



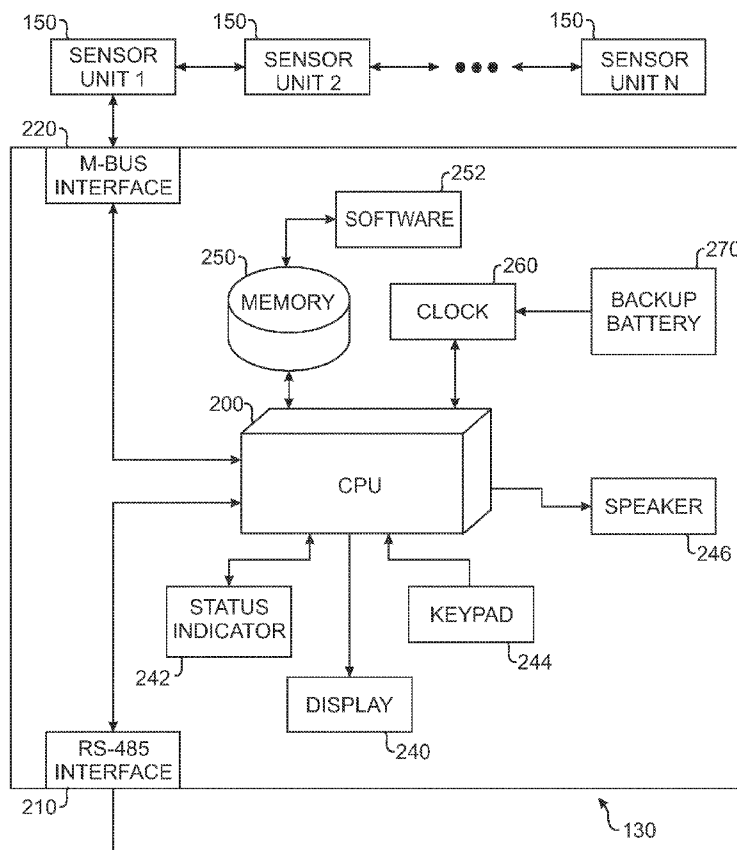
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(19) **United States**(12) **Patent Application Publication****Wang et al.**(10) **Pub. No.: US 2007/0026107 A1**(43) **Pub. Date:****Feb. 1, 2007**(54) **SYSTEM AND METHOD FOR PREDICTING
MOLD GROWTH IN AN ENVIRONMENT****Publication Classification**(75) Inventors: **Jianrong Wang**, Sugar Land, TX (US);
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(US)(51) **Int. Cl.****A23B 4/12** (2006.01)**A23L 1/31** (2006.01)(52) **U.S. Cl.** **426/55**

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TIONAL, LLC**, Tavernier, FL (US)(21) Appl. No.: **11/532,372**(22) Filed: **Sep. 15, 2006****Related U.S. Application Data**(63) Continuation-in-part of application No. 11/379,250,
filed on Apr. 19, 2006.(60) Provisional application No. 60/672,812, filed on Apr.
19, 2005.(57) **ABSTRACT**

Mold growth monitoring and prediction systems and methods for an environment are disclosed. The system includes a processing unit, a temperature sensor, and a humidity sensor. The processing unit obtains a temperature reading and a humidity reading of the environment from the sensors. The processing unit uses an algorithm to determine a probability of mold growth based on the temperature reading, the humidity reading, and a time reading. For example, the algorithm defines an envelope based on temperature, humidity, and one or more species of mold. The envelope substantially separates conditions detrimental to mold growth from conditions conducive to mold growth for the species of mold. The processing unit uses the algorithm to determine whether the temperature reading and the humidity reading fall within detrimental or conducive conditions to mold growth. Based on the conditions, the processing unit either increases or decreases the probability of mold growth.



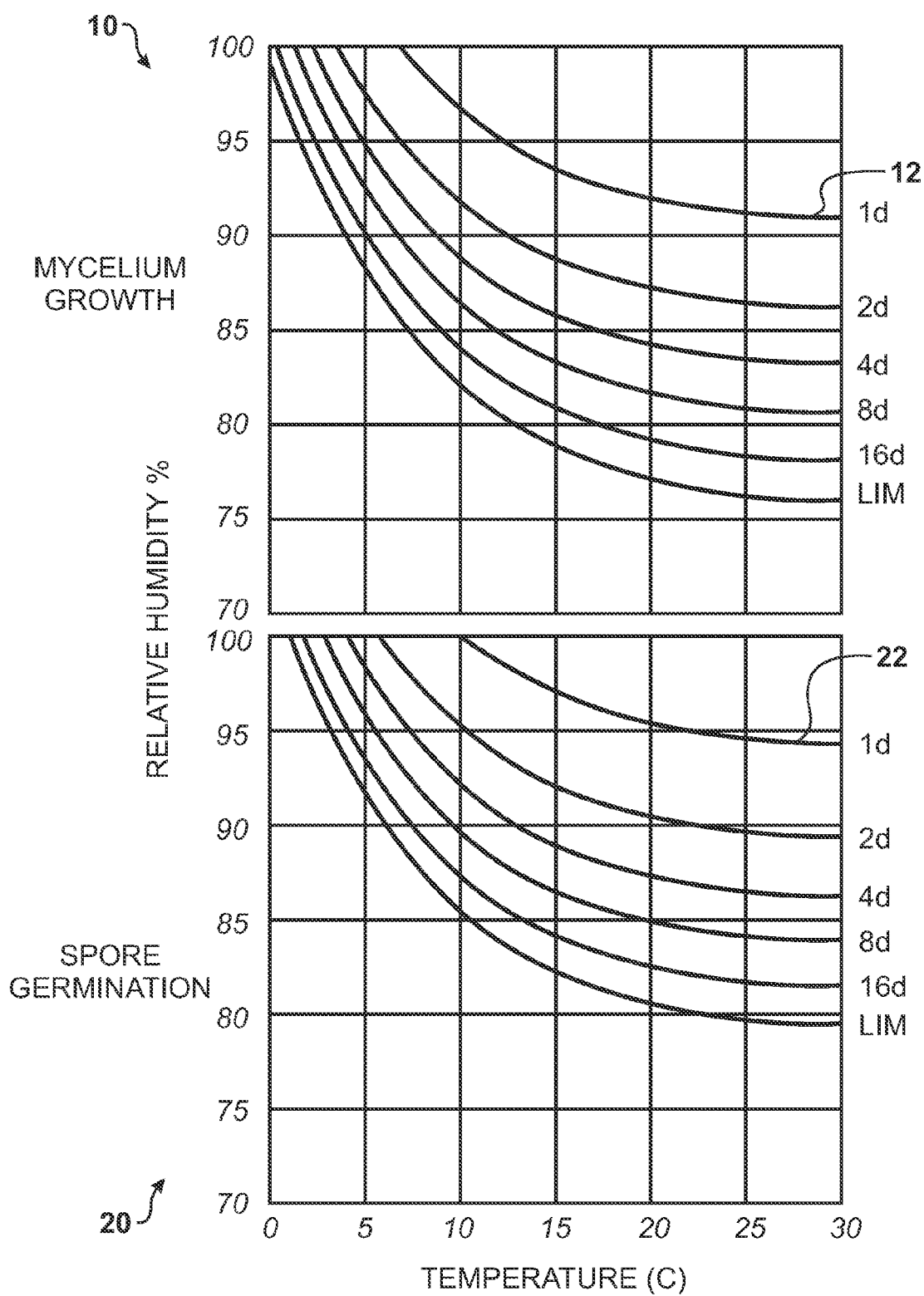


FIG. 1
(PRIOR ART)

