



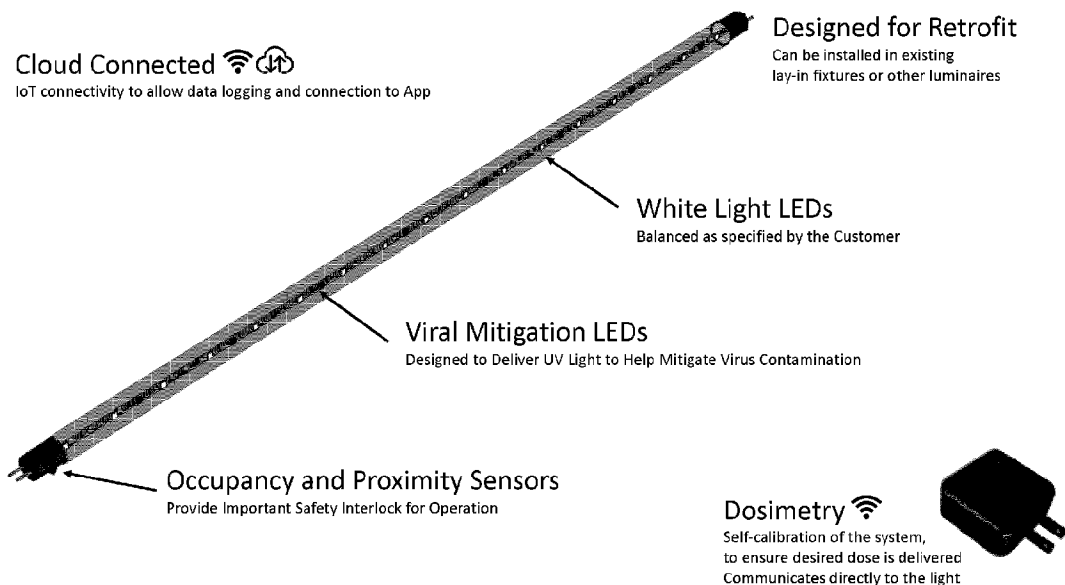
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(54) Title: STERILIZING LIGHT SYSTEM



(57) **Abrégé/Abstract:**

A sanitizing light system is provided and includes an ultraviolet light source configurable to illuminate a target region, a sensor module configured to detect an occupancy in a target region, and a controller coupled to the sensor module to determine when the target region is in an unoccupied state at least partially based on the detection of the occupancy of the target region, the controller being configured to control the ultraviolet light source at least partially based on the determined unoccupied state of the target region.

Abstract

A sanitizing light system is provided and includes an ultraviolet light source configurable to illuminate a target region, a sensor module configured to detect an occupancy in a target region, and a controller coupled to the sensor module to determine when the target region is in an unoccupied state at least partially based on the detection of the occupancy of the target region, the controller being configured to control the ultraviolet light source at least partially based on the determined unoccupied state of the target region.

Sterilizing Light System

The Challenge

COVID-19, as with many viruses and communicable illnesses, transmits primarily through person to person exchange, both by proximity, and from contaminated objects. With people in close proximity to each other droplets from sneezing and coughing can carry the virus from person to person, and commonly touched surfaces if contaminated with virus-containing droplets can similarly cause transmission. In particular, long after the issue of airborne transmission has passed, contaminated surfaces remain a significant mode of transmission. Touching a contaminated doorknob, for example, carries the risk for anyone touching it of transferring the virus to their hands, which could lead ultimately to contracting the illness if they touch their nose, mouth, or face. In order to reduce transmission, steps must be taken to reduce the amount of airborne and surface live virus that is available for transmission. Frequent hand washing and surface wipe-downs help, but they depend on an individual's vigilance to be effective.

Sanitizing UV lighting can provide a significant and cost-effective enhancement of all sanitization protocols, and when included with appropriate controls in a monitored system, they can be safe, autonomous and not dependent on the time or vigilance of healthcare, cleaning and maintenance workers to achieve their efficacy. Safe Antivirus Technologies Inc. (SATI) has been working to address this challenge and develop a device to achieve significantly improved levels of sanitation through the use of UV light.

Overview

Exposure to ultraviolet wavelengths is a well-described sanitization strategy in the scientific literature and can achieve rapid inactivation of viruses upon direct illumination from UV light. In addition to new, stand-alone applications, an illuminator that can supply appropriate UV light in existing lighting fixtures and luminaires has, until now, been non-existent. SATI's solution enables commercial and institutional buildings to significantly reduce the accumulation, and

thus transmission, of viruses from common surfaces without the need for significant, time-consuming retrofit to existing building infrastructure.

The anti-virus lighting solution developed by SATI includes a framework for rapid deployment of a robust UV light, with appropriate real-time feedback control, integrated with required room illumination, to be installed in offices, boardrooms, public washrooms, and other high-traffic areas that would help minimize the spread of viral diseases by reducing the active virus on common surfaces available to spread transmission. This lighting system will also supply the standard “white-light” room lighting, and will monitor occupancy as both a safety interlock, and to ensure that spaces are appropriately exposed to UV illumination once vacated. Moreover, the system includes wireless connectivity to dosimetry and data-logging, for quality assurance, and subsequent data-analytics allowing tracking of effectiveness and additional safety protocols. The system will provide for enhanced sanitation of viruses in work and other environments, increased piece of mind for employees, greatly improved occupational health and safety for workers beyond the current COVID-19 crisis.

Device Description

The antivirus lighting system (AVLS) provides a means to effect automatic room sanitation to reduce potential pathogens in illuminated airborne spaces and illuminated surfaces on a regular, repeatable schedule, enhancing the control of infections, and improving public health. The system has been designed for new installation in a variety of luminaire packages, or perhaps more crucially, for retrofit within existing lighting fixtures, most particularly, standard 2ft x 4ft lay-in tubs that are prevalent in the majority of office and public spaces.

