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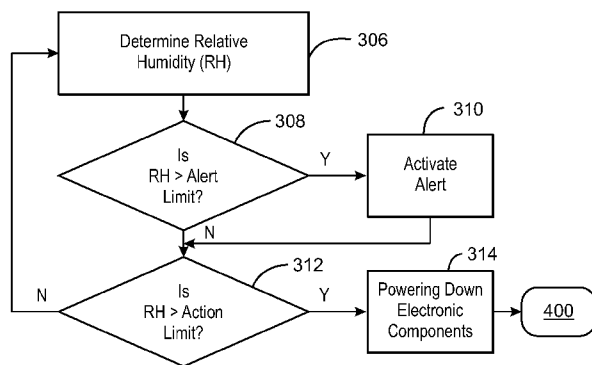
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**Declarations under Rule 4.17:**

- as to the identity of the inventor (Rule 4.17(i))
- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))

[Continued on next page]

- (54) **Title:** PROTECTING A COMPUTING DEVICE FROM ENVIRONMENTAL ISSUES IN AN ENCLOSURE



(57) **Abstract:** Example techniques for protecting computing device from corrosive environments in enclosures are provided. A method includes determining a relative humidity in an enclosure. A determination is made if the relative humidity is greater than an alert limit, and, if so, an alert is activated. A determination is made if the relative humidity is greater than an action limit, and, if so, the equipment in the enclosure is powered down.



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## PROTECTING A COMPUTING DEVICE FROM ENVIRONMENTAL ISSUES IN AN ENCLOSURE

### BACKGROUND

**[0001]** Environmental conditions can irreversibly damage electronic systems. For example, exposure to condensing or corrosive atmospheres can lead to shorting or corrosive degradation. Specifications on humidity and temperature are generally provided to purchasers of systems. However, unforeseen circumstances may lead to exposure of the electronic part to conditions outside of the specification.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0002]** Fig. 1 is a schematic of an example of protecting electronic components in a data center from environmental conditions;

**[0003]** Fig. 2A is a block diagram of an example system for protecting electronic components in a data center from environmental conditions;

**[0004]** Fig. 2B is a block diagram of another example system for protecting electronic components in a data center from environmental conditions;

**[0005]** Fig. 3A is a process flow diagram of an example method for protecting electronic components from environmental conditions;

**[0006]** Fig. 3B is a process flow diagram of another example method for protecting electronic components from environmental conditions;

**[0007]** Fig. 4A is a process flow diagram of an example of a method for restarting a system after it has been shutdown to protect it from environmental conditions; and

**[0008]** Fig. 4B is a process flow diagram of an example of a method for restarting a system after it has been shutdown to protect it from environmental conditions.

### DETAILED DESCRIPTION

**[0009]** The performance requirements of some electronic devices may require them to be constructed of certain materials, such as metallic alloys, that are prone to corrosion or oxidation. Corrosion or oxidation can irreversibly damage the performance of the device. In mission critical applications, operational failures of a device due to

corrosion and or oxidation may be problematic. Many corrosion processes are driven by the presence of water. The most common origin of corrosion is condensing water, wherein free-standing water droplets can occur in or on the device.

**[0010]** The environmental conditions of a device may lead to the corrosion or oxidation leading to the operational failures. For example, exposure to high humidity environments, especially in the presence of temperature variations, may lead to condensation on electronic parts, leading to electrochemical corrosion, shorting, or longer term corrosion processes. Further, the presence of corrosive materials in the atmosphere, such as salt particles or corrosive gases may initiate or exacerbate corrosion. Although many of the environments that can cause corrosion or oxidation are nominally out of specification, often there is no mechanism to prevent a customer from, intentionally, carelessly, or inadvertently, operating the device in that environment.

**[0011]** As described herein, sensors may be added at the component level or the enclosure level to alert on environmental conditions and take appropriate action. The action may include alerting the user that the environment is harmful, shutting the device down before it is damaged, or taking automated corrective action to protect the device, such as turning on dehumidifiers or heaters. Further, proper device function may be verified during startup after the environmental condition is corrected.

**[0012]** Fig. 1 is a schematic 100 of an example of protecting electronic components 102 in a data center 104 from environmental conditions. The data center 104 may have a number of enclosures 106, such as cabinets holding racks that hold the electronic components 102. In this example, each of the enclosures 106 may be equipped with a humidity 108 and temperature sensor 110. Further, the data center 104 itself may be equipped with one or more data center humidity sensors 112 and data center temperature sensors 114. Other sensors may be included in the data center 104, such as a particle sensor 116 or an atmospheric composition sensor 118, among others.

**[0013]** Alerting devices may be included to inform users when the humidity is past an alert limit, such as a humidity level that is higher than the specifications. The alerting devices may include a data center alerting device 120, a floor alerting device 122, or a cabinet alerting device 124. As described herein, each of these levels may be

considered to be enclosures. The alerting devices may include a flashing light, a horn, and a computer message on an operation screen, among others.

**[0014]** The data center 104 may include a heating, ventilation, and air conditioning (HVAC) unit 126 to control humidity and temperature in the data center 104. The HVAC unit 126 may include other units that may be activated if a high humidity or other environmental condition is detected. These other units may include an auxiliary filter system 128 and a dehumidifier 130, among others.

**[0015]** The HVAC unit 126 may be used along with the other units 128 and 130 to prevent or mitigate environmental conditions detected by the sensors 108-118 that may damage the electronic components 102. For example, the data center 104 may be located proximate to an ocean shore 132. In addition to providing a high humidity environment, waves 134 may create an aerosol including salt particles 136. If a door 138 to the data center 104 is frequently opened, or left open, the inside of the data center 104 may become humid, warm, or both. Further, the salt particles 136 may infiltrate the data center 104, creating a corrosive environment. Certain enclosures 106, such as cabinets 140 near the door 138 or the HVAC unit 126 may see the effects first, such as condensation from the humidity. The sensors 108 and 110 in these cabinets may detect that the humidity is higher than an alert limit, for example, at a relative humidity level that is within 5 % or 10 % of condensation, and activate an alerting device, such as a cabinet alerting device 124. As the relative humidity level increases, it may approach a level at which condensation will form, at which point a control system may shut down the electronic components 102 to avoid damage.

