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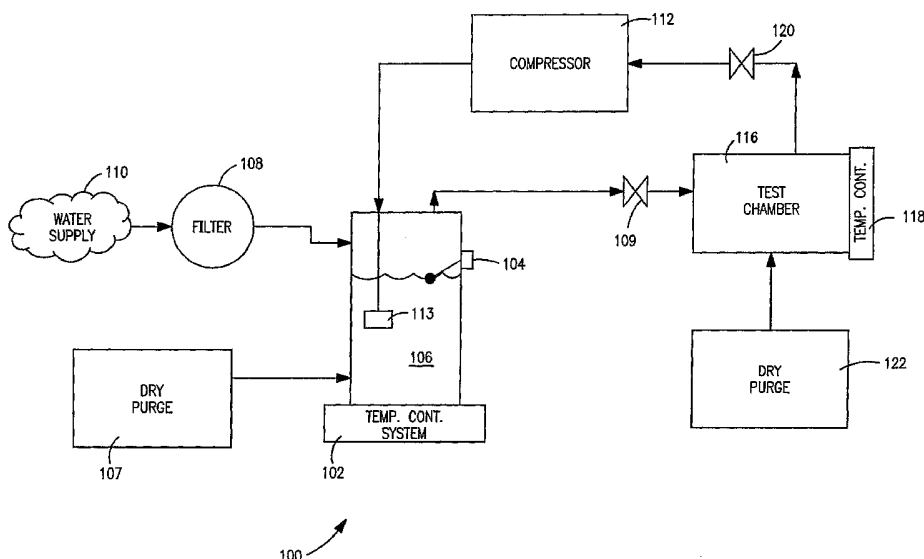
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(54) Title: METHODS AND APPARATUS FOR OPTIMIZING ENVIRONMENTAL HUMIDITY



(57) Abstract: A humidity control apparatus and methods for use with, e.g., an environmental test chamber. In one embodiment, the apparatus comprises a system having a test chamber, a water tank, motive source for a gaseous humidity carrier, and temperature controllers for the tank and chamber. The carrier gas (e.g., air) is diffused through the water tank, thereby saturating the gas to a prescribed humidity level. This saturated gas is then passed into the chamber, and the environment within the chamber (i.e., humidity and temperature) controlled by the controller(s) so as to maintain the desired humidity level. The apparatus disclosed has the primary advantage of reducing or even substantially eliminating condensation within the test chamber when humidity levels are increased.

METHODS AND APPARATUS FOR OPTIMIZING ENVIRONMENTAL HUMIDITY

Priority

This application claims priority to U.S. provisional patent application Serial No. 60/690,171 filed June 13, 2005 of the same title, which is incorporated herein by reference in its entirety.

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1. Field of the Invention

This invention relates to environmental control in systems wherein a device under test (DUT) is conditioned. More particularly, this invention discloses a method and apparatus for producing a controllable change in humidity level at a temperature and saturation level that can be supported by the environment in which it is delivered.

2. Description of Related Technology

The ability to create and control environments of a prescribed humidity is important in a number of fields including, *inter alia*, testing and conditioning of materials and components (e.g., electronics). For example, it may be desirable to condition or expose an electronic component to a prescribed temperature/humidity profile for a period of time for qualification testing or the like, such as by placing the component within a test chamber.

Traditional methods used in humidity control systems and/or vaporizers for use in environmental chamber testing, such as for a device under test (DUT), typically

utilize one of two methods to increase the humidity in the chamber environment, both of which suffer from one or more inherent flaws.

One popular method to create humidified air comprises forcing airflow across a water surface or a water-wicked material. Subsequently, much like natural air currents across large bodies of water such as lakes or oceans, the moving body of air absorbs moisture and the subsequent body of air increases in moisture content. Conversely, when the velocity of the humidified air reduces as it exits the device and contacts an environment unable to support the elevated moisture content, the water vapor suspended within the gas can condense and fall out of the atmosphere in a liquid form. Alternatively, if the moisture-laden air is accelerated in given direction or along a surface (e.g., in a moisture separator), the moisture within the air will be released.

These prior art systems output air saturated with moisture over and above that which can be fully supported by the environment in which being humidified. This results in excessive moisture condensation on the surfaces that are at or below the dew point of the humidifying air (and even possibly submersion of certain components in more extreme cases), and can result in (i) damage to chamber and DUT components, (ii) less than optimal or inaccurate test results, and (iii) creation of hazardous conditions due to the presence of moisture along with electrical potential/current.

Systems used with closed environments such as test chambers, often traditionally use steam-type injectors. These systems super heat the water and then produce a controlled injection of a limited quantity of super-saturated gas in the form of steam into the closed environment. Theoretically the volume injected disperses in the available gas within the confined environment and creates a consistent increase in the humidity. In reality however, such dispersion is not uniform, and the gas in the environment cannot fully support the steam as water vapor. The moisture accordingly condenses out of the atmosphere in the form of liquid water. All the surfaces of the chamber, plus its ambient atmosphere, are below the dew point of the higher moisture-content steam that is supplied, resulting in a fairly significant quantity of liquid water that condenses and accumulates in the chamber.

Other prior art methods utilize high pressure water injected into the chamber environment via an atomizer to increase the humidity, but this is fundamentally just another variation on the previously described humidifier/vaporizer method. The water

droplets when atomized into an environment with a higher temperature will result in a large percentage being supported as water vapor; however, the moisture that cannot be supported will condense as liquid water, resulting in similar problems as were encountered in the steam-type injection approach.

A variety of related or other approaches to humidification are evidenced in the prior art. For example, United States Patent No. 3,987,133 to Andra issued October 19, 1976 entitled "Humidifier" discloses a humidifier for conditioning fluid for delivery to a test chamber, such as an incubator, includes means for automatically regulating the quantity, level and temperature of a body of water through which mixed gases, such as air and CO₂, are bubbled to entrain moisture in the gases. The water is heated to below its boiling point. The relative humidity of the saturated mixture delivered to the test chamber is usually at least 90% at temperatures between about 30 C – 60 C.