In one embodiment, a combined room illuminator and sanitation device (referred to alternatively herein as an “illuminator module”) replaces existing T5-sized fluorescent or LED lighting tubes. Room illumination and energy efficiency are equivalent to the high-efficiency LED lighting, providing the same long-life, and zero maintenance operation. The AVLS system adds UV LEDs to effect wide-scale sanitation of room interiors, on a regular, repeatable, and auditable schedule. In some configurations, occupancy sensors ensure that a sanitation cycle only begins once the room has been vacated for a period of time, and visible and audible signals

generated prior to, during, and/or after sanitation ensure safety in operation by alerting nearby people of the system function.

In some configurations, the illuminator module is wireless technology enabled, allowing connectivity as an IoT device (internet of things), or through dedicated wireless communication using Wi-Fi, Bluetooth, Zigbee, or another suitable wireless protocol. This connectivity provides a means for the adjustment, in real-time if desired, of the sanitation illumination wavelength (through, for example, the entire range of UVC at 200nm through to UVA at up to 400nm, or other desired wavelength), and the intensity of illumination. The control loop may be through a calibrated external dosimeter that will measure the delivered dose of UV at a desired surface or height within a room, or through a real-time feedback control using a connected dosimeter to communicate in real-time with the illuminator module through the sanitation cycle, or the illuminator module may be calibrated off-line and operated in an open-loop mode.

Operation

In one present embodiment, the operation of a sanitation cycle is as follows:

- 1) A pre-set time of day “sanitation window” in which the sanitation cycle can be undertaken is selected and programmed into the illuminator module at the time of installation, or modified later by an authorized user.
- 2) In normal daily operation, the system operates in “sanitation standby mode” – the failsafe condition where the UV LEDs are disconnected and cannot operate – as an added safety and cost saving feature, both the room white light LEDs and the UV sanitation LEDs share a single power supply – so long as the room lights are on, the UV LEDs cannot be activated. This provides an additional layer of safety, as the room light is noticeably off as the sanitation cycle is being completed. Moreover, the sharing of a single power supply cuts manufacturing costs and reduces the part count and failure modes.
- 3) Once the room has been unoccupied for a period of time, the system enters the “sanitation ready” mode, indicating that a sanitation cycle will occur at the next “sanitation window”. Activation of this mode is accompanied by a light flash, and audible signal to provide

appropriate safety warnings. The “sanitation ready” mode will immediately reset to “stand-by mode” should the room at any time become occupied prior to the sanitation window.

- 4) If uninterrupted in the “sanitation ready” mode, the unit will wait for the next sanitation window, and provided none of the safety interlocks have been tripped (proximity and motion sensors, door monitors, etc.), will switch from white light LEDs to the UV sanitation LEDs. There will be a pre-cycle audible tone, and a series of light flashes to indicate the imminent sanitation cycle. Assuming there are no proximity or occupancy sensor trips that immediately reset the system into standby mode, the sanitation cycle begins. There are two modes of operation of the sanitation cycle, closed-loop feedback, and calibrated open loop.
 - a) Closed loop feedback provides a means for a remote dosimeter to record the real-time dose of UV that is delivered to the dose sensor and communicate back to the illuminator to adjust the light delivered to meet the required sanitation specification. This system can self-adjust for desired dose, compensating for any changes in the UV illumination system’s efficiency (dust on the illuminator module for example) and provides the greatest assurance of sanitation, recording the time, duration, and dose for each sanitation cycle. This data can be collected and stored locally, by a control module with which the illumination module is in communication, or broadcast directly to the cloud for subsequent data analytics. The data can be used by organizations and property managers to correlate to sick days for example against baseline.
 - b) The calibrated open loop operation uses the same or a similar dosimeter to record delivered UV sanitation during the illuminator module installation and set-up, communicating received sensor information back to the illuminator module for subsequent open loop operation. The illuminator module then enters a “repeat mode”, delivering the timed intensity dose determined during the set-up on each sanitation event. There is no real-time monitoring, and the system requires periodic re-calibration to ensure it is operating within desired parameters.

- 5) Continuous monitoring of safety interlocks ensure that the sanitation cycle is immediately stopped should the room become occupied during a sanitation cycle, and the failed sanitation event logged for future reference.
- 6) The completed sanitation cycle is logged, and the system re-enters “standby mode”, with an audible “all-clear” tone, and light flash. Occupancy data may be logged or not, as desired by the user.

Figure 1 shows a T5 replacement tube embodiment of the illuminator module, showing key elements, and wireless calibration module/dosimeter for real-time monitoring and offline calibration of the UV sanitation device.

Features

Spectrum

The illumination spectrum of both the room “white” light and the UV sanitation light may be selected to meet requirements of a given application. The white light may be selected to meet the illumination needs of the user, ranging from approximately 2,500K to 6,000K (warm white to cool/blue white).

Figure 2 shows a standard light bulb embodiment of the illuminator module. Connects to the same calibration and monitoring dosimeter as the T5 unit.

The spectrum of the UV sanitation devices can be selected, and may in some embodiments are adjustable in real-time, from approximately 200nm in the UVC range to over 400nm in the UVA range, although in some embodiments shorter or longer wavelengths may be preferred. The selection is based upon the particular sanitation requirements, the required duration of sanitation, other operating conditions (including room configuration), and safety.

Figure 3 shows a wireless dosimeter with key features.

Wavelength used for sanitation may be altered throughout a sanitation cycle, to improve sanitation generally, to improve selective sanitation and elimination of specific pathogens, to improve the time required for a sanitation operation, or for other reasons. Wavelength may be skewed during an exposure cycle, combined, added, subtracted, or applied in other manners to affect a sanitation cycle. Such a wavelength profile, encompassing the wavelengths used, the skewing, if any, the additive or subtractive nature of wavelengths use, and other alterations to the sanitation wavelength are being claimed as novel.