**[0016]** Fig. 2A is a block diagram of an example system 200 for protecting electronic components in a data center from environmental conditions. In this example, a control system 202 performs the functions described herein. The control system 202 may be part of a central management system for the data center, or may be located in smaller enclosures, such as a floor or individual cabinet. Further, the functions may be distributed among management controllers in individual enclosures

**[0017]** The control system 202 may include a processor 204 that is configured to execute stored instructions, as well as a memory device 206 that stores instructions that

are executable by the processor 204. The processor 204 can be a single core processor, a dual-core processor, a multi-core processor, a computing cluster, or the like. The processor 204 may be coupled to the memory device 206 by a bus 208 where the bus 208 may be a communication system that transfers data between various components of the control system 202. In embodiments, the bus 208 may be a PCI, ISA, PCI-Express, or the like.

**[0018]** The memory device 206 can include random access memory (RAM), e.g., SRAM, DRAM, zero capacitor RAM, eDRAM, EDO RAM, DDR RAM, RRAM, PRAM, read only memory (ROM), e.g., Mask ROM, PROM, EPROM, EEPROM, flash memory, or any other suitable memory systems. The control system 202 may also include a storage device 210. The storage device 210 may include non-volatile storage devices, such as a solid-state drive, a hard drive, a tape drive, an optical drive, a flash drive, an array of drives, or any combinations thereof.

**[0019]** The processor 204 may be connected through the bus 208 to a human machine interface (HMI) 212 configured to couple the control system 202 to one or more I/O devices. The I/O devices may include an input device 214, such as a keyboard, a mouse, or a pointing device, wherein the pointing device may include a touchpad or a touchscreen, among others. The HMI 212 may include a display driver to couple the control system 202 to a display device 216. The display device 216 may be a built-in component of the control system 202, or connected externally to the control system 202. The display device 216 may include a display screen, a computer monitor, a television, or a projector, among others. In some embodiments, the display screen may include a touch screen for input to the control system 216, for example, as part of a wall mounted HVAC control interface. The display device 216 may be used to alert a user when the humidity, temperature, or atmospheric composition are approaching or at levels that may damage the electronic components. Other devices may be coupled to the HMI 212 to alert users to the problematic conditions, such as visual alerting devices 218 and audible alerting devices 220.

**[0020]** Any number of sensors may be coupled to the control system 202 to measure environmental conditions. These sensors may include humidity sensors 222 coupled to

a humidity sensor interface 224. The humidity sensors 222 may include any number of types such as resistance and capacitance sensors that measure relative humidity or thermal conductivity sensors that measure absolute humidity. Examples of sensors that may be used include relative humidity sensors available from Honeywell Corporation as the Humidicon™ line of sensors, or the Si70xx line of sensors available from Silicon Labs of Austin, Texas, among others. In some examples, the humidity sensors may include temperature sensors that are constructed into a single unit with the humidity sensors. An inexpensive temperature and humidity monitor, such as the Honeywell HIH-5030-001, may be used to measure the humidity and temperature in the environment. This sensor can be incorporated into each device or each system.

**[0021]** If separate temperature sensors 226 are used, they may be coupled to the control system 202 through a temperature sensor interface 228. The temperature sensors 226 may include resistance temperature detectors (RTDs), thermocouples, and other devices. Temperature detectors may be available, for example, from the Honeywell Corporation, among many others.

**[0022]** Atmospheric composition sensors 230 may be coupled to the control system 202 by an atmospheric sensor interface 232. The atmospheric composition sensors 202 may detect Chlorine, Sulfur Dioxide, Nitrogen Oxides or other harmful gases. The detection of these gases might be accomplished by measuring oxidation-reduction potentials (ORP). For example, a chlorine gas sensor is available as the SensoriC series from Wenglor GMBH of Tettnang, Germany. Any number of other sensor technologies may be used, including infrared (IR) absorbance, catalytic bead sensors, and photoionization sensors, among others. For example, many of these sensor types are available from International Sensor Technology of Irvine, California.

**[0023]** Particle sensors 234 may be coupled to the control system by a particle sensor interface 236. The particle sensors 234 may include an aerosol particle detector that uses light scattering of a high intensity light beam, such as a laser, to detect and measure the concentration of particles in the atmosphere. The particles may include dust particles, salt particles, or other potentially damaging particles, depending on the location and environment of the electronic enclosure. For example, particle counters

may be available as Aerosol Sensor and Monitors from the Shinyei Technology Company of Kobe, Japan, or as Environmental Particle Counters from TSI incorporated of Shoreview, Minnesota.

**[0024]** The control system 202 may include an HVAC interface 238 which may interface and control an HVAC system (not shown), in addition to dehumidifiers 240 and auxiliary filters 242. While the HVAC system may cool and filter the air under normal conditions, the dehumidifiers 240 and auxiliary filters 242 may be activated when conditions of high humidity or high particulates, respectively, are detected.

**[0025]** A network interface controller (NIC) 244 may also be linked to the processor 204. The NIC 233 may link the control system 202 to a network 246, for example, within an enclosure such as a cabinet or data center. The network 246 may couple the control system 202 to computing devices 248 and power systems 250, so that the control system 202 may initiate a controlled shutdown of the computing devices 248 if environmental conditions are problematic. This may include instructing the computing devices 248 to save the current state and, once this is complete, instructing the power systems 250 to turn off. The network 246 may also be in communication with a computing cloud 252, such as remote systems connected over a local area network (LAN), a wide area network (WAN), or the Internet. The control system 202 may report the environmental conditions to the remote systems, and may, for example, send alerts out through the cloud. Further, the control system 202 may inform the remote systems that a shutdown is imminent and to be prepared to take over the computing duties from the computing devices 248.

**[0026]** The storage device 210 may include a number of modules configured to provide the control system 202 with the environmental monitoring functionality. For example, a humidity measurement module 254 may be utilized to obtain a humidity measurement from a humidity sensor 222. A temperature module 256 may be used to obtain a temperature reading, for example, from a temperature sensor 226 or a temperature sensor constructed into a humidity sensor 222.