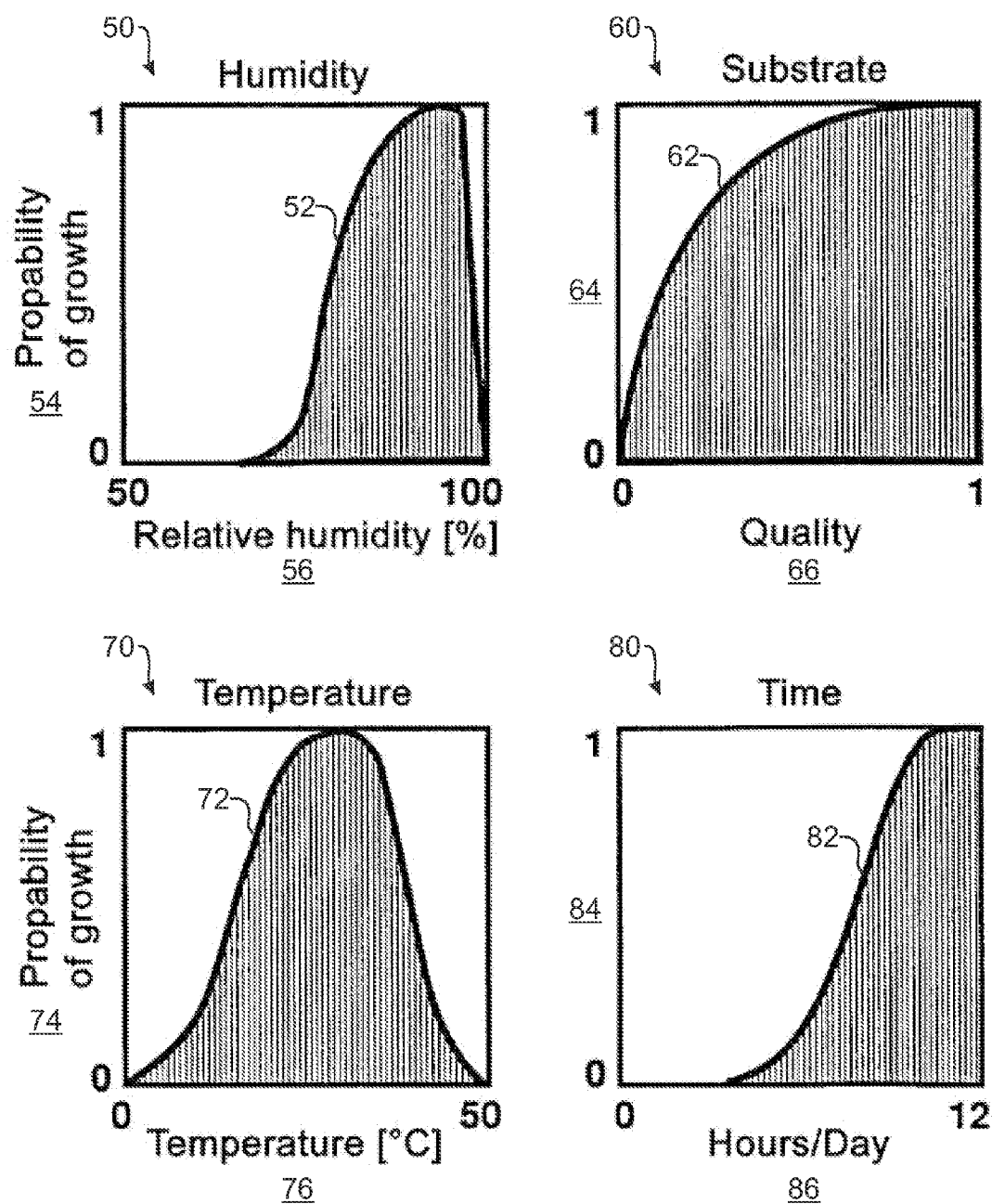


FIG. 2

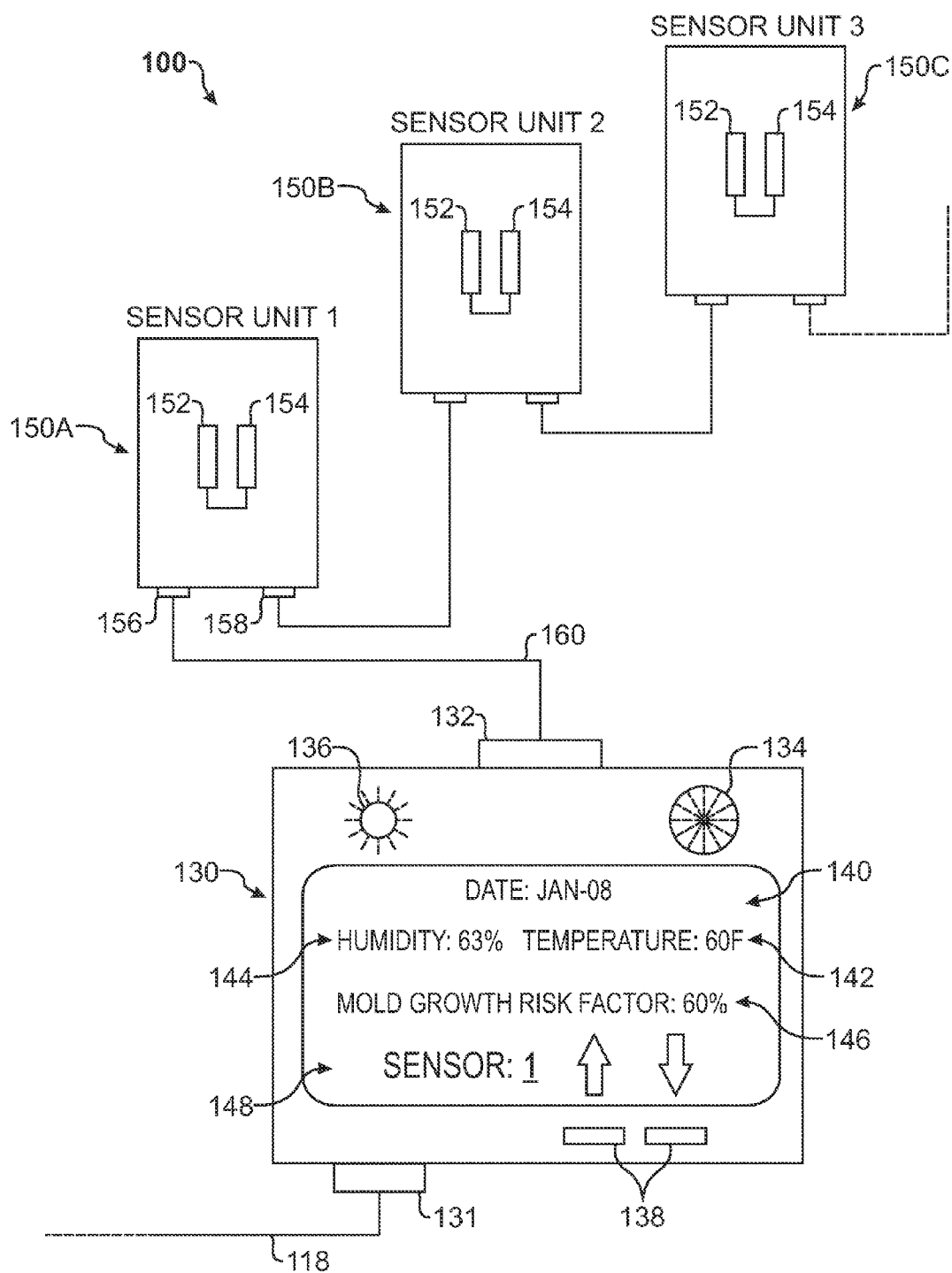


FIG. 3

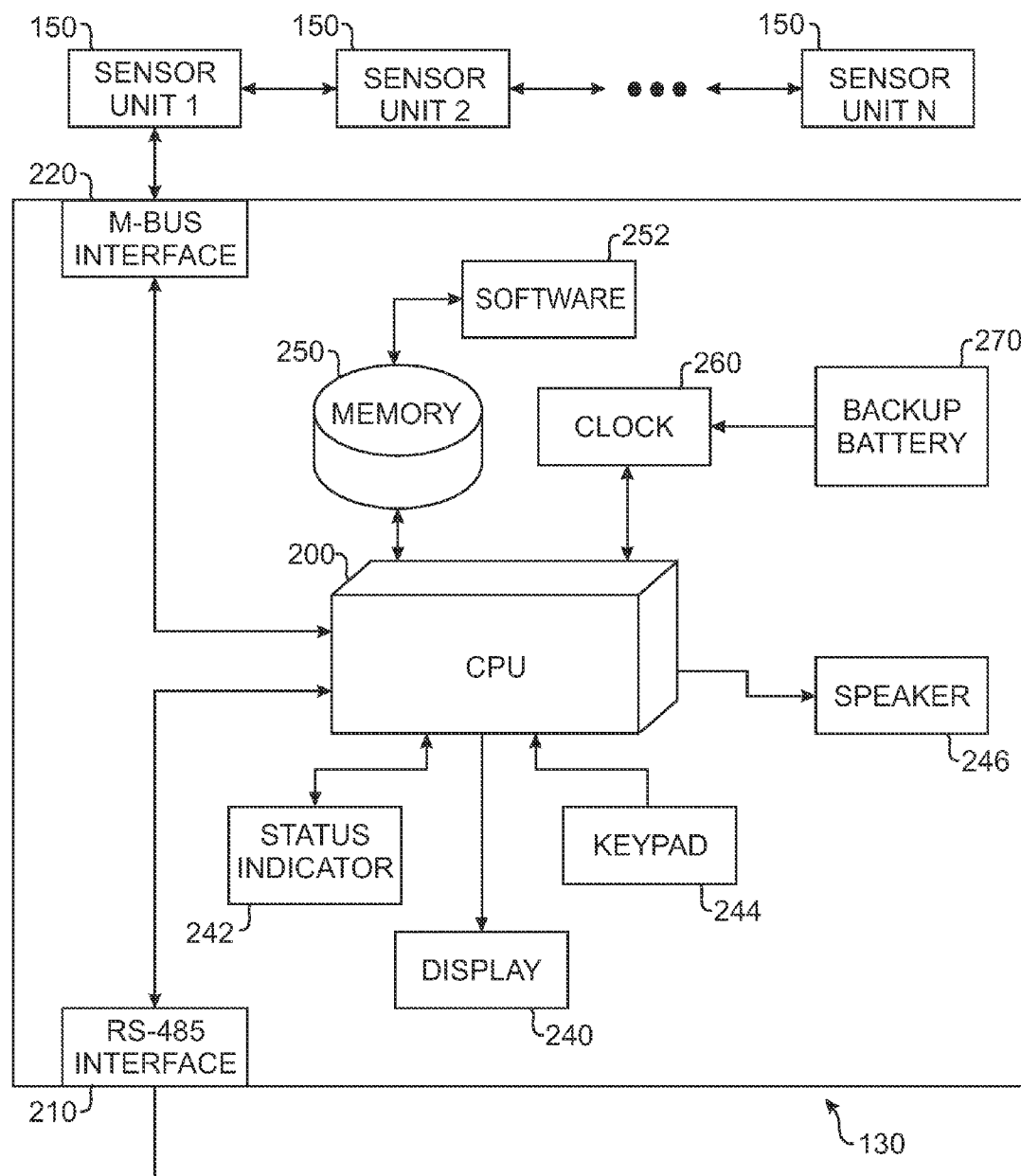


FIG. 4

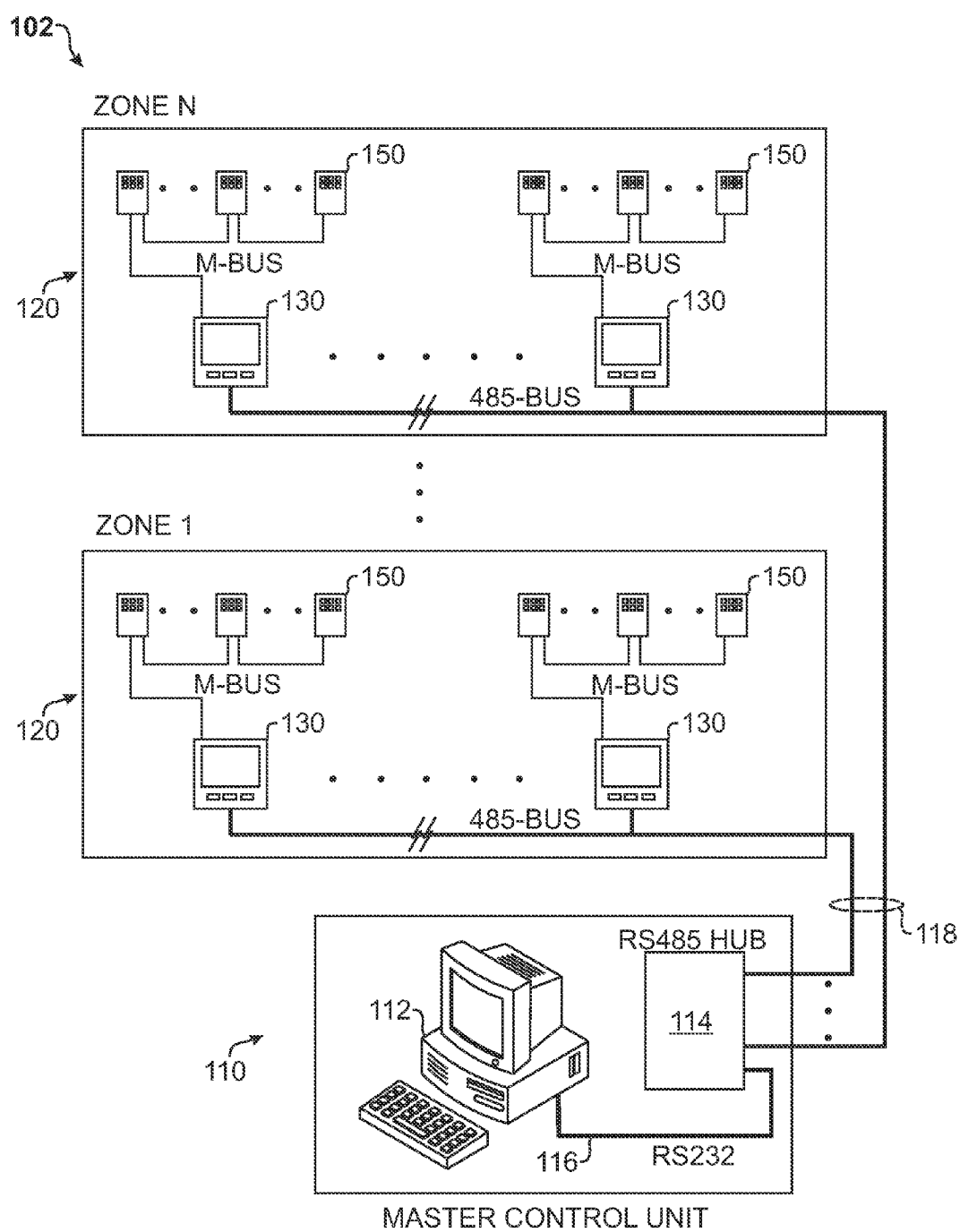


FIG. 5

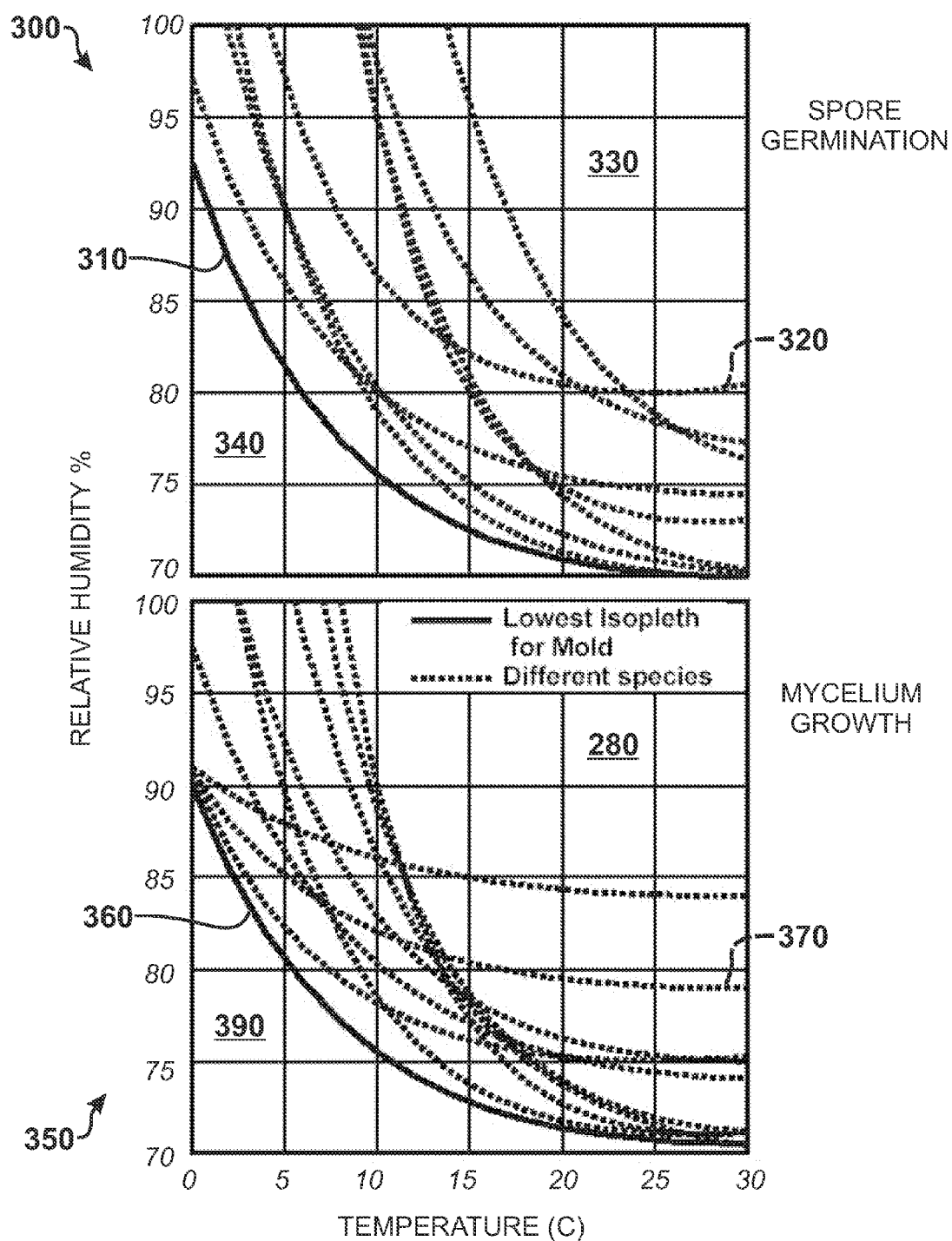


FIG. 6

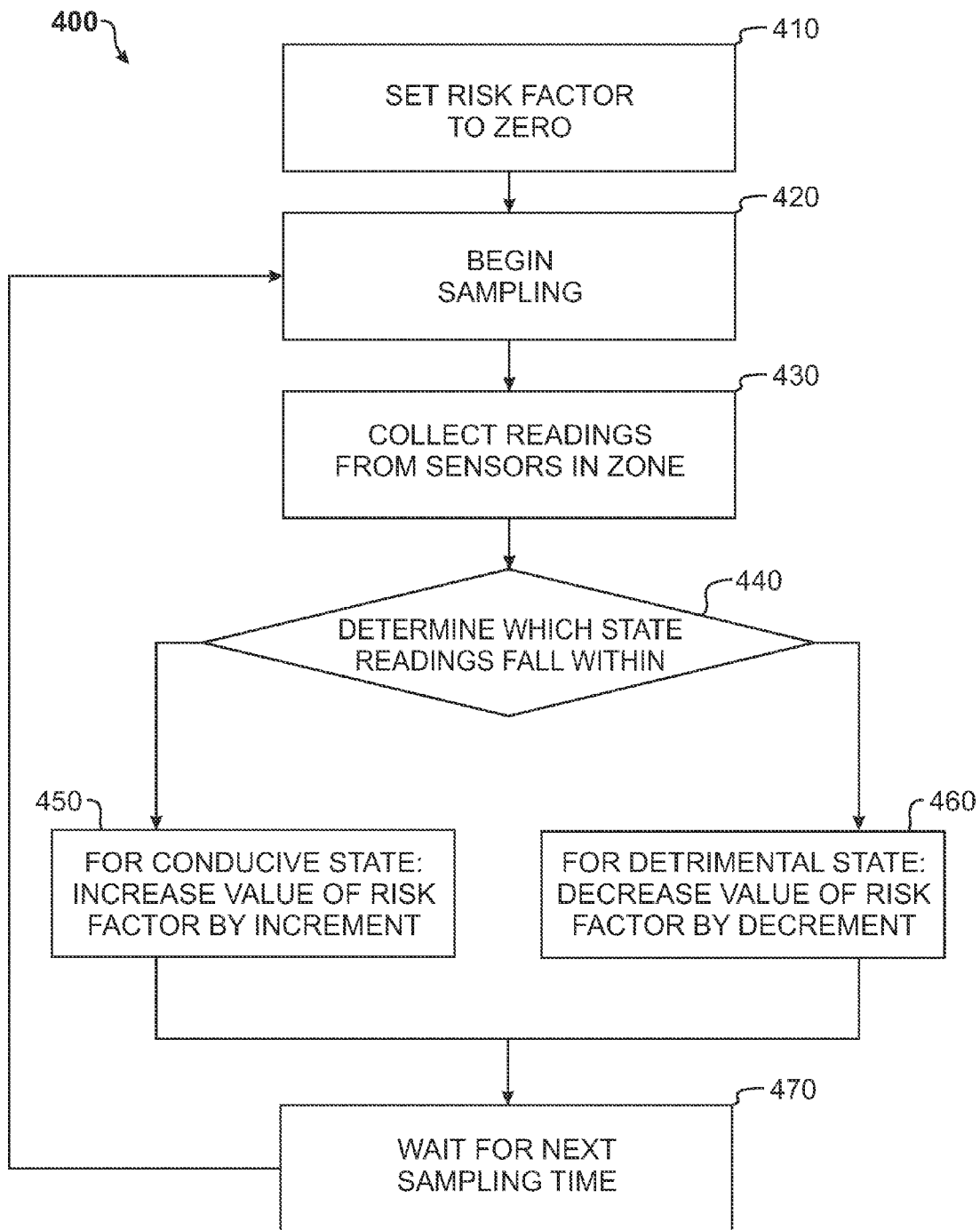


FIG. 7

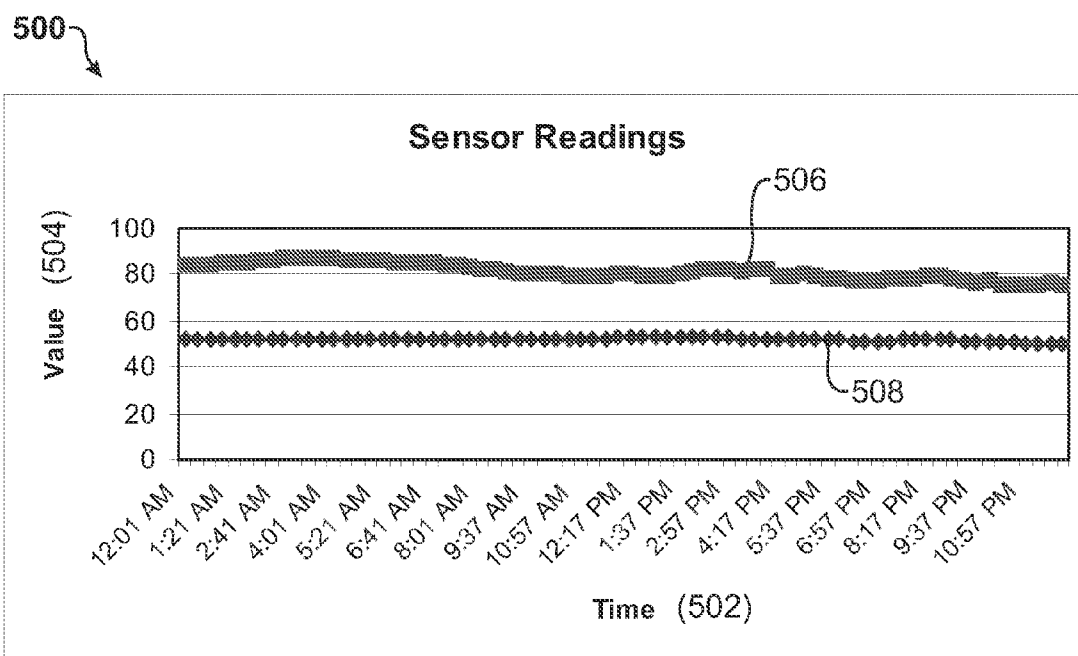


FIG. 8A

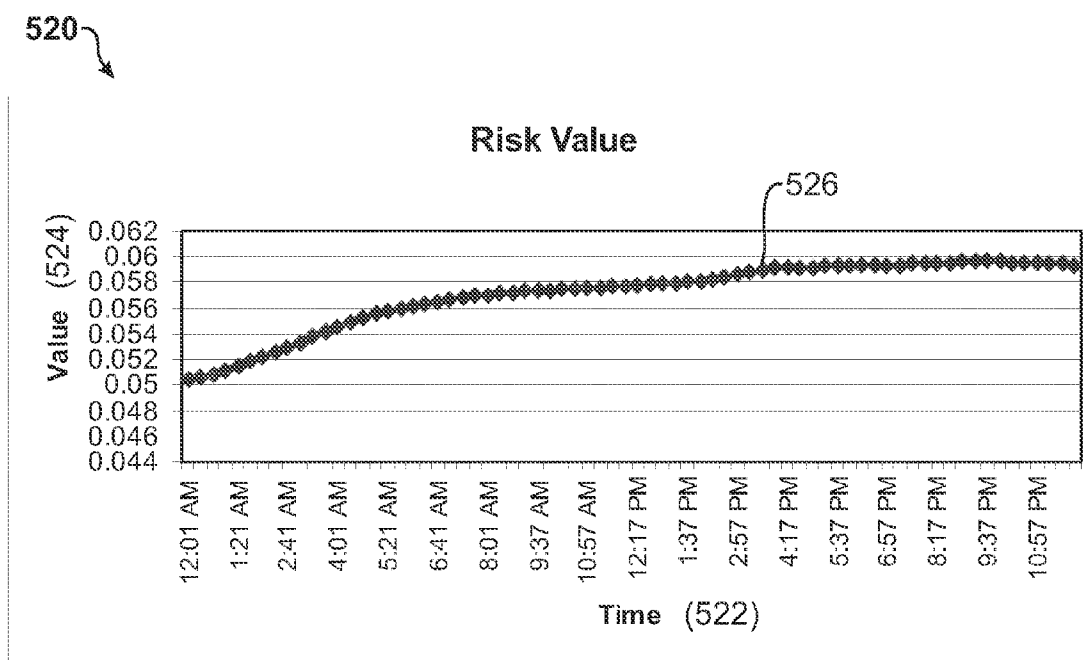


FIG. 8B

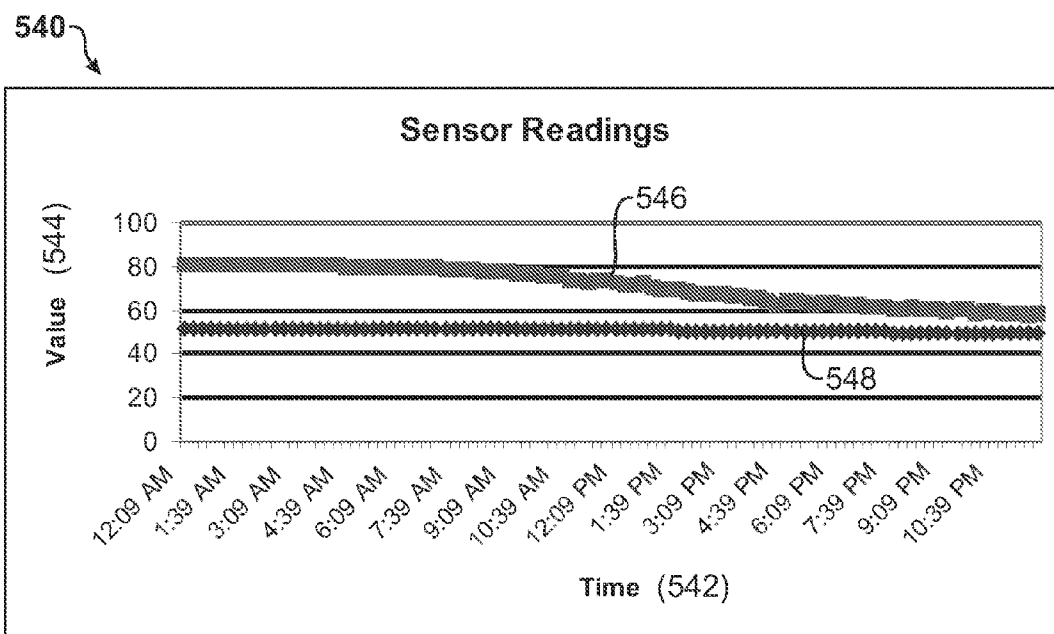


FIG. 9A

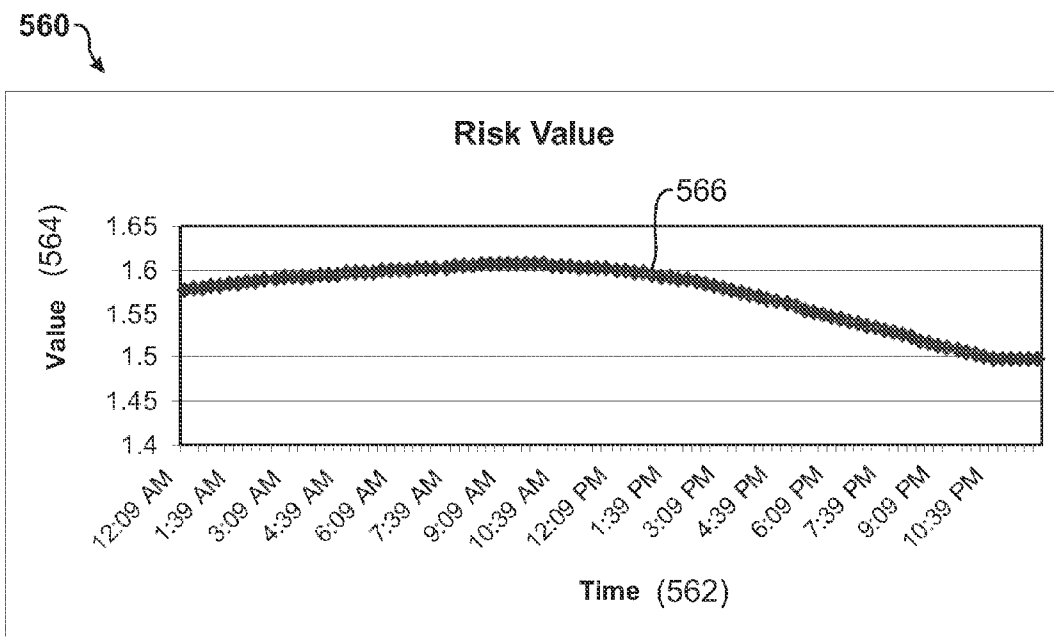


FIG. 9B

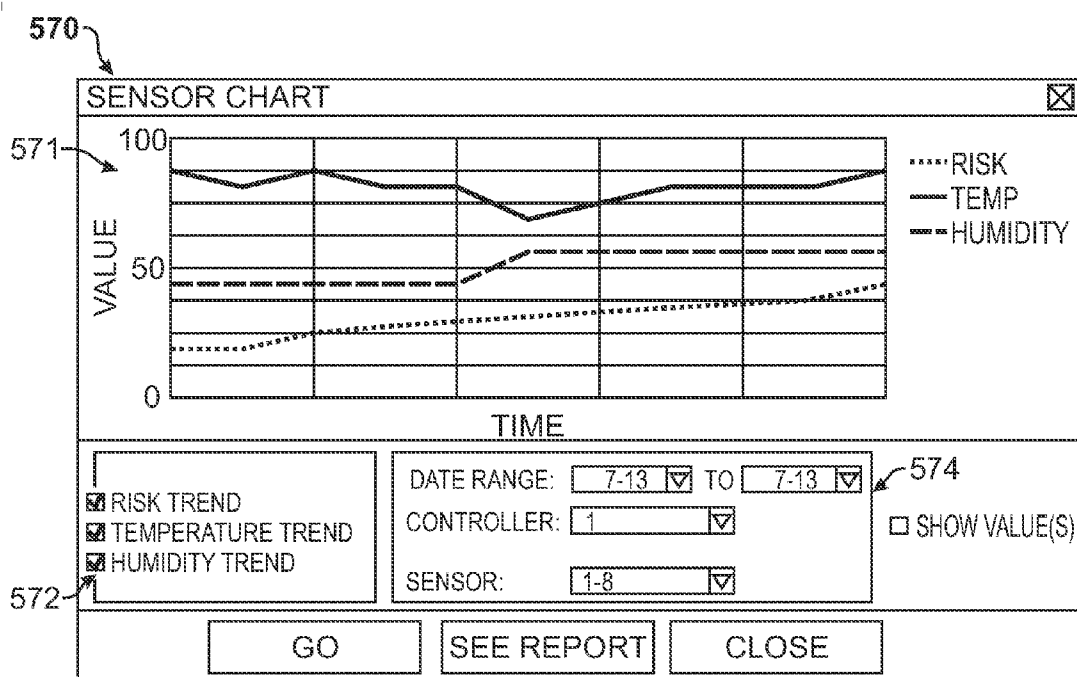


FIG. 10A

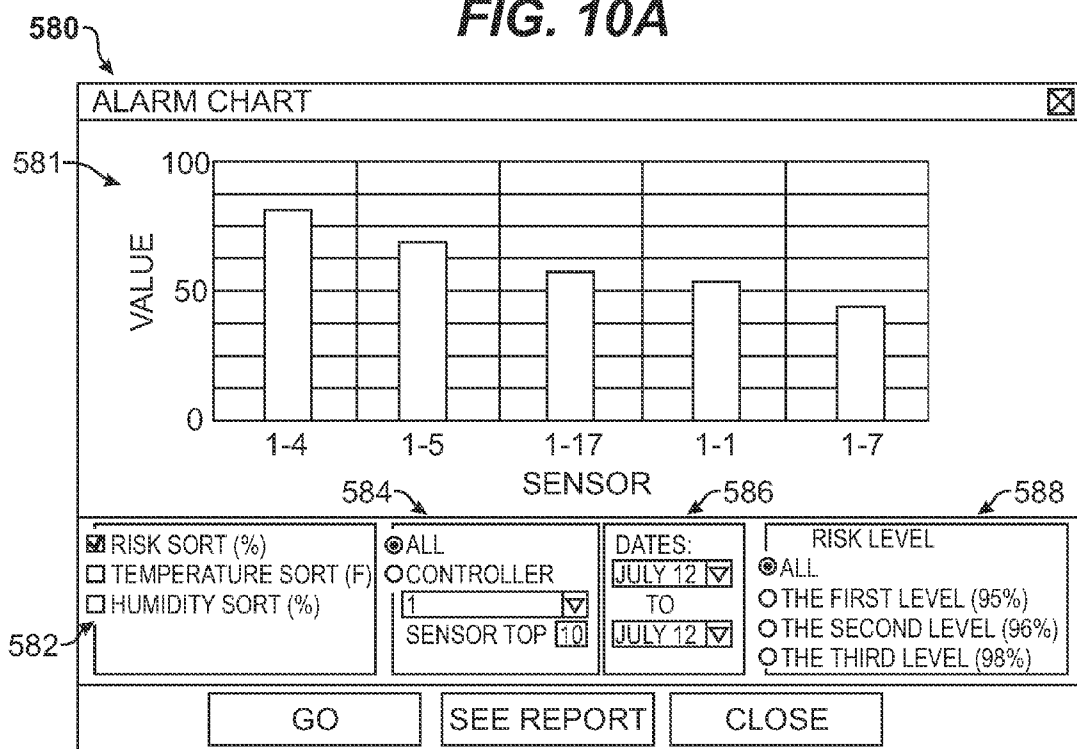


FIG. 10B

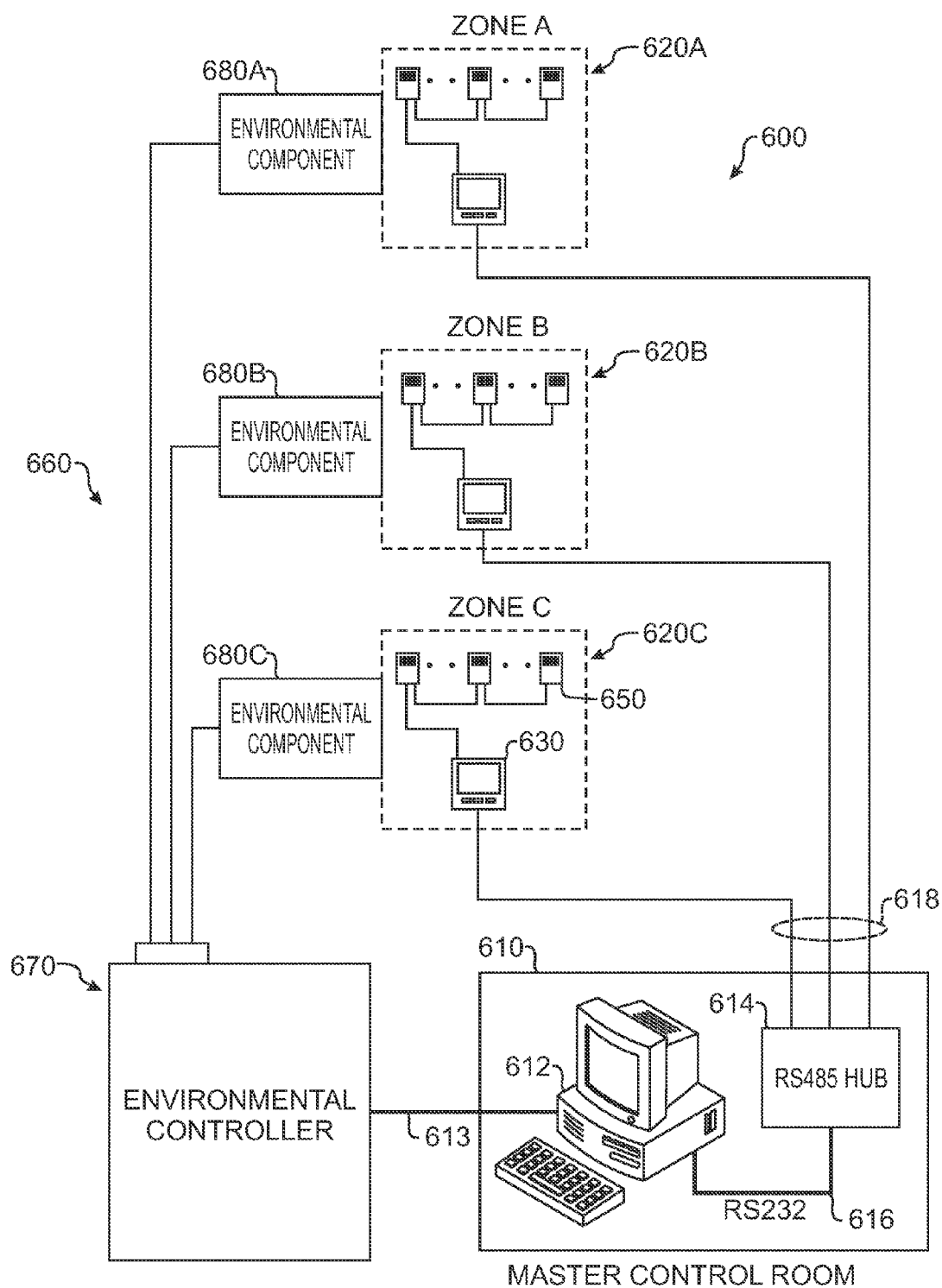


FIG. 11

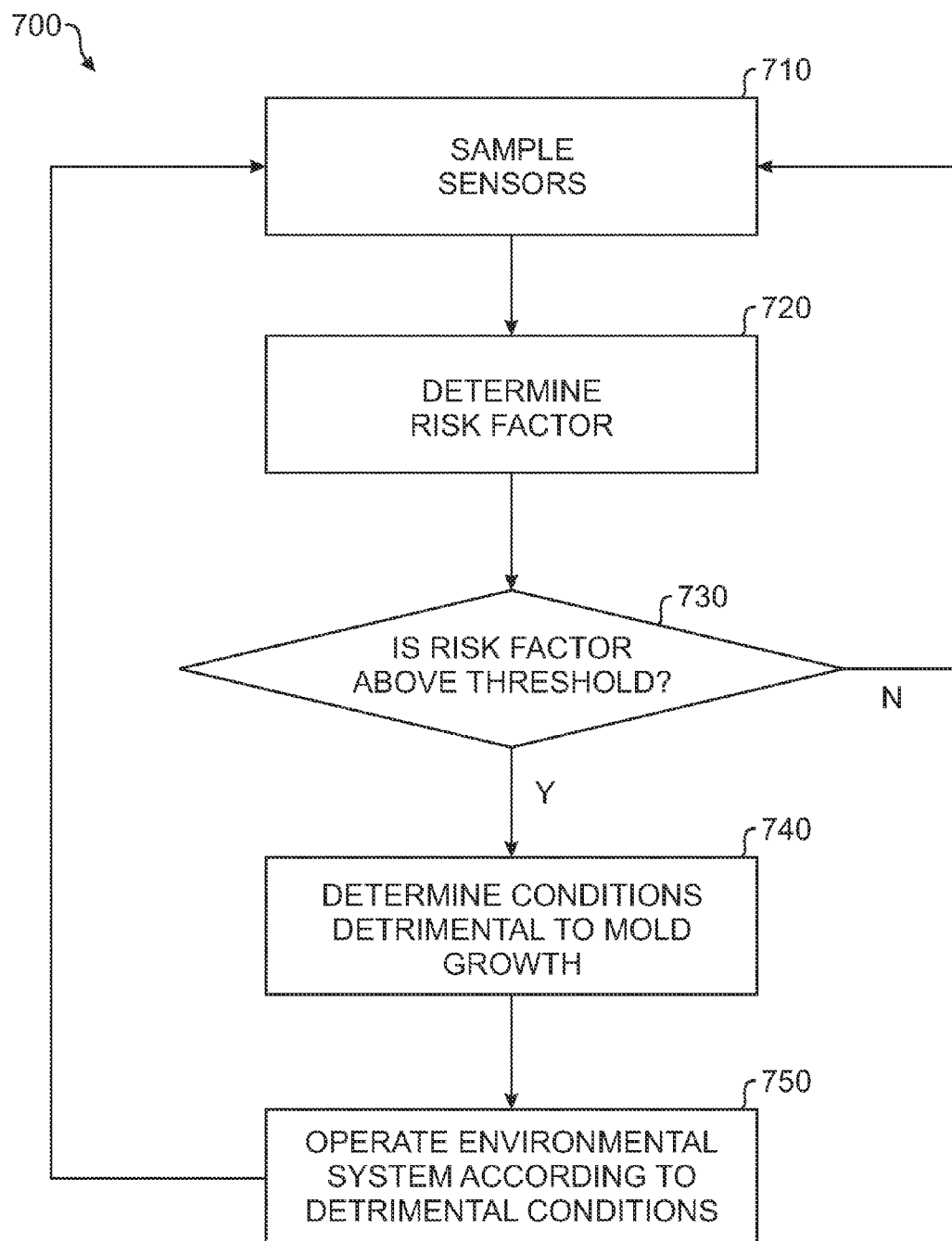


FIG. 12

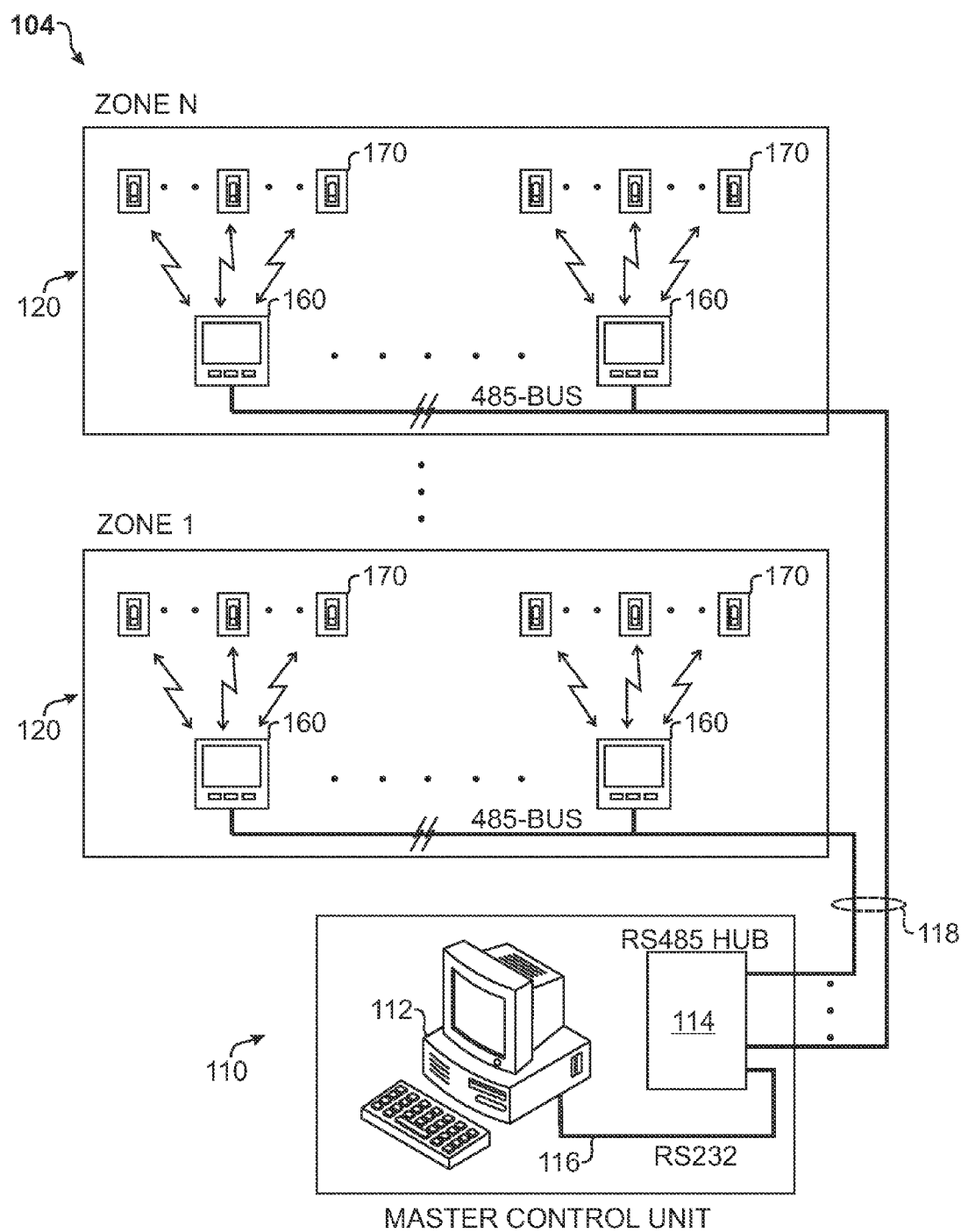


FIG. 13

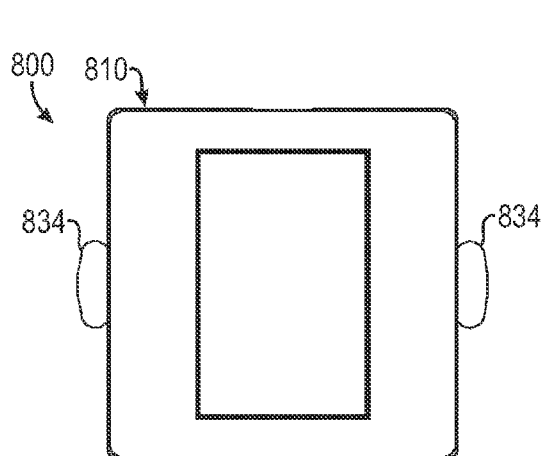


FIG. 14A

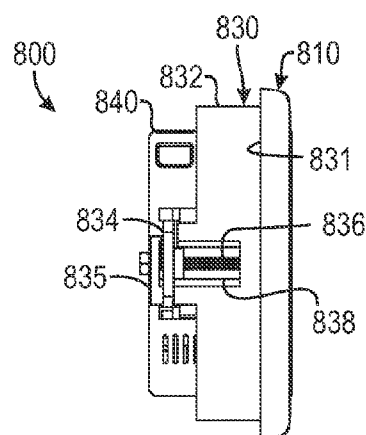


FIG. 14B

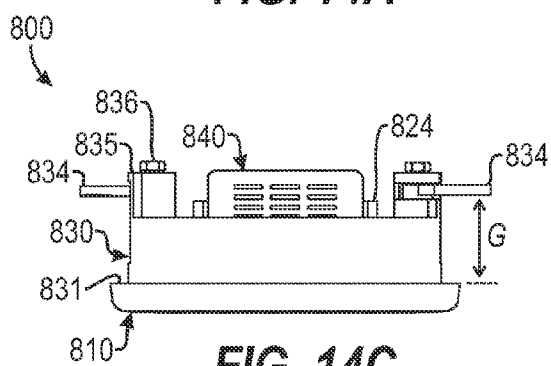


FIG. 14C

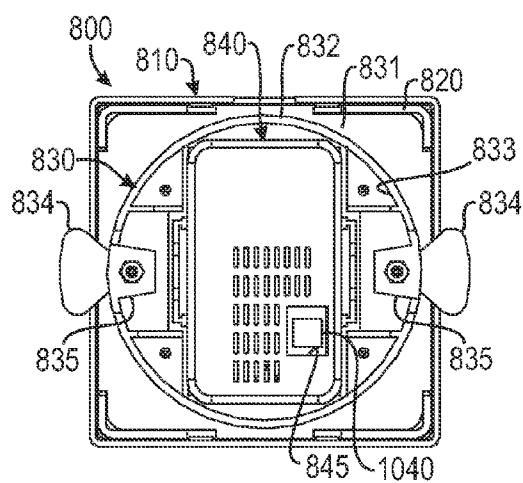


FIG. 14D

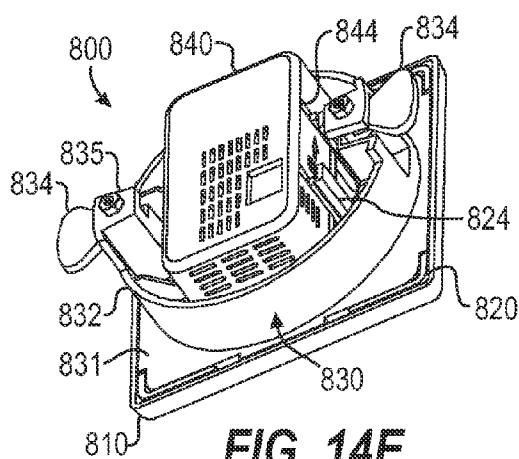


FIG. 14E