United States Patent No. 4,667,522 to Kawahara issued May 26, 1987 and entitled "Humidity testing apparatus" discloses a humidity testing apparatus comprising a test chamber with external heaters for superheating the steam and preventing condensation in the testing zone. The test chamber is divided into an upper humidity testing section and lower condensate collection and removal section by a horizontal heating plate extending from the back wall to a front edge adjacent to and spaced apart from the front of the test chamber, the heating plate extending from one sidewall to the opposing sidewall of the chamber. Convection currents are introduced into the chamber by the heating plate which is maintained at a temperature above the walls of the chamber. The test chamber has a steam inlet opening in the back wall thereof defining a steam flow path into the upper chamber, and a substantially vertical steam baffle plate extending upward from the heating plate and positioned adjacent to the steam inlet opening in the steam flow path. The bottom wall has a condensate outlet opening in the bottom wall thereof.

United States Patent No. 4,852,389 to Mayer, et al. issued August 1, 1989 and entitled "System for controlled humidity tests" discloses a system for controlled humidity tests wherein gas transmission through a barrier may be measured, including apparatus for controllably mixing a dry gas and wet gas, for conveying the mixed gas to a test chamber or chambers for measurement of relative humidity and gas transition through a barrier, including gas transmission conduits having a pressure drop of less

than 1 percent of ambient pressure, and including conduit temperature controls to maintain a controlled first temperature in the test chamber or chambers, and controlled higher temperatures in all other gas conduits.

United States Patent No. 5,247,247 to Kase issued September 21, 1993 and entitled "Low temperature IC handling apparatus" discloses a low temperature IC handling apparatus having pre-measurement and post-measurement drying chambers which are provided at entrance and/or exit of a low temperature IC test chamber and connected therewith via shutters. The drying chambers are provided with low humidity nitrogen gas supply units, and a mechanism for supplying an IC to be measured to the low temperature IC test chamber and a mechanism for unloading a measured IC from the low temperature IC test chamber. A control unit for controlling these mechanisms is provided. Frosting on the seam between the low temperature IC test chamber and the drying chambers and on movable components in these chambers can be prevented and dew condensation on ICs after completion of the measurement at fixed low temperature can be prevented. Therefore, operating efficiency can be considerably increased.

United States Patent No. 5,824,918 to Zuk issued October 20, 1998 and entitled "Relative humidity control system for corrosion test chamber" discloses a method and apparatus for controlling the level of relative humidity within a corrosion test apparatus. The corrosion test apparatus includes a testing chamber, an atomizer which fogs the testing chamber with de-ionized water, a sensor which senses a relative humidity level within the testing chamber, a humidifying valve coupled to the atomizer which regulates a supply of pressurized air to the atomizer, and a controller coupled to the sensor and to the humidifying valve. The controller includes a heating control loop mechanism which generates an output signal proportional to a differential between a relative humidity set point and the relative humidity level. The humidifying valve regulates the supply of operating medium to the atomizer based on the output signal. The atomizer regulates the amount of operating liquid fogged into the test chamber based on the supply of operating medium received from the humidifying valve. The corrosion test apparatus also includes a dehumidifying valve which regulates a supply of ambient air to the testing chamber based on the differential between the relative humidity set point and the relative humidity level, and a passive,

low-cost, low maintenance air amplifier coupled to the dehumidifying valve which draws ambient air into the testing chamber.

United States Patent No. 6,023,985 to Fournier issued February 15, 2000 and entitled "Controller for an environmental test chamber" discloses an apparatus for performing environmental testing on a device, and a method for controlling the atmospheric conditions of the apparatus. The apparatus includes a test chamber and at least one air heater for controlling air temperature within the test chamber. The apparatus further includes at least one liquid heater for disposed in connection with a liquid reservoir for heating the liquid to control humidity within the test chamber. Finally, the apparatus includes first and second controllers for controlling the at least one air heater and the at least one liquid heater, and thus for controlling the temperature and humidity within the test chamber. In accordance with the method, the method includes the steps of beginning a testing cycle at a first temperature and a first humidity, and first elevating the temperature of a test chamber to at least a second temperature (where the second temperature is higher than the first temperature), while maintaining the humidity at a substantially constant level. Then, the method holds the temperature in the test chamber at a near constant temperature for a period of time. Finally, after the temperature has been elevated to its desired (target) temperature, the method elevates the humidity in the test chamber from the first humidity to at least a second humidity (where the second humidity is higher than the first humidity), while holding the temperature at a substantially constant value.

United States Patent No. 6,272,767 to Botruff, et al. issued August 14, 2001 and entitled "Environmental test chamber" discloses an environmental test chamber that comprises a first chamber and a second chamber separated by a partition. The first chamber receives one or more electronic components to be tested. The first chamber includes an exhaust area through which air is introduced to the first chamber and an intake area from which air is evacuated from the first chamber. The exhaust area and intake area are both fitted with a panel having a plurality of apertures. The size and/or the distance between the apertures is varied to provide a uniform airflow through the first chamber, thereby insuring that each electrical component housed within the first chamber experiences the desired temperature and humidity conditions. An air intake assembly is provided which draws air into a control panel chamber housing the electrical circuitry necessary to operate the environmental test chamber, and transports

the air into the second chamber to thereby permit both the control panel chamber and the second chamber to receive ambient air. An air manifold is positioned below the partition and injects dry, compressed air upward through the partition to thereby pressurize the same. Pressurization of the partition assures that heated air and/or moisture residing within the first chamber does not migrate into the second chamber and thus avoids thermal and humidity gradients within the first chamber.