**[0027]** Once temperature and humidity are measured, a relative humidity module 258 may use these values to calculate the relative humidity. The calculation of the

relative humidity may not be needed if the humidity sensor 222 directly measures this value. An atmospheric composition module 260 may use the atmospheric composition sensor 230 to detect and measure the amounts of corrosive gases in the environment. These may be for specific gases, such as chlorine, or may be a more general ORP of a gas stream from an enclosure. Further, the atmospheric composition module 260 may use the particle sensor 234 to detect and measure the concentration of particles suspended in the air in the enclosure.

**[0028]** If problems are detected in an enclosure, the control system 202 may take action. For example, an alert module 262 may activate a visual alerting device 218, and audible alerting device 220, or both. Different levels of activation of the alerting devices 218 and 220 may be performed to indicate different actions. For example, the visual alerting device 218 may be activated to indicate that the relative humidity in an enclosure, such as a cabinet, floor, or data center, is above a specified limit, such as 55 %, 60 %, 70%, or higher. An audible alerting device 220 may be activated if the relative humidity crosses a higher threshold, for example, to indicate that a shutdown is imminent. A humidity control module 264 may activate the dehumidifier 240 to lower the humidity in the enclosure, for example, when the alert limit is exceeded. Further, a filter control module 266 may activate an auxiliary filter unit 242 to lower the particle concentration in the enclosure.

**[0029]** A power control module 268 may be used to initiate the shutdown of computing devices 248, for example, if mitigation procedures fail. The shutdown may be a controlled shutdown, for example, if the humidity is approaching condensation slowly. In this example, the power control module 268 may instruct the computing devices 248 in the enclosure having the environmental problems to save their work and power down. If the humidity is fast approaching condensation, the power control module 268 may be used to perform an emergency shutdown of the computing devices 248 to prevent damage from condensation. In either example, the power control module 268 may use the network 246 to inform remote systems in the cloud 252 that computing devices 248 are being powered down.

**[0030]** The block diagram of Fig. 2A is not intended to indicate that the system 200 is to include all of the components shown in Fig. 2A. For example, the particle sensors 234 and atmospheric composition sensors 230 may not be used in some implementations, as described in the example in Fig. 2B. Further, any number of additional components may be included within the system 200, depending on the details of the specific implementation. For example, the system may be distributed among a number of management controllers located on computing devices 248 throughout a data center.

**[0031]** Fig. 2B is a block diagram of another example system for protecting electronic components in a data center from environmental conditions. Like numbered items are as described with respect to Fig. 2A. Not all units will be present in all examples. For example, as shown in Fig. 2B, the system may not include various systems, such as an atmospheric composition sensor, a particle sensor, or systems to actively modify the environment, such as auxiliary filter systems or a dehumidifier.

**[0032]** Fig. 3A is a process flow diagram of an example method 300 for protecting electronic components from environmental conditions. The method 300 may be performed by the systems 100 and 200 shown in Figs. 1 and 2. The method begins at block 302 with the measurement of temperature. The temperature may be used to calculate a relative humidity, dewpoint, or other value. Further, the temperature may be used to predict the onset of a condensing environment. In examples in which relative humidity is directly measured, the temperature may be used as part of the calibration of the humidity sensor, e.g., being used to correct for changes in the response of the humidity sensor as the temperature increases or decreases.

**[0033]** At block 304, the humidity in the enclosure is measured. This may be a relative humidity (RH), measured by a capacitive or resistive sensor, or may be an absolute humidity, measured by a thermal conductivity or other device.

**[0034]** At block 306, the RH is calculated based on the temperature and humidity measurements. If a RH has been measured, the value is corrected for temperature at this point. The RH may be used to predict when the environment becomes condensing.

For example, a condensing environment can be predicted by monitoring the temperature and humidity of the ambient environment over time.

**[0035]** At block 308, a determination is made as to whether the RH is greater than an alert limit. The alert limit may be a specification limit or any other selected value. If the RH is greater than the alert limit, at block 310 an alerting device may be activated, as described herein. Process flow would then proceed to block 312.

**[0036]** At block 312, a determination is made as to whether a relative humidity is greater than an action limit. The action limit may be the dew point, indicating that condensation is imminent, or may be some value lower to provide time to save work and shut down the protected systems. For example, the action limit may be at about 90 % RH, 85 % RH, 80 % RH, or lower, depending on the sensitivity of the system to damage from condensation. If the RH is greater than the action limit, at block 314, electronic components in the enclosure, such as the computing devices, are powered down. This may include instructing the computing devices to save their work and shut off. Depending on the RH level, it may include merely powering the device off. Process flow would then proceed to the method 400 described with respect to Fig. 4.

**[0037]** At block 316, a determination is made as to whether the change in RH versus time is greater than a change limit. For example, a rapid drop in temperature in a humid environment, such as 10 °C / hr at 50 % relative humidity, or a rapid increase in relative humidity, such as greater than 20 % per hour, will increase the likelihood of condensation occurring on the device. As a further example, if the current environment in an enclosure is at about 30° C and about 80 % RH, a rate of change for temperature cannot exceed -3° C/hour to avoid condensation. To detect this scenario, the temperature and relative humidity may be used to predict when a condensing environment is occurring or about to occur. The safety margins may be adjusted based on environmental rates of change and current environmental conditions. If so, process flow proceeds to block 314. If not, process flow returns to block 302 to continue to monitor the system.

**[0038]** The blocks shown in Fig. 3A are not intended to imply that every block is needed or that other systems may not be present. For example, an external

meteorological site may provide the temperature and humidity measurements. Further, while the measurement is expressed as relative humidity, it can be understood that other measurements providing similar data, such as the dew point, may be used in place of, or in addition to, the relative humidity.

**[0039]** Further, other sources of corrosion can be measured and alerted in the method. For example, airborne particles or gases such as, but not limited to, chlorine, sulfur dioxide, HCl, NaCl, ammonia, and nitrous oxide, may trigger alerts. Sensors to detect all or some of the possible corrosive gases may be included, depending on the likelihood of their presence in the device's projected application and the severity of the consequences of undetected corrosion.

**[0040]** Fig. 3B is a process flow diagram of another example method for protecting electronic components from environmental conditions. Like numbered items are as described with respect to Fig. 3A. In this simplified example, the relative humidity is determined at block 306, without necessarily determining separate temperature and humidity values. The RH is used to activate alerts or initiate shutdown procedures.