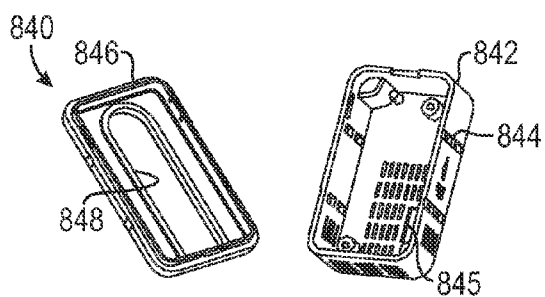


FIG. 15D

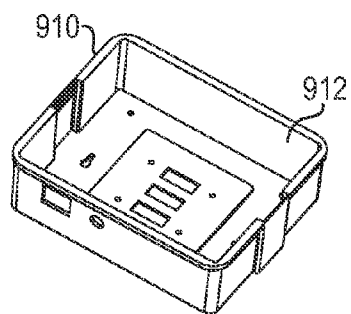


FIG. 16D

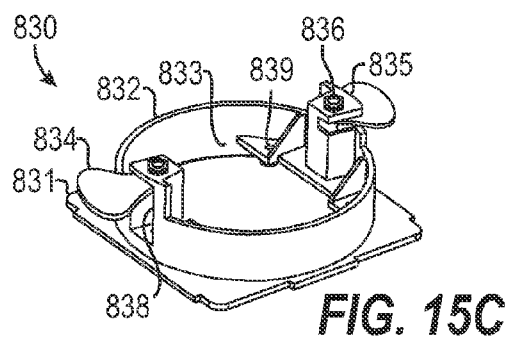


FIG. 15C

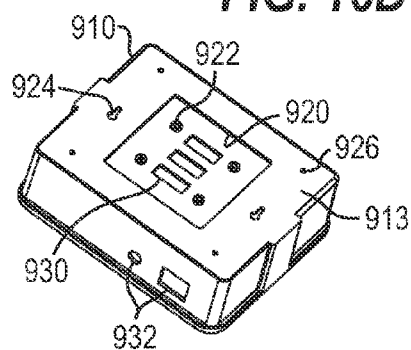


FIG. 16C

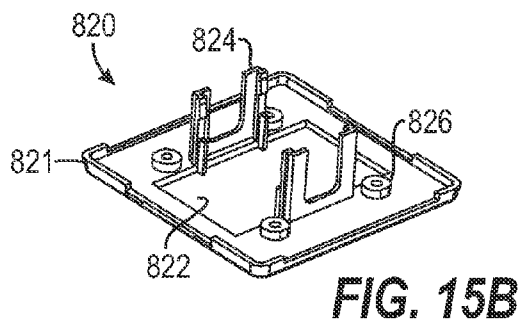


FIG. 15B

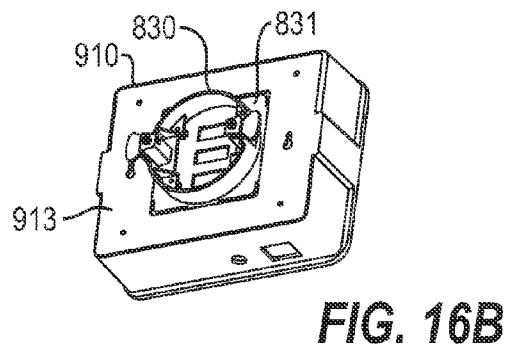


FIG. 16B

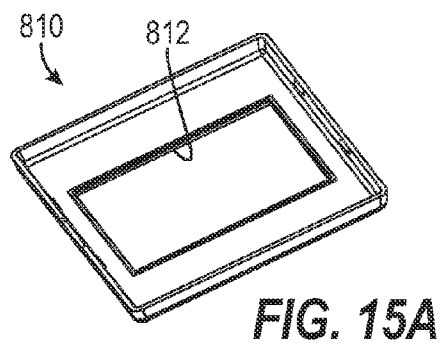


FIG. 15A

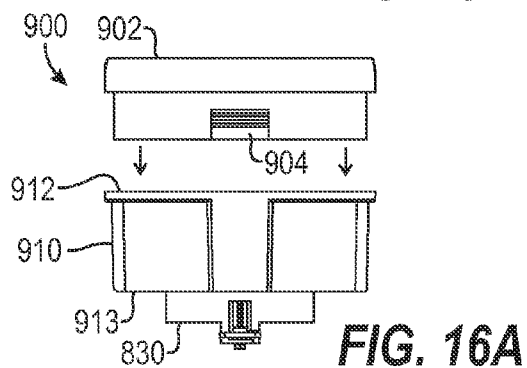


FIG. 16A

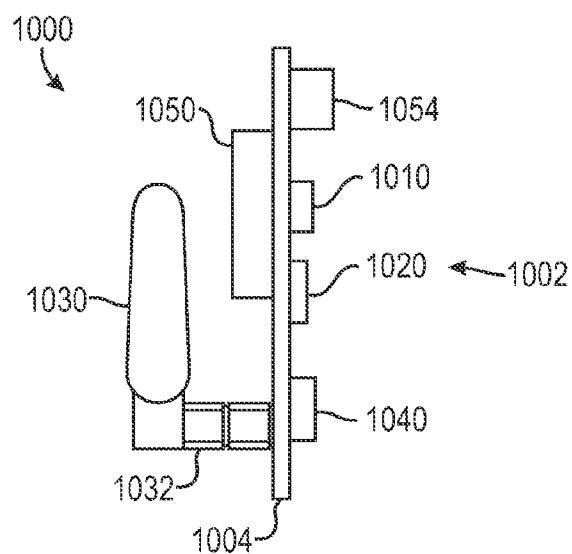


FIG. 17

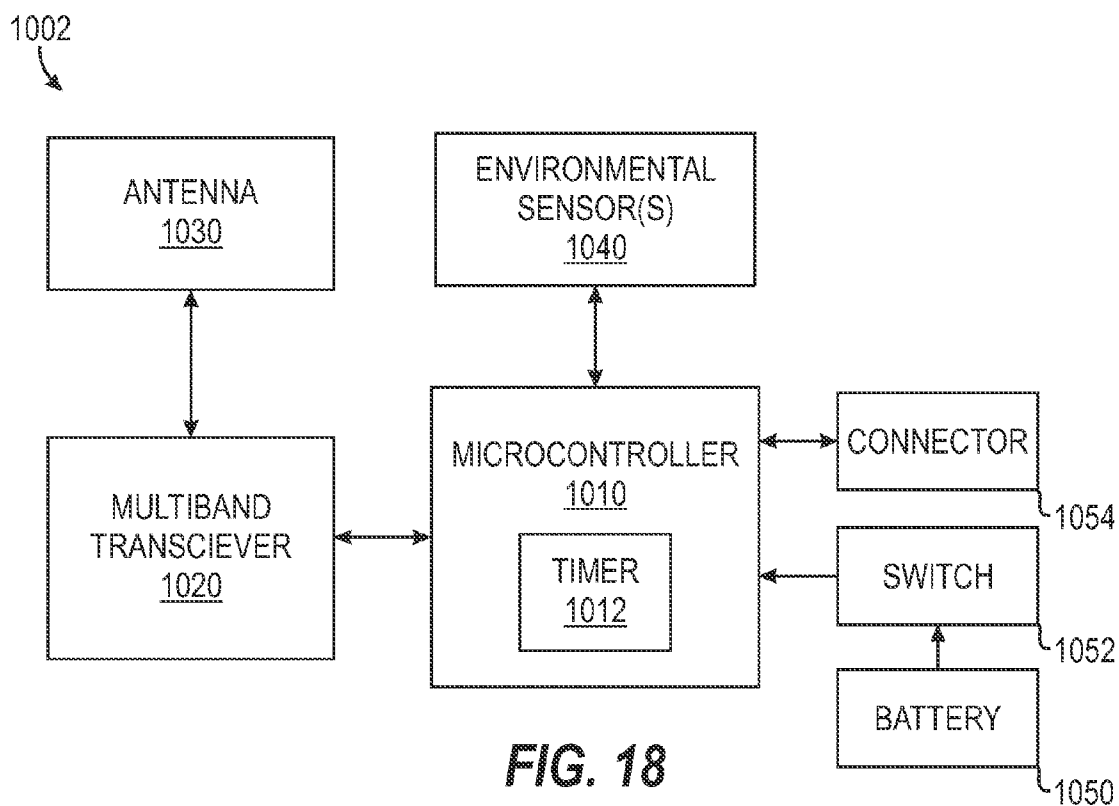


FIG. 18

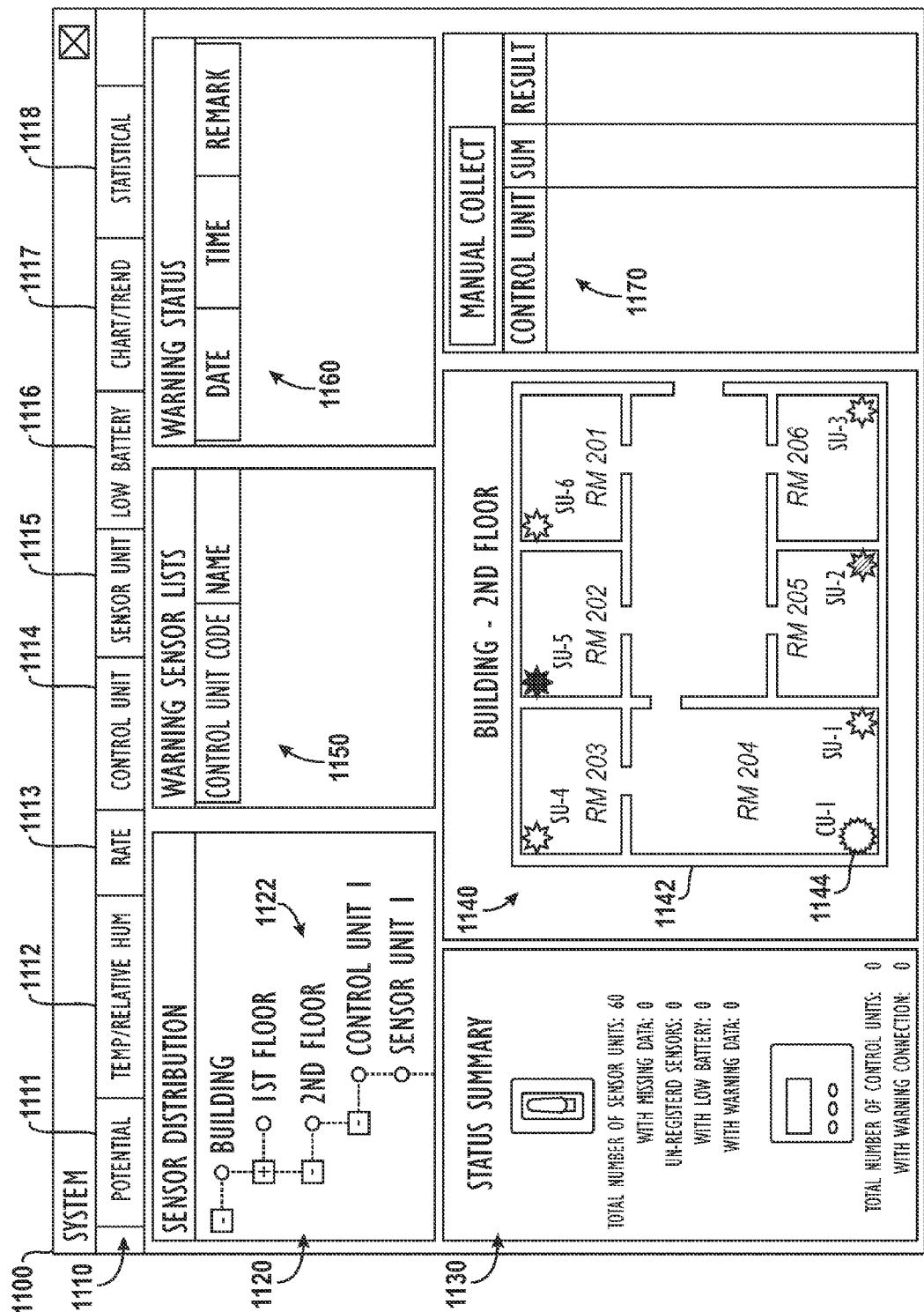


FIG. 19

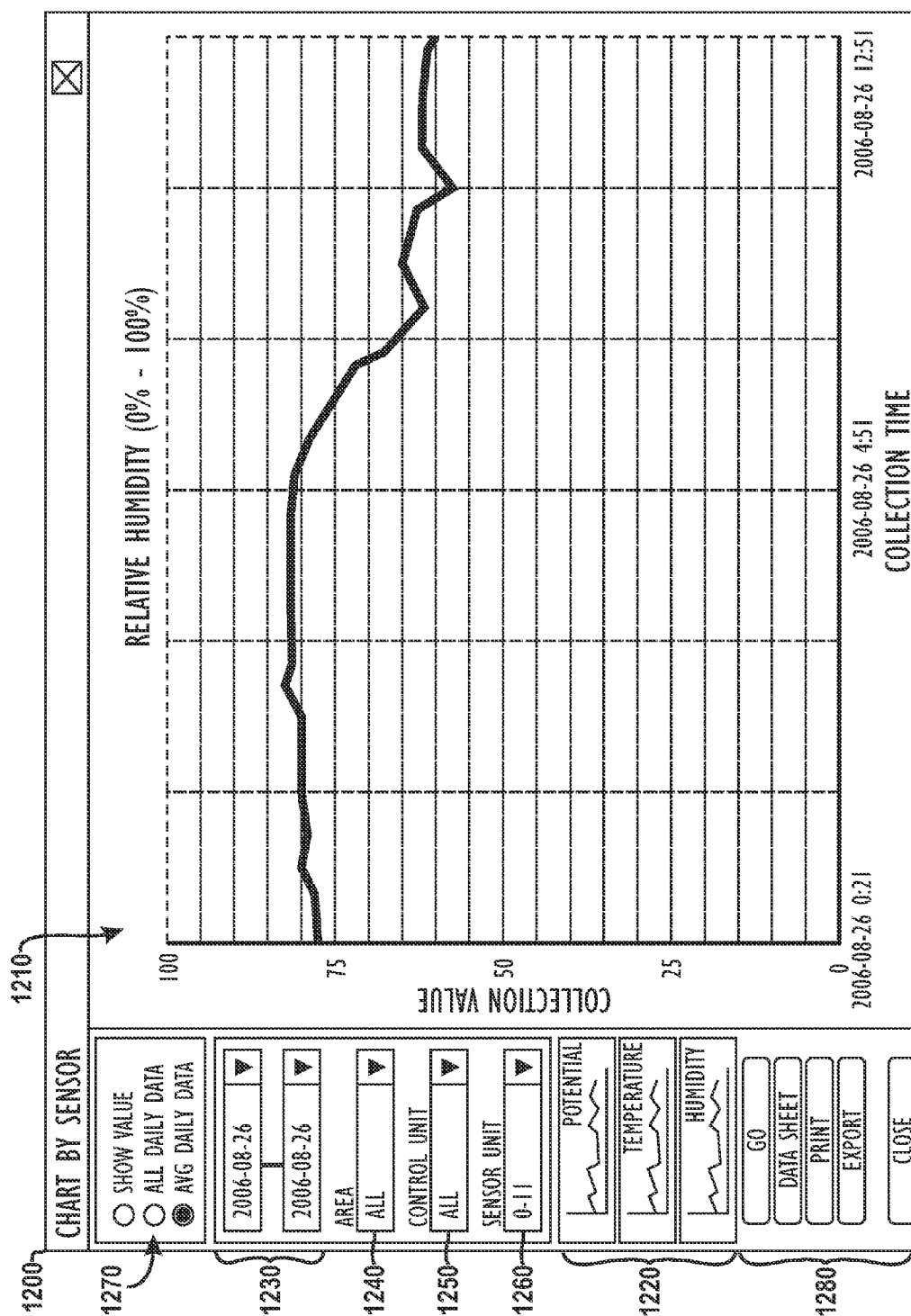


FIG. 20

1400
1300

SET UP	SYSTEM PARAMETERS		1320
★ SYSTEM PARAMETERS	APPLICATION A. RESIDENTIAL ○ SINGLE FAMILY HOME ○ CONDOMINIUM ○ APARTMENT/TOWNHOUSE B. COMMERCIAL ● OFFICE BUILDING ○ HIGH-RISE ○ SCHOOL	FUNCTION MONITOR ☒ RELATIVE HUMIDITY MONITOR ☒ TEMPERATURE MONITOR ☒ POTENTIAL MONITOR ☒ RELATIVE HUMIDITY CHANGE RATE MONITOR ☒ TEMPERATURE CHANGE RATE MONITOR	1340