United States Patent No. 6,892,591 to Grossman, et al. issued May 17, 2005 and entitled "Multiple-blower relative humidity controlled test chamber" discloses an accelerated weathering apparatus that includes a test chamber, a specimen supporting means, a light source powered by a power source controlled by a ballast, at least one chamber air temperature sensor, a black panel temperature sensor, and a multiple blower system and control means. A first blower draws and circulates outside or fresh air and as second blower optionally draws recirculated air into an air mixing duct. The speeds of the fresh air and recirculated air blowers are independently regulated and controlled by a blower controller based on the chamber air temperature and black panel temperature, respectively. In addition, a humidifier and humidity controller regulates humidity within the system as required.

Despite the foregoing variety of different prior art approaches to humidification, there is a significant need for improved methods and apparatus for producing a controllable change in the humidity levels of, *inter alia*, a testing environment while simultaneously mitigating the formation and accumulation of condensation.

Summary of the Invention

In a first aspect of the invention, an improved system adapted for humidity and temperature control is disclosed. In one embodiment, the system comprises a test chamber, water tank, motive source (e.g., compressor or pressurized bottle), and controller. The system is adapted to maintain the desired humidity (and temperature) conditions within the chamber without generating significant condensation therein.

In a second aspect of the invention, a water tank for use in the aforementioned system is disclosed. In one embodiment, the tank comprises a level control system for maintaining a substantially constant level, and an aerator adapted to diffuse (bubble) the carrier gas through the water, thereby raising the humidity level of the carrier gas by a prescribed amount and in a predictable fashion. The tank is also adapted to include its

own temperature control system which can be used to, *inter alia*, control the tank (and water) temperature to selectively cause condensation to occur within the tank, as opposed to any connected test environment.

In a third aspect of the invention, a controller architecture for use in the aforementioned system is disclosed. In one embodiment, the controller architecture comprises two substantially independent temperature controllers for the test chamber and the water tank. One or both of these controllers may be linked to a humidity sensor (such as one sensing the interior volume of the test chamber) in order to maintain the prescribed conditions of humidity and temperature within the chamber. In another embodiment, the temperature controllers are coupled or integrated, so as to provide a coordinated “smart” control process that dynamically controls the temperatures of the two components (as well as monitoring humidity). Other parameters such as tank water level (which controls the amount of interaction between the diffused gas and the water), and pump operation/speed, may also be controlled. The aforementioned controllers may also be programmed to provide various test profiles for temperature and/or humidity as desired.

In a fourth aspect of the invention, an improved method for maintaining the humidity within a test chamber is disclosed. In one embodiment, the method comprises: providing a desired humidity level for the chamber; sensing the actual humidity level within the chamber; determining whether an increase or decrease in humidity within the chamber is required based at least in part on comparison of the desired and actual levels; and if the humidity level needs to be decreased, performing at least one of (i) a dry purge process; or (ii) lowering the temperature of a volume from which humid gas is supplied to the chamber, thereby causing any condensation to selectively occur within the volume as opposed to said chamber. In one embodiment, the volume comprises a water tank with its own temperature control system.

Brief Description of the Drawings

The features, objectives, and advantages of the invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings, wherein:

Fig. 1 is a functional block diagram of one embodiment of the humidity and temperature control system of the invention, showing the various components thereof.

Fig. 1a is a functional block diagram of the water tank of the system of Fig. 1, wherein a temperature controller is utilized to heat or cool the water reservoir within the tank.

Fig. 1b is a functional block diagram showing one exemplary configuration of the filtering apparatus used in the system of Fig. 1, the filtering apparatus being used to remove matter such as e.g., VOC's (volatile organic compounds) from the water supply prior to entering the water tank.

Fig. 1c shows a functional block diagram of one exemplary embodiment of an air compressor in accordance with the principles of the present invention.

Fig. 1d is a functional block diagram illustrating an exemplary test chamber configuration according to the present invention, wherein a temperature control apparatus is utilized to heat or cool the chamber.

Fig. 1e is a functional block diagram showing one exemplary embodiment of the dry purge system of Figs. 1a and 1d.

Fig. 1f is a functional block diagram of another embodiment of the water tank of the system of Fig. 1, wherein the dry purge system is disposed after the tank outlet isolation valve.

Fig. 2 is a logical flow chart showing one exemplary embodiment of the method for controlling humidity within the test chamber in accordance with the present invention.

Fig. 2a is a logical flow chart showing another exemplary embodiment of the method for controlling humidity within the test chamber in accordance with the present invention, wherein water temperature is utilized to control increases and/or decreases in chamber humidity.

Detailed Description of the Preferred Embodiment

Reference is now made to the drawings wherein like numerals refer to like parts throughout.

As used herein, the term "device under test" or "DUT" refers generally to any component, material, assembly, or device which is being tested, evaluated, or conditioned. DUT's can include, without limitation, electronic or mechanical devices or

assemblies, integrated circuits, semiconductors, diodes, material specimens or samples, or crystals.

As used herein, the term “humidity” refers generally to the concentration of one material in another. In the exemplary instance, humidity refers to the relative water (vapor) content within air; however, the term is also meant to encompass water content in other gases, and even the content of non-water liquids carried within air or other types of gases.

It is noted that while the following description is cast primarily in terms of an improved apparatus and method for use in controlling temperature and humidity within an environmental test chamber, the present invention may be used in conjunction with any number of different applications and temperature/humidity control apparatus. Accordingly, the following discussion of the test chamber-based system below is merely exemplary of the broader concepts.

Overview

The present invention overcomes the limitations of the prior art by providing methods and apparatus for delivering the humidified air at a temperature and saturation level that can be supported by the environment to which it is delivered, thereby effectively eliminating the accumulation of liquid water within the testing chamber. In the exemplary embodiment of the apparatus, condensation will only occur if and when the humid gas contacts a surface or environment that is below the dew point of the set level for its operation. This condensation process is controlled such that it can only occur in a tank existing outside of the test chamber, thus preventing the condensation of water vapor within the chamber used for conditioning or evaluating the DUT. Specifically, the carrier gas supply is fed through a re-circulating system with a separate environment that is used to control humidity levels, and hence the levels of condensation within the test chamber can be advantageously reduced.