**[0041]** Fig. 4A is a process flow diagram of an example of a method 400 for restarting a system after it has been shutdown to protect it from environmental conditions. The method starts at block 402 with the measurement of temperature, proceeds to block 404 for the measurement of humidity, and then to block 406 for the calculation of RH. Blocks 402-406 are similar to, and as explained with respect to blocks 302-306 of Fig. 3A.

**[0042]** At block 408, a determination is made as to whether the RH is less than the alert limit or another value determined to be sufficient to provide drying of the system in a reasonable time, such as 48 hours, 24 hours, or less. If not, process flow returns to block 402 to continue to monitor the temperature and humidity. If so, process flow proceeds to block 410 to determine if the selected drying time has passed. If not, process flow returns to block 402.

**[0043]** If the selected drying time has passed, at block 412, the devices are powered and testing procedures are initiated. For example, the devices in question can run an automatic extended test sequence. At block 416, a determination is made as to

whether the target units are testing fully operational. If so, at block 416, normal operations are resumed, and the method 300 of Fig. 3A is restarted for monitoring. If not, process flow proceeds to block 418, at which the faulty units are powered down and reported. If some units are functional in an enclosure, the functional units may be allowed to return to normal operations while the faulty units are powered down and reported.

**[0044]** Fig. 4B is a process flow diagram of an example of a method for restarting a system after it has been shutdown to protect it from environmental conditions. Like numbered items are as discussed with respect to Fig. 4A. Fig. 4B is a simplified procedure showing the core steps that may be used in some embodiments.

**[0045]** While the present techniques may be susceptible to various modifications and alternative forms, the exemplary examples discussed above have been shown only by way of example. It is to be understood that the technique is not intended to be limited to the particular examples disclosed herein. Indeed, the present techniques include all alternatives, modifications, and equivalents falling within the scope of the present techniques.

CLAIMS

## WHAT IS CLAIMED IS:

1. A system for protecting a computing device from environmental issues in an enclosure, comprising  
a humidity sensor disposed in an enclosure;  
a temperature sensor disposed in the enclosure; and  
a control system to:  
activate an alert when an atmosphere in the enclosure is approaching a  
condensing environment; and  
initiate a shutdown of the computing device in the enclosure when the  
atmosphere in the enclosure has reached a condensing  
environment.
2. The system of claim 1, comprising:  
an atmospheric composition sensor disposed in an enclosure; and  
the control system to activate an alert when the atmosphere in the  
enclosure is corrosive.
3. The system of claim 1, wherein the enclosure comprises a cabinet.
4. The system of claim 1, wherein the enclosure comprises a room, or a data center.
5. The system of claim 2, wherein the atmospheric composition sensor measures an oxidation reduction potential of the atmosphere.
6. The system of claim 1, comprising:  
a particle sensor disposed in the enclosure; and

the control system to activate an alert when a number of particles in the atmosphere is above a preselected level.

7. The system of claim 1, comprising:  
a conductivity sensor; and  
the control system to activate an alert when conductive particles are present.

8. The system of claim 1, comprising:  
a filter system; and  
the control system to activate the filter system when a number of particles is above a preselected level.

9. The system of claim 1, comprising:  
a dehumidifier; and  
the control system to activate the dehumidifier when a relative humidity is above a preselected level.

10. The system of claim 1, comprising:  
an alert system; and  
the control system to activate the alert system when the shutdown of the computing device is initiated.

11. A method for protecting a computing device from environmental issues in an enclosure, comprising:  
determining a relative humidity in an enclosure;  
determining if the relative humidity is greater than an alert limit, and, if so,  
activating an alert; and  
determining if the relative humidity is greater than an action limit, and, if so,  
powering down the computing device in the enclosure.

12. The method of claim 11, comprising determining if a change in the relative humidity over a time period is greater than a change limit, and, if so, powering down the computing device in the enclosure.

13. The method of claim 11, comprising, after powering down the computing device in the enclosure due to relative humidity greater than an action limit:

determining if the relative humidity in the enclosure is less than the alert limit; if

so,

determining if a set amount of time has passed; if so,

initiating startup and testing procedures.

14. A method for protecting a computing device from environmental issues in an enclosure, comprising restarting the computing device after powering down the computing device due to relative humidity greater than an action limit by:

determining if the relative humidity in the enclosure is less than an alert limit; if

so,

determining if a set amount of time has passed; if so,

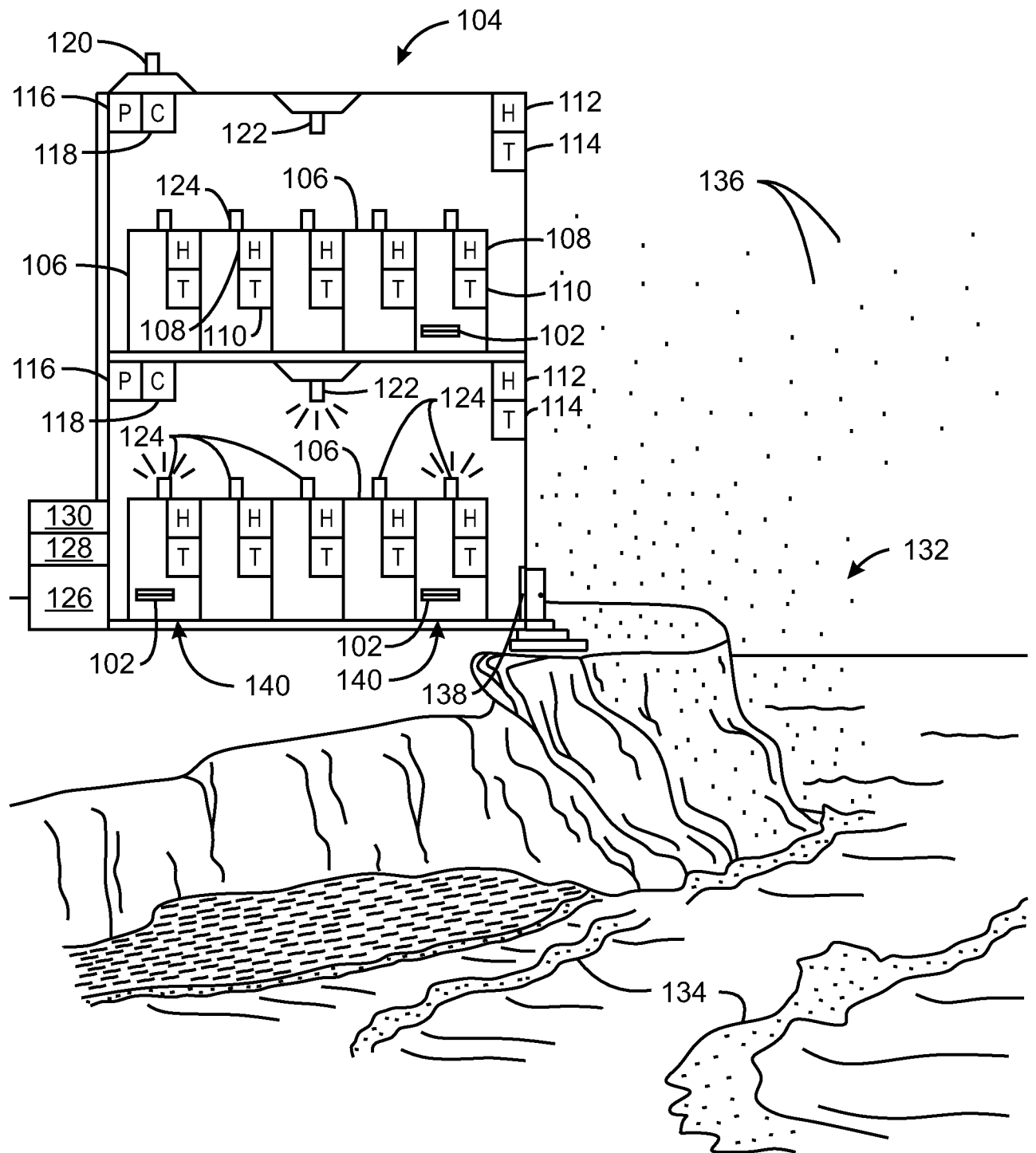
initiating startup and testing procedures.

