication between the processor and the Internet.

37. The method of claim 36, wherein the network connection between the processor and the remote device is established over the Internet.

38. The method of claim 31, further comprising receiving at the processor web data from the Internet, the web data being specific to the physical location of the pump.

39. The method of claim 38, further comprising controlling operation of the pump in response to the web data.

40. The method of claim 31, wherein the remote device comprises one of a server, a cloud platform, a personal computer, a smartphone, a lighting system, a pool cleaning system, a pool or spa control system, a valve actuator, a water feature, a sanitization system, a heating system, and a cooling system.

41. A method for remotely monitoring and controlling a pump for a pool or a spa, comprising the steps of:

assigning by a processor of the pump an Internet Protocol (IP) address to the pump;

establishing a network connection between the processor of the pump and a remote device;

providing for remote monitoring of operational parameters associated with the pump from the remote device over the network connection;

providing for remote control of the pump from the remote device over the network connection;

retrieving by the processor data on factory specified operating parameters for pump water level from a memory, receiving at the processor operational water level data from the remote device, and determining by the processor if the operational water level data is within the factory specified operating parameters;

transmitting a message to a user if the operational water level data is within the factory specified operating parameters;

determining by the processor if water level has not been within the factory specified operating parameters for a threshold amount of time; and

controlling the pump to periodically increase speed if the water level has been within the factory specified operating parameters for a threshold amount of time.

42. The method of claim 41, further comprising indicating an air leak to the user if the water level has not been within the factory specified operating parameters for a threshold amount of time.

43. The method of claim 41, wherein the processor is configured to control the pump and the remote device.

44. The method of claim 41, further comprising establishing a second network connection between the processor of the pump and a second remote device.

45. The method of claim 44, further comprising providing for control of the second remote device from the pump over the second network connection based on data received by the processor.

46. The method of claim 41, wherein the pump includes a housing enclosing (i) the processor and (ii) a network communication subsystem for providing direct communication between the processor and the Internet.

47. The method of claim 46, wherein the network connection between the processor and the remote device is established over the Internet.

48. The method of claim 41, further comprising receiving at the processor web data from the Internet, the web data being specific to the physical location of the pump.

49. The method of claim 48, further comprising controlling operation of the pump in response to the web data.

50. The method of claim 41, wherein the remote device comprises one of a server, a cloud platform, a personal computer, a smartphone, a lighting system, a pool cleaning system, a pool or spa control system, a valve actuator, a water feature, a sanitization system, a heating system, and a cooling system.

51. A method for remotely monitoring and controlling a pump for a pool or a spa, comprising the steps of:

assigning by a processor of the pump an Internet Protocol (IP) address to the pump;

establishing a network connection between the processor of the pump and a remote device;

providing for remote monitoring of operational parameters associated with the pump from the remote device over the network connection;

providing for remote control of the pump from the remote device over the network connection;

retrieving by the processor factory specified life expectancy data for a shaft seal from a memory;

determining by the processor a life expectancy alert threshold based on the factory specified life expectancy data;

receiving at the processor operational data on runtime of the shaft seal

determining by the processor if the runtime of the shaft seal exceeds the life expectancy alert threshold; and controlling, by the processor, the pump based on the determination by the processor of whether the runtime of the shaft seal exceeds the life expectancy alert threshold.

52. The method of claim 51, wherein the processor is configured to control the pump and the remote device.

53. The method of claim 51, further comprising establishing a second network connection between the processor of the pump and a second remote device.

54. The method of claim 53, further comprising providing for control of the second remote device from the pump over the second network connection based on data received by the processor.

55. The method of claim 51, wherein the pump includes a housing enclosing (i) the processor and (ii) a network communication subsystem for providing direct communication between the processor and the Internet.

56. The method of claim 55, wherein the network connection between the processor and the remote device is established over the Internet.

57. The method of claim 51, further comprising receiving at the processor web data from the Internet, the web data being specific to the physical location of the pump.