System

Referring now to Fig. 1, one exemplary embodiment of the conditioning system 100 of the invention is described in detail. It will be appreciated that while described in the content of a water-based system using air as a carrier gas, the present

invention may be adapted to other types of environments and/or carrier gases (such as without limitation inert gases such as nitrogen or argon), such adaptation being readily performed by those of ordinary skill provided the present disclosure.

The system 100 of the illustrated embodiment comprises a water tank 106 with temperature control system 102, make-up water supply 110, water level switch 104, water level fill valve 105, water filtration device 108, valve assembly (to isolate outlet from the tank 106 to the chamber environment) 109, a gas pump or compressed gas source 112, aerator block 113, test chamber 116 and associated temperature control system 118, and humidity measuring device 119. One or more dry purge systems 107, 122 for the tank and chamber, respectively, are also provided to permit more rapid reductions in humidity.

The system 100 is configured to re-circulate the humidity-carrying gas (e.g., air, although other gases may be used) from the chamber 116 at a substantially constant gas flow rate. Because the volume of the water reservoir 117 in the tank 106 is also controlled through the use of a control mechanism (here, the float switch 104), the tank level remains substantially constant resulting in a relatively constant contact time with the supplied carrier gas. The contact time is controlled in effect by the depth of the water in the tank, since the carrier gas is bubbled up through the tank water volume 117 (the lighter gas rising within the denser water). In addition to passing re-circulated gas through the water in the tank 106, the humidity can also be controlled by either (i) individually raising or lowering the temperature of the water in the tank, or (ii) controlling the temperature of both the water bath and the testing environment.

As previously noted, condensation will only occur if and when the humid carrier gas contacts a surface or environment that is below the dew point of the set level for its operation. This condensation process is controlled such that it can only occur in the water tank 106, thus preventing the condensation of water vapor within the chamber 116 used for conditioning or evaluating the DUT.

The foregoing system components, and the operation of the system in general, are now described in greater detail.

Water Tank Assembly

Referring now to Fig. 1a, an exemplary embodiment of the water tank 106 for use with the system 100 is described. The water tank 106 has an inlet 124 wherein air, or any other suitable gas carrier, may be drawn from a source such as the linear air compressor 112 (shown in Fig. 1c), discussed subsequently herein. The gas used to aerate the water in the tank 106 may be obtained either from some connected environment (such as the chamber 116), or in the alternative may be drawn from some other pre-defined gaseous source (such as a compressed gas tank) in order to maintain desired conditions such as purity.

In the illustrated embodiment, gas is fed to the water tank 106 from the linear air compressor pump 112 and subsequently piped to an aerator block 113 located inside of the water tank 106. The aerator block apparatus 113 can be integrated within the water tank 106, similar to that disclosed in US Patent No. 4,367,182, incorporated herein by reference in its entirety, or alternatively may comprise a separate assembly. Myriad different configurations for the aerator compatible with the present invention will be recognized by those of ordinary skill. Using a separate aerator assembly may be desirable for, *inter alia*, ease of maintenance or replacement, depending on the conditions of its operation.

While it is contemplated that a linear air compressor pump 112 is best suited for providing the gas to the aerator 113 in this particular application, other methods of supplying air or other gases to the water tank 106 may be used consistent with the invention. For example, this air supply may also be achieved by piping from a tank of pressurized air, thus eliminating the requirement for a pump apparatus (and associated electrical power supplies and controls). As previously noted, other gases (such as for example inert gases such as nitrogen or argon) may be substituted or even mixed with the air supplied by the pump as well, either initially at startup or continually during operation of the system. For example, in one variant, a predetermined percentage of the bottled gas is mixed with the pumped air using a mixing valve of the type well known in the prior art. In another variant, mixed gases are used, such as where two or more discrete gases from pressurized cylinders are mixed at a prescribed concentration with one another before introduction into the tank 106.

The gas stream, once inside the water tank 106, flows through the aerator device 113 and bubbles through the water reservoir within the tank 106. The use of

the aerator device serves the primary purpose of separating the gas stream into smaller individual bubbles and multiplies the surface area of the gas bubbles available to contact the water within the reservoir many times over. This helps maximize the amount of water vapor (i.e., humidity) that the gas can absorb in a given period of time. The humidified gas then exits the tank through a flow control valve 109 and ultimately into the chamber environment 116 containing the DUT to be tested/conditioned. It will be appreciated that any number of different aerator configurations and placements within the tank 106 may be used with the invention, such as where an elongated tube or rod having an array of diffusion holes is used. Alternatively, a plurality of aerators distributed around the tank interior may be used. Yet other mechanisms for achieving the desired effect (i.e., increased absorption of moisture into the gas) may be utilized alone or in conjunction with the aforementioned configurations as well.

Desirably, the water tank 106 will have a "dry air" purging system 107 also, or in the alternative the dry purging system may be attached directly to the environmental chamber (see Fig. 1d, item 122) with the valves 109,120 between the water tank 106 and environmental chamber 116 optionally closed during purging depending on the particular system architecture that is chosen. The purge system(s) 107, 122 are used to purge the tank volume and chamber volume, respectively, of the humidity-laden air, such as when a reduction in humidity is desired. The dry purging systems 107, 122 may comprise, for example, means for dispensing nitrogen or argon gas from a liquid nitrogen/argon source such as a pressurized bottle.

It will be noted that when purging, a means for maintaining the desired pressure level in the chamber/tank may be required, so as to preclude over-pressurization. For example, where the system 100 is substantially sealed, a relief valve and/or use of design leakage past seals in the chamber door can be used to ensure no unwanted pressurization of the system components.