15. The method of claim 14, comprising:

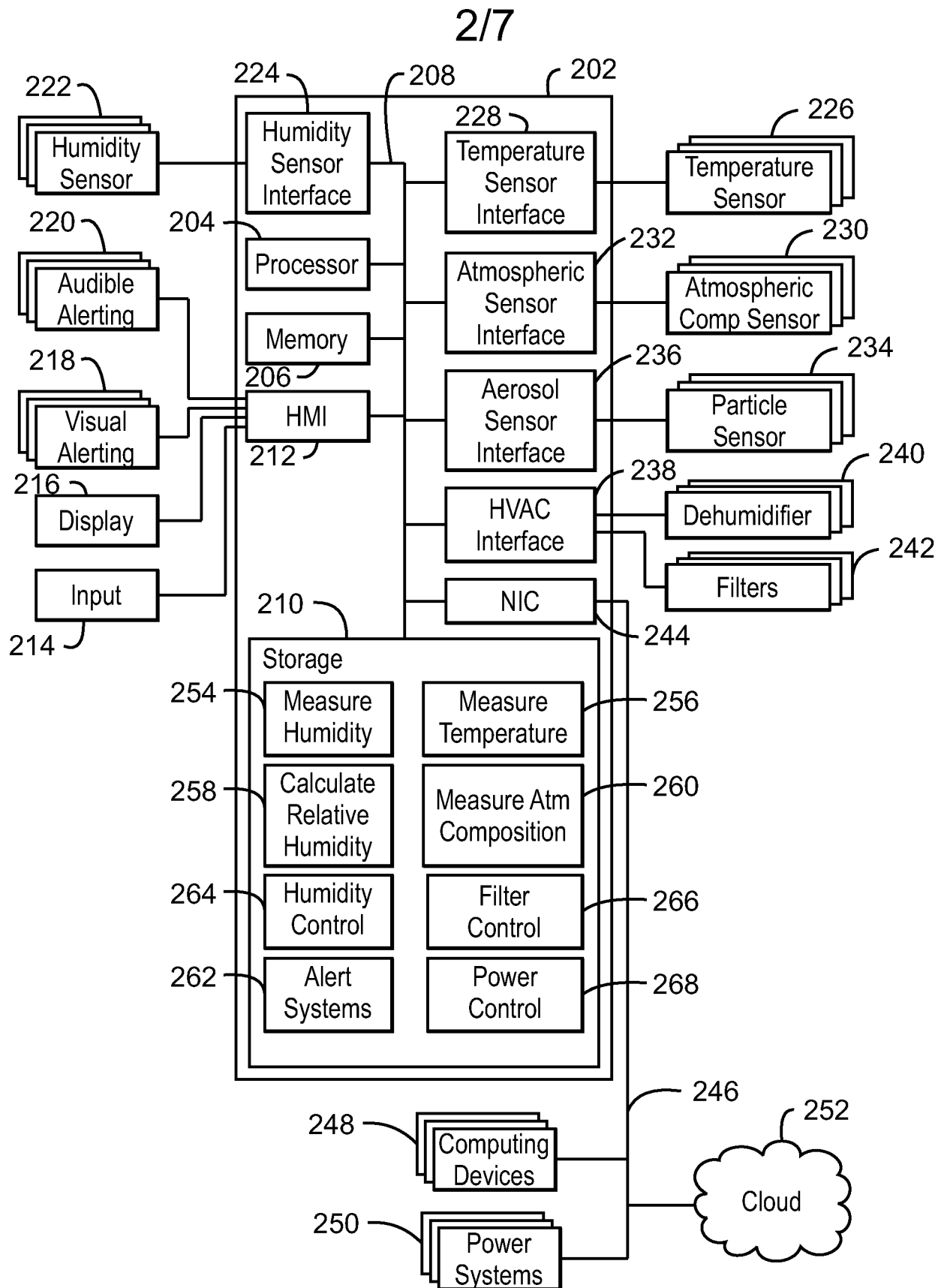
determining if all units in the enclosure are functional; and, if not,

shutting down faulty units and reporting.

