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Yang et al.

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(54) **INTELLIGENT UV RADIATION SYSTEM**

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(22) Filed: **Nov. 19, 2012**

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B05D 3/06 (2006.01)

(52) **U.S. Cl.**
CPC ***B05D 3/06*** (2013.01)
USPC **250/370.08**

(58) **Field of Classification Search**
CPC H05B 37/00; H05B 37/03; H05B 41/36
USPC 250/370.08
See application file for complete search history.

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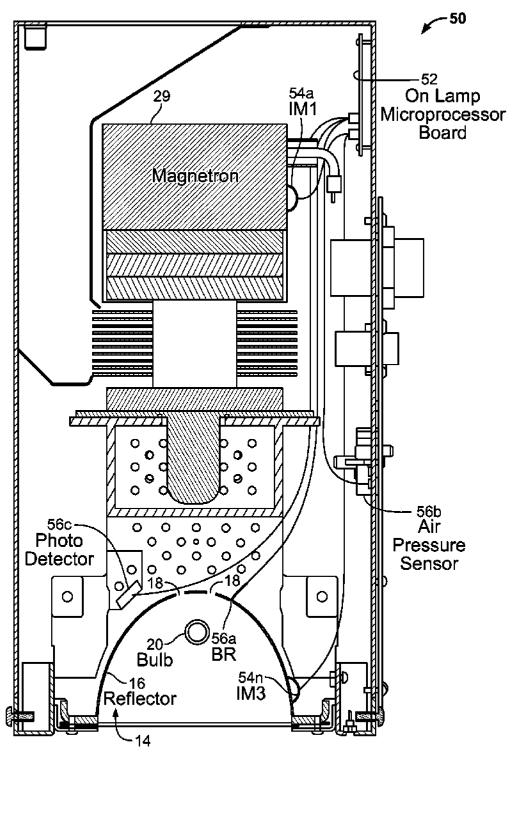
(57) **ABSTRACT**

An "intelligent" UV curing assembly is disclosed. The "intelligent" assembly permits automated monitoring of performance parameters, part lifetime, and inventory control of internal parts. The "intelligent" assembly includes an on lamp microprocessor. The on lamp microprocessor may be configured to recognize the internal parts, record accumulated working time of each part, and sample and process data from the plurality of "intelligent" sensors.

20 Claims, 8 Drawing Sheets



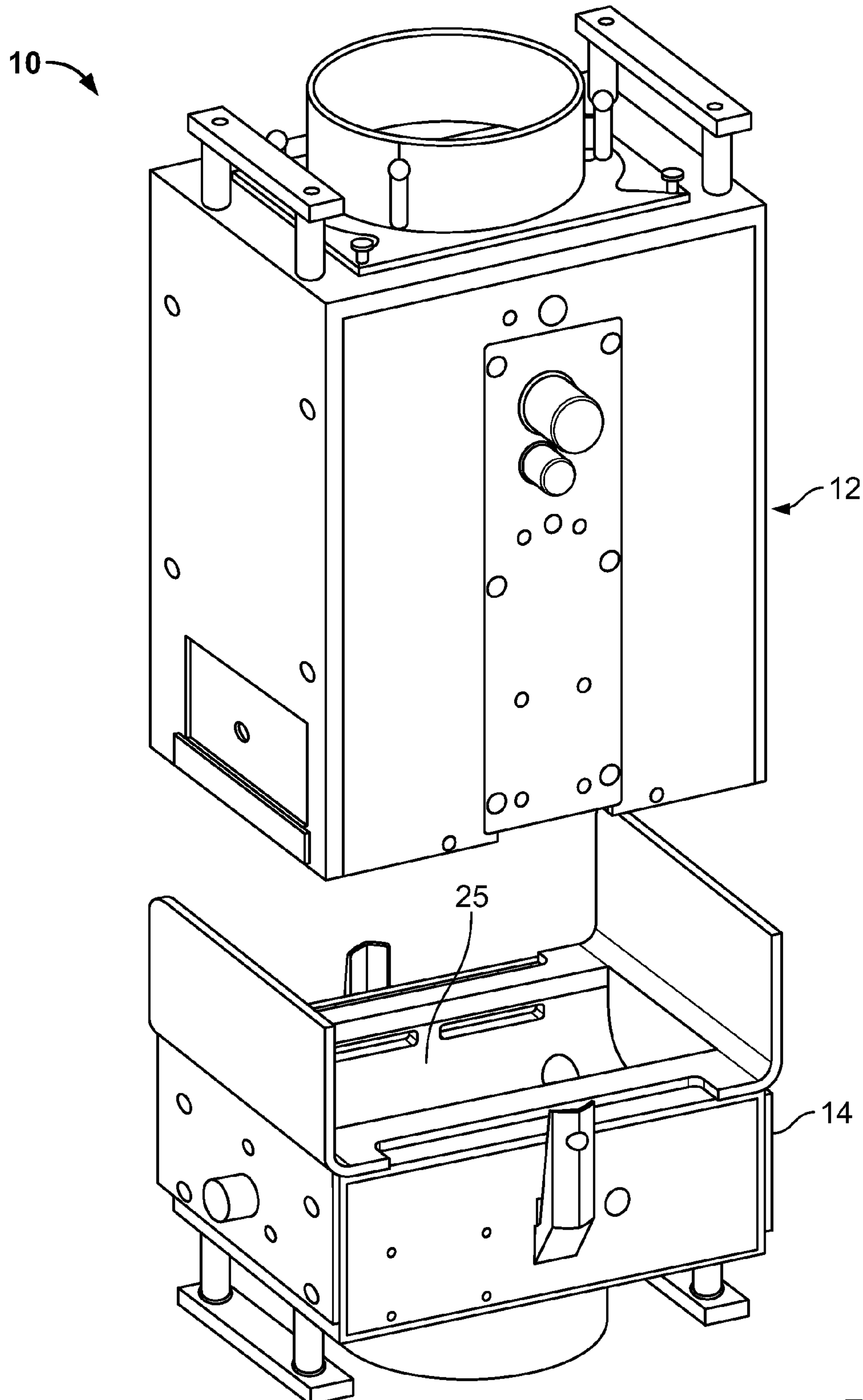


FIG. 1
(Prior Art)