In another variant, purging can be accomplished by simply evacuating the chamber of humid air. For example, a pump (such as the linear pump 112 described elsewhere herein) can be used to simply draw the higher-humidity air out of the chamber 116, in favor of a lower-humidity replacement. Such replacement atmosphere may simply be the existing ambient around the chamber 116, although the humidity and other conditions of this air are not controlled. A more preferable

solution is to supply a purge gas (e.g., nitrogen) into the chamber as previously described, while simultaneously evacuating the moisture-laden air from the chamber using the pump 112.

While the foregoing systems for removing humidity from a gas (e.g., air) are well known in the art, one other exemplary method for doing so is by pumping the gas stream through a cylinder filled with a desiccant, such as for example Drierite™. In one exemplary embodiment, as best shown in Fig. 1e, when it is desired to decrease the humidity within the closed portion of the system, the gas flow can be diverted through a desiccant cylinder 150, instead of through the aerating device 113 located in the water tank 106. The desiccant is useful in absorbing moisture out of the gas, and subsequently lowering the relative humidity of the gas circulating to the environmental chamber 116. If a desiccant such as Drierite™ is used, the desiccant can be loaded into a clear polycarbonate cylinder 150 so that it will be readily apparent when the moisture absorbing ability of the desiccant (i.e., by a color change in the material) has been exhausted, thereby visually signaling that the desiccant needs to be replaced.

In the alternative, it may not be necessary to replace the desiccant but rather it may be recharged by heating the desiccant (such as by direct heating, or loading it into an oven or other source of heat) to evaporate the moisture from the desiccant

As yet another alternative, a moisture separator apparatus such as that used in steam systems may be employed to separate the moisture from the carrier gas. For example, well known centrifugal moisture separators comprise a comparatively high-velocity gas flow path which causes the gas to rapidly change direction (accelerate). Such acceleration induces the heavier water entrained within the gas to be separated from the lighter gas, and collect on nearby structures (such as fins or flow channels disposed in the gas/moisture path). The separated moisture can then be collected, such as via a simple drip system. Myriad different configurations of moisture separators are known to those of ordinary skill, and hence not described further herein.

Returning again to Fig. 1a, the illustrated water tank 106 has a level control switch 104 that maintains the volume of water contained within the tank at a substantially constant level, providing a substantially constant gas/water contact time for the bubbled gas stream. This is desirable, as the switch 104 ensures that an adequate volume of water always remains within the tank 106. This simplifies the

process of achieving a desired humidity level within a reasonable amount of time, since one variable (i.e., contact time, which is directly related to the humidity content of the air being supplied to the chamber 116) is effectively removed from the control process equation.

In one exemplary embodiment, the level control switch 104 comprises a float switch of the type well known in the fluidic arts. The use of a float switch 104 is particularly desirable due to its simplicity in design, low cost, and repeatability and accuracy in maintaining a desired level of water. However, it will be appreciated that other types of switches (and in fact approaches to maintaining a substantially constant contact time) may be used. For example, in one variant, two discrete conductivity sensors are used to control the tank level; the first (lower) switch is closed when the tank level falls below a certain desired vertical height (as detected by a lack of conductivity or electrical current flow), whereas the second switch is opened when such conductivity or current exists. As yet another exemplary alternative, a concentric water/gas tube arrangement is used, wherein gas bubbled from the bottom of a first tube rises within the annulus created between it and a second, larger diameter tube containing water. Myriad other approaches may be substituted.

The water tank 106 is also fitted with a temperature control system 102, including one or more heating elements, that can be used to either pre-heat or maintain the water at a given water temperature. In the illustrated embodiment, the temperature control system 102 comprises a low-current thermal platform of the type well known in the art, such as those manufactured by Sigma Systems Inc. of San Diego, CA, with an exemplary maximum temperature setting of 85° C and a minimum setting of 20° C. This device uses a resistive heating element and a liquid nitrogen cooling system, although other techniques for heating and/or cooling may be utilized.

The relationship between the temperatures of the environmental chamber 116 and the water tank 106 can be determined (such as via temperature sensors present in respective ones of the two components) and controlled to, *inter alia*, maintain a desired humidity level at the outlet, and therefore maintain a desired humidity level within the environment chamber 116. For example, in the exemplary embodiment, the temperature controller(s) monitor and maintain the temperature of the water bath via the temperature probe surface, and the chamber temperature via the airflow, although other approaches can be used.

The importance of controllable heating element(s) within the tank temperature control system 102 also relates in part to the fact that moisture absorption and humidity level has a direct relationship with ambient air temperature. As a general rule, the higher the temperature of the air, the more moisture that can be held as water vapor within the air, and conversely the cooler the air, the less moisture that can be held as gaseous water vapor. This characteristic can be observed with natural phenomena such as fog. Fog is formed when a warmer body of air containing water vapor cools below its "dew point". At this cooler temperature, the air can no longer support the level of water vapor contained within it and this water vapor condenses into a liquid form (visible fog). Similarly, by controlling the temperature of the water in the tank 106 in a desired relationship with the temperature of the testing chamber 116, condensation that would otherwise occur inside of the chamber 116 can be minimized and even eliminated completely, occurring alternatively within the tank volume 106.

It will also be appreciated that where the test chamber is maintained at a pressure other than atmospheric (e.g., pressurized to greater than one (1) atmosphere, or drawn to a pressure below one atmosphere so as to form a relative vacuum), the moisture-carrying capability of the gaseous carrier medium (e.g., air) may also be affected. In such instances, the relationship between the chamber and tank temperatures and pressures can be considered, such as via use of an algorithm and computerized controller that periodically determines the appropriate values for each of the parameters in order to maintain the desired test chamber conditions. Such computerized controller and algorithm may have as its inputs, for example, the temperatures of the water bath in the tank 106, the air temperature in the chamber 116, the pressures in each of the foregoing, and the relative humidity within the chamber 116. Using well known pre-programmed mathematical relationships, the controller apparatus can maintain the humidity level, temperature, and pressure within the chamber 116 at the desired levels. Such a computerized configuration is particularly useful where frequent changes in temperature, pressure, and/or humidity are required by the test regime. For example, one such regime may comprise stepping temperature from a low level to a high level while maintaining pressure and humidity constant. Alternatively, the regime may call for variation of all three parameters as a function of time. Precisely maintaining such conditions manually would be difficult at best,

especially where frequent changes are required, since stabilization times would not be reached.