1/7

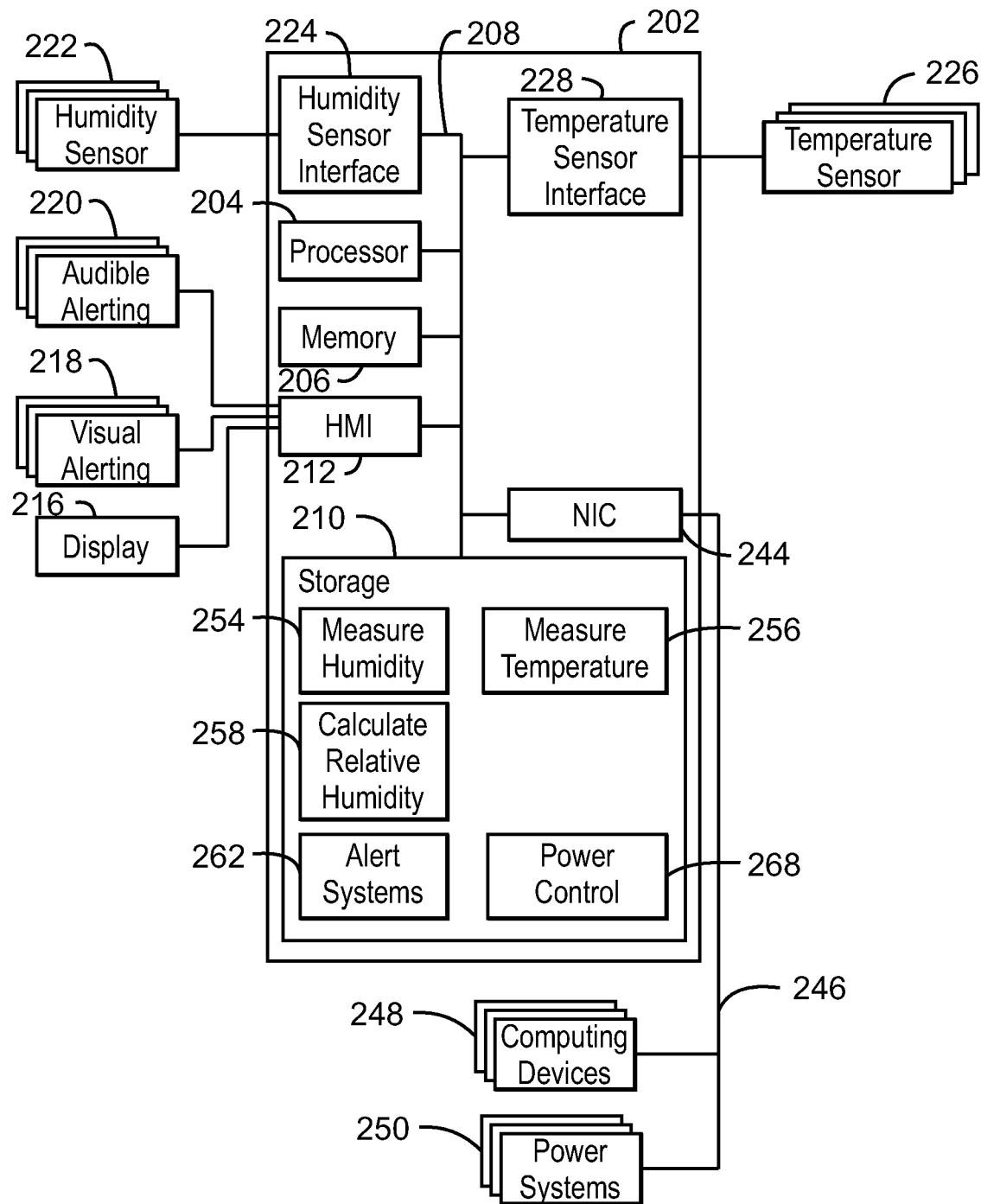


100  
FIG. 1



200  
FIG. 2A

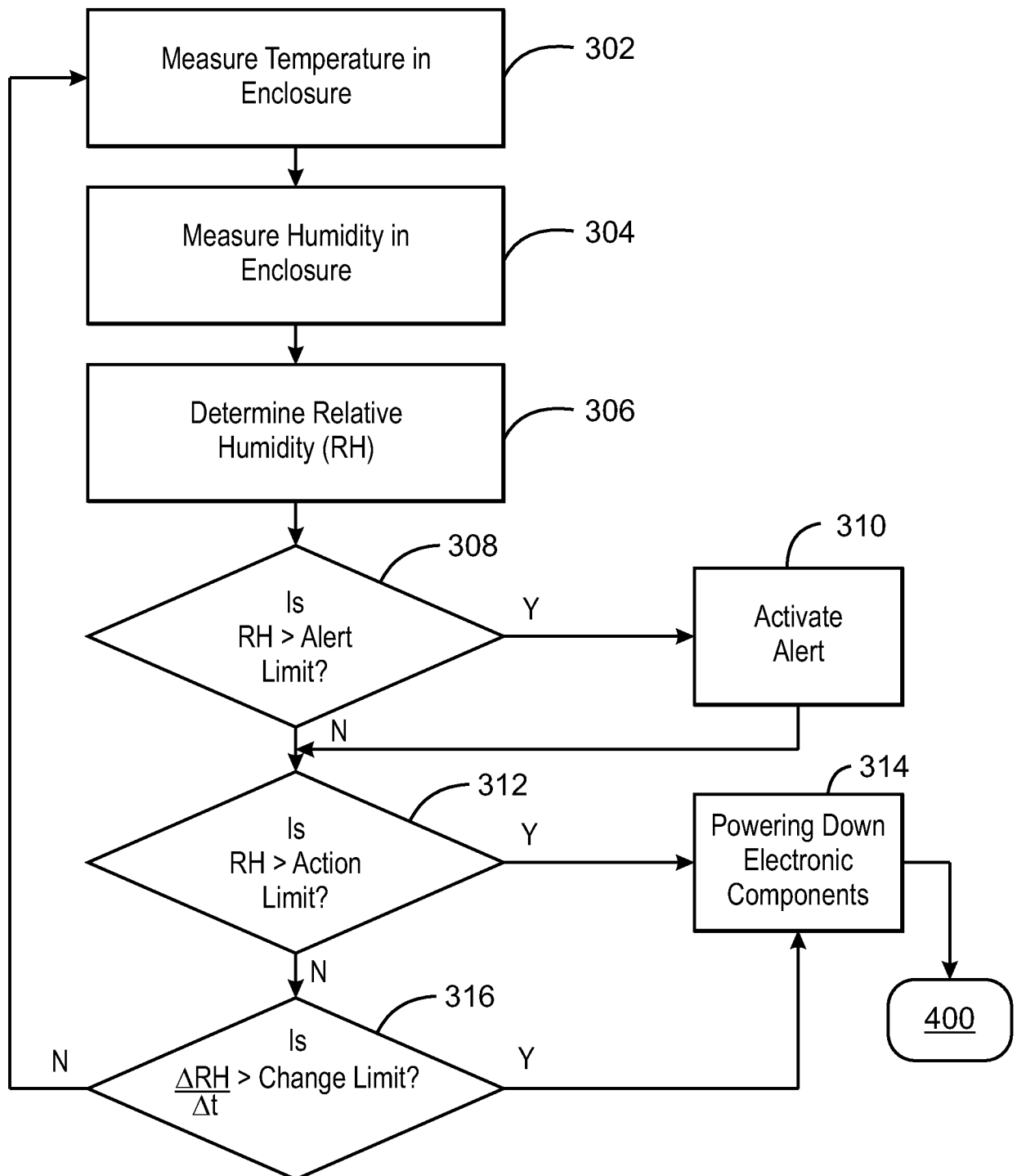
3/7



200

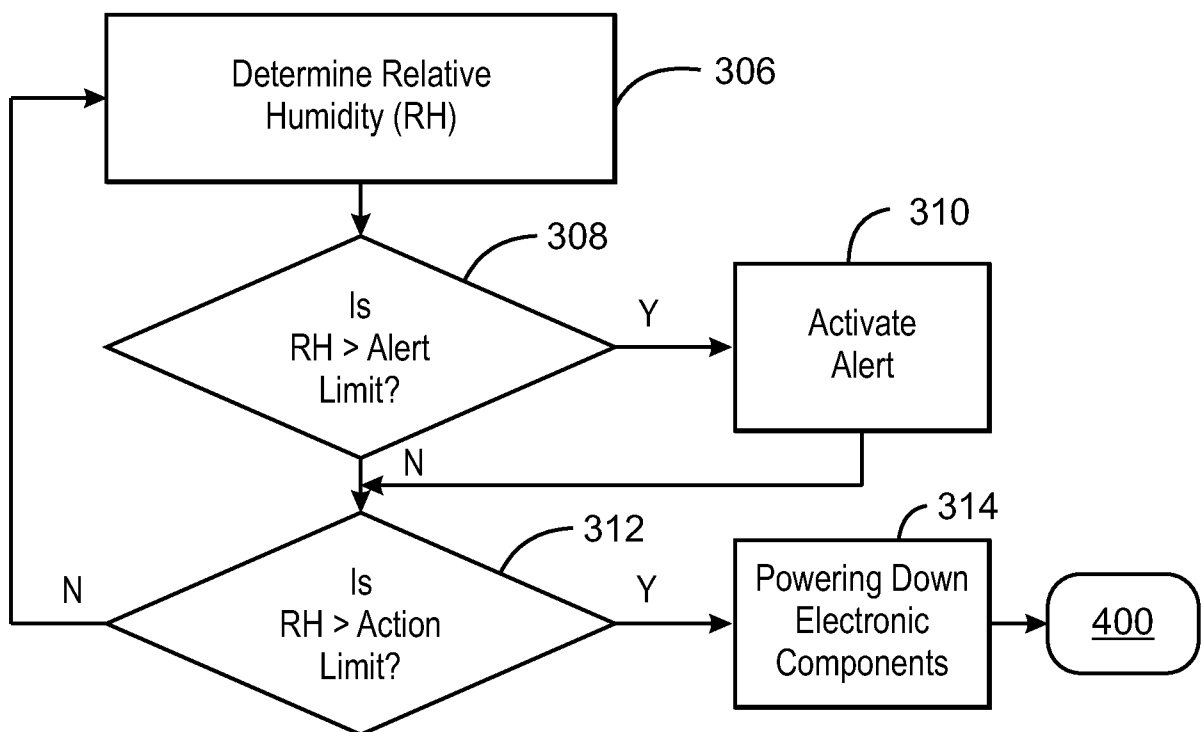
FIG. 2B

4/7



300  
FIG. 3A

5/7



300  
FIG. 3B

6/7

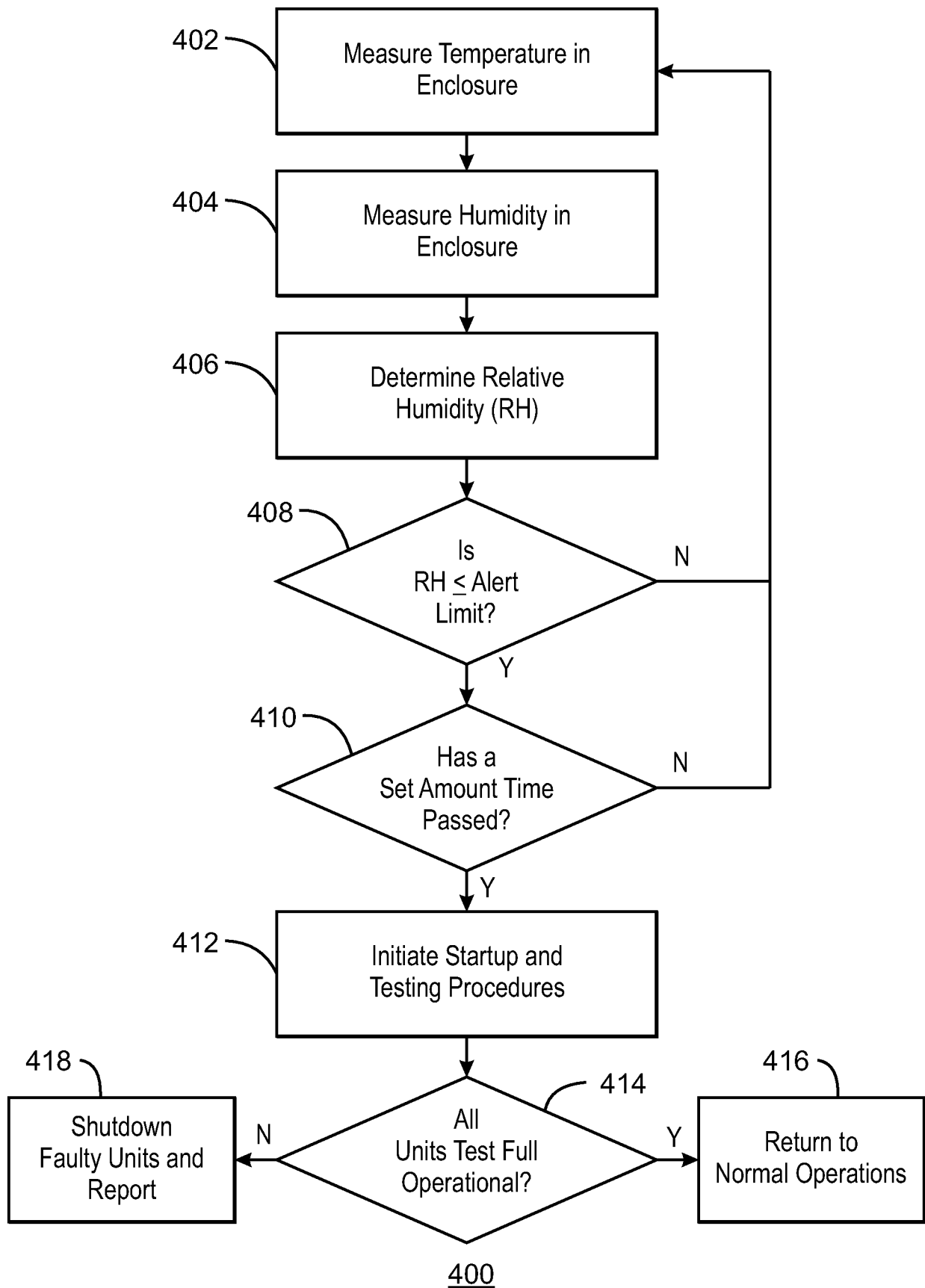
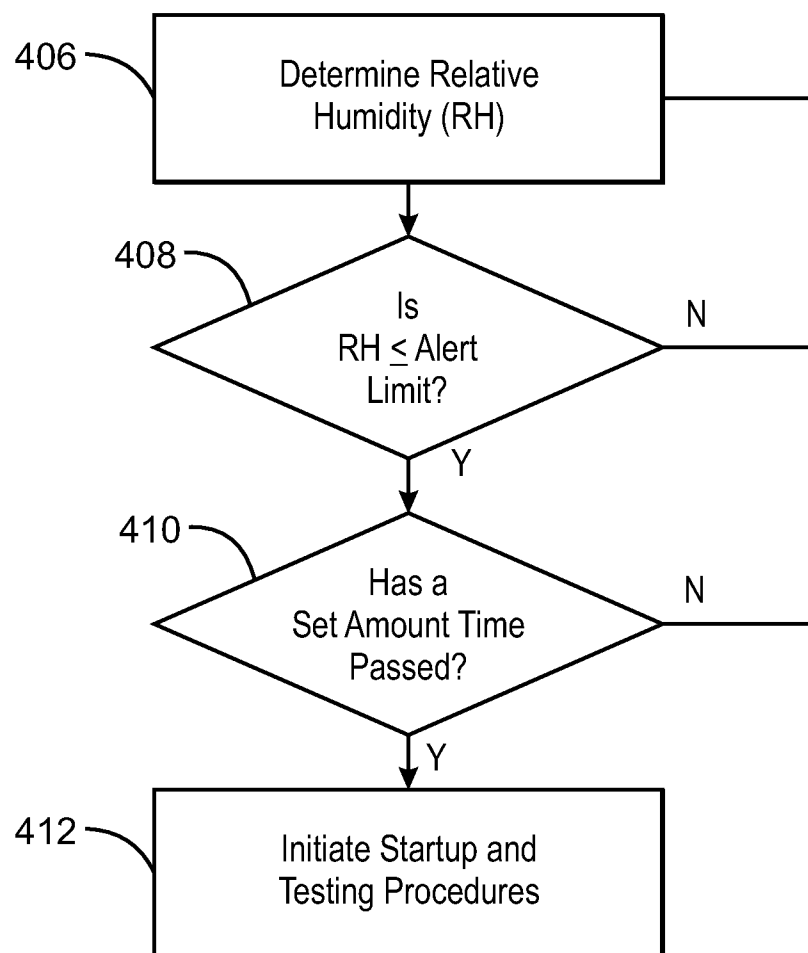


FIG. 4A

7/7



400  
FIG. 4B

## INTERNATIONAL SEARCH REPORT

International application No.  
**PCT/US2015/042679****A. CLASSIFICATION OF SUBJECT MATTER****G08B 21/18(2006.01)i, G08B 21/20(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

G08B 21/18; G08B 17/10; G06F 19/00; G06F 17/00; G01N 33/38; H04L 9/00; G09G 3/10; G05D 23/19; G08B 21/20

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) &amp; Keywords:protecting system, monitoring, detection, humidity, particle, alert, shutdown

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                             | Relevant to claim No. |
|-----------|----------------------------------------------------------------------------------------------------------------|-----------------------|
| X         | US 2011-0118896 A1 (DAVID CARR HOLLOWAY) 19 May 2011<br>See paragraphs [4], [5], [7], [29]; and claims 1, 18.  | 1,3,4,9-15            |
| Y         |                                                                                                                | 2,5-8                 |
| Y         | US 2010-0324835 A1 (MICHAEL J. FOX et al.) 23 December 2010<br>See paragraphs [8], [64], [69]; and figure 1.   | 2,5                   |
| Y         | US 2002-0195956 A1 (STEPHEN MICHAEL MOLNAR et al.) 26 December 2002<br>See paragraphs [16]-[19]; and figure 3. | 6-8                   |
| A         | US 2003-0120436 A1 (DENNIS A. LONIGRO et al.) 26 June 2003<br>See paragraphs [3]-[10]; claim 1; and figure 2.  | 1-15                  |
| A         | EP 1437701 A2 (THE BOEING COMPANY) 14 July 2004<br>See paragraphs [10]-[15]; claim 1; and figure 1.            | 1-15                  |



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of mailing of the international search report

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**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

**PCT/US2015/042679**

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