Wavelength profiles may be linear skewing, exponential skewing, logarithmic skewing, or more complex combinations of these and other profiles. Wavelength profiles may also include periods with multiple wavelengths, varying in intensity with intensity profiles (see section below).

Wavelength profiles may be determined empirically using the collected data from the system's operation, through literature searches, through a combination of both empirical and theoretical, or through other means. Profiles may be proprietary, and where greater efficacy is determined, may be patentable separately from the device or the control system. Wavelength profiles and may or may not operation in concert with either of intensity or duration profiles.

Specified wavelength profiles can be transmitted to the illuminator module, via initiation by either the illuminator module or a server, and a means to track the profile used in each sanitation cycle can be provided, such as local storage means within the illuminator module or a control module.

Intensity

Intensity may be pre-set or may be adjustable to allow for consideration of sanitation requirements, operational limitations or needs, exposure times, and safety. There may be communication between the illuminator module and a wired or wireless remote sensor to provide calibration and/or feedback information for the correct illumination operation for the desired sanitation protocol. Adjustments may be made between sanitation cycles in an open loop mode to account for degradation of UV light which may be due to dust/dirt on illumination lenses or reflective surfaces, reduction in efficiency of the LED emitter devices over time, or for

other reasons. Intensity may also be adjusted in real-time through feedback from the wired or wireless dosimeter, which could include PID control, bang-bang control, or other feedback algorithms. Intensity may be selected to ramp up or down over a sanitation cycle, or to adopt other more complex profiles either during, or between cycles, for greater efficacy, or other reasons. A profile may be selected from a database of illumination profiles, to effect sanitation preferentially for particular pathogens, to achieve a higher degree of sanitation, or for other reasons.

Intensity profiles may be linear increasing or decreasing, exponential increasing or decreasing, logarithmic increasing or decreasing, or more complex combinations of these and other profiles. Illumination profiles may also include periods with the UV illuminators off, or periods with one or more bright flashes of UV. Intensity profiles may or may not operate in concert with either of wavelength or duration profiles. In one embodiment, the UV illumination emitted by the illuminator module may be ramped slowly from the start of the cycle for increased safety.

Profiles may be determined empirically using the collected data from the system's operation, through literature searches, through a combination of both empirical and theoretical, or through other means. Profiles may be proprietary, and where greater efficacy is determined, may be patentable separately from the device or the control system.

Specified intensity profiles can be transmitted to the illuminator module, via initiation by either the illuminator module or a server, and a means to track the profile used in each sanitation cycle can be provided, such as local storage means within the illuminator module or a control module.

Duration

The duration of the sanitation cycle may be pre-set or may be adjustable to allow for consideration of sanitation requirements, operational limitations or needs, exposure times, and safety. There may be communication between a wired or wireless remote sensor to provide calibration and/or feedback information for the correct illumination operation for the desired sanitation protocol. Adjustments, such as extensions of the exposure time, or reductions to the duration of exposure, may be made between sanitation cycles in an open loop mode to account

for degradation of UV light which can arise due to dust/dirt on illumination lenses or reflective surfaces, reduction in efficiency of the LED emitter devices over time, or for other reasons.

Duration may also be adjusted in response to feedback from the wired or wireless dosimeter, which can include PID control, bang-bang control, or other feedback algorithms. Duration may be selected to increase or decrease during a sanitation cycle, to increase or decrease for the next sanitation cycle, or to change in other ways for greater efficacy, to meet sanitation requirements, or other reasons. A duration profile may be selected from a database of duration profiles, to effect sanitation preferentially for particular pathogens, to achieve a higher degree of sanitation, or for other reasons.

Duration profiles may include periods with the UV illuminators modules off, or periods with one or more bright flashes of UV, and may or may not operation in concert with either of intensity or wavelength profiles. Duration profiles may be determined empirically using the collected data from the system's operation, through literature searches, through a combination of both empirical and theoretical, or through other means. Profiles may be proprietary, and where greater efficacy is determined, may be patentable separately from the device or the control system.

Dosimeter

The claimed units have as an integral part of their embodiment a wireless or wire-connected dosimeter, allowing factory or job-site measurement of the UV light dose emitted from the unit, which may be used for calibration, real-time monitoring, data collection, assurance of the delivered UV dose, or for other reasons.

The dosimeter has one or more sensors capable of detecting the UV light emitted from the antivirus light for sanitation, and a means to record, display, transmit, or otherwise utilize the dose information collected from the integrated sensor. The dose information may be used as part of the control system for the sanitation cycle, including providing feedback for adjustments of either the intensity or the wavelength, or both. The dosimeter may also be used to allow monitoring, and control of any or all of wavelength profiles, intensity profiles, and duration profiles. The dosimeter may contain internal memory to record sanitation and other events,

may be cloud connected to allow remote monitoring and historian recording of sanitation and other events, or may have other means of recording and communicating sensor readings. The dosimeter may include connectivity to external controls, including mobile device applications, IoT devices, or other control or data collection devices.

Retrofit

The illuminator modules are configured to be directly fit into existing luminaires and lighting fixtures in some scenarios, taking the place of existing light bulbs and tubes. In one embodiment, the illuminator module will have the dimensions and electrical connections consistent with replacement of a standard T5 fluorescent tube-type bulb. In another embodiment, the illuminator module will be designed as a direct replacement for existing medium-based light bulbs (E26/27 base). In another embodiment, the illuminator module will fit within GU10 recessed lighting fixtures. The illuminator module may also be designed to fit within other luminaires and other fixtures using standard or non-standard light-bulb packages.