In addition, other methods of control that can be utilized to optimize system and DUT temperature control, such as the method and apparatus disclosed in co-owned U.S. Patent No. 6,449,534 entitled "METHOD AND APPARATUS FOR OPTIMIZING ENVIRONMENTAL TEMPERATURE FOR A DEVICE UNDER TEST", incorporated herein by reference in its entirety. In this approach, various parameters such as the chamber temperature and the core temperature of the DUT (and differentials there between), are used as inputs to controlling the amount of heat applied to or removed from the chamber, while also observing system (chamber) and DUT upper and lower operating limits.

In one embodiment, a method of controlling the environmental parameters of a device under test (DUT) is used which incorporates the calculation of a moveable temperature setpoint which will 1) maximize the speed of the thermal test or conditioning routine; 2) respect the limits of the DUT with respect to both absolute skin temperature limits and thermal stress; 3) respect the thermal limitations of the test or conditioning equipment being used; and 4) maximize the thermal uniformity of the DUT when the user's specified temperature setpoint is reached in the DUT core. A system operating range (SOR) and DUT operating range (DOR) are calculated based on the thermal and stress limits of the DUT, temperature control system (TCS), and thermal conditioning apparatus. A control setpoint (CSP) which is different than the desired DUT core temperature specified by the user (i.e., the PSP) is then calculated based on the difference between the PSP and the secondary temperature sensing probe input temperature, the value of two predetermined setup parameters, and the relationship between the SOR and DOR, so as to effectuate varying amounts of heat transfer between the thermal conditioning environment and the DUT. As the desired DUT core temperature is approached, movement of the control setpoint is terminated and the differential between core and skin temperature of the DUT reduced accordingly until the user-specified setpoint is reached.

An algorithm incorporating the method described above may also be used. In one exemplary embodiment, the computer program is compiled into an object code format which is stored on a magnetic storage medium, and which is capable of being run on a digital computer processor. The algorithm receives inputs (via the host

computer system, described below) from instrumentation associated with the thermal conditioning system, such as chamber/device temperature probes, and calculates the Control Setpoint (CSP) which is fed back to the thermal conditioning system to effectuate control of the chamber and device temperature.

Variable differential thermal limits may also be employed as a function of the core temperature of the DUT in order to control thermal shock to the DUT during various temperature transitions.

The methods of co-owned and co-pending U.S. Application Serial No. 10/219,144 filed August 14, 2002 and entitled "METHOD AND APPARATUS FOR LATENT TEMPERATURE CONTROL FOR A DEVICE UNDER TEST", which is incorporated herein by reference in its entirety, may also be employed if desired to provide enhanced accuracy in controlling temperatures in latent applications. In one such variant, the method generally comprises: controlling the temperature of a second object which is able to transfer energy to or from the first object to achieve a first temperature; observing at least one event associated with the first object after the second object has achieved the first temperature; and subsequently controlling the temperature of the second object based at least in part on the at least one event. The first object comprises, e.g., a DUT, and the second object a thermal conditioning device (e.g., thermal platform, oven, or chamber). The thermal conditioning device is first brought to the desired DUT temperature, and the DUT subsequently observed (such as via temperature probe) to identify both (i) a change in DUT temperature, reflecting response to the thermal conditioning device change in temperature; and (ii) stabilization of the DUT temperature. The heating or cooling applied to the thermal conditioning device is then adjusted based on the observed difference between the desired DUT temperature and the actual DUT temperature.

Thermal conditioning apparatus useful with the present invention for latent temperature control generally comprises: at least one device for collecting data related to temperature of a first object and a second object; and a controller, operatively coupled to the at least one device and adapted to control the temperature of the second object, the controller adjusting the temperature of the second object to a first temperature, and thereafter only after receiving data indicating a substantially stable temperature of the first object. In one variant, the controller comprises an embedded

controller having a computer program running thereon, the program adapted to implement the latent temperature control methodology previously described.

Similarly, these methods and apparatus may be readily adapted for latent changes in humidity as well, such as for example by configuring the control system to detect artifacts present in the humidity profile within the chamber.

Once the desired humidity level is reached within the testing chamber 116, the valves 109, 120 can optionally be closed to minimize the transfer of humidity by natural convection or other means. This process can be automated if desired, such as via a control signal generated by way of a chamber humidity sensor that actuates one or more solenoid operated valves. As an alternative, the system may continue to function with the linear compressor 112 continuing to pump air into the test chamber 116, with the humidity being maintained at the desired level by controlling pump motor speed, water bath temperature, and/or other parameters of the system in response to sensors (i.e., temperature and humidity sensors) installed within various points of the system 100.

Referring now to Fig. 1b, prior to the water entering the tank 106, the supply water is optionally passed through the filtration device 108 to remove undesirable substances such as, e.g., Volatile Organic Compounds (VOC's) that have the potential to contaminate the system 100 by "out-gassing" from the water into the gas flow, as temperature is increased. This filtration device 108 may comprise a mechanical filter (e.g., filter medium, mesh or the like), an ionic or chemical filter (such as an ion exchange bed), or yet other type of device.

Another advantage of using a filtration device 108 as shown in Fig. 1b is the removal of suspended solids or particulates that can deposit onto the inside tank and piping surfaces (especially those of any heating elements, which would have accelerated rates of general and stress corrosions due to elevated temperatures), thereby otherwise increasing maintenance costs and reducing the efficiency of the system as these deposits became significant.