★ CONTROL UNIT ADDRESSES	ALARM EVENT SETTINGS (IN ONE DAY) GENERATE ALARM IF EVENT OCCURS OVER SPECIFIED NUMBER OF TIMES IN ONE DAY CONTROL UNIT LOW POWER 5 CONTROL UNIT COMMUNICATION BREAK 5 CONTROL UNIT CRC ERROR 5 SENSOR LOST DATA 5 SENSOR TEMPERATURE WARNING 4 SENSOR REL. HUM. WARNING 2 SENSOR TEMPERATURE CHANGE RATE WARNING 5 SENSOR REL. HUM. CHANGE RATE WARNING 5 SENSOR POTENTIAL WARNING 3 SENSOR LOW BATTERY WARNING 5		
★ AREA CODE	RANGE AND CHANGE RATE 20 < RELATIVE HUMIDITY (%) < 95 32 < TEMPERATURE (F) < 99 40 % LOW POTENTIAL (1-100%) 60 % MIDDLE POTENTIAL (1-100%) 80 % HIGH POTENTIAL (1-100%) 40 %/HOUR < RELATIVE HUMIDITY 20 F/HOUR < TEMPERATURE		
★ SENSOR ADDRESSES	DEFAULT OK EXIT		
★ CLEAR SENSOR			

FIG. 21

SYSTEM AND METHOD FOR PREDICTING MOLD GROWTH IN AN ENVIRONMENT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This is a continuation-in-part of U.S. patent application Ser. No. 11/379,250, filed 19 Apr. 2006, which is incorporated herein by reference, to which priority is claimed, and which claims priority to U.S. Provisional Application Ser. No. 60/672,812, filed 19 Apr. 2005.