The retrofit illuminator module may include connectivity to external controls, including mobile device applications, IoT devices, or other control or data collection devices.

New Design

The illuminator modules can be designed to meet emerging standards for LED lights, including but not limited to, flat panels, integrated LED recessed lighting fixtures, integrated LED surface mounted lighting fixtures, LED or standard lighting wall sconces, LED HID or other high bay lights, or other room and space lighting fixtures.

The new design illuminator module may include connectivity to external controls, including mobile device applications, IoT devices, or other control or data collection devices.

Control Theory

The system is designed with safety as the first priority, and the various control loops all integrate a safety control loop as part of their operation. The remaining control-loops comprise the Initialization Cycle, Calibration Cycle, Sanitation Cycle, and the Feedback Control Cycle. Each

of these in accordance with a particular embodiment is described in some detail below with respect to Figs. 4 to 7.

Initialization Cycle

The system goes through an initialization cycle upon each power-up event, as shown in Fig. 4. This cycle comprises the various calibration and safety check required to ensure that the illuminator module is in an appropriate “ready” state to undertake subsequent lighting and sanitization cycles. The cycle is outline briefly below:

1. The cycle starts by checking the internal system for the calibration state – if the illuminator module is within the allowed range of the calibration set point, it immediately moves into “Sanitation Stand-By Mode”. This mode allows normal operation of the room light in white-light mode, and enters the safety loop to continuously ensure that the light is not operating incorrectly, and that sanitation cycles are only being undertaken with the allowed operational envelope.
2. If the calibration state is not within the set point range, that is, the illuminator module is out of calibration, there is the option for the system to provide immediate feedback to the user, and the illuminator module waits for an external command to begin the calibration loop. This external command can originate from the local environment, or can be enabled using internet connectivity remotely, or can be initiated using other means.
 - 2.1. If the calibration loop is not enabled within a pre-set time interval after the out-of-calibration error is detected,
 - 2.1.1. Then the illuminator module will revert to “Room Light Only Mode”. In this mode, the sanitation light will only operate as a standard room light, delivering white light illumination only.
 - 2.1.2. The event of “Out of Calibration Error” is recorded, and the user informed of the failure.
 - 2.1.3. Additional records may result, either locally, through a wireless connection to a record keeping device, to the cloud for storage or other data manipulation, or other means.

- 2.1.4. In some embodiments, a warning indicator on the illuminator module , or transmitted from the unit to receiving unit, or transmitted to a wireless device such as a cellular phone, or to other devices using other means may be included.
- 2.2. If the calibration loop is enabled within the pre-set time interval after the out-of-calibration error is detected,
 - 2.2.1. Then the illuminator module will move into the “Calibration Cycle” described below
 - 2.2.2. Upon completion of the calibration cycle, the illuminator module will re-start back at the beginning of step 1, going through the same safety and validation procedures.

Calibration Cycle

The Calibration Cycle shown in Fig. 5 allows the illuminator module to self-calibrate its output of sanitation UV light, to ensure that the correct dose of energy is delivered to surfaces and spaces within the room to effect the desired pathogen reduction (in this example, COVID-19). As with all control loops, the importance of safe operation is at the forefront, and checks of safety interlocks are continuously made throughout the cycle. Checks are also made to ensure that there are no room occupants, and the cycle may include in some embodiments, specific manual intervention to initiate the Calibration Cycle. The Calibration Cycle comprises:

1. The Calibration Cycle starts with a check of all safety interlocks. Safety interlocks include, occupancy sensors, proximity sensors, door sensors, power monitors, or other means to affect the safe operation of the sanitation UV light. The logic of the system deliver a “TRUE” reading when the all of the safety interlock sensors included in the illuminator module and connected externally to the unit using wireless or wired or other connection means, deliver a TRUE signal, that is, when all are within their safe operation set point range. If any one, or more than one, sensor is FALSE, then the safety interlocks will halt the process. This results in:
 - 1.1. The system halts
 - 1.2. UV illuminators are disabled
 - 1.3. A report is generated to inform the user, and the report may be filed offline

- 1.4. The illuminator module enters a state looking for manual reset to restart the process – if reset command is received within the pre-set interval, then the process restarts at the beginning of step 1
2. If the safety interlocks are TRUE, then the illuminator module will enter the Calibration Cycle, receiving data from the wireless or wire connected dosimeter, and using this received reading to set the calibration of the UV light to be used for sanitation.
3. At any time if any of the safety interlocks enters a FALSE condition, then the illuminator module will immediately halt, record and transmit the fault, and inform the user.
4. Successful calibration data is stored locally, and transmitted externally for further data analysis and quality assurance.

Sanitation Cycle

The sanitation cycle shown in Fig. 6 involves the operation of the UV light to affect the sanitation of the room and surfaces within the room, using the calibration data, and may include closed loop feedback from the wireless or wire connected dosimeter.

Feedback Cycle

This control loop refers to the general feedback mechanisms for both closed and open loop operation of the illuminator module, and is shown in Fig. 7. Various control points, including abort and UV real-time or open loop features are incorporated to ensure that the illuminator module affects the desired illumination profile. These can include specific wavelength, intensity, and duration profiles, either individually, or in combination, or other UV illumination protocols to affect the desired sanitation.

Claim:

1. A sanitizing light system, comprising:

an ultraviolet light source configurable to illuminate a target region;

a sensor module configured to detect an occupancy in a target region; and

a controller coupled to the sensor module to determine when the target region is in an unoccupied state at least partially based on the detection of the occupancy of the target region, the controller being configured to control the ultraviolet light source at least partially based on the determined unoccupied state of the target region.