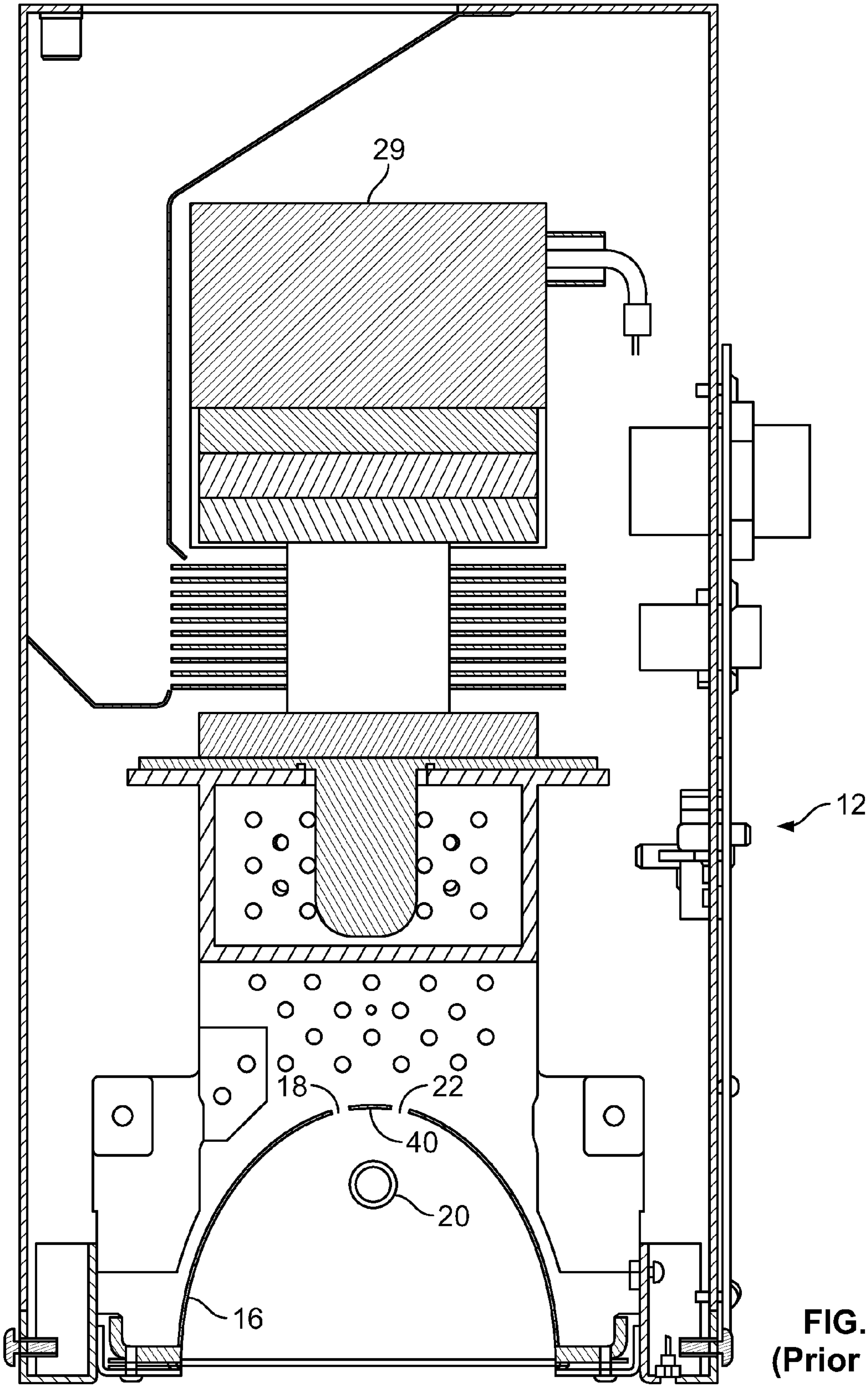


FIG. 2
(Prior Art)

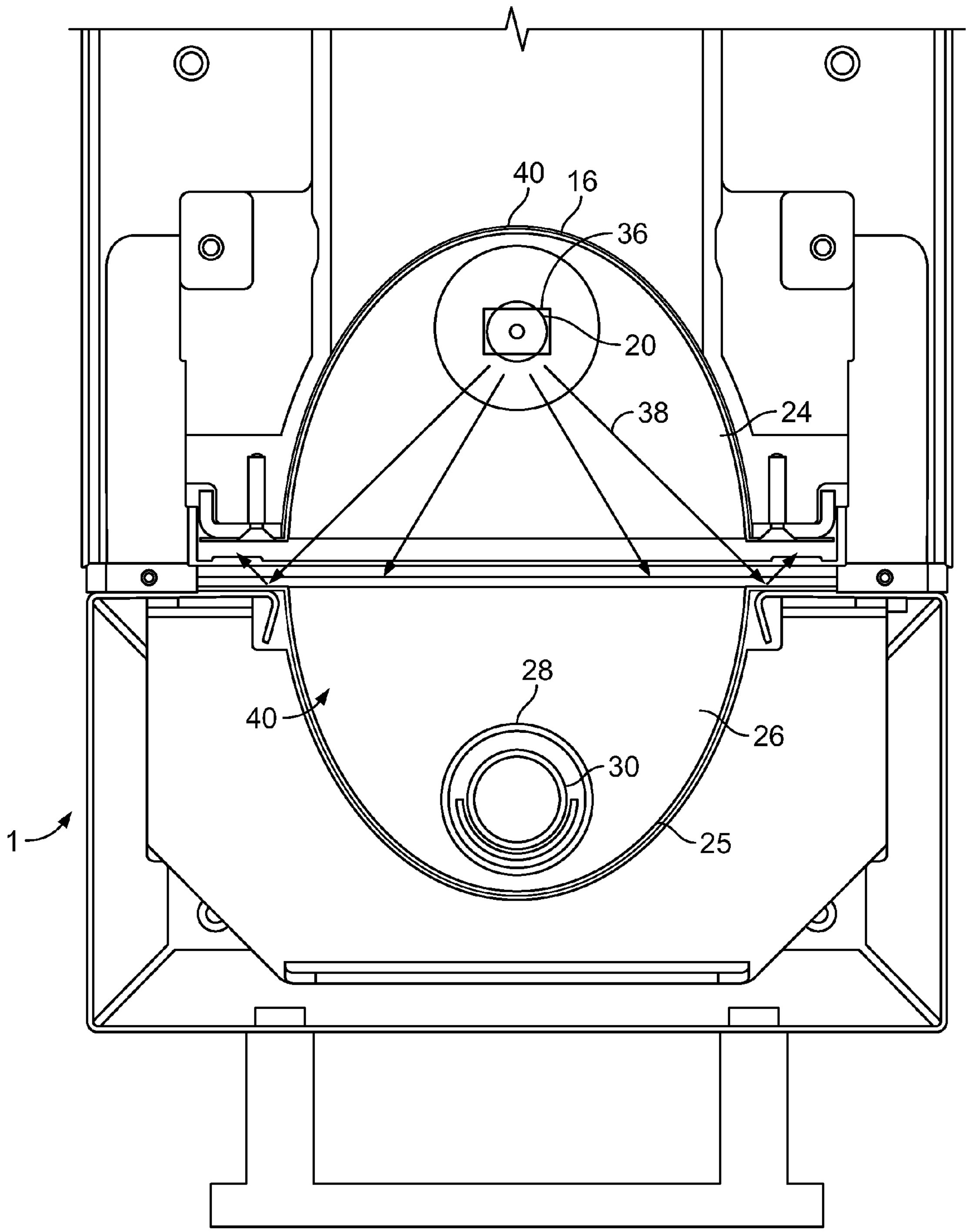


FIG. 3
(Prior Art)