FIELD OF THE DISCLOSURE

[0002] The subject matter of the present disclosure generally relates to a system and method for predicting mold growth in an environment and more particularly relates to a system and method for monitoring temperature and humidity conditions of an environment and determining a probability of mold growth in the environment to produce a mold warning and/or to operate an environmental system to decrease the potential mold growth.

BACKGROUND OF THE DISCLOSURE

[0003] Molds are members of the kingdom fungi and live extensively throughout nature. Molds can grow indoors and can cause various health risks or environmental damage. Molds have three phases of growth, which include spore germination, mycelium growth, and sporulation. Four conditions (temperature, humidity, nutrients, and time) contribute to the potential for mold growth in an environment. Typical indoor environments where mold grows include moist basements, bathrooms, kitchens, or any place where moisture is present. Mold only requires a few nutrients and can grow on various substrates, including, but not limited to, wood, ceiling tiles, gypsum wallboard (sheetrock), cardboard, paper, cellulosic surfaces, carpet, etc.

[0004] The influence of temperature, relative humidity, nutrients, and time on mold growth is known in the art. Referring to graphs 10 and 20 of FIG. 1, for example, isopleths 12 and 22 of spore germination for various molds are shown as functions of temperature and relative humidity. The isopleths 12 and 22 are determined from experimental measurements of spore germination for species of mold on a given substrate. The isopleths are arranged according to time (e.g., days of 1d, 2d, 4d, 8d, 16d, and LIM) in which a particular level of spore germination occurs (e.g., the length of time after which the first germination occurs at a given temperature and relative humidity). The lowest isopleths (LIM) represent limits of the conditions conducive to spore germination for the given substrate. Below these limits, spore germination does not occur for the mold at the temperature and relative humidity levels.

[0005] One technique known in the art to detect mold involves sampling the air in an environment to identify the various types and quantities of mold spores interspersed in the air. A collection device obtains a predetermined amount of air from the environment, and the sample is then analyzed in a laboratory. Another technique known in the art to detect mold involves taking direct samples (e.g., swab or tape-lifted samples) of suspect surfaces to confirm and identify the presence of mold. Direct sampling identifies the types of mold found, but not a spore count. Again, the sample is then analyzed in a laboratory. To detect hidden mold, it is known

in the art for an inspector to use a hygrometer, a boroscope (fiber optics), and a moisture meter to find hidden mold behind walls, ceilings and floors, for example, and to determine areas of potential mold growth and continuing moisture penetration.

[0006] Unfortunately, the prior art techniques are only effective at detecting mold after it is allowed to develop. Furthermore, there are thousands of species of molds, and the prior art techniques are typically designed to detect only specific species of mold. Therefore, a need exists in the art for a system and method to determine proactively the probability of growth of one or more species of mold in an environment and to control proactively the conditions of the environment to reduce or reverse mold growth.

[0007] The subject matter of the present disclosure is directed to overcoming, or at least reducing the effects of, one or more of the problems set forth above.

SUMMARY OF THE DISCLOSURE

[0008] Mold growth prediction systems and methods for an environment are disclosed. The system includes a processing unit, a temperature sensor, and a humidity sensor. The processing unit has an interface for obtaining a temperature reading and a humidity reading of the environment from the sensors. The processing unit also has a memory for storing an algorithm to determine a probability of mold growth and has a processor communicatively coupled to the interface and the memory. The processor processes the temperature reading, the humidity reading, and a time reading according to the algorithm to determine the probability of mold growth. For example, the algorithm defines an envelope based on temperature, humidity, and one or more species of mold. The envelope substantially separates conditions detrimental to mold growth from conditions conducive to mold growth for the species of mold. The processor uses the algorithm to determine whether the temperature reading and the humidity reading fall within detrimental or conducive conditions to mold growth. Based on the conditions, the processor either increases or decreases the probability of mold growth, and the processor can then control an environmental system to address the mold growth.

[0009] In one embodiment, the mold growth prediction system includes at least one sensor unit and at least one processing unit. The sensor unit and the processing unit each have wireless devices for communicating data therebetween. The wireless sensor unit can include control circuitry having a timer, wireless communication circuitry communicatively coupled to the control circuitry, and one or more sensors communicatively coupled to the control circuitry to obtain temperature data and humidity data. In one embodiment, the sensor unit can be mountable to a hole in a wall using a mounting assembly. The mounting assembly has a base member defining a passage therethrough and having sides clamping to a hole in a wall. The assembly also has a holding member attachable to the base member and having a plurality of legs that attach to a housing containing the electronics of the sensor unit.

[0010] The foregoing summary is not intended to summarize each potential embodiment or every aspect of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The foregoing summary, preferred embodiments, and other aspects of subject matter of the present disclosure

will be best understood with reference to a detailed description of specific embodiments, which follows, when read in conjunction with the accompanying drawings, in which:

[0012] FIG. 1 illustrates generalized isopleths of spore germination and mycelium growth for one kind of mold.

[0013] FIG. 2 illustrate a schematic view of conditions (relative humidity, temperature, quality, and time), which can be used to determine the probability of growth for mold.

[0014] FIG. 3 illustrates one embodiment of a mold growth prediction system according to certain teachings of the present disclosure.

[0015] FIG. 4 illustrates the monitoring unit for the mold growth prediction system of FIG. 3.

[0016] FIG. 5 illustrates another embodiment of a mold growth prediction system for an environment according to certain teachings of the present disclosure.

[0017] FIG. 6 illustrates graphs showing isopleths for different species of mold.

[0018] FIG. 7 illustrates an embodiment of the operation of the disclosed prediction system.

[0019] FIGS. 8A-8B graphically illustrate examples of sensor readings and calculated values for mold growth risk factor.

[0020] FIGS. 9A-9B graphically illustrate additional examples of sensor readings and calculated values for mold growth risk factor.

[0021] FIGS. 10A-10B illustrate example screens of a user interface for a master control computer.

[0022] FIG. 11 illustrates one embodiment of an integrated monitoring and environmental system according to certain teachings of the present disclosure.

[0023] FIG. 12 illustrates one embodiment of the operation of integrated monitoring and environmental system of FIG. 11.

[0024] FIG. 13 illustrates yet another embodiment of a mold growth prediction system according to certain teachings of the present disclosure.

[0025] FIGS. 14A-14E illustrate various views of one embodiment of a wireless sensor mounting assembly for the mold growth prediction system of FIG. 13.

[0026] FIGS. 15A-15D respectively illustrate isolated views of a face, a holder, a mounting member, and a sensor enclosure of the wireless sensor mounting assembly of FIGS. 14A-14E.

[0027] FIGS. 16A-16D illustrate one embodiment a control unit for the mold growth prediction system of FIG. 13.

[0028] FIG. 17 illustrates a side view of one embodiment of a sensor unit for use with the sensor enclosure of FIG. 15D.

[0029] FIG. 18 schematically illustrates one embodiment of electronic components for a sensor unit for the mold growth prediction system of FIG. 13.

[0030] FIG. 19 illustrates one embodiment of a screen for a graphical user interface of the disclosure mold growth prediction system of FIG. 13.

[0031] FIG. 20 illustrates one embodiment of a graph screen for the graphical user interface of FIG. 19.

[0032] FIG. 21 illustrates one embodiment of a parameter screen for the graphical user interface of FIG. 19.

[0033] While the disclosed systems and methods are susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and are herein described in detail. The figures and written description are not intended to limit the scope of the inventive concepts in any manner. Rather, the figures and written description are provided to illustrate the inventive concepts to a person skilled in the art by reference to particular embodiments, as required by 35 U.S.C. § 112.

DETAILED DESCRIPTION

[0034] Referring to FIG. 2, graphs schematically show how four conditions (i.e., relative humidity, temperature, quality, and time) that influence mold growth can be used to determine the probability of mold growth. In the humidity graph 50, for example, curve 52 shows how the probability 54 of mold growth corresponds to relative humidity 56. As shown by curve 52, the probability 54 is practically non-existent when the relative humidity 56 is close to fifty-percent, but the probability 54 increases as the relative humidity 56 is closer to one-hundred percent. At a level of relative humidity 56 quite close to one-hundred percent, the probability 52 of mold growth decreases sharply.

[0035] In the substrate graph 60, for example, curve 62 shows how the probability 64 of mold growth corresponds to the quality 66 of the substrate on which the mold grows. The quality 66 of the substrate refers to the quality of the material that the mold can use for nutrients. Typical substrates include carpet, wood, wallpaper, etc. As shown by curve 62, the probability 64 for growth increases with the quality 66 of the substrate.

[0036] In the temperature graph 70, for example, curve 72 shows how the probability 74 of mold growth corresponds to the temperature 76 of the environment. As shown by curve 72, the probability 74 for mold growth exhibits a bell-shape, where the highest probability 74 occurs somewhere between 0 and 50-degrees Celsius and the probability 74 tapers towards both upper and lower temperatures.

[0037] In the time graph 80, for example, curve 82 shows how the probability 84 of mold growth increases with the passage of time 86 (e.g., hours or days). It will be appreciated that the various graphs 50, 60, 70, and 80 are interdependent such that one condition (e.g., relative humidity) could alter the probability curve of another condition (e.g., time). For example, a high probability due to a conducive level of relative humidity will result in an accelerated time curve for mold growth.

[0038] To determine the probability of mold growth in an environment, the systems and methods of the present disclosure incorporate experimental data similar to that shown in FIG. 2. The experimental data captures the interdependence of relative humidity, temperatures, substrates, and time for various species of mold. The types of substrates may be particular for a given environment, or a general nutrient level of substrate may be assumed based on the circumstances. Isopleths, such as discussed below with

reference to FIG. 6, for the various species are produced from the experimental data. The information in these isopleths is then analyzed by numerical techniques and then incorporated into an algorithm that can be implemented electronically by a mold prediction system.

[0039] Referring to FIG. 3, an embodiment of a mold growth prediction system 100 according to certain teachings of the present disclosure is illustrated. The prediction system 100 includes one or more monitoring units 130—only one of which is shown in FIG. 3. The prediction system 100 also includes a plurality of sensor units 150 that are distributed throughout an environment. The monitoring unit 130 is communicatively coupled to the sensor units 150, and the monitoring unit 130 uses the sensor units 150 to monitor for conditions (e.g., temperature and relative humidity) conducive to the growth of mold in the environment over intervals of time. (In one embodiment, the temperature and relative humidity readings are taken approximately every 30-minutes, which is believed to generate a sufficient amount of historical data without too much power consumption.) As discussed herein, there is an envelope of conditions conducive to mold growth. If the monitored conditions of a zone or area near sensor units 150 in the environment are within the envelope, then the risks for mold growth are increased for that particular zone. If, however, the monitored conditions of the zone or area are outside the envelope, then the risks for mold growth are reduced for that particular zone or area.

[0040] In the present embodiment, the monitoring unit 130 includes an interface 132, a speaker 134, a warning indicator 136, control keys 138, and a display panel 140. The interface 132 is preferably based on the Meter-Bus (“M-Bus”) protocol, which is a European standard used for remotely reading heat-meters and various sensors. The M-Bus offers a number of advantages, including a reduced wiring requirement, individually addressable sensors, and short reading intervals. The interface 132 is communicatively coupled to an input connection terminal 156 of a first of the sensor units 150. This input connection terminal 156 can include connections for ground, VCC, and data connections. An output connection terminal 158 of the first of the sensor units 150 is then connected to another of the sensor units 150. The output connection terminal 158 includes connections for ground, VCC, and data connections. The additional sensor units 150 of the system 100 are then connected serially in this same manner.

[0041] The sensor units 150 can be mounted into or onto walls or other structural components of an environment. Each of the sensor units 150 can house both a temperature sensor or thermistor 152 and a relative humidity sensor or hydrometer 154. These sensors 152 and 154 respectively monitor transient states of the temperature and relative humidity conditions near the unit 150 and relay their readings to the monitoring unit 130 via the interface 132. Typically, the temperature and humidity sensors 152 and 154 of the sensor units 150 are sensitive to the resistance and capacitance of the connection circuit. This sensitivity can make it difficult for the sensor units 150 to be fully exchangeable. Preferably, the sensor units 150 selected for the disclosed system 100 are exchangeable so that the connection may not impact the measurement accuracy.

[0042] In a preferred embodiment, the sensors 152 and 154 of the sensor unit 150 are MEMS based sensors from

Sensirion, Hygrometrix, and Kelian electronics. For example, suitable Sensirion sensors include Model SHT11 and Model SHT10, which are a single chip relative humidity and temperature multi-sensor module. Suitable Kelian thermistor sensors include Model CL-M52R and Model KL-103-88377. A suitable Hygrometrix sensor includes Model HMX2000-HT.

[0043] The monitoring unit 130 may be more or less sophisticated than shown in FIG. 3 depending on the particular implementation of the prediction system 100. In one embodiment of the prediction system 100, for example, the monitoring unit 130 can be a stand-alone device added to a facility or building and capable of independently determining the risk factor for mold growth associated with its connected sensor units 150. The various sensor units 150 can be positioned in rooms or areas where it is desirable to monitor for potential mold growth. The monitoring unit 130 can be positioned in a location where a user can access the unit 130, see the warning indicator 136, hear the speaker 134, and/or use the display panel 140 and control keys 138. In such a stand-alone embodiment, the monitoring unit 130 can collect the sensor readings from the sensor units 150 and can calculate a probability for mold growth or risk factor using an algorithm as disclosed herein. The monitoring unit 130 can then display the calculated mold growth risk factor 146 for a selected zone or sensor unit 150 on the display panel 140.

[0044] Alternative embodiments and implementations of the disclosed prediction system 100 may not use or require such a stand-alone monitoring unit 130. For example, the various hardware and software components disclosed herein in connection with the monitoring unit 130 can be implemented as or integrated into a computer system, an environmental control system, or a security system. In one alternative embodiment, for example, the monitoring unit 130 can calculate the mold growth risk factor for the areas associated with its connected sensor units 150. Then, the monitoring unit 130 can display the calculated risk factor and/or can send the calculated risk factor to a master control computer via an RS-485 interface 131 and RS-485 Bus 118. (An example of such a master control computer is disclosed below as element 112 of FIG. 5). In yet another alternative embodiment, the monitoring unit 130 can communicate its sensor readings to a master control computer (112; FIG. 5) via the RS-485 interface 131 and RS-485 Bus 118 without first calculating the mold growth risk factor. Then, the master control computer (112; FIG. 5) can determine the mold growth risk factor and can present relevant information, alarms, trends, history, etc. for the user.

[0045] Various designs for the display panel 140 on the monitoring unit 130 can be used to display information for users. Among other information (e.g., the date and zone name), the display panel 140 in the present embodiment displays the current temperature condition 142, the current humidity condition 144, and the calculated mold growth risk factor 146 associated with a selected sensor unit identifier 148. The display panel 140 can also show trends, such as temperature trends, humidity trends, and risk factor trends. In one embodiment, the display panel 140 can be a touch screen. Alternatively, the monitoring unit 130 has control keys 138. Using the control keys 138, a user can change the information displayed on the panel 140 or can alter information used by the monitoring unit 130. The speaker 134

can produce a warning sound if the mold growth risk factor **146** for a zone or sensor unit exceeds a predetermined threshold. Similarly, the warning indicator **136** can produce a warning light if such a case occurs.

[0046] Additional forms of information can be displayed on the display **140** of the monitoring unit **130**. Some examples of information include the number of sensor units **150** connected to the monitoring unit **130**, the number of collected sensor records stored in the monitoring unit **130**, and the identification number of the monitoring unit **130**. The display **140** can also show which sensors have failed to collect data. In addition, various functions may be accessible using the display **140** of the monitoring unit **130**. Some example functions include running tests of selected sensor units **150** and setting ID numbers for the monitoring unit **130** and connected sensor units **150**.

[0047] Referring to FIG. 4, the monitoring unit **130** of FIG. 3 is schematically illustrated in more detail. The monitoring unit **130** includes a central processing unit (CPU) **200**, a Meter-BUS communication interface **220**, a display **240**, a status indicator **242**, a key pad **244**, a speaker **246**, a memory **250**, a clock **260**, and a backup power supply **270**. The prediction system **130** may or may not include the display **240**, status indicator **242**, keypad **244**, and/or speaker **246** depending on the implementation.

[0048] In one embodiment, the CPU **200** includes a main microcontroller, such as the P89V51RD2 microcontroller from Phillips Semiconductors that has 64-kB Flash and 1024 bytes of data RAM. In addition, the CPU **200** includes a sensor microcontroller, such as the P87LPC767 microcontroller from Phillips Semiconductors.

[0049] The memory **250** stores software **252** and other data for the monitoring unit **130**. The software **252** includes instructions for managing the sensor units **150** connected to the monitoring unit **200** and can include an algorithm according to the teachings of the present disclosure for calculating a mold growth risk factor. The memory **250** is preferably an electrically erasable programmable read-only memory (EEPROM), such as the CAT24C161 from Catalyst Semiconductor that has a Precision Reset Controller and Watchdog Timer. The clock **260** is a Real-Time Clock (RTC), such as the PCF8563 from Phillips Semiconductors.

[0050] The display **240** is an LCD Display Panel HS162-4, which can display a plurality of characters. The key pad **244** preferably has a plurality of keys to perform various functions, such as making a selection, changing a selection, or navigating screens. Among a number of possible functions, for example, a user can use the keys **244** to enter information to the CPU **200** and to page through temperature and humidity readings, status displays of sensor positions, system fault displays, etc.

[0051] The power supply (not shown) for the unit **130** can be a battery or conventional power supply. For battery power, the unit **130** preferably uses circuits and components known in the art for maintaining low power consumption. The backup battery **270** can be a miniature Li-battery unit for system power off to keep the clock **260** working normally.

[0052] As noted previously, the communication interface **220** of the monitoring unit **130** is preferably based on the Meter-Bus ("M-Bus") protocol to communicate with the

sensor units **150**. The sensor units **150** are connected in series and connected through one pair of lines to the M-Bus communication interface **220**. The monitoring unit **130** can alternatively use the RS-485 communication protocol to communicate with the sensor units **150**. In either case, the data format for communication from the CPU **200** to the sensor units **150** can include a sequence number, a command, a length (bytes) of the communication, data[0]. . . data[m], and a cyclic redundancy check (CRC) for error detection. Likewise, the data format for communication from sensor units **150** to the CPU **200** can include a sequence number, a status of the sensor module, a length (bytes) of the communication, data[0]. . . data[m], and a cyclic redundancy check (CRC) for error detection. One skilled in the art will appreciate that other embodiments of the monitoring unit **130** can use other protocols for the interface **220**, including, but not limited to, a wireless interface and protocol. Moreover, depending on the implementation of the disclosed monitoring unit **130**, the interfaces **220** may include a plurality of inputs/outputs for the various sensor units **150**.