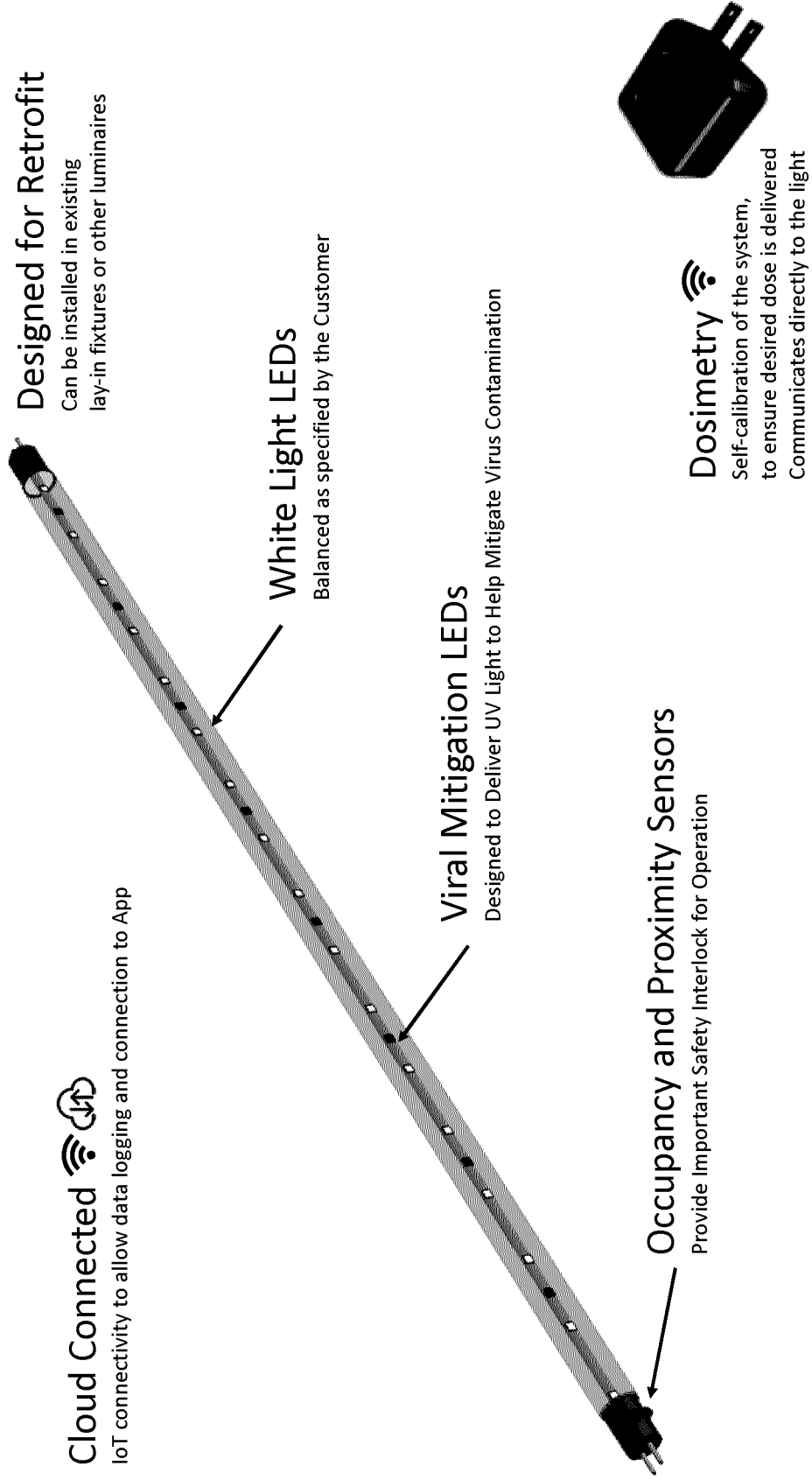


FIG. 1

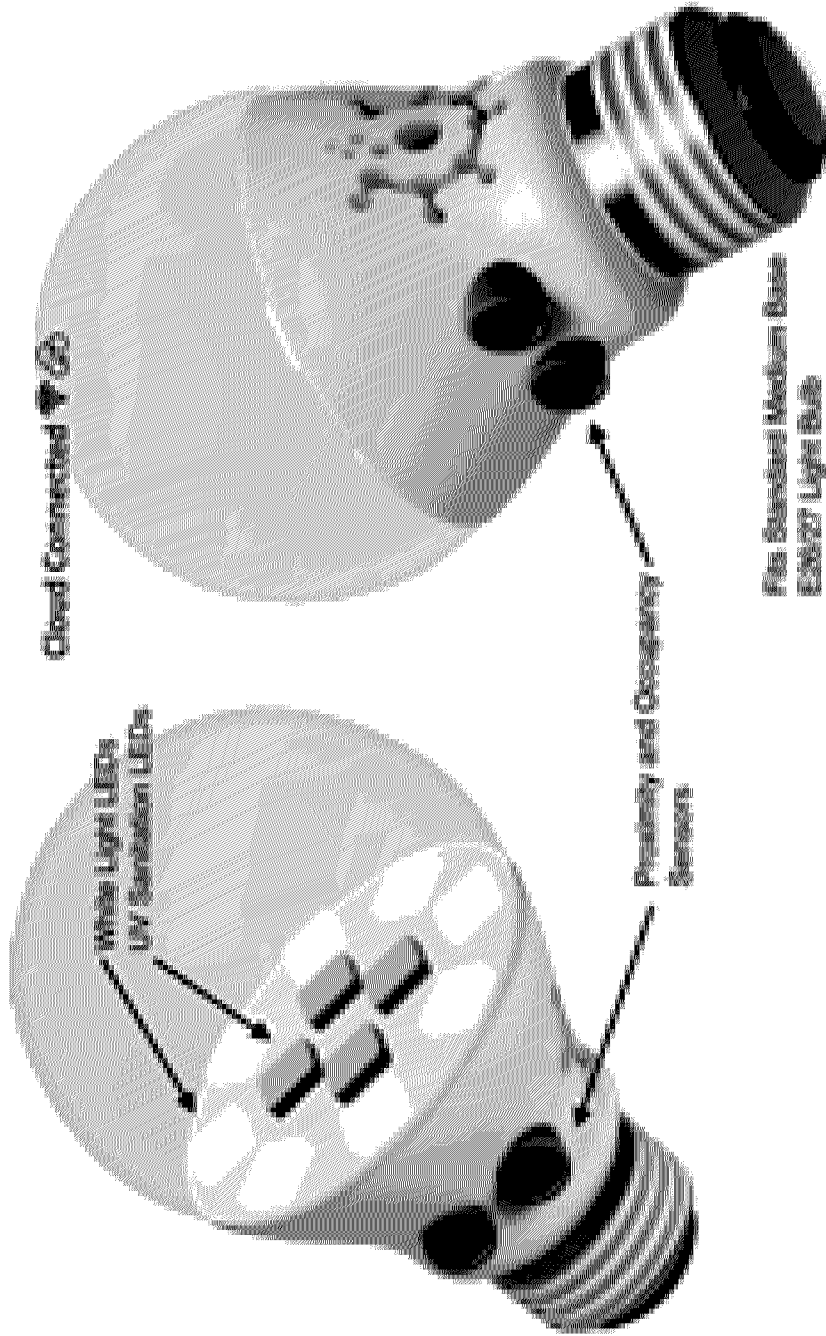


FIG. 2

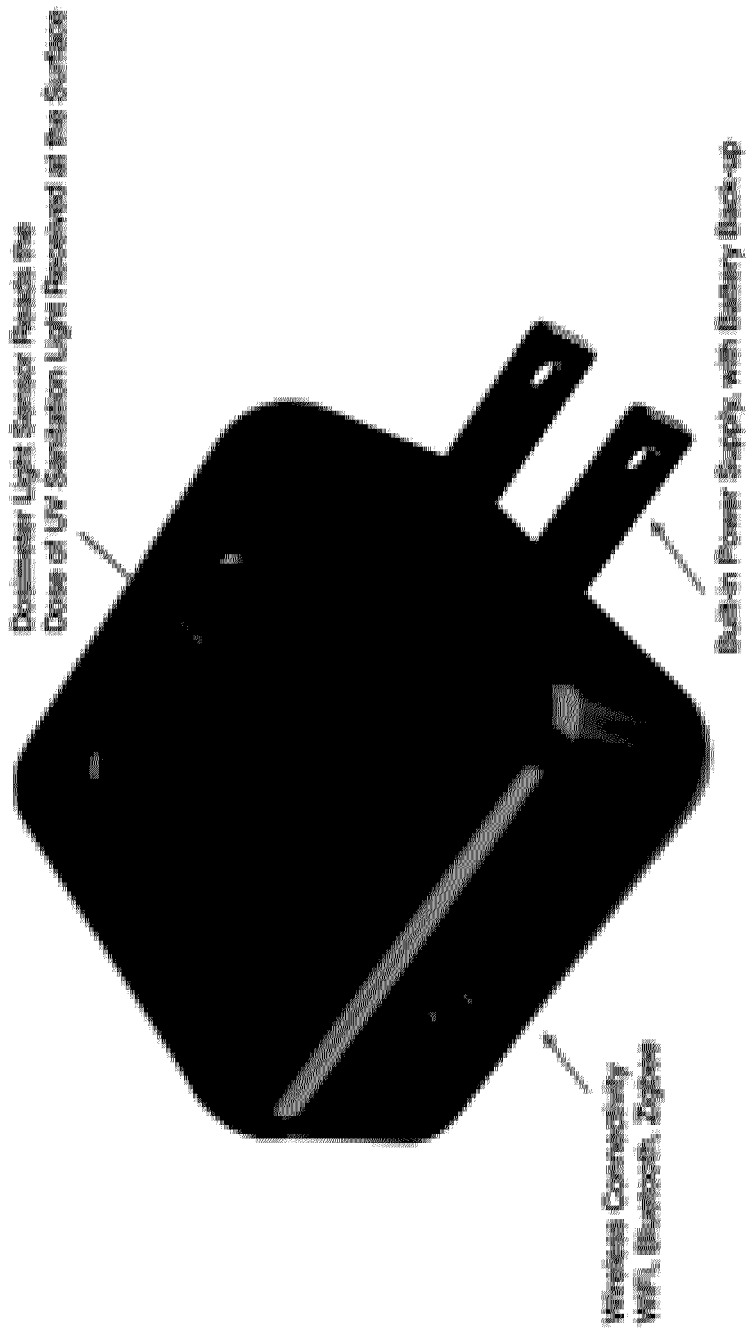


FIG. 3

INITIALIZATION CYCLE

REPRESENTATIVE FLOW CHART

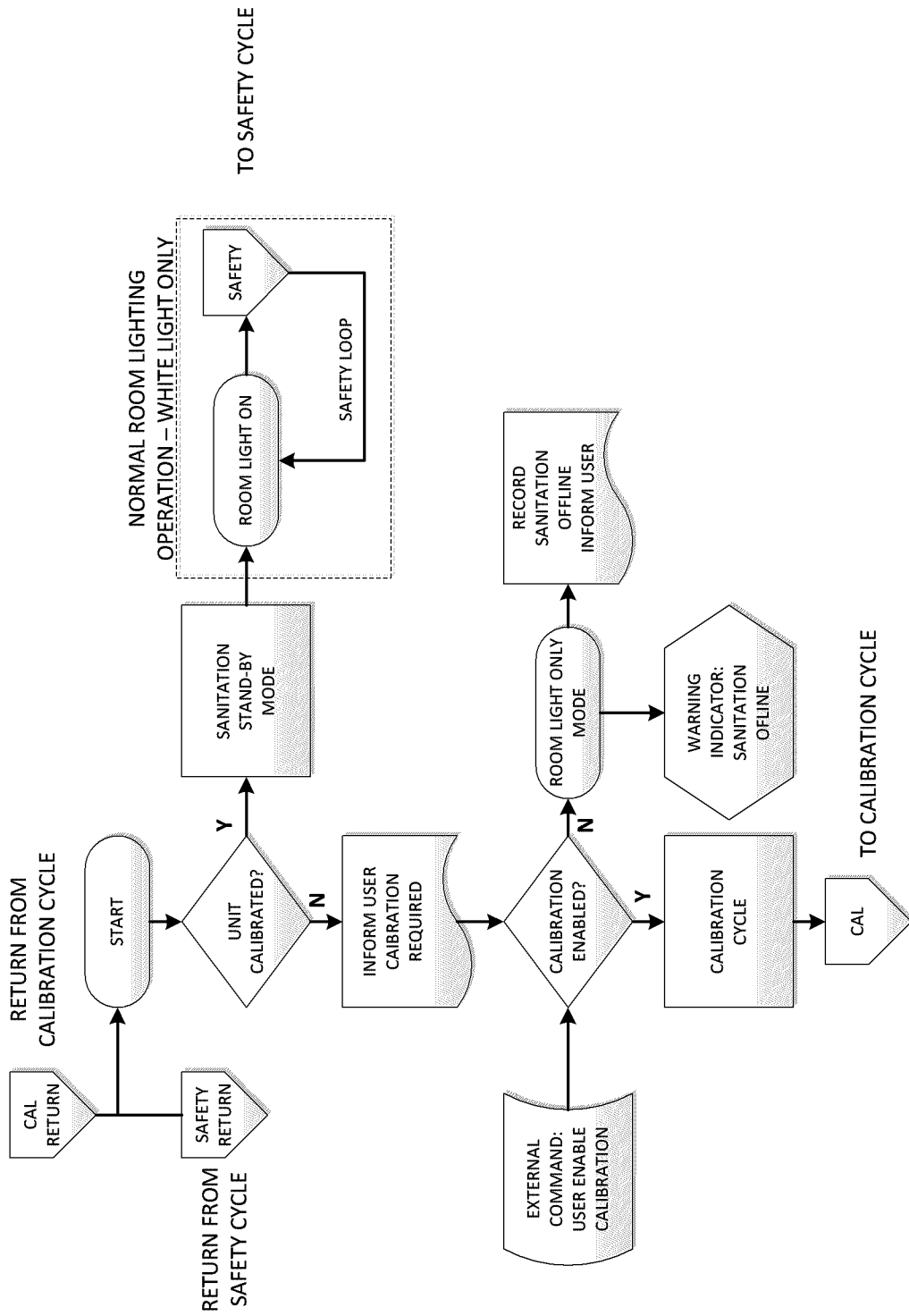