Because the individual compounds making up the VOC's and suspended solids vary based on the source of the water used, it is also normally desirable that the filtration system used be designed to treat a broad spectrum of contaminants. However, in cases where specific or problem contaminants are known beforehand, a filtration device better suited for these particular contaminants may be substituted.

Referring now to Fig. 1c, an exemplary embodiment of the air compressor apparatus 112 is described. The compressor 112 provides the required gas stream to the water tank 106 for use in conditioning the test chamber 116. In the illustrated embodiment, the air compressor 116 comprises a linear air compressor and is activated by a power controller 114 in response to signals from the humidity sensors and/or the temperature controllers 102, 118. The gate valve 109 between the tank and the chamber 116 opens when the compressor 112 is activated (detected using any number of means such as via an output pressure switch or signal from the electrical power supply indicated a connected status), and conditioned air is drawn from the chamber 116 through the compressor 112 to the aerator assembly 113 in the tank 106. Air is expelled through the water via the aerator and returns to the chamber 116 via the discharge valve 109 (e.g., gate valve) in a saturated form. Once the desired humidity level is obtained, the compressor 112 is secured (or its output is ported to another pathway within the system), and/or the gate valve 109 optionally closed.

The desired compressor start/stop functionality can also optionally be implemented using a delay timer, so that the compressor and valve have a minimum cycle time to avoid excessive cycling. This may also be used with a pressure and/or humidity control band, such that the compressor does not continually cycle as the pressure or humidity rises above and falls below a single setpoint. Control bands are well known in the controller arts, and accordingly not described further herein.

The position of the isolation valves 109, 120 may be determined via use of either micro-switches or proximity switches of the type well known in the art, and also used as part of the compressor control process. For example, the closed position of the valve(s) can form an interlock on the compressor controller to preclude startup against a dead head. The output of the compressor can also be used to maintain the discharge valve 120 open (such as where the output pressure is applied under the valve seat), with an electrically operated solenoid being used to initially position the valve, and thereafter not being required. Once the compressor output diminishes (such as when power is secured or the output recirculated via another path), the valve 120 closes under its own spring pressure.

Environmental (Test) Chamber and Control Apparatus

Referring now to Fig. 1d, exemplary embodiments of the test chamber 116 and associated control system are described in detail. In one embodiment of the system 100 (Fig. 1), both the test chamber 116 and the water tank 106 have respective “segregated” sources of temperature control 102, 118. These sources of control may be linked or integrated into one controller (as previously described) so as to produce a “smarter” system with a higher level of control functionality and performance, or alternatively maintained as separate control entities. For example, in certain low-cost applications, coordination between the controllers (and the attendant increase in cost) is largely unnecessary, since controlling temperature in a “local” mode provides more than adequate performance. Conversely, where a high degree of control precision and/or programmatic sophistication (e.g., multi-variate control) is required, an integrated control scheme is best used.

In one such segregated configuration, the temperature of the chamber 116 is controlled and set by the primary controller 118 to the required temperature. The secondary controller 102, which controls the temperature of the water in the water tank, is set to the temperature required to produce the required humidity in the test chamber 116. Due to the thermal latency of the water tank 106, these two temperatures may be obtained concurrently during the increase in the temperature profile (ramp-up). The controllers utilized to provide such temperature control may comprise, e.g., “open loop” or “closed loop” controllers of the type well known in the art, although the latter is more common in test chamber applications. A common closed-loop controller such as a PID (proportional-integral-derivative) controller utilizes a feedback loop that is used to control input as a function of output and a calculated error function. Such controllers utilize data read from one or more sensors, and control the input to be applied based on a user-defined logic program. In the present embodiment, temperature (and optionally humidity) sensors offer feedback signals useful in temperature/humidity control. The humidity sensor is preferably a solid state humidity sensor as these sensors offer accuracy as well as minimal required maintenance. Other humidity sensors such as wet wick type sensors could also be used if desired. Controllers such as the closed-loop controller used in environmental chambers discussed above are well understood in the art and as such will not be discussed further herein. It will be appreciated, however, that the invention is in no

way limited to open- or closed-loop controllers (PID or otherwise). For example, a fuzzy logic or Bayesian decision controller could be utilized with equal success.

While it is desirable to increase the temperature of the water bath of the tank 106 in conjunction with the conditioned test chamber 116 to achieve higher humidity levels without condensation, either or both of these variables may be changed in order to reduce the humidity within the system. For example, closing the isolation valve 109 between the tank 106 and the environmental chamber 116 and increasing the temperature of the chamber reduces the relative humidity level in the chamber, or alternatively, reducing the temperature level within the bath while the testing environment temperature remains constant will also have the effect of reducing the humidity. Such control can also be achieved by the application of a purge of "dry" gas (either via the tank purge system 107, the chamber system 122, or both simultaneously). Factors such as control accuracy, desired latency, and power efficiency may be considered in selecting which of the foregoing control methods is most desirable.

For example, if the test requires a common temperature with only a change in humidity over time, this change in humidity might most simply be accomplished by varying the water temperature within the tank water only. If a testing temperature must increase with a subsequent change in the humidity, whether it is to increase or decrease, this might best be accomplished by simply varying the control of the water tank temperature, or alternatively varying tank temperature in conjunction with the heating element within the chamber (e.g., electrical resistive heater) so as to reduce the latency of the temperature increase of the tank water.

If on the other hand, the temperature of the chamber is to be decreased, then the tank temperature should either be maintained at a temperature lower than the controlled chamber temperature (approximately 15°C less), or the chamber purged with a dry gas to reduce the humidity level at or below the maximum humidity that can be supported by the air at the new (lower) temperature set point. The dry purge process can be accomplished using for example a cryogenic (e.g., liquid nitrogen) purging apparatus as is well understood in the environmental chamber arts, or via use of some other alternative dry purging method such as the desiccant cylinder previously discussed herein, depending on the allowable/desired latency.