[0053] As alluded to previously, the monitoring unit **130** can be a stand-alone device or can be connected to a computer system or the like. To connect such a computer system, the monitoring unit **130** can include an RS-485 communication interface **210**. The RS-485 communication interface **210** uses RS-485 communication protocol and can include a Maxim MAX1487 transceiver for RS-485 communication with a main control computer, such as discussed below with reference to the embodiment of FIG. 5.

[0054] Referring to FIG. 5, another embodiment of a mold prediction system **102** according to certain teachings of the present disclosure is schematically illustrated. The prediction system **102** electronically monitors an environment and determines a probability of mold growth in the environment. The prediction system **102** includes a master control unit **110** having a master control computer **112** and a communication hub **114**. The communication hub **114** can be an RS-485 Hub connected to the master control computer **112** via an RS-232 connection **116**. A plurality of monitoring units **130** and sensor units **150** are connected to the communication hub **114**. In the present example, the monitoring units **130** and sensor units **150** are separated into a plurality of zones or areas **120** (e.g., zone . . . zone N), which can help organize the monitoring and reporting of mold growth in the environment. The environment can be a room, building, facility, or any location where monitoring of mold growth is desirable.

[0055] The monitoring units **130** are similar to the embodiments discussed above with reference to FIGS. 3 and 4. The monitoring units **130** are connected to the communication hub **114** via an RS-485 BUS **118**. Each monitoring unit **130** has one or more sensor units **150** connected serially via an M-BUS.

[0056] The sensor units **150** are similar to the embodiments discussed above with reference to FIGS. 3 and 4. The sensor units **150** are distributed throughout the environment and can be located near a sink, food storage area, kitchen, windowsill, attic, closet, or anywhere that it is desirable to monitor for mold growth. Placement of the sensor units **150** depends on a number of factors, including, but not limited to, the type of environment being monitored, any equipment

or other items located near the sensor units **150**, the distance of the sensor units **150** from a potentially mold prone area, implementation specific criteria, any interference from other equipment, the potential for generating false readings, etc. One skilled in the art of monitoring temperature and humidity will appreciate these and other factors when distributing the sensor units **150** throughout the environment.

[0057] Using the standard of the RS-485 communication protocol and the hub **114**, the master control computer **112** can be linked to numerous monitoring units **130**, but the master control computer **112** preferably links to no more than two-hundred and fifty-five (255) monitoring units **130**. In addition, each monitoring unit **130** can be linked to up to about one-hundred and twenty-eight (128) sensor units **150**. Preferably, the maximum length of wiring from a given sensor unit **150** to the master control computer **112** does not exceed 1000-m.

[0058] During operation, the sensor units **150** collect data related to temperature and relative humidity in the environment. The monitoring units **130** gather the data from their associated sensor units **150**. To track the collected data, the sensor units **150** and the monitoring units **130** have serial or identification numbers. The monitoring units **130** communicate collected data to the master control computer **112**. In one embodiment, the monitoring units **130** only communicate collected temperature readings and humidity readings (and optionally time readings) to the master control computer **112**, which calculates the mold grow risk factors. Alternatively, the monitoring units **130** calculate the mold growth risk factors and communicate collected temperature readings and humidity readings (and optionally time readings) along with the mold growth risk factors to the master control computer **112**.

[0059] Software operating on monitoring unit **130** and/or the master control computer **112** is used to analyze the collected data and to generate warnings or perform other functions disclosed herein. For example, a user of the master control computer **112** and associated software can review the sensor readings and calculated mold growth risk factors for the various sensor units **150** and zones **120** of the environment. The software operating on the master control computer **112** can generate alarms when the risk factor of a given sensor unit **150** or zone **120** meets or exceeds a predetermined threshold. The software can also perform various known mathematical analyses on the readings of the sensor units **150**. For example, the software can determine average readings and risk factors for a collection of sensor units **150** in a zone **120** and can forecast values for the risk factor using modeled values. The monitoring units **130** and the master control computer **112** may be capable of displaying similar information and performing similar functions.

[0060] Now that details related to how the monitoring units (**130**; FIG. 3-5) and sensor units (**150**; FIG. 3-5) collect readings of temperature, humidity, and time have been discussed, we now turn to a discussion how the collected data is analyzed. As discussed above, the monitoring unit (**130**; FIG. 3-5) and/or the master control computer (**112**; FIG. 5) can perform the functions of analyzing the collected data. During the analysis, an algorithm is used to determine a probability of mold growth for the environment using the temperature readings, the humidity readings, and the time readings. The algorithm is based on information associated

with mold growth. Before discussing the algorithm in detail, we first discuss the forms of information associated with mold growth upon which the algorithm is based.

[0061] Referring to FIG. 6, graphs **300** and **350** illustrate isopleths for various species of mold. Graph **300** has a plurality of isopleths **320** that represent spore germination for various species of mold, and graph **350** has a plurality of isopleths **370** that represent mycelium growth for the various species of mold.

[0062] In graph **300**, the spore germination isopleths **320** for the various species of mold are plotted against temperature (C) and relative humidity (%). As shown, the various species have spore germination isopleths **320** fall within different ranges of temperature and relative humidity. The graph **300** further includes an envelope **310**, which is determined as a threshold for any spore germination to develop for the various species of mold. The area **330** of the graph **300** above or exceeding the values of the envelope **310** represents a Conducive State **330** conducive to spore germination for the various species of mold. Contrariwise, the area **340** of the graph **300** below or less than the values of the envelope **310** represents a Detrimental State **340** detrimental to spore germination for the various species of mold.

[0063] Similarly, in the graph **350**, the mycelium growth isopleths **370** for the various species of mold are plotted against temperature (C) and relative humidity (%). As shown, the various species have mycelium growth isopleths **370** fall within different ranges of temperature and relative humidity. The graph **350** further includes an envelope **360**, which is determined as a threshold for any mycelium growth to develop for the various species of mold. The area **380** of the graph **350** above or exceeding the values of the envelope **360** represents a Conducive State **330** conducive to mycelium growth for the various species of mold. Contrariwise, the area **390** of the graph **350** below or less than the values of the envelope **360** represents a Detrimental State **340** detrimental to mycelium growth for the various species of mold.

[0064] These graphs **300** and **350** plot the envelopes **310**, **360** and isopleths **320**, **370** based on a given time interval and substrate quality. Experimental data of relative humidity levels, temperatures, substrates, and time intervals for the various species of mold can be used to develop information for the disclosed system. The types of substrates may be particularly suited for a given environment in which the prediction system is intended to be installed. Alternatively, a general nutrient level of substrates may be used based on the circumstances. In addition, the information on isopleths and envelopes similar to those shown in FIG. 6 can be developed for various time intervals, such as a plurality of days. The information is then stored in the disclosed system and/or implemented into software for the disclosed system using various techniques known in the art.

[0065] By monitoring the temperature and relative humidity in a zone being monitored with sensors, the monitored conditions are analyzed using the software algorithm and stored information of the disclosed system. For example, if the monitored temperature is 25-degrees Celsius and the relative humidity is 75% for a given time interval and substrate quality (either general or specific), then the conditions may lie within Conducive States **330/380** of both graphs **300**, **350** conducive to both spore germination and

mycelium growth. By contrast, if the monitored temperature is 15-degrees Celsius and the relative humidity is 70%, then the conditions may lie within Detrimental States **340**, **390** of both graphs **300**, **350** detrimental to both spore germination and mycelium growth.

[**0066**] Based on which of the Conducive or Detrimental States the conditions fall and based on the length of time occurring within those conditions, the software algorithm of the disclosed system determines the probability of mold growth for the zone. In general, a longer period of time where conditions occur in Conducive States **330**, **380** beyond the envelopes **310**, **360** will correspond to greater potential for spore germination and mycelium growth. Likewise, the higher the conditions in Conducive States **330**, **380** are beyond the envelopes **310**, **360** will also correspond to greater potential for spore germination and mycelium growth. In contrast, a longer period of time where conditions occur in Detrimental States **340**, **390** under the envelopes **310**, **360** will correspond to less potential for spore germination and mycelium growth and potentially to elimination of existing mold. Likewise, the lower the conditions in Detrimental States **340**, **390** are below the envelopes **310**, **360** will also correspond to less potential for spore germination and mycelium growth and potentially to greater elimination of existing mold.

[**0067**] Accordingly, the software algorithm of the disclosed system is configured to use stored information similar to that shown in graphs **300**, **350** to determine the probability of mold growth and potentially to control the mold growth in the environment. As will be appreciated, the stored information can be coded as part of the software algorithm as one or more formulas or can be implemented in searchable files stored in memory. Furthermore, a particular implementation may be tailored to monitor a common group of mold species or to monitor one or more specific mold species, and the software implementation can be tailored to monitor such species. Further details related to monitoring the conducive and detrimental states for spore germination and mycelium growth are discussed below with reference to FIG. 7.

[**0068**] Referring now to FIG. 7, an embodiment of an algorithm **400** for evaluating the conditions conducive and detrimental to mold growth is illustrated in flow chart form. As noted above, such an algorithm **400** can be incorporated into software for the disclosed system used to predict and provide early warning of potential mold growth. Among the four conditions (temperature, relative humidity, time, and materials/nutrients) influencing mold growth, the influence of the temperature, relative humidity, and time on mold growth are used in the present embodiment of the algorithm. For example, the algorithm has an equation that incorporates the dependence of at least the temperature and relative humidity on time. However, each of the four conditions that determine mold growth can be considered in the algorithm **400**. For example, the quality of various substrates can be used in the algorithm because the sensors are placed in various places in the environment having known materials, such as carpet, wallpaper, wood structures, tile, cloth, PVC pipe, etc. Therefore, the particular attributes of the substrate in the area of the sensor (e.g., the substrates level of nutrients conducive to mold growth) can be used to further tailor the determination of mold growth near the sensor.

[**0069**] In the algorithm **400**, an initial value of the probability or risk factor for mold growth in a zone is set to zero (Block **410**). In general, the risk factor for mold growth can be allowed to range from 0 to 1. If the value of the risk factor is negative after performing the computations discussed below, the risk factor can be set to zero. Similarly, if the value of the risk factor is greater than 1 after performing the computations discussed below, the risk factor can be set to 1. Adjusting the risk factor in this manner will allow for reporting the value of the risk factor in the form of a percentage from 0 to 100%.

[**0070**] The system begins sampling the sensors for temperature and humidity readings (Block **420**). The frequency of the sampling can be suited for the particular implementation. For example, the sampling can occur at predetermined time intervals, such as every 10-minutes, so that the risk factor for the zone can be regularly monitored and updated. The system receives or obtains the readings of the temperature and relative humidity from the environment (Block **430**). For example, the sensors in a zone detect the temperature and relative humidity levels at discrete times, and the readings are communicated to the central processing unit via the communication interface. It will be appreciated that a plurality of zones can be simultaneously monitored, monitored in staggering intervals, etc. In addition, it will be appreciated that the frequency of monitoring can be varied.

[**0071**] The system determines whether the monitored readings fall within a state conducive to mold growth or within a state detrimental to mold growth. The "mold growth" can refer to only spore germination, only mycelium growth, or both spore germination and mycelium growth, such as described above with reference to FIG. 6. It will be appreciated that various known mathematical techniques can be used to process data to determine the risk factor for mold growth. For example, known mathematical techniques, such as correlation, interpolation, curve fitting, history data matching, and neural networks, can be used.

[**0072**] If the condition of the readings fall within a Conducive State for mold growth, the conditions will contribute a positive value to the risk factor for mold growth based on the time it takes to grow mold (e.g., for spore germination and/or mycelium growth to occur). Therefore, the sampling frequency or the predetermined interval between readings is used to determine passage of time. Then, the risk factor is increased by an increment based upon the value of the conditions, duration in the current conditions, and the predetermined amount of time and levels conducive to the plurality of species or one or more specific species of mold being monitored (Block **450**).

[**0073**] In one embodiment of an equation for incrementing the risk factor, the risk factor at current sampling time equals the risk factor at the previous sampling time plus an increment occurring in the duration from the past sampling period. The increment is a positive value inversely proportion to the time it takes to grow mold from predetermined experimental data. For example, if the Conducive State indicates that it takes X days to grow one or more species of mold under certain conditions, and the sampling rate is Y hours, then the increment is based on the equation:

$$\text{Increment} = \frac{Y}{(24X)}$$

[0074] If the conditions in the readings fall within a Detrimental State, the conditions will contribute a negative value to the risk factor for mold growth based on the time it takes to stop, reverse, or eliminate mold growth (e.g., stop spore germination and/or stop or kill mycelium growth). Then, the risk factor is decreased by an decrement based upon the value of the conditions, duration in the current conditions, and the predetermined amount of time and levels detrimental to the plurality of species or one or more specific species of mold being monitored (Block 460).

[0075] In one embodiment of an equation for decreasing the risk factor, the risk factor at the current sampling time equals the risk factor at the previous sampling time plus any decrement occurring in the duration from the past sampling period. The decrement is a negative value and can be based on the exponential function:

$$\text{Decrement} = -Ae^{-(BT+CH)}$$

[0076] T represents the temperature reading, and H represents relative humidity reading. The parameters A, B, and C are non-negative values determined from the predetermined experimental data for the group of mold species or one or more specific mold species being monitored.

[0077] After adjusting the risk factor to reflect recent conditions monitored in the environment, the system waits for the next sampling time (Block 470). When the next sampling time arrives, the system returns to Block 420 to begin a new sampling cycle to update the risk factor or probability of mold growth.

[0078] As discussed previously with reference to FIGS. 3-5, the sensor units 150 generate temperature and relative humidity readings at a plurality of intervals, and the monitoring units 130 collect these readings. The collected readings are then communicated to the master control unit 110, which analyzes the readings. To analyze the readings, the master control unit 110 can track historical data and maintain running calculations of the risk factor for mold growth in various zones 120 and various locations of particular sensor units 150 of the system 100 in the environment. This historical data can be displayed on the master control computer 112 using software in various forms, such as using graphs.

[0079] Referring to FIGS. 8A-8B, examples of sensor readings and calculated risk values are graphically illustrated. Graph 500 of FIG. 8A shows relative humidity readings 506 and temperature readings 508 for a day of readings from one sensor unit. Humidity readings 506 are graphed as a function of time 502 and values 504 in units of percentage of relative humidity. The values 504 for the humidity readings 506 range from about 77 to 87-% relative humidity. Temperature readings 508 are graphed as a function of time 502 and values 504 in Celsius. The values 504 for the temperature readings 508 range from about 50 to 52-degrees Celsius. Graph 520 of FIG. 8B shows the calculated value of the mold growth risk factor 526 based on the sensor readings of FIG. 8A. The risk factor 526 is

graphed as a function of time 522 and values 524. As shown, the risk factor 526 generally increases as time passes and as the temperature readings (508) and relative humidity readings (506) moderately increase and decrease during the day.

[0080] Referring to FIGS. 9A-9B, another example of sensor readings and calculated risk values are graphically illustrated. Graph 540 of FIG. 9A shows relative humidity readings 546 and temperature readings 548 for a day of readings. Humidity readings 546 are graphed as a function of time 542 and values 544 in units of percentage of relative humidity. The values 544 for the humidity readings 546 range from about 57 to 81-% relative humidity. Temperature readings 548 are graphed as a function of time 542 and values 544 in Celsius. The values 544 for the temperature readings 548 range from about 49 to 51-degrees Celsius. Graph 560 of FIG. 9B shows the calculated value of the mold growth risk factor 566 based on the sensor readings of FIG. 9A. The risk factor 566 is graphed as a function of time 562 and value 564. As shown, the risk factor 566 generally decreases as time passes, as the temperature readings (548) remain relatively constant, and as the relative humidity readings (546) decrease during the day.

[0081] Referring to FIGS. 10A-10B, example screens 570 and 580 for a graphical user interface of a master control computer (112; FIG. 5) are illustrated. Screen 570 of FIG. 10A shows a graph 571 of selected trends 572 of a selected sensor 574. For the trends 572, the user can select to display risk, temperature, and/or humidity. To select the sensor 574, the user can specify the controller number (i.e., the ID for a monitoring unit) and the sensor number (i.e., the ID number of a sensor unit). The user can also specify a date range.

[0082] Screen 580 of FIG. 10B shows a graph 581 of highest values for selected sensors. In fields 582, the user can sort the display on the graph 581 by risk, temperature, and/or humidity. In fields 584, the user can select to generate the graph from all of the sensors or only some of those associated with a designated controller (i.e., monitoring unit). In fields 586, the user can select date ranges. Finally, the user can specify what risk levels to display including all or some percentage in fields 588. One skilled in the art will appreciate that a user interface of a master control computer can have these and other screens.

[0083] In addition to monitoring, displaying, and analyzing the readings and risk factor information, the mold growth prediction system of the present disclosure can proactively alter aspects of the environment to control or reduce the potential for mold growth in the environment. Referring to FIG. 11, a prediction system 600 and an environmental system 660 according to one embodiment of the present disclosure are illustrated. The prediction system 600 is integrated with the environmental system 660. The prediction system 600 can be substantially similar to other embodiments disclosed herein. For example, the prediction system 600 includes a master control unit 610 having a master control computer 612 connected to a RS-485 Hub 614 via a RS-232 connection 616. The hub 614 connects to various zones 620A-C distributed in the environment via RS-485 connections 618. The zones 620A-C include monitoring units 630 and sensor units 650 similar to those discussed previously. The master control unit 610 receives temperature and humidity readings of the various zones

620A-C and determines the risk factor or probability of mold growth for the sensor units 650 and the various zones 620A-C.

[0084] Rather than merely indicate the risk factors (e.g., display the risk factors for a user or produce an alarm), the master control unit 610 further includes an interface 613 with an environmental controller 670 of the environmental system 660 for the environment. Although the prediction system 600 and environmental controller 670 are shown as separate entities or units in the present embodiment, it will be appreciated that the monitoring and environmental control of the present disclosure can be implemented within a single entity or unit or within more than two entities or units.

[0085] The environmental controller 670 is coupled to a plurality of environmental components or units 680A-C, which can be heating, ventilation, and air-conditioning (HVAC) components, dehumidifiers, humidifiers, fans, and other components coupled to the environmental controller 670 that can alter the environmental conditions of the zones 620A-C. The environmental controller 670 controls the various components 680A-C. Although each zone 620A-C of the environment is shown with its own environmental component 680 in the present embodiment, it will be appreciated that various zones of an embodiment can have more than one environmental component 680 or one environmental component 680 can service more than one zone depending on the particular implementation. The environmental controller 670 can control the heating, ventilation, and air conditioning of the environment by operating the various environmental components 680, such as operating air-conditioning to lower the temperature, operating air-conditioning to reduce relative humidity, operating heating to raise the temperature, operating a dehumidifier to reduce the relative humidity, diverting airflow, distributing airflow, etc.

[0086] During operation, the prediction system 600 receives temperature and humidity readings from the sensor units 650 in the zones 620A-C of the environment. Based on the readings, the prediction system 600 determines the risk factor or probability of mold growth in the zones 620A-C over time using techniques disclosed herein. When a zone (e.g., zone 620A) develops an unacceptable risk factor or probability of mold growth, the prediction system 600 determines what combination of conditions (e.g., temperature, humidity, time) would be detrimental to any mold growth in the zone 620A and could potentially stop, reverse, or kill any current mold growth in the zone 620A. The prediction system 600 relays the combination of detrimental conditions (temperature, humidity, time) to the environmental controller 670. In turn, environmental controller 670 controls the environmental component 680A associated with zone 620A with operational parameters consistent with the combination of detrimental conditions (e.g., temperature, humidity, time) for addressing the mold growth in zone 620A.