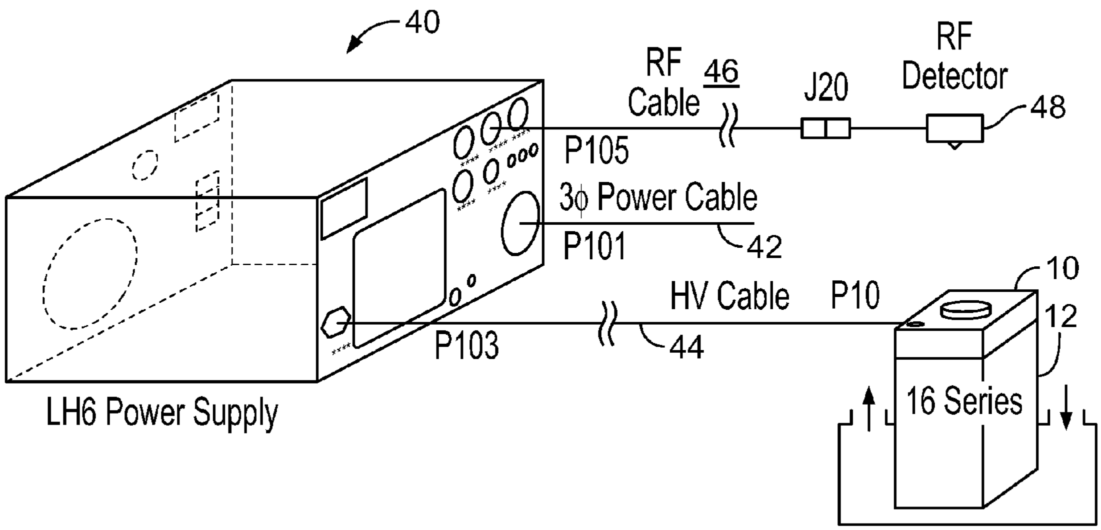

40
RF
Cable
46
J20
RF
Detector
48
P105
3ϕ Power Cable
P101
42
HV Cable
P10
10
12
P103
44
16 Series
LH6 Power Supply

FIG. 4

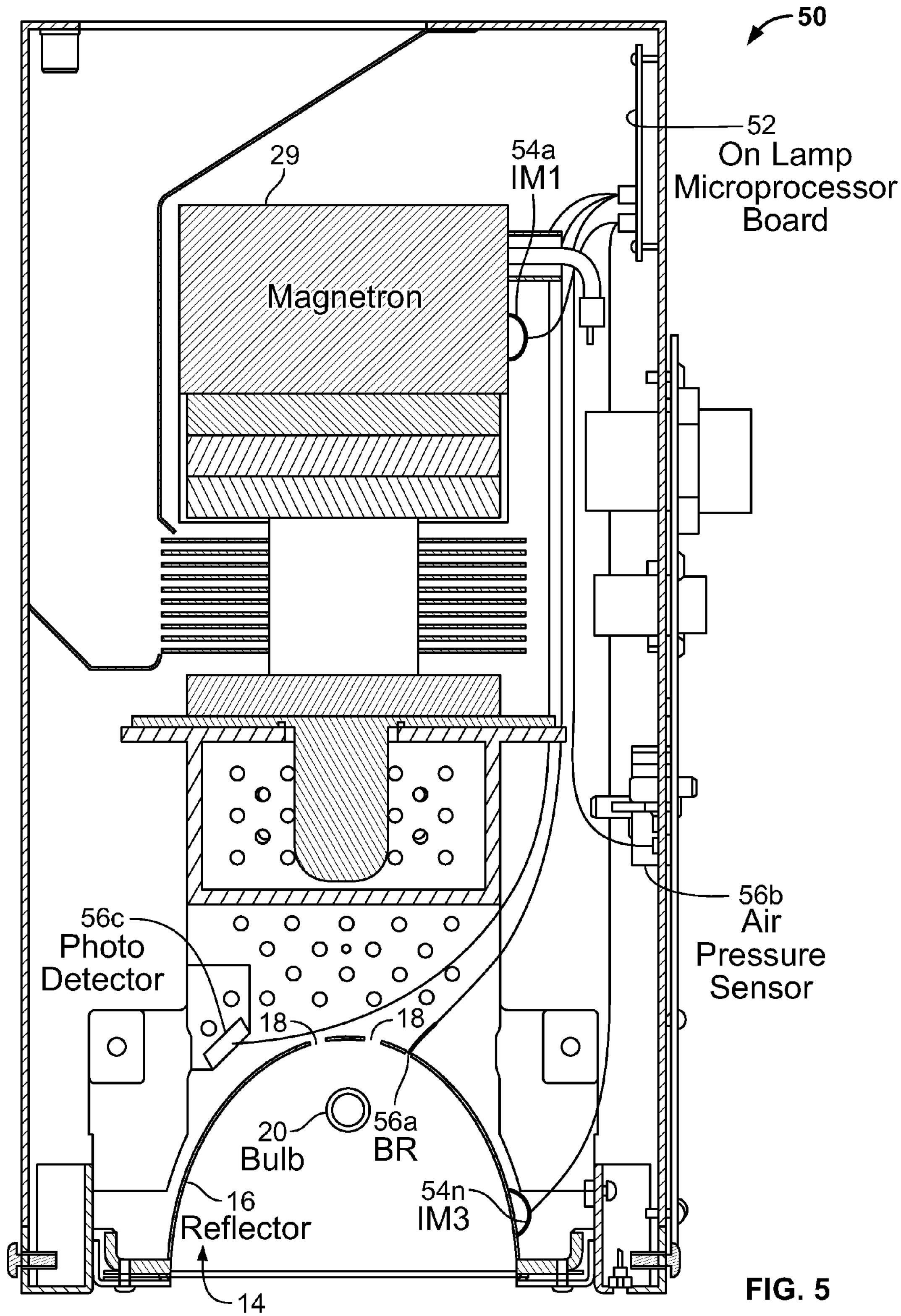

50
52
On Lamp
Microprocessor
Board
29
54a
IM1
Magnetron
56b
Air
Pressure
Sensor
56c
Photo
Detector
18
18
20
Bulb
56a
BR
54n
IM3
16
Reflector
14