Fig. 4

CALIBRATION CYCLE

REPRESENTATIVE FLOW CHART

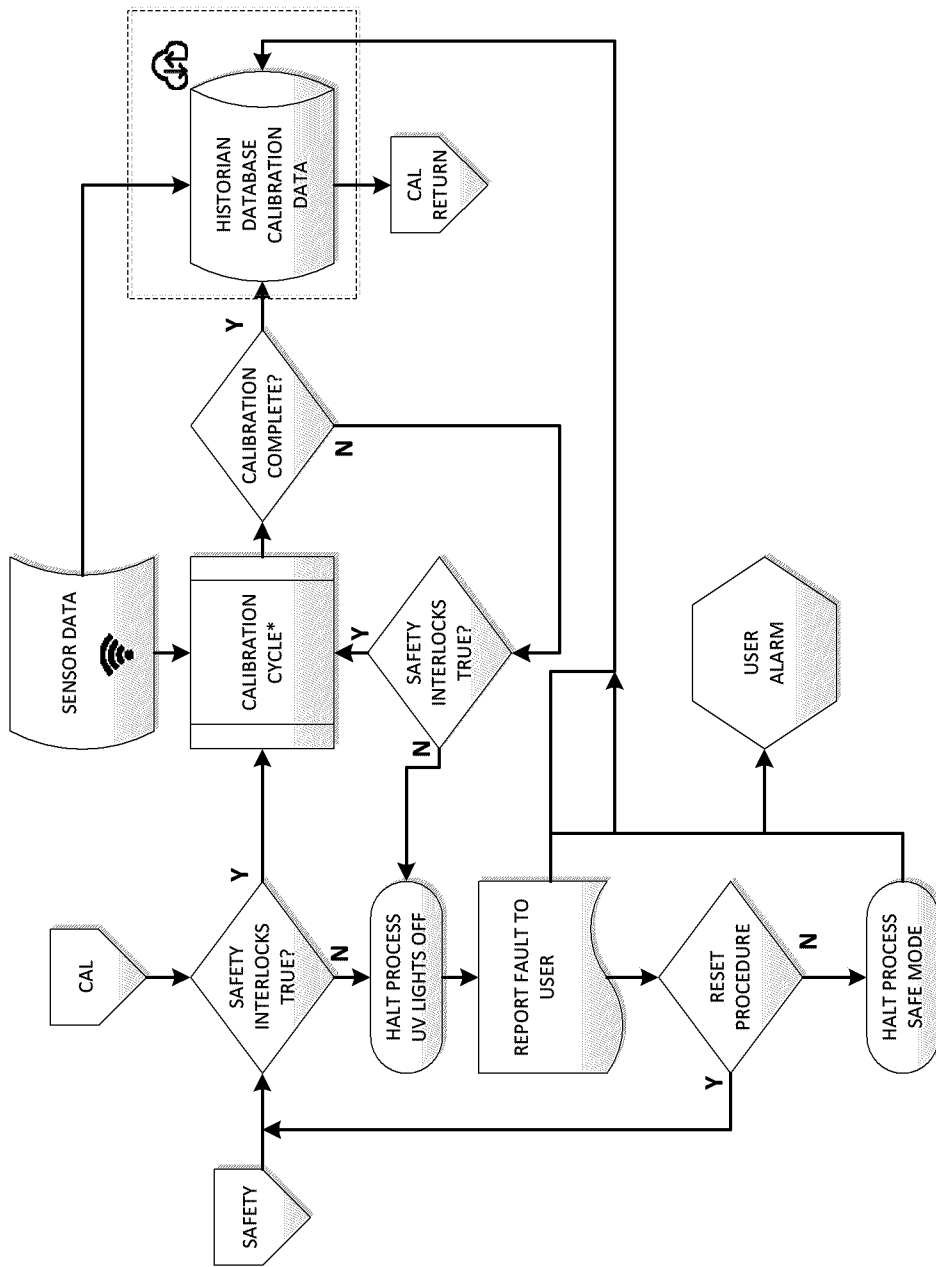


Fig. 5

FEEDBACK CYCLE

REPRESENTATIVE FLOW CHART

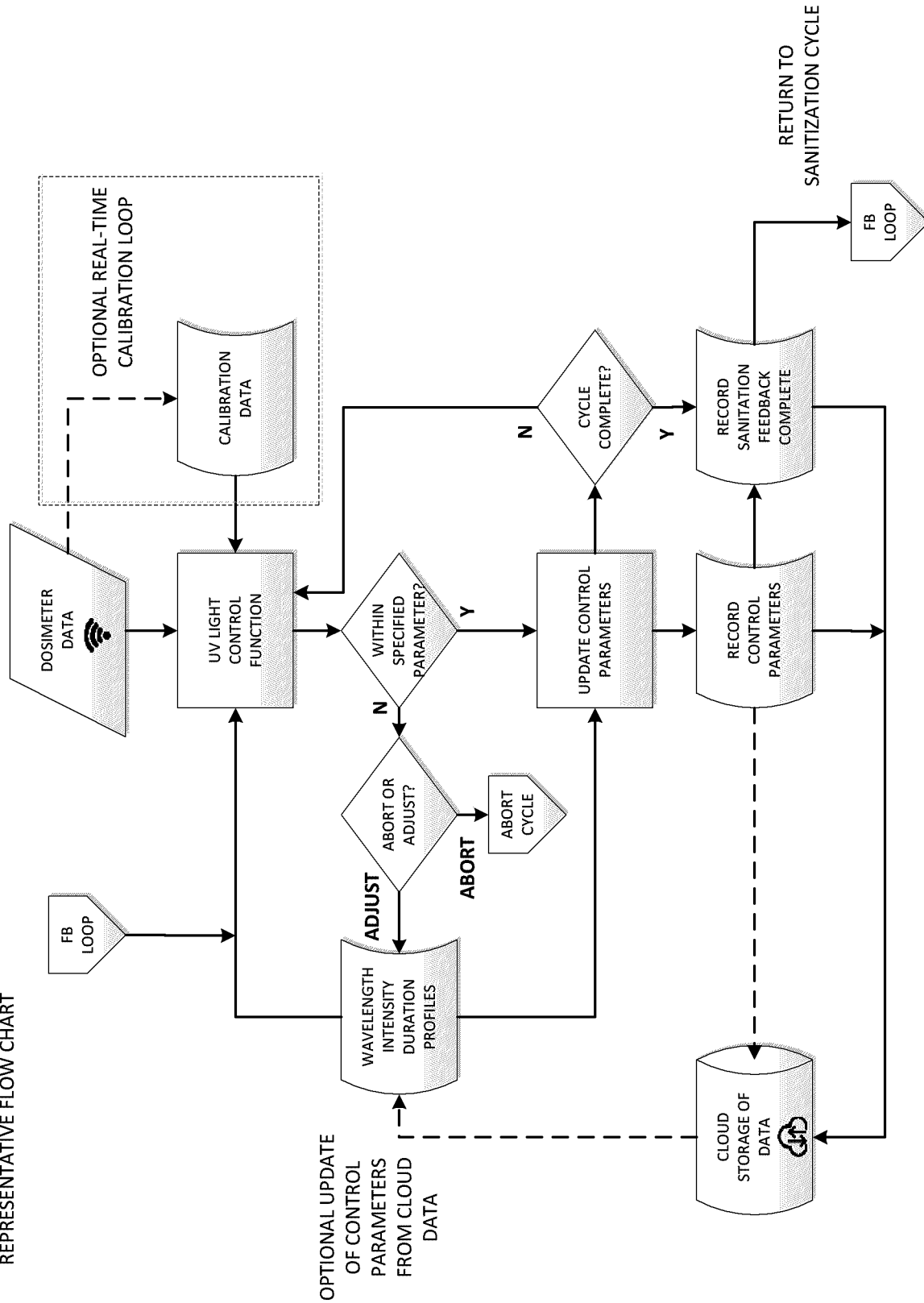


Fig. 7

Cloud Connected 

IoT connectivity to allow data logging and connection to App

Designed for Retrofit

Can be installed in existing
lay-in fixtures or other luminaires

White Light LEDs

Balanced as specified by the Customer

Viral Mitigation LEDs

Designed to Deliver UV Light to Help Mitigate Virus Contamination

Occupancy and Proximity Sensors

Provide Important Safety Interlock for Operation

Dosimetry 

Self-calibration of the system,
to ensure desired dose is delivered
Communicates directly to the light