[0087] For example, the risk or probability of mold growth in zone 620A may reach 75%, the current temperature reading may be T_{Current} , and the current relative humidity reading may be H_{Current} . Based on the species of mold being monitored in zone 620A, the current readings (T_{Current} , H_{Current}), and the techniques for addressing mold growth disclosed herein, the prediction system 600 may determine that a new temperature level of T_{New} and new humidity level

of H_{New} applied to the zone 620A for a period of time could potentially address the mold growth in zone 620A. At least the new temperature level and time interval can be sent to the environmental controller 670, which can then operate the HVAC component 680A associated with zone 620A to maintain the desired temperature for the time interval. The environmental controller 670 may have its own sensors for monitoring the time and temperature of the zone.

[0088] Alternatively, the prediction system 600 and environmental system 660 can operate in a cooperative relationship. For example, the prediction system 600 can send only a new temperature level for zone 620A to the environmental controller 670, which can then operate the HVAC component 680A associated with zone 620A to maintain the desired temperature. The environmental controller 670 may have its own sensors for monitoring the time and temperature of the zone, or it can use the sensors 650 of the prediction system 600. The prediction system 600 then continues monitoring the zone 620A with the sensor units 650 to determine when and if the desired new temperature is met. The current operation can be maintained until the time interval expires and the prediction system 600 instructs the environmental controller 670 to cease its proactive operation. Alternatively, the current operation can be maintained until the prediction system 600 detects the desired relative humidity or determines a particular reduction in the risk factor and instructs the environmental controller 670 to cease its proactive operation of the HVAC component 680A.

[0089] In one possible extension of the integrated prediction system 600 and environmental system 660, the temperature sensors within the sensor units 650 can be used to detect significantly elevated temperatures caused by a potential fire in the environment. The master control unit 610 can be configured to detect such significantly elevated temperature readings and can communicate an alarm to a security system or fire alarm system of the environment.

[0090] Referring to FIG. 12, an embodiment of an algorithm 700 for interfacing a prediction system with an environmental system to control mold growth is illustrated in flow chart form. As discussed above in the embodiment of FIG. 11, the disclosed prediction system can be integrated with or coupled to the environmental system. Based on the determinations made by the prediction system with respect to mold growth, the prediction system operates in conjunction with the environmental system to address or control the growth of mold in the environment.

[0091] To begin, the prediction system samples the sensors (Block 710) and determines the risk factor or probability for mold growth (Block 720) in a manner similar to that described above with reference to FIG. 7. A determination is then made whether the risk factor is above threshold criteria (Block 730). For example, the threshold criteria can be a particular value of the risk factor (e.g., 75%) or the threshold criteria can be a particular value of the risk factor (e.g., 75%) for a particular amount of time (e.g., 24 hours). Other than the use of a threshold for the determination, it will be appreciated that various other forms of criteria can be employed. For example, issues related to hysteresis may be integrated into the determination of Block 730. In addition, the threshold criteria may have more than one level of severity. For example, a first level for the threshold criteria may recognize a low level of risk for mold growth, a second

level for the threshold criteria may recognize a medium level of risk for mold growth, and third level for the threshold criteria may recognize a high level of risk for mold growth. Each of these levels can have corresponding levels of action for the disclosed system to implement as discussed below.

[0092] If the risk factor does not meet or exceed the threshold criteria at Block 730, then the system returns to sampling the sensors according to Block 710. If, however, the risk factor does meet or exceed the threshold criteria at Block 730, then the system determines which detrimental conditions (temperature, relative humidity, and/or time) would be detrimental to mold growth for the environment under the circumstances. For example, operation of the air conditioning unit for a certain amount of time in the zone may reduce the temperature and relative humidity to a level that will stop, reverse, or kill any existing mold growth within the zone. Finally, the environmental system is operated according to the detrimental conditions to address or control the mold growth in the zone (Block 750). The system can then return to sampling the sensors in Block 710 so that the system operates in a looped operation.

[0093] As noted previously with respect to FIG. 5, communications between sensor units 150 and the control units 130 can be wired by an M-Bus, for example. As also noted previously, however, communications between sensor unit 150 and control units 130 can be wireless. Referring to FIG. 13, another embodiment of a mold prediction system 104 according to certain teachings of the present disclosure is schematically illustrated. This embodiment of the prediction system 104 is substantially similar to the embodiment of the system 102 in FIG. 5 so that like reference numerals are used for like components. In the present embodiment, sensor units 170 are wirelessly connected to control units 160. Because they are not wired, the wireless sensor units 170 can be more conveniently placed in locations of a building or the like. In one embodiment, the wireless sensor units 170 may have an open space range of about 80-120 meters, while more powerful wireless sensor units 170 could also be used that provide an open space range of about 500 meters. The number of sensor units 170 and control units 160 to use and the location in which they are positioned in an environment depends on a number of implementation specific details.

[0094] The control units 160 in the present embodiment are substantially similar to those disclosed in previous embodiments. To handle wireless communications, however, the control units 160 in the present embodiment include wireless transceivers (not shown) and antennas (not shown) for communicating with the wireless sensor units 170. Preferably, the wireless transceivers of the control units 160 are capable of multiband wireless communication. The control units 160 may still have a wired RS-485 interface with the master control unit 110, although additional embodiments of the disclosed system 104 may use wireless interfaces between the control units 160 and the master control unit 110 based on the teachings disclosed herein.

[0095] Among other topics, discussion will focus on how the wireless sensor units 170 can be mounted to a wall or other structure, what electronic components comprise the wireless sensor unit 170, how the wireless sensor units 170 are configured, and how the wireless sensor units 170 communicate with the control units 160.

[0096] Turning first to a discussion of how the wireless sensor units 170 of the system 104 of FIG. 13 can be

mounted, FIGS. 14A-14E respectively illustrate front, side, top, back, and perspective views of one embodiment of a wireless sensor mounting assembly 800 shown in an assembled state. The mounting assembly 800 includes a face 810, a holder 820, a mounting member 830, and a sensor enclosure 840, each of which are respectively shown in isolated views of FIGS. 15A-15D. The assembly 800 installs on a wall, such as sheet rock, or other structure to hold the components of a wireless sensor unit.

[0097] To install the assembly 800, a hole is first drilled in the wall, and a narrow portion 832 of the mounting member 830 is positioned in the hole so that a flat portion 831 of the mounting member 830 rests against the outside of the wall. To insert the narrow portion 832 into the hole, ears 834 on towers 835 of the narrow portion 832 are rotated into a central passage 833 defined through the mounting member 830. Once inserted, screws 836, which are accessible from the front of the member 830, are rotated. As the screws 836 are initially rotated, the ears 834 are turned outward from the central passage 833 to the position at which they are shown in the FIG. 15C, for example. With continued rotation of the screws 836, the ears 834 remain extended outward but ride down the threaded portions of the screws 836 and along side slots 838 defined in the towers 835 of the narrow portion 832. The movement of the ears 834 forces the mounting member 830 to clamp or grip the edges of the hole in the wall between the ears 834 and the flat portion 831 to hold the mounting member 830 in the hole. (The clamping ability can best be seen in FIG. 14C by the adjustable gap G formed between the ears 834 and the flat portion 831 of the mounting member 830).

[0098] Next, a wireless sensor unit 1000, which is shown in FIG. 17 and discussed in detail later, is positioned in the sensor enclosure 840 by attaching or screwing it to a first enclosure portion 842 shown in FIG. 15D. Then, a second enclosure portion 846 with an opening 848 for the wireless antenna (1030; FIG. 17) is snap fit on the first enclosure portion 842. The assembled enclosure 840 with enclosed wireless sensor unit (1000) is then installed on the holder 820 by snap fitting legs 824 of the holder 820 into slots 844 on the enclosure 840. Once installed, the wireless antenna (1030) is positioned adjacent a thinned area 822 in a front portion 821 of the holder 820.

[0099] Subsequently, the front portion 821 of the holder 820 is snap fit onto the flat portion 831 of the mounting member 830 already positioned on the wall so that the sensor enclosure 840 is positioned within the central opening 833. Screws (not shown) then fasten the holder 820 to the mounting member 830 through screw holes 826 and 839. Finally, the face 810, which can define a central opening 812, is snap fit to the front of the holder 820 to hide the screws. After being installed in this manner, the sensor enclosure 840 can be readily accessed by removing the face 810, unscrewing the holder 820 from the mounting member 830, removing the holder 820 from the opening 833 of the mounting member 832, and unattaching the enclosure 840 from the legs 824 of the holder 820.

[0100] Components of the mounting assembly 800 discussed above can also be used to mount other elements of the disclosed system 104 of FIG. 13 to walls or other structures. Referring to FIGS. 16A-16D, for example, one embodiment of a control unit 900 for mounting to a wall or

other structure is illustrated in various views. FIG. 16A shows a side view of the control unit 900 having a main electronics portion 902 and a back housing 910, which are shown unassembled. Electronics, power circuitry, a display panel, a wireless transceiver, and other components (not shown) are housed in the main electronics portion 902, which can be removed from an internal chamber 912 of the back housing 910. Snaps or other means 904 can be used to connect the main electronics portion 902 removably to the back housing 910.

[0101] As shown in FIGS. 16A-16B, the back housing 910 can be attached to the same mounting member 830 as discussed previously to mount the control unit 900 to a wall or other structure. To achieve this, the mounting member 830 is positioned in a hole in a wall as previously discussed. The backside 913 of housing 910 is positioned against the exposed flat portion 831 of the mounting member 830. As best shown in FIG. 16C, the back side 913 of the housing 910 has an indentation 920 to accommodate the exposed flat portion 831 so the back housing 910 can position flush against the wall. Screws (not shown) are threaded through holes 922 in the back housing 910 to attach it to the mounting member 830.

[0102] The back housing 910 also can be mounted in other ways so that it can also include key slots 924 and other mounting holes 926. Besides using the mounting member 830, the back housing 910 defines rear openings 930 for ventilation and for running any necessary wires from the back housing 910 and into the wall to which it is mounted. Openings 932 in the side of the back housing 910 can be used for a power cable and communication cables to connect to the main electronics portion 902.

[0103] As discussed previously, the enclosure 840 holds components of a wireless sensor unit. Referring now to FIG. 17, one embodiment of a wireless sensor unit 1000 is illustrated in a side view. The wireless sensor unit 1000 includes various electronic components 1002 on a printed circuit board (PCB) 1004. The electronic components 1002 include a microcontroller 1010, a transceiver 1020, a wireless antenna 1030, one or more environmental sensors 1040, a battery 1050, a physical connector 1054, and any other necessary elements.

[0104] The wireless antenna 1030 is preferably positioned on the front side of the PCB 1002, and the one or more environmental sensors 1040 are preferably positioned on the backside of the PCB 1002. In this way, the antenna 1030 can face out from the wall to which it is mounted, while the environmental sensor 1040 can face into the interior of the wall where mold growth is likely to occur. (As can be seen in the back view of FIG. 14D, the sensor enclosure 840 preferably has an opening 845 in its back to expose the one or more environmental sensors 1040 contained in the enclosure 840.)

[0105] The wireless antenna 1030 is also preferably attached to the PCB 1004 by a rotatable coupling 1032 so that the antenna 1030 can be moved to access the battery 1050 or the like. The physical connector 1054 can be used initially to configure the sensor unit 1000 by connecting it to a control unit (not shown) as discussed below. The battery 1050 can be any conventional battery. Additional details of the electronic components 1002 of the wireless sensor unit 1000 are discussed below.

[0106] FIG. 18 schematically shows one embodiment of the electrical components 1002 for the wireless sensor unit 1000 of FIG. 17. The electronic components 1002 include the microcontroller 1010, a timer or clock 1012, the wireless transceiver 1020, the antenna 1030, the one or more environmental sensors 1040, the battery 1050, a switch 1052, and the physical connector 1054. Additional electronic components are not shown. The microcontroller 1010 preferably includes the timer 1012 integrated therein. One suitable example of a microcontroller with integrated timer is the MSP430F123IDW, which is a low-power mixed signal microcontroller with a built-in 16-bit timer available from Texas Instruments. The wireless transceiver 1020 is preferably a multi-band wireless transceiver. The wireless transceiver 1020 is coupled to the microcontroller 1010 and the antenna 1030 and is used for wireless communications. One example of a suitable wireless transceiver is the nRF905 single-chip radio transceiver for the 433/868/915 MHz Industrial, Scientific, and Medical (ISM) radio bands available from Nordic Semiconductor. The antenna 1030 is coupled to the wireless transceiver 1020 and can be configured for 50-ohm RF input and output.

[0107] The one or more environmental sensors 1040 obtain temperature and relative humidity data. In a preferred embodiment, a single digital temperature and relative humidity sensor 1040 is used, such as the SHT11 digital humidity and temperature sensor available from Sensirion. The physical connector 1054, which can be a J3 connector, is used for directly connecting the microcontroller 1010 to a control unit (not shown) for configuring the microcontroller 1010. The switch 1052 controls power from the battery 1050 to the various components of the sensor unit 1000.

[0108] With an understanding of various components the mold growth prediction system 104 of FIG. 13, we now discuss how the disclosed system 104 is configured and set up. The wireless sensor units 170 must be configured with various parameters to operate with the control units 160 of the disclosed system 104. The parameters to be configured for the wireless sensor units 170 include the sensor unit's ID number, its wireless frequency band, and the sampling interval/rate for its environment sensor (not shown). Groups of wireless sensor unit 170 are associated with one control unit 160, and each of the wireless sensor units 170 of a group is given a unique sensor ID number to distinguish it from the other wireless sensor units 170 associated with the same control unit 160. The range of the sensor ID numbers can be from 0 to 127, because each control unit 160 can preferably be associated with up to no more than 128 sensor units 170. The wireless frequency band for each sensor unit 170 must be the same as that used by the wireless receiver or transceiver (not shown) of its associated control unit 160. In one embodiment, the various control units 160 may be capable of using any of 16 predefined frequencies.

[0109] The parameters for the sensor units 170 can be configured either by using its associated control unit 160 or by using the master control unit 110 (e.g., computer 112). To set up the sensor unit 170 using its associated control unit 160, the sensor unit 170 in one embodiment can be connected to the control unit 160 by a cable or other coupling. For example, the cable may couple a J12 connector on the control unit 160 to a J3 connector on the sensor unit 170 (e.g., physical connector 1054 on sensor unit 1000 of FIG. 17). With the sensor unit 170 and the control unit 160

powered on and communicatively connected, a user operates the user interface of the control unit **160** for sensor setup mode as discussed in previous embodiments, and the user then sets and saves the sensor ID number for the connected sensor unit **170**. The sampling interval/rate may be set up in a similar fashion, or it may be set up with the master control unit **110** as discussed below.

[0110] A sound can be generated from the control unit **160** to indicate a successful setup. After a successful setup of the sensor's ID number, the control unit **160** can automatically set the wireless frequency band of the sensor unit **170** to be the same as that used by the control unit **160**. After these stages of setup are successfully finished, the sensor unit **170** is turned off and then on again, and the sensor unit **170** will transmit a set of data to the associated control unit **160** so

control unit **160**. Conversely, the sensor units **170** preferably receive data from a control unit **170** only if the frequency band of the wireless sensor unit **170** is the same as that of the control unit **160** and only if the targeted address in the transmission matches the address of the sensor unit **160**. Circuitry in the control units **160** and the sensor units **170**, such as the microcontroller (**1010**; FIG. 17), verify the addresses and other data in the wireless transmissions.

[0114] In one embodiment, the address of a sensor unit **170** is composed of four bytes having the format of: 0xCC, Sensor ID, Sensor ID, 0xCC. The first and last bytes have fixed Hex values of 0xCC (204), and the middle two bytes are for the ID assigned to the sensor unit **170**, which can range from Hex values of 0x00 (0) to 0x7F (127). In one embodiment, the data transmitted by a sensor unit **170** is composed of eight bytes and has the format:

Command Code	Sensor ID Number	Wireless Frequency Band	Time Lapses between samplings	Temperature	Relative Humidity	Battery Status
1 byte fixed at 0x31	1 byte ranging from 0x00–0x7F	1 byte ranging from 0x00–0x0F	1 byte Ranging from 0–255 min.	2 bytes	1 byte	1 byte

that the control unit **160** can display the sensor ID number for confirmation. These steps are performed for each of the various sensor units **170** and their associated control units **160** for the disclosed system **104**.

[0111] The parameters of the sensor unit **170** can also be configured using software operating on the computer **112** and the linkage between the computer **112** with the associated control unit **160** to which the sensor unit **170** is connected. For example, the control unit **160** can use a J12 connector linked to a 9-pin D-share connector on the computer **112**. The software operating on the computer **112** has a parameter setup window for configuring the sensor ID number, the wireless frequency band, and the sampling interval/rate for the sensor unit **170**. An example of a parameter setup window is illustrated in FIG. 21.

[0112] After set up, the sensor units **170** can be installed in locations of an environment to collect data for monitoring temperature and humidity and predicting mold growth. During operation, the sensor units **170** distributed throughout the environment communicate wirelessly with the wireless transceiver (not shown) of its associated control unit **160**. The wireless communications transmit temperature and humidity data according to the purposes disclosed herein. Processing of the temperature and humidity data and time data to predict mold growth and monitor an environment have been previously described and are not repeated here. Instead, the discussion will now focus on the communication protocol and format of the data transmitted between the sensor units **170** and the control units **160**.

[0113] Data that is transmitted between a sensor unit **170** and its associated control unit **160** is composed of an address of a targeted receiver and values of data. To help handle data transmitted from multiple sensor units **170** in an installation, the control unit **160** receives data from sensor units **170** only if the frequency bands of the wireless sensor units **170** are the same as that of the control unit **160** and only if the address in the transmission matches the address of the

[0115] The command code is always a fixed Hex value in the present example. In other embodiments, various command codes can be used for various purposes. As can be seen, the sensor ID number is provided in the data transmitted from the sensor unit **170** to the control unit **160** so the ID can be associated to the appropriate location of the sensor unit **170** in the implementation of the disclosed system **104**. As also part of the confirmation, the data transmitted from the sensor unit **170** includes the wireless frequency band and the time lapses between samplings so that the control unit **160** can use that data for confirmation. The time lapses between samplings (e.g., sampling interval) can range from 0 to 255-min. At a value 0, the sampling interval is 8-seconds.

[0116] In one embodiment, the address of a control unit **160** is also composed of four bytes and can have a fixed format of: 0xCC, 0x12, 0x34, 0xCC. With the fixed format, any given sensor unit **170** needs only to store the same fixed control unit address and send that fixed address when transmitting data. In other embodiments, the address of the control units **160** can also include configurable IDs if the sensor units **170** include circuitry for storing and handling configured addresses.

[0117] In one embodiment, the data transmitted by a control unit **160** is composed of eight bytes and has the format:

Command Code	Sensor ID Number	Wireless Frequency Band	Time interval between samplings
1 byte fixed at 0x31	1 byte ranging from 0x00–0x7F	1 byte ranging from 0x00–0x0F	1 byte Ranging from 0–255 min.

[0118] Again, the sampling interval can range from 0 to 255-min. At a value 0, the sampling interval is 8-seconds.