FIG. 5

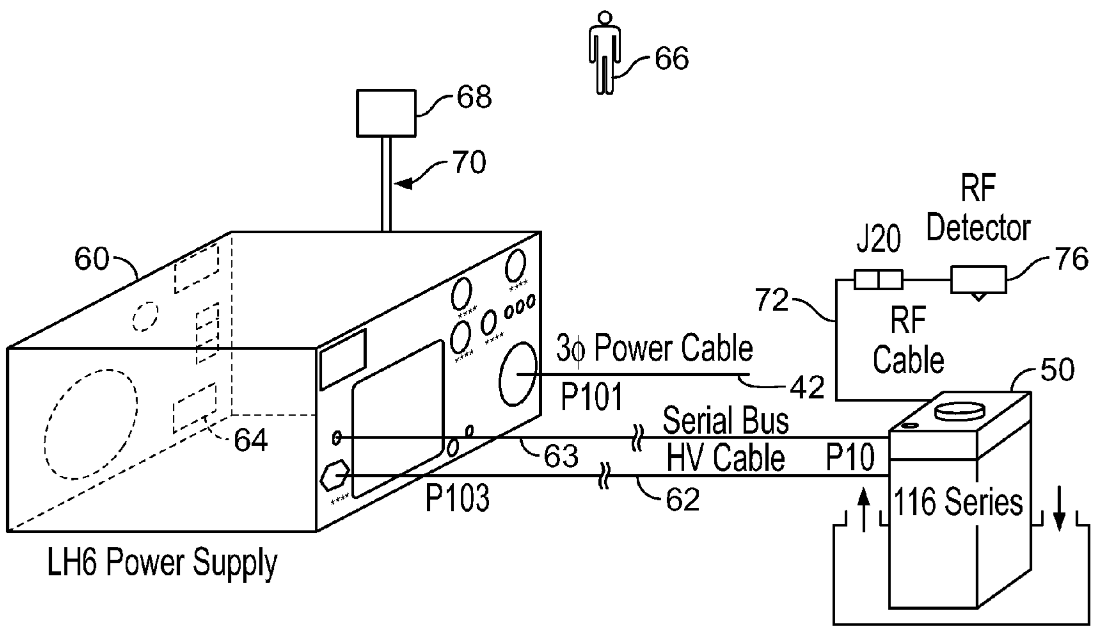

66
68
70
60
64
LH6 Power Supply
RF
Detector
J20
76
72
RF
Cable
50
3ϕ Power Cable
P101
42
Serial Bus
HV Cable
P10
63
P103
62
116 Series

FIG. 6

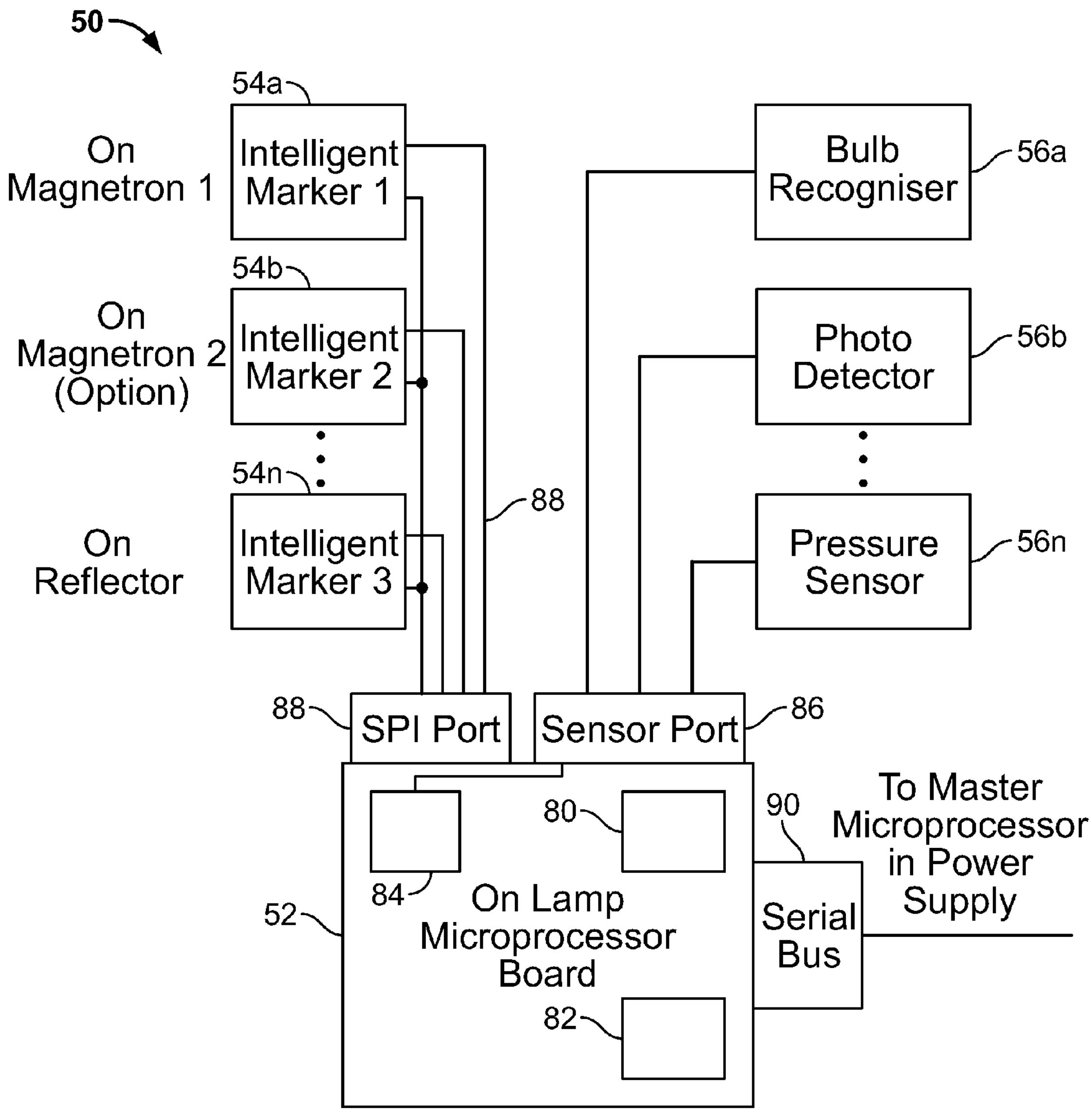

50
54a
On
Magnetron 1
Intelligent
Marker 1
54b
On
Magnetron 2
(Option)
Intelligent
Marker 2
54n
On
Reflector
Intelligent
Marker 3
88
Bulb
Recogniser
56a
Photo
Detector
56b
Pressure
Sensor
56n
88
SPI Port
Sensor Port
86
80
90
To Master
Microprocessor
in Power
Supply
84
On Lamp
Microprocessor
Board
52
Serial
Bus
82