58. The method of claim 57, further comprising controlling operation of the pump in response to the web data.

59. The method of claim 51, wherein the remote device comprises one of a server, a cloud platform, a personal computer, a smartphone, a lighting system, a pool cleaning system, a pool or spa control system, a valve actuator, a water feature, a sanitization system, a heating system, and a cooling system.

60. A method for remotely monitoring and controlling a pump for a pool or a spa, comprising the steps of:

assigning by a processor of the pump an Internet Protocol (IP) address to the pump;

establishing a network connection between the processor of the pump and a remote device;

providing for remote monitoring of operational parameters associated with the pump from the remote device over the network connection;

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providing for remote control of the pump from the remote device over the network connection; retrieving by the processor factory specified parameters for filter debris level from a memory; receiving at the processor operational data from a sensor in the remote device; determining by the processor if the remote device needs to be serviced; and controlling operation of the pump to maintain a flow rate; wherein the remote device is a filter.

61. The method of claim 60, further comprising retrieving by the processor factory specified parameters for pump energy consumption from a memory, receiving at the processor operational data on pump energy consumption, and determining by the processor if the pump energy consumption exceeds the factory specified parameters.

62. The method of claim 60, wherein the processor is configured to control the pump and the remote device.

63. The method of claim 60, further comprising establishing a second network connection between the processor of the pump and a second remote device.

64. The method of claim 63, further comprising providing for control of the second remote device from the pump over the second network connection based on data received by the processor.

65. The method of claim 60, wherein the pump includes a housing enclosing (i) the processor and (ii) a network communication subsystem for providing direct communication between the processor and the Internet.

66. The method of claim 65, wherein the network connection between the processor and the remote device is established over the Internet.

67. The method of claim 60, further comprising receiving at the processor web data from the Internet, the web data being specific to the physical location of the pump.

68. The method of claim 67, further comprising controlling operation of the pump in response to the web data.

69. The method of claim 60, wherein the remote device comprises one of a server, a cloud platform, a personal computer, a smartphone, a lighting system, a pool cleaning system, a pool or spa control system, a valve actuator, a water feature, a sanitization system, a heating system, and a cooling system.

70. A method for remotely monitoring and controlling a pump for a pool or a spa, comprising the steps of: assigning by a processor of the pump an Internet Protocol (IP) address to the pump; establishing a network connection between the processor of the pump and a remote device;

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providing for remote monitoring of operational parameters associated with the pump from the remote device over the network connection; providing for remote control of the pump from the remote device over the network connection; receiving at the processor a clean filter indication from the remote device; retrieving by the processor test filter system setpoints from a memory; controlling the pump to operate at the test filter system setpoints; receiving at the processor operational data from the remote device; saving the operational data from the remote device to memory; controlling the pump to return to a normal operation; and activating a timer for a predetermined period of time.

71. The method of claim 70, further comprising controlling the pump to operate at the test filter system setpoints upon expiration of the timer, receiving at the processor current operational from the remote device, and determining by the processor a variance between the saved operational data and the current operational data.

72. The method of claim 70, wherein the processor is configured to control the pump and the remote device.

73. The method of claim 70, further comprising establishing a second network connection between the processor of the pump and a second remote device.

74. The method of claim 34, further comprising providing for control of the second remote device from the pump over the second network connection based on data received by the processor.

75. The method of claim 70, wherein the pump includes a housing enclosing (i) the processor and (ii) a network communication subsystem for providing direct communication between the processor and the Internet.

76. The method of claim 36, wherein the network connection between the processor and the remote device is established over the Internet.

77. The method of claim 70, further comprising receiving at the processor web data from the Internet, the web data being specific to the physical location of the pump.

78. The method of claim 38, further comprising controlling operation of the pump in response to the web data.

79. The method of claim 70, wherein the remote device comprises one of a server, a cloud platform, a personal computer, a smartphone, a lighting system, a pool cleaning system, a pool or spa control system, a valve actuator, a water feature, a sanitization system, a heating system, and a cooling system.

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