[0119] Each sensor unit 170 associated with the same control unit 160 will be configured with the same wireless frequency as that control unit 160. Adjacent control units 160 in an installation are preferably not configured with the same wireless frequency so that transmissions from associated sensor units 170 intended for one control unit 170 will not be inadvertently received by an adjacent control unit 160. The range of wireless frequencies have settings from 0 to 15 (i.e., sixteen distinct frequencies), which may be adequate in most installations to segregate the various control units 160, although additional settings may be possible. The control unit's ID number and wireless frequency band are setup by the control unit 160. The clock time of the control unit 160 and the sampling intervals for the sensor units 170 are setup by the master control unit 110.

[0120] During operation, the sensor units 170 are set to be active, and the control units 160 are set to be reactive. The sensor units 170 include the clocks or timers (e.g., integrated timer 1012 of the microcontroller 1010 of FIG. 18) that are used to track time intervals between samplings made with the environmental sensors (1040; FIG. 18) of the sensor units 170. Between the time intervals for sampling, the sensor units 170 preferably operate in a low-power mode to conserve the power of their batteries (1050; FIG. 18). In the low-power mode, power from the batteries (1050) is used primarily to operate the timers (1012) and any other necessary components of the sensor units 170. In this way, the multiband transceiver (1020; FIG. 18) is preferably not powered to receive transmissions from the control unit 160 to conserve power.

[0121] When the time arrives for a sensor unit 170 to make its next sampling, the sensor unit 170 exits from the low-power mode of operation, and the microcontroller (1010) obtains temperature and relative humidity data with the one or more environmental sensors (1040). The microcontroller (1010) also obtains status of the battery (1050), such as whether it is exhibiting a low power condition. Then, the sensor unit 170 wirelessly transmits the collected data with the wireless transceiver (1020) according to the protocol discussed above.

[0122] In turn, the control unit 160, which is always in a receiving mode, receives the transmitted data and logs the received data from the sensor unit 170. Whenever the control unit 160 receives the data from the sensor unit 170, the control unit 160 returns a handshake signal to the sensor unit 170. The handshake signal, which is transmitted at the same frequency band as the sensor unit 170, includes the address of the sensor unit 170 and information for the next sampling interval. The sensor unit 170 receives the handshake signal and updates its next sampling interval, which may or may not be the same as the previous interval depending on whether a fixed interval is used or whether the interval has been modified by the master control unit 110. Then, the sensor unit 170 enters the low-power mode again until the timer (1012) reaches the time for the next sampling interval.

[0123] If the sensor unit 170 does not receive the handshake signal from the control unit 160 within some time limit (e.g., 20-ms), then the sensor unit 170 enters low-power mode for a waiting period (e.g., 8-seconds). At the end of the waiting period, the sensor unit 170 again exits low-power mode and retransmits the data. The sensor unit

170 may repeat the steps of powering down and retransmitting data up to about 4-times or so until it receives a handshake signal from its associated control unit 160. If a handshake signal is never received, the data that could not be transmitted may be lost because the sensor unit 170 may have limited storage capacity and is configured to conserve power. The sampling interval for the next sample to be made by the sensor unit 170 will remain unchanged. The sensor unit 170 then returns to low-power mode until the time of the old sampling interval is reached, at which point it will obtain new data and repeat the transmission steps above.

[0124] In other embodiments, the sensor unit 170 may have a wired power supply in addition to or as an alternative to having only battery power. In addition, the sensor unit 170 may have more storage capacity in other embodiments. In these embodiments, the sensor unit 170 may be capable of storing more data for longer periods of time until it can be uploaded or transmitted to the control unit 160.

[0125] As discussed previously with reference to FIGS. 10A-10B, the master control computer 112 can include a graphical user interface for a user to control, monitor, and configure a mold growth prediction system according to the present disclosure. Referring to FIG. 19, one embodiment of a main screen 1100 for a graphical user interface of the disclosure mold growth prediction system 104 of FIG. 13 is illustrated. The main screen 1100 includes a tool bar 1110 for accessing various tools, including, but not limited to, a "potential" tool 1111 for accessing a graph of mold growth potential, a "temperature/relative humidity" tool 1112 for accessing graphs of temperature and relative humidity, and a "rate" tool for accessing a screen to adjust the rates of obtaining environmental readings by the sensor units. A "control unit" tool 1114 and "sensor unit" tool 1115 can be used to access lists of control units and sensor units for the implementation so that a user can configure (e.g., adding/deleting) information about the control units and sensor units, such as location, room, floor, level, associated control unit, address, etc. The lists can be searchable by date ranges or other criteria. A "low battery" tool 1116 can be used to access a searchable lists of sensor units that have had low battery conditions. Finally, a "chart/trend" tool 1117 can be used to access charts and trends, and a "statistical" tool 1118 can be used to access statistics related to mold growth prediction and other details for the implementation.

[0126] In addition to the tools on the tool bar 1110, the main screen 1100 includes a sensor distribution field 1120, a status summary field 1130, a layout field 1140, a warning sensor list 1150, a warning status list 1160, and a manual data collection field 1170. The sensor distribution field 1120 has an expandable/collapsible tree 1122 showing the arrangement of various locations, control units, and sensor units for an implementation of the mold growth prediction system. The status summary 1130 shows general information about the mold growth prediction system, such as the number of sensors, those with missing data, those that are un-registered, those with low battery, and those with warning data. In addition, the status summary 1130 can show general information about the control units of the system.

[0127] The layout field 1140 shows an image 1142 of the selected building, location, or portion thereof having the control units and sensor units. The image 1142 can be a scanned image imported into the graphical user interface or

may be an imported file from another program. The location of the various control units and sensor units of the system are displayed as icons **1144** on the image **1142**. Textual labeling (e.g., “CU-1,” “SU-1,” etc.) may also be provided. The icons **1144** can be dynamic and color-coded. For example, selecting one of the icons **1144** with a pointer can be used to access detailed information or parameters of the selected control or sensor unit. In another example, the colors of the icons **1144** can change depending on whether a sensor or control unit has a warning condition, low battery, out of boundary temperature or relative humidity, or a mold growth prediction value above a predetermined amount, for example.

[**0128**] The warning sensor list **1150** can show those sensor units that have a warning condition, such as a mold growth prediction value above a predetermined parameter, a low battery, etc. The sensor units may be indicated by control unit code and name. The warning status list **1160** can show the various warnings associated with the mold growth prediction system. The manual data collection field **1170** can be used to collect real-time data with the mold growth prediction system.

[**0129**] Referring to FIG. **20**, one embodiment of a graph screen **1200** for the graphical user interface of FIG. **19** is illustrated. The graph screen **1200** shows a graph **1210** of collected data (e.g., relative humidity). This graph screen **1200** as well as screens for showing mold growth prediction values and temperature can be accessed by selecting one of the graph fields **1220** of the screen **1200**. Parameters for the graph **1210** can be set using date ranges **1230**, selectable areas **1240** of an implementation, selectable control units **1250**, and selectable sensor units **1260**. The data used for the graph **1210** can be set using parameters **1270** for values, all daily data, or average daily data. Controls **1280** on the screen **1200** allow the user to search stored data according to the selected parameters in fields **1230-1260** for creating a graph **1210**, to display the data as a data sheet, to print the data, or to export the data.

[**0130**] Referring to FIG. **21**, one embodiment of a parameter screen **1300** for the graphical user interface of FIG. **19** is illustrated. The parameter screen **1300** allows the user to define parameters for the mold growth prediction system. The parameters that are set with this screen **1300** will be applied to all sensor units and control units of the disclosed system. Other embodiments of parameters screens may allow users to set parameters to a particular sensor or control unit or group of such units.

[**0131**] In the system parameter screen **1300**, an application field **1310** is provided for defining the type of application in which the mold growth prediction system is implemented. Which type of application is selected may affect certain default values, such as temperature and humidity limits, or may adjust how mold growth is predicted. Function monitor fields **1320** allows the user to select which environmental conditions to monitor, such as relative humidity, temperature, potential for mold growth, the rate of change of relative humidity, the rate of change of temperature, and any combination thereof.

[**0132**] Range and change rate fields **1330** allows the user to set ranges and change rates for relative humidity, temperature, and potential for mold growth. For example, the range of relative humidity and the range of temperature can be set between high and low values. Any data obtained by

sensor units outside these ranges would potentially generate an alarm or warning condition. Regions of potential for mold growth can be designated as having a low potential, middle potential, or high potential depending on the calculated potential for mold growth. The demarcation of the low, middle, and high potentials can affect elements of the graphs discussed above, alarm conditions of the system, and other features. Likewise, upper limits of the rates of change for relative humidity and temperature can be set so that data indicating a rate of change above the limits would potentially generate an alarm or warning condition.

[**0133**] Alarm event setting fields **1320** can be used to set how many events must occur before an alarm or warning condition is generated. For control units, alarms may be generated for low power, communication breaks, and Cyclical Redundancy Checks (CRC) errors in transmitted data received by the control units. For sensor units, alarms may be generated for lost data, temperature warnings, relative humidity warnings, temperature rate of change warnings, relative humidity rate of change warnings, potential for mold growth warnings, and low battery warnings.

[**0134**] In addition to the parameter screen **1300**, a user can access other set up screens using controls **1400**. With “control unit addresses,” the user can configure addresses and other details of the control units for the implementation. With “area codes,” the user can set up and define the various areas of an implementation, building, rooms, floor, etc. With “sensor unit addresses,” the user can configure addresses and other information for the sensor units. “Clear Sensor” can be used to delete information related to a sensor. The graphical user interface can provide these and other set up screens for a user to configure and manage the system.

[**0135**] The screens of the graphical user interface of FIGS. **19-21** are meant to be exemplary. It will be appreciated that the graphical user interface of the disclosed system can include additions user interface screens for monitoring and controlling the disclosed system.

[**0136**] The foregoing description of preferred and other embodiments is not intended to limit or restrict the scope or applicability of the inventive concepts conceived of by the Applicants. In exchange for disclosing the inventive concepts contained herein, the Applicants desire all patent rights afforded by the appended claims. Therefore, it is intended that the appended claims include all modifications and alterations to the full extent that they come within the scope of the following claims or the equivalents thereof.

What is claimed is:

1. A mold growth prediction system, comprising:

at least one sensor unit having a first wireless device, a timer, and one or more sensors, the one or more sensors obtaining temperature data and humidity data of an environment according to a time interval of the timer, the first wireless device transmitting the obtained temperature data and humidity data; and

at least one processing unit having a second wireless device, the second wireless device receiving the transmitted temperature data and humidity data, the at least one processing unit determining a probability of mold growth for the environment based on the temperature data, the humidity data, and time data related to the time interval.

2. The system of claim 1, wherein a computer includes at least a portion of the at least one processing unit.

3. The system of claim 1, wherein a control unit includes at least a portion of the at least one processing unit.

4. The system of claim 1, wherein the first and second wireless devices each comprise a wireless transceiver capable of transmitting and receiving multi-band wireless frequencies.

5. The system of claim 4, wherein in response to receiving the transmitted temperature data and humidity data, the at least one processor transmits a response to the at least one sensor unit with the second wireless device, the response including time-related information indicating when the at least one sensor unit is to obtain new data.

6. The system of claim 5, wherein the first wireless device receives the response from the second wireless device, and wherein the at least one sensor unit configures the timer interval of the time based on the time-related information in the response.

7. The system of claim 1, wherein the at least one processing unit comprises:

at least one control unit having a communication interface; and

a computer communicatively coupled to the communication interface of the at least one control unit.

8. The system of claim 7, wherein the communication interface comprises an RS-485 interface.

9. The system of claim 8, further comprising a hub connected to the RS-485 interface of the control unit and connected to the computer via an RS-232 connection.

10. The system of claim 1, wherein the at least one sensor unit includes a plurality of sensor units, each of the sensor units having a different sensor identifier to differentiate the temperature and humidity data transmitted by each of the sensor units to the at least one processing unit.

11. The system of claim 10, wherein the at least one processing unit includes a plurality of control units, each of the control units having one or more of the sensor units associated thereto, each of the second wireless devices configured for one of a plurality of wireless frequencies, whereby the first wireless devices of the sensor units associated with a given one of the control units is configured for the same wireless frequency as the given one of the control units.

12. The system of claim 1, wherein the at least one processing unit comprises an algorithm for determining the probability of mold growth based on the temperature data, the humidity data, and the time data related to the time interval.

13. The system of claim 12, wherein the algorithm is configured to:

determine whether the temperature data and the humidity data fall within conditions detrimental to mold growth,

determine a decrement value based on the detrimental conditions, and

decrease a previous probability of mold growth by the decrement value to produce a current probability of mold growth.

14. The system of claim 12, wherein the algorithm is configured to:

determine whether the temperature data and the humidity data fall within conditions conducive to mold growth,

determine an incremental value based on the conducive conditions, and

increase a previous probability of mold growth by the incremental value to produce a current probability of mold growth.

15. A wireless sensor unit for an environmental monitoring system, comprising:

control circuitry having a timer;

wireless communication circuitry communicatively coupled to the control circuitry;

one or more sensors communicatively coupled to the control circuitry to obtain temperature data and humidity data,

wherein the control circuitry is configured to:

obtain temperature data and humidity data with the one or more sensors at a first time value of the timer;

transmit the obtained temperature data and humidity data via the wireless communication circuitry; and

process an acknowledgment if received with the wireless communication circuitry in response to the transmitted temperature data and humidity data.

16. The wireless sensor unit of claim 15, wherein the control circuitry comprises a microcontroller having the timer integrated therein.

17. The wireless sensor unit of claim 15, wherein the wireless communication circuitry comprises:

a wireless transceiver; and

an antenna communicatively coupled to the wireless transceiver.

18. The wireless sensor unit of claim 15, wherein to process the acknowledgment, the control circuitry is configured to determine if a first identifier in the acknowledgment matches a second identifier assigned to the wireless sensor unit.

19. The wireless sensor unit of claim 15, wherein to process the acknowledgment, the control circuitry is configured to:

obtain a second time value from the acknowledgment, and

assign the second time value to the timer.

20. The wireless sensor unit of claim 19, further comprising a battery supplying power to the wireless sensor unit, wherein the control circuitry is configured to operate in a low power mode until the second time value assigned to the timer.

21. The wireless sensor unit of claim 19, wherein the control circuitry is further configured to:

obtain temperature and humidity data with the one or more sensors at the second time value of the timer;

transmit the obtained temperature and humidity data via the wireless communication circuitry; and

process another acknowledgment if received with the wireless communication circuitry in response to the transmitted temperature and humidity data.

22. The wireless sensor unit of claim 15, wherein to transmit the obtained temperature and humidity data via the wireless communication circuitry, the control circuitry is configured to transmit a signal with the wireless communication circuitry at a predefined wireless frequency assigned to a designated receiver.

23. The wireless sensor unit of claim 15, wherein to transmit the obtained temperature and humidity data via the wireless communication circuitry, the control circuitry is configured to transmit a signal with the wireless communication circuitry, the signal including an assigned identifier for the wireless sensor unit.

24. The wireless sensor unit of claim 23, wherein to transmit the obtained temperature and humidity data via the wireless communication circuitry, the control circuitry is configured to construct the signal having the assigned identifier, the first time value, a temperature value, a humidity value, and a battery status.

25. The wireless sensor unit of claim 15, wherein control circuitry is configured to:

wait to receive the acknowledgment with the wireless device for a waiting period; and

retransmit the obtained temperature and humidity data via the wireless device at least one time if the acknowledgment is not received after the waiting period.

26. A wall-mountable sensor unit for an environmental monitoring system, comprising:

an electronics assembly having at least one sensor and having wireless communication circuitry to transmit data obtain with the at least one sensor;

a housing containing the electronics assembly; and

a mounting assembly at least including:

a base member defining a passage therethrough and having sides clamping to a hole in a wall; and

a holding member attachable to the base member and having a plurality of legs, the legs attaching to the housing containing the electronics assembly and positioning the housing through the passage of the base member to hold the electronics assembly in the hole in the wall.

27. The wall-mountable sensor unit of claim 26, wherein the electronics assembly comprises:

a circuit board having a front face and a back face, the at least one sensor attached to the back face of the circuit board; and

an antenna attached to the front face of the circuit board and electrically coupled to the wireless communication circuitry on the circuit board,

wherein the circuit board mounts in the housing and the housing attaches to the legs of the holding member such that the antenna faces outside the hole in the wall and the at least one sensor faces inside the hole in the wall.

28. The wall-mountable sensor unit of claim 26, wherein the housing removably snap fits to the legs of the holding member.

29. The wall-mountable sensor unit of claim 26, wherein the base member comprises:

a first face portion;

a narrow portion connected to the first face portion and being positionable in the hole of the wall; and

at least two ears moveable on sides of the narrow portion, the ears being moveable on the sides of the narrow portion and clamping the wall between the ears and the first face portion to hold the base member to the hole.

30. The wall-mountable sensor unit of claim 29, wherein the holding member comprises a second face portion having the plurality of legs connected thereto, the second face portion of the holding member attaching to the first face portion of the base member.

31. The wall-mountable sensor unit of claim 30, further comprising a cover plate snap fitting to the second face portion of the holding member exposed outside the hole of the wall.

32. An electronic environmental monitoring method, comprising:

obtaining temperature data and humidity data for an environment at time intervals at a plurality of sources;

wirelessly transmitting the obtained temperature data and humidity data from the sources;

receiving the transmitted temperature data and humidity data at at least one destination associated with the plurality of sources;

wirelessly transmitting acknowledgments from the at least one destination to the sources in response to receiving the transmitted temperature data and humidity data; and

processing the received temperature data and humidity data based on time data related to the time intervals.

33. The method of claim 32, wherein the act of processing the received temperature data and humidity data based on time data related to the time intervals comprises determining a probability of mold growth using the temperature data, the humidity data, and the time data in conjunction with stored information on mold growth.

34. The method of claim 33, wherein the stored information on mold growth comprises an equation defining an envelope based on temperature, humidity, and one or more species of mold, the envelope substantially separating conditions detrimental to mold growth from conditions conducive to mold growth for the species of mold.

35. The method of claim 33, wherein the act of determining the probability of mold growth comprises:

determining whether the temperature data and the humidity data fall within conditions detrimental to mold growth;

determining a decrement value based on the detrimental conditions; and

decreasing a previous probability of mold growth by the decrement value to produce a current probability of mold growth.

36. The method of claim 33, wherein the act of determining the probability of mold growth comprises:

determining whether the temperature data and the humidity data fall within conducive conditions to mold growth;

determining an incremental value based on the conducive conditions; and

increasing a previous probability of mold growth by the incremental value to produce a current probability of mold growth.

37. The method of claim 32, wherein the act of wirelessly transmitting the obtained temperature data and humidity data from the sources comprise wirelessly transmitting signals at a predefined wireless frequency assigned to the at least one destination.

38. The method of claim 32, wherein the act of wirelessly transmitting the obtained temperature data and humidity data from the sources comprise wirelessly transmitting signals having different identifiers for each of the sources to

differentiate the transmitted signals at the at least one destination.

39. The method of claim 32, wherein the act of wirelessly transmitting acknowledgments from the at least one destination to the sources in response to receiving the transmitted temperature data and humidity data comprises constructing the acknowledgments to include time values for the time intervals of each of the sources to obtain data and to include identifiers assigned to each of the sources.

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