FIG. 7

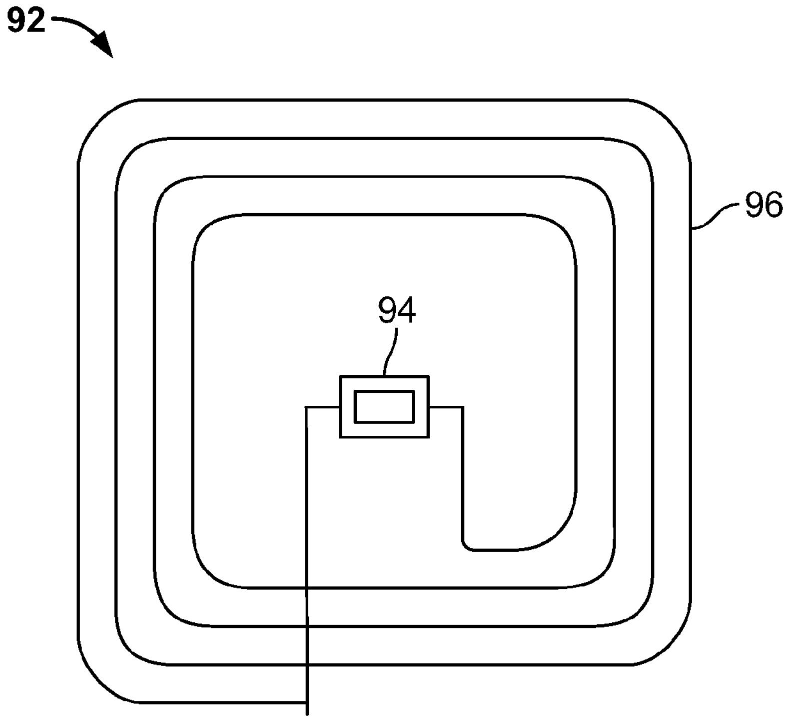


FIG. 8A

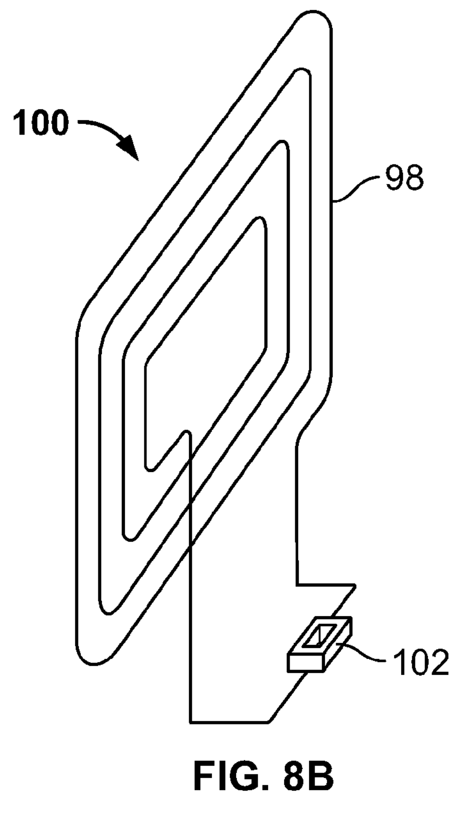


FIG. 8B

INTELLIGENT UV RADIATION SYSTEM

FIELD OF THE INVENTION

The invention relates generally to ultraviolet (UV) curing lamp assemblies, and more particularly, to a UV curing lamp assembly that includes on-board intelligence for automated inventory and monitoring of internal parts.

BACKGROUND OF THE INVENTION

Radiant energy is used in a variety of manufacturing processes to treat surfaces, films, and coatings applied to a wide range of materials. Specific processes include, but are not limited to, curing (i.e., fixing, polymerization), oxidation, purification, and disinfection. Processes employing radiant energy to polymerize or effect a desired chemical change are rapid and often less expensive compared to a thermal treatment. The radiation can also be localized to control surface processes and allow preferential curing only where the radiation is applied. Curing can also be localized within the coating or thin film to interfacial regions or in the bulk of the coating or thin film. Control of the curing process is achieved through selection of the radiation source type, physical properties (for example, spectral characteristics), spatial and temporal variation of the radiation, and curing chemistry (for example, coating composition).

A variety of radiation sources are used for curing, fixing, polymerization, oxidation, purification, or disinfections applications. Examples of such sources include, but are not limited to, photon, electron, or ion beam sources. Typical photon sources include, but are not limited to, arc lamps, incandescent lamps, electrodeless lamps and a variety of electronic and solid-state sources (i.e., lasers). Conventional arc type UV lamp systems and microwave-driven UV lamp systems use tubular bulb envelopes made of fused quartz glass or fused silica.

FIG. **1** is a perspective view of a microwave-powered UV curing lamp assembly showing an irradiator and a light shield assembly in the prior art. FIG. **2** is a partial cross-sectional view of the lamp assembly of FIG. **1** showing a half-elliptical primary reflector and a light source of circular cross-section. FIG. **3** is a partial cross-sectional internal view of the light shield assembly of FIG. **1** showing a half-elliptical primary reflector and a light source of circular cross-section mated to a secondary reflector and end reflectors.

Referring now to FIGS. **1-3**, the apparatus **10** includes an irradiator **12** and a light shield assembly **14**. The irradiator **12** includes a primary reflector **16** having a generally smooth half-elliptical shape with openings **18** for receiving microwave radiation to excite a light source **20** (to be discussed herein below), and a plurality of openings **22** for receiving air flow to cool the light source **20**. The light source **20** includes a lamp (e.g., a modular lamp, such as a microwave-powered lamp having a microwave-powered bulb (e.g., tubular bulb with a generally circular cross-section) with no electrodes or glass-to-metal seals). The light source **20** is placed at the internal focus of the half-ellipse formed by the primary reflector **16**. The light source **20** and the primary reflector **16** extend linearly along an axis in a direction moving out of the page (not shown). A pair of end reflectors **24** (one shown) terminate opposing sides of the primary reflector **16** to form a substantially half-elliptical reflective cylinder. The light shield assembly **14** of FIGS. **1-3** includes a secondary reflector **25** having a substantially smooth elliptical shape. A second pair of end reflectors **26** (one shown) terminates opposing sides of the secondary reflector **25** to form a substantially half-elliptical reflective cylinder.

A work piece tube **30** of circular cross-section is received in circular openings **28** in the end reflectors **26**. The center of the openings **28** and the axis of the work piece tube **30** are typically located at the external focus of the half-ellipse formed by the primary reflector **16** (i.e., the foci of the half-ellipse formed by the secondary reflector **25**). The work piece tube **28** and the secondary reflector **25** extend linearly along an axis in a direction moving out of the page (not shown).

In operation, gas in the light source **20** is excited to a plasma state by a source of radio frequency (RF) radiation, such as a magnetron **29** located in the irradiator **12**. The atoms of the excited gas in the light source **20** return to a lower energy state, thereby emitting ultraviolet light (UV). Ultraviolet light rays **38** radiate from the light source **20** in all directions, striking the inner surfaces of the primary reflector **16**, the secondary reflector **25**, and the end reflectors **24**, **26**. Most of the ultraviolet light rays **38** are reflected toward the central axis of the work piece tube **30**. The light source **20** and reflector design are optimized to produce the maximum peak light intensity (lamp irradiance) at a surface of a work product (also propagating linearly out of the page) placed inside the work piece tube **30**.

FIG. **4** shows a plurality of cable connections between the irradiator **12** of FIGS. **1-3** and a conventional external power supply **40**. Current irradiators manufactured by Fusion UV Systems of Gaithersburg, Md. are powered with high voltage DC and monitored for analog parameters, such as the detection and measurement of radio-frequency (RF) and ultraviolet (UV) radiation leakage. The external power supply **40** includes a three-phase power cable **42** for receiving conventional AC power. The external power supply **40** converts AC power to high voltage DC power in the range of 4 kV-7 kV DC. The high voltage DC power is applied to a high voltage HV cable **44** that extends between the external power supply **40** and the irradiator **12**. The HV cable **44** typically includes seven analog signal wires (not shown): two wires for carrying the High Voltage (HV) DC power to the irradiator **12**; two wires for powering a filament associated with a microwave-powered UV-emitting bulb **20** (i.e., the light source **20**); one wire each for a photo detector and a pressure switch sensor; and a seventh wire for a cable interlock. An RF cable **46** for monitoring microwave leakage conditions is located between the external power supply **40** and an RF detector **48**, which needs to be mounted close to the irradiator **12**.

Unfortunately, the currently employed cables **44**, **46** between the external power supply **40** and the irradiator **12** have a number of drawbacks. The cables **44**, **46** have a limited range due to losses in the cable. Current irradiators **12** are not user friendly for product upgrading, standardizing and compatibility. For example, certain critical monitorable parameter, including UV power, temperature, air pressure, and part type require the installation of additional sensors inside the irradiator **12**. The cables **44**, **46** do not permit changes necessary to accommodate remote monitoring of the above-cited parameter because of limited I/O and significant tethering that requires close proximity of the external power supply **40** to the irradiator **12**.

Current irradiators **12** do not permit the monitoring of UV output power that emanates from the UV-emitting bulb **20**. Each UV-emitting bulb **20** is not identical in its UV output power. There are certain UV curing applications where multiple UV-emitting bulbs **20** are mounted adjacent to one another. Manual adjustments are required to lower or increase the voltage to equalize variations in UV output power from lamp to lamp. Therefore, it would be desirable to permit automatic monitoring and adjustment of UV output power.

Currently employed pressure switches (not shown) do not permit real time monitoring of air pressure inside the irradiator **12**. The rate of flow of air inside the irradiator **12** is critical to the life of the UV-emitting bulb **20** and the magnetron **29**. It is therefore desirable to install a monitorable pressure sensor that can transmit real time data back to a controller. Further, a monitorable pressure sensor can be integrated with a "smart blower" to automatically manage airflow and changing of speed of the "smart blower" based on data received from the monitorable pressure sensor.

Accordingly, what would be desirable, but has not yet been provided, is a microprocessor-controlled UV curing irradiator for monitoring internal sensors for performance parameters, part lifetime, and inventory control without necessitating major changes to a high voltage power supply.

SUMMARY OF THE INVENTION

The above-described problems are addressed and a technical solution is achieved in the art by providing an "intelligent" irradiator that permits automated monitoring of performance parameters, part lifetime, and inventory control of internal parts. The irradiator includes an on lamp microprocessor. The on lamp microprocessor may be configured to recognize internal parts, record accumulated working time for each part, sample and process data from the plurality of sensors, and communicate with a master computer processor located within an external "intelligent" power supply via a serial bus cable.

According to an embodiment of the present invention, the on lamp microprocessor is configured to communicate with a plurality of intelligent markers (IMs) associated with one or more internal magnetrons and an internal primary reflector. The intelligent markers may comprise at least one of a radio frequency identification tag (RFID) or a small footprint microcontroller adhered to each part to be monitored. The on lamp microprocessor communicates with the IMs via standard serial links such as a serial peripheral interface (SPI) bus. The on lamp microprocessor also communicates with a plurality of analog/digital sensors that includes one or more temperature detectors operating as a bulb recognizer (BR), an air pressure sensor for detecting a rate of air flow from an internal fan within the irradiator, a UV power sensor, and an RF detector for microwave leaking detection.

The "intelligent" irradiator communicates with an "intelligent" external power supply modified to include a master computer processor for controlling the irradiator and reading data processes by the on lamp microprocessor over a digital serial communication bus for communication between the irradiator and the power supply using an inexpensive standard communication protocol (e.g., CAN bus).

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention may be more readily understood from the detailed description of an exemplary embodiment presented below considered in conjunction with the attached drawings and in which like reference numerals refer to similar elements and in which:

FIG. **1** is a perspective view of a UV curing lamp assembly showing an irradiator and a light shield assembly in the prior art;

FIG. **2** is a partial cross-sectional view of the lamp assembly of FIG. **1** showing a half-elliptical primary reflector and a light source of circular cross-section;

FIG. **3** is a partial cross-sectional internal view of the lamp assembly interconnected with the light shield assembly of FIG. **1**, showing a half-elliptical primary reflector and a light source of circular cross-section mated to a secondary reflector and end reflectors;

FIG. **4** shows a plurality of cable connections between the irradiator of FIGS. **1-3** and a conventional external power supply;

FIG. **5** is a partial cross-sectional view of the irradiator of FIG. **2** modified to include intelligent control, according to an embodiment of the present invention;

FIG. **6** shows a plurality of cable connections between the irradiator of FIG. **5** and an external power supply modified to operate with the irradiator, according to an embodiment of the present invention;

FIG. **7** is an electrical schematic block diagram of the on lamp microprocessor board mounted within the irradiator of FIGS. **5** and **6**, according to an embodiment of the present invention;

FIG. **8**A depicts a conventional RFID tag having a semiconductor chip and a coiled antenna located within a common plane; and

FIG. **8**B depicts a modified version of the RFID tag of FIG. **8**A, wherein a semiconductor chip is located in the horizontal plane and the coiled antenna is located in the vertical plane, according to an embodiment of the present invention.

It is to be understood that the attached drawings are for purposes of illustrating the concepts of the invention and may not be to scale.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **5** is a partial cross-sectional view of the UV curing irradiator **12** of FIG. **2** modified to include intelligent control (i.e., an irradiator **50**), according to an embodiment of the present invention. The irradiator **50** includes an on-lamp microprocessor board **52**, a plurality of intelligent markers **54***a*-**54***n* (labeled IMl-IMn), and a plurality of sensors **56***a*-**56***n* (e.g., a bulb recognizer labeled BR **56***a*, an air pressure sensor **56***b*, and a photo detector **56***c*), configured as shown. The placement of the components **52**, **54***a*-**54***n*, and **56***a*-**56***n* in FIG. **5** represents a preferred, though not exclusive layout. A description of each of the intelligent components **52**, **54***a*-**54***n*, and **56***a*-**56***n* is presented in connection with FIG. **6** hereinbelow.

FIG. **6** depicts a plurality of cable connections between the irradiator **50** and an external power supply **60** modified to operate with the irradiator **50**, according to an embodiment of the present invention. The external power supply **60** includes a three-phase power cable **42** for receiving conventional AC power. The external power supply **60** converts AC power to high voltage DC power in the range of 4 kV-7 kV DC. The high voltage DC power is applied to a modified high voltage (HV) cable **62** extending between the external power supply **60** and the irradiator **50**. The HV cable **62** includes two wires for carrying the High Voltage (HV) DC power and a plurality of additional conductors for controlling and monitoring of the filament current of the magnetron **29**. A serial bus cable **63** includes two or more digital serial communication wires for communication between the external power supply **60** and the irradiator **50** using a standard serial communication protocol (e.g., a CAN bus). A master computer processor **64** within the external power supply **60** is configured to control and receive serial data to/from the on-lamp microprocessor board **52**. The master computer processor **64** is also configured to communicate with an external intelligent control system (not shown) for receiving commands from and presenting data to a user **66** on a monitor **68** over a standard serial link **70** (e.g., CAN bus). An RF cable **72** for monitoring microwave radiation leakage from the irradiator **50** extends from the external power supply **60** to an RF detector **76**. Note that the RF cable **72** associated with the RF detector **76** is generally a short local cable compared to a relatively long cable connected between the irradiator **12** and the external power supply **40** of FIG. **2**.

FIG. **7** is an electrical schematic block diagram of the on lamp microprocessor board **52** mounted within the irradiator **50** of FIGS. **5** and **6**, according to an embodiment of the present invention. The on lamp microprocessor board **52** includes an on lamp microprocessor **80** in signal communication with a computer-readable storage medium **82** (i.e., volatile and non-volatile memory, such as RAM and Flash memory, respectively). The on lamp microprocessor **80** may be any commercial 8/16 bit microprocessor having sufficient speed to process command and data from the plurality of sensors **56***a*-**56***n* via an 8 channel analog-to-digital converter (ADC) **84** via a sensor port **86**. The on lamp microprocessor **80** further controls and reads digital data from the plurality of intelligent markers **54***a*-**54***n* (labeled IMl-IMn) via a serial bus **88** and serial bus port **90** that employs a standard serial bus protocol that may be, but is not limited to, the Serial Peripheral Interface bus (SPI bus) protocol.

According to an embodiment of the present invention, on lamp microprocessor **80** may be configured to: (1) recognize parts, including one or two magnetrons **29** associated with the intelligent markers IM**1** and IM**2**, respectively, the primary reflector **16** associated with the intelligent marker IM**3**, and, the microwave-powered, UV-emitting bulb **20** (i.e., the light source **20**) associated with the bulb recognizer (BR); (2) record accumulated working time for each part, which is storable in non-volatile memory (i.e., the computer-readable storage medium **82**); (3) sample and process data from the plurality of sensors **56***a*-**56***n*, which may include, but are not limited to, one or more temperature sensors **56***a* operating as the bulb recognizer (BR) for detecting the type of the UV-emitting bulb **20**, an air pressure sensor **56***b* for detecting the rate of air flow from an internal fan (not shown) within the irradiator **50**, a photo detector **56***c* for measuring UV light output from the irradiator **50**, and other optional sensors such as a filament current sensor and an HV cable interlock (not shown); and (4) communicate with the master computer processor **64** within external power supply **60** via the serial bus cable **63**.

Parts may be recognized by analog/digital means via the plurality of sensors **56***a*-**56***n* over the sensor port **86** (e.g., the bulb recognizer (BR)) and digital means via the intelligent markers **54***a*-**54***n* (labeled IMl-IMn) over the serial bus port **90**. As used herein, an intelligent marker (IM) refers to, but is not limited to, a semiconductor chip that permanently maintains manufacturing information, such as, but not limited to, a produced date, a part number, and a life time limit. The irradiator **50** may include, but is not limited to, one or both of two types of IMs: a radio frequency identification tag (RFID) or a small footprint microcontroller. An IM may be permanently adhered to a part using epoxy or other adhesive.

When an IM is an RFID tag, the RFID tag is configured to communicate wirelessly via radio frequency (RF) waves for exchanging data with a reader (not shown). Several types of RFID products are known, such as the Texas Instruments' RI-103-114A-01 and ATMEL's AT88SCRF-ADK2. RFID tags have been employed in such diverse applications as driver licenses, passports, and bus, metro and, highway passes. Current RFID tag designs, such as the RFID tag **92** shown in FIG. **8**A, include a semiconductor chip **94** and a coiled antenna **96**. The RFID tag **92** is not suitable for mounting directly on a magnetron **29** or a reflector since the magnetron **29**/reflector it is made of metal. The metal of the magnetron **29**/reflector shields the coiled antenna **96**, thereby reducing the production of sufficient current for "reading" RFID data stored from the semiconductor chip **94**. An improvement is shown in FIG. **8**B, wherein the magnetron **29**/reflector does not shield a coiled antenna **98** of an RFID tag **100** because the coiled antenna is located in a vertical plane, while a chip **102** of the RFID tag **100** is located and mounted on the magnetron **29**/reflector in a horizontal plane.

An alternative solution for implementing an IM is to employ a microcontroller with a very small footprint, such as the 8-bit PIC10F222T-I/OT microcontroller produced by Microchip Technology or the ATTINY10-TSHR produced by Atmel. The small footprint microcontroller type IM may be connected to the on lamp microprocessor board **52** via 3 to 5 wires. In such circumstances, the on lamp microprocessor **80** communicates with the small footprint microcontroller via the serial bus **88** over the serial bus port **90** to access information pre-written by the manufacturer of the part to be tracked.

A major difficulty in implementing an IM for use as a recognizer (BR) is the high operating temperature of the UV-emitting bulb **20**. A fully-operating UV-emitting bulb **20** has a temperature in the range of about 700° C.-900° C., which may damage all but a few expensive military specification microcontrollers. In addition, the IM would be exposed to high levels of UV and microwave radiation. Therefore, adhering an inexpensive semiconductor-based IM to the UV-emitting bulb **20** is prohibitive.

An alternative implementation of a BR may take advantage of a characteristic of microwave-powered bulbs manufactured by Fusion UV Systems, Inc. of Gaithersburg, Md. Such bulbs contain a trace amount of an isotope of the radioactive element Krypton (i.e., "Kr 85"), which decays to non-radioactive byproducts after a predetermined amount of time (i.e., just enough to permit the microwave-powered bulb to reach operating temperature). If an irradiator does not employ Kr 85, the time for the microwave-powered bulb to ramp up to full operating temperature is significantly extended, resulting in potential harmful effects to the magnetron **29**. In such circumstances, a sensor may be employed that recognizes the presence of Kr 85. A sensor that detects radiation emitted by Kr 85 may be remotely mounted at a safe distance from the UV-emitting bulb **20** within the irradiator **50**. A radiation detector-based sensor may include, but is not limited to, a small Geiger counter, a CMOS or CCD imager that is operable with the on lamp microprocessor **80** to recognize the emission spectrum of Kr 85, or in a preferred embodiment, a PIN diode used as a radiation detector, such as the UM9441 or UM9442 manufactured by Microsemi Corp.

Still another approach for implementing a BR is to analyze the behavior of the UV-emitting bulb **20** in the presence of Krypton. During bulb ignition, the emission spectrum from the UV-emitting bulb **20** has a characteristic optical transition wavelength specific to Krypton. This optical transition wavelength will only be emitted when the UV-emitting bulb **20** is first ignited, when mercury pressure is very low. A photo detector may then be employed as the BR to detect the brief Krypton emission during ignition.

Certain internal parts of the irradiator **50** monitored by the IMs **54***a*-**54***n* are intended to be disposable, such as, but not limited to, the UV-emitting bulb **20** and the primary reflector **16**. All disposable parts inside the irradiator **50** may have pre-written information stored in the IMs **54***a*-**54***n* as part of an inventory tracking system. Stored information may include, but is not limited to, a part number, a manufacturing date, and a life time limit. The data representing this information may be communicated from the IMs **54**a-**54**n to the on lamp microprocessor **80** and then to the master computer processor **64** in the external power supply **60**.

In operation, upon initial installation and any subsequent installation of each of the disposable parts, information stored in the IMs **54**a-**54**n may be read by the on lamp microprocessor **80** over the serial bus **88**. The on lamp microprocessor **80** assigns to each part a part ID. The on lamp microprocessor **80** records a start date and time for each of the monitored parts. The on lamp microprocessor **80** may compare the working time of the part to its expected maximum life time. When the working time approaches or exceeds a pre-established expiration date, the on lamp microprocessor **80** sends a message over serial bus cable **63** to the master computer processor **64** within external power supply **50**, and from there to the user via the serial link **70** (e.g., a CAN bus serial link) and/or a network (e.g., the Internet), that it is time to check and/or replace the part. An external monitoring system at the user site may be configured to count and display the working time of each part. Additionally, the on lamp microprocessor **80** may store a life time limit for each part that is 20%-30% greater than the stated manufacturer's life time limit. When the working time exceeds the stored life time limit, the part and/or the irradiator **50** may be disabled by the master computer processor **64** or by shutting down the external power supply **60**.

The irradiator **50** is upgradeable without requiring changes to the external power supply **60** or the cables **62**, **63**. For example, the irradiator **50** may be equipped with an optional non-contact infrared (IR) sensor employed as a temperature sensor. Employing a non-contact temperature sensor avoids damage due to potential overheating of the UV-emitting bulb **20**, which may reach temperatures upwards of 1000° C. An exemplary IR sensor suitable for use in the irradiator **50** is a TPD 333/733 thermopile manufactured by Perkin Elmer.

The irradiator **50** may also be equipped with an optional UV sensor for detecting the power level of UV radiation emitted by the UV-emitting bulb **20**. A type of UV power sensor suitable for use in the irradiator **50** may include is a UV light power density photodiode. In the prior art irradiator **12**, a measured output UV power level (not shown) is used as an aid for manual adjustment of UV light power output. The conventional external power supply **40** of FIG. **4** may be equipped (not shown) with a display that indicates only the percentage electric power needed for driving the magnetron **29**.

Conventional irradiators **12** are operable to employ UV-emitting bulbs **20** of different lengths and types. For a particular length and type of the UV-emitting bulb **20**, it is necessary for a user to manually employ an external UV light power detector to measure the UV light power emanating from the UV-emitting bulb **20**. Employing an on-lamp UV power detector permits automatic adjustment and display of UV power without any manual calibration.

According to an embodiment of the present invention, referring gain to FIG. **6**, one or more of the sensors **56**a-**56**n may be replaced with one or more photo detectors operable to perform several of the functions outlined above, including Kr 85 characteristic measurements, UV power detection, and a light interlock function.

The irradiator **50** illustrated in FIGS. **5**-**8**B has several advantages over the prior art irradiator **12** illustrated in FIGS. **1**-**3**. The digital serial communication wires within the serial bus cable **63** are configured primarily for carrying device configuration, command, and status transmission. As a result, data flow between the on lamp microprocessor **80** and the master computer processor **64** is relatively low, thereby permitting the use of an inexpensive standard communication protocol/cables (e.g., a CAN bus). According to an embodiment of the present invention, the on lamp microprocessor **80** is responsible for processing data received from the plurality of sensors **56**a-**56**n the IMs **54**a-**54**n locally, with only processed results sent to the master computer processor **64**.

Referring again to FIG. **6**, since all of connections between the sensors **56**a-**56**n, the IMs **54**a-**54**n and the on lamp microprocessor board **52** are local connections within the irradiator **50**, only wiring for power and serial communication within the HV cable **62** and the serial bus cable **63**, respectively, are needed between the irradiator **50** and the external power supply **60**. As a result, the HV cable **62** and the serial bus cable **63** are lower cost alternatives to the HV cable **44**. Further, the quality of signals is improved, and the distance between the irradiator **50** and the external power supply **60** may be varied. In some application, it may be desirable to shorten the HV cable **62** and the serial bus cable **63** to improve signal transmission quality and reduce cabling costs. Alternatively, it may be desirable to increase the length of the HV cable **62** and the serial bus cable **63** so that the external power supply **60** and the irradiator **50** may be located on different floors of a facility. Still further, it is relatively easy to add additional sensors to the irradiator **50** without modifying the HV cable **62** and/or serial bus cable **63** and/or any port/board within the external power supply **60**.

It is to be understood that the exemplary embodiments are merely illustrative of the invention and that many variations of the above-described embodiments may be devised by one skilled in the art without departing from the scope of the invention. It is therefore intended that all such variations be included within the scope of the following claims and their equivalents.

What is claimed is:

1. An intelligent ultraviolet curing apparatus, comprising:
an irradiator comprising a plurality of components;
a microprocessor mounted within the irradiator;
a plurality of intelligent markers in signal communication with the microprocessor and configured to monitor a plurality of components; and
a plurality of sensors in signal communication with the microprocessor and configured to sense a plurality of operating conditions associated with the plurality of components.

2. The apparatus of claim **1**, wherein the plurality of intelligent markers comprises at least one of a radio frequency identification tag and a small footprint microcontroller.

3. The apparatus of claim **2**, wherein the small footprint microcontroller is configured to be adhered to each monitored component.

4. The apparatus of claim **2**, wherein the at least one radio frequency identification tag comprises a coiled antenna mounted in a vertical plane relative to a magnetron and an internal chip mounted in a horizontal plane relative to the magnetron.

5. The apparatus of claim **1**, wherein the microprocessor is configured to communicate with each of the plurality of intelligent markers through a standard serial bus.

6. The apparatus of claim **5**, wherein the standard serial bus is the serial peripheral interface bus.

7. The apparatus of claim **1** wherein each of the plurality of intelligent markers is configured to maintain manufacturing information including at least a produced date, a part number, and a life time limit.

8. The apparatus of claim **1**, wherein the microprocessor is configured to:

recognize type and parameters of each of the plurality of components;

record accumulated working time of each of the plurality of components;

sample and process data from the plurality of sensors; and

communicate with a master computer processor via a serial bus.

9. The apparatus of claim **8**, wherein the serial bus is a CAN bus.

10. The irradiator of claim **1**, wherein the plurality of monitored components is at least one of one or more magnetrons and a primary reflector.

11. The irradiator of claim **1**, wherein the plurality of sensors is at least one of one or more temperature detectors operating as a bulb recognizer, an air pressure sensor for detecting a rate of air flow from an internal fan, a UV power sensor, and an RF detector for microwave leaking detection.

12. The apparatus of claim **1**, wherein the plurality of sensors includes at least a bulb recognizer configured to recognize a presence of Kr 85 in a microwave-powered lamp within the irradiator.

13. The apparatus of claim **12**, wherein the bulb recognizer is one of a Geiger counter, a CMOS or CCD imager operable with the microprocessor to recognize the emission spectrum of Kr 85, or a PIN diode.

14. The apparatus of claim **12**, wherein the bulb recognizer is a photo detector configured to detect an initial ignition wavelength of Kr 85.

15. The apparatus of claim **12**, wherein at least one of the plurality of components is disposable.

16. A method of operating and intelligent ultraviolet curing apparatus, comprising the steps of:

providing an irradiator comprising:

a plurality of components,

a microprocessor mounted within the irradiator, and

a plurality of intelligent markers and a plurality of intelligent markers in signal communication with the microprocessor;

monitoring, using the plurality of intelligent markers, the plurality of components; and

sensing, using the a plurality of sensors, a plurality of operating conditions associated with the plurality of components.

17. The method of claim **16**, further comprising:

reading, using the microprocessor, information stored in the intelligent markers upon initial installation and subsequent installation of a disposable component;

assigning to each of the plurality of monitored components a part ID; and

recording a start date and time for each of the monitored components.

18. The method of claim **17**, further comprising comparing a working time of a monitored component to its expected maximum life time.

19. The method of claim **18**, further comprising, when the working time approaches or exceeds a pre-established expiration date, sending a message that indicates that it is time to check or replace the monitored component.

20. The method of claim **18**, further comprising, when the working time approaches exceeds a stored life time limit, disabling the monitored component.

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