In order to minimize the possibility of undesirable condensation within the testing chamber, the gas flow aerated through the water bath of the tank 106 should not begin again until the bath temperature is equal to or below that of the conditioned air within the testing chamber. Alternatively, the flow of humid air may simply be isolated from the environmental chamber (such as via a recirculation path) until the temperature of both the water tank and environmental chamber reach a minimally acceptable level that will not produce significant condensation within the tank.

Fig. 1f shows Fig. 1f is a functional block diagram of another embodiment of the water tank of the system of Fig. 1, wherein the dry purge system is disposed after the tank outlet isolation valve. This configuration allows the valve 109 to be closed when the chamber is purged to reduce humidity values.

Methods for Controlling Humidity

Referring now to Fig. 2, one exemplary method for controlling the desired humidity is disclosed. It is recognized that while cast primarily in terms of the system 100 previously described herein, the methodology of the invention may be readily adapted to other systems and equipment configurations.

In step 202, a humidity level for the chamber is programmed by a user to a desired "set-point" value. This set-point value may be set in conjunction with a chamber temperature if desired, and one or both may also be varied according to a programmatic regime as previously described.

In step 204, the controller utilizes feedback from a sensor (e.g., a solid state or other humidity sensor or detector sensing the chamber environment) to determine whether an increase or decrease in humidity is required as compared to the set-point. As previously discussed, the aforementioned sensor may also comprise one or more temperature sensors (such as those within both the water tank 106 and the testing chamber 116), used in conjunction with the humidity sensor.

If the humidity level needs to be decreased, a dry purge process will be implemented in step 206 as previously discussed herein. Alternatively, if the humidity level needs to be increased, the linear air compressor 112 is activated (or if running, its output ported to the chamber 116) in response to sensor feedback. If isolated, the chamber is also unisolated (e.g., by opening the isolation valve between the tank and the chamber). Conditioned (humid) air is drawn from the chamber 116 through the

compressor inlet and discharged from the compressor to the aerator assembly in the tank per step 208. Air is expelled (diffused) through the water in the tank, and returns to the chamber 116 in a saturated form.

In step 210, the controllers monitor the sensor signals and determine whether or not the desired humidity level has been achieved within the chamber. If the desired humidity level has not been reached, the linear air compressor will continue to run (step 212) until such condition is achieved.

Once the desired humidity level is obtained, the compressor is turned off (or its output ported away from the chamber 116, such as via a recirculation line), and the isolation valve optionally closed, per step 214.

As previously noted, to avoid significant quantities of condensation, the temperature of the chamber 116 and the water of the tank may be controlled as well as part of the method 200. For example, one simple control scheme would be to maintain the temperature of the chamber constant, yet adjust the temperature of the tank 106 as needed. Fig. 2a illustrates one embodiment of this alternate methodology. Accordingly, when a reduction in humidity is desired, the tank/bath temperature is lowered, and any resulting condensation occurs within the tank volume (and not the chamber 116). Alternatively, when a humidity increase is desired, the temperature of the tank and the chamber can be increased, such that the increasingly humid carrier gas supplied to the chamber is not introduced into a chamber having colder walls (thereby precipitating condensation).

The foregoing approaches may also be combined, such as where both purges and temperature changes are utilized.

It will be recognized that while certain aspects of the invention are described in terms of a specific sequence of steps of a method, these descriptions are only illustrative of the broader methods of the invention, and may be modified as required by the particular application. Certain steps may be rendered unnecessary or optional under certain circumstances. Additionally, certain steps or functionality may be added to the disclosed embodiments, or the order of performance of two or more steps permuted. All such variations are considered to be encompassed within the invention disclosed and claimed herein.

While the above detailed description has shown, described, and pointed out novel features of the invention as applied to various embodiments, it will be understood

that various omissions, substitutions, and changes in the form and details of the device or process illustrated may be made by those skilled in the art without departing from the invention. The foregoing description is of the best mode presently contemplated of carrying out the invention. This description is in no way meant to be limiting, but rather should be taken as illustrative of the general principles of the invention. The scope of the invention should be determined with reference to the claims.

WHAT IS CLAIMED IS:

1. Humidity control apparatus, comprising:
 - a water tank comprising a first temperature controller;
 - a test chamber;
 - a compressor operatively coupled between said water tank and said test chamber; and
 - an aerator, said aerator being operatively coupled to said compressor and located at least partly within said water tank;wherein said compressor, tank, and controller cooperate to maintain a desired humidity level within said chamber without forming significant amounts of condensation therein.
2. The humidity control apparatus of Claim 1, further comprising a chamber temperature controller, said chamber temperature controller controlling chamber temperature according to the method comprising:
 - determining the allowable operating range of at least one of said chamber temperature controller and test chamber;
 - determining the allowable operating range associated with an object disposed within said test chamber; and
 - calculating a control setpoint based at least in part on said allowable operating ranges of said at least one of chamber temperature controller and test chamber, and on said object.
3. The humidity control apparatus of Claim 2, further comprising providing data related to the temperature of said object; and
 - wherein said act of determining the allowable operating range associated with an object disposed within said test chamber is based at least in part on said data.
4. The humidity control apparatus of Claim 1, further comprising a test chamber temperature controller comprising a temperature control algorithm providing input thereto, and said chamber controller controls temperature of an object within said test chamber according to the method comprising:
 - providing data related to the internal temperature of said object to said algorithm;
 - determining the allowable operating range associated with said object based at least in part on said data;

evaluating whether a valid control setpoint can be calculated based at least in part on said allowable operating ranges of at least one of said chamber temperature controller and said test chamber, and said object; and

calculating said valid control setpoint.

5. The humidity control apparatus of Claim 1, further comprising:
a first temperature probe adapted to generate first signals related to the temperature of a device under test (DUT);

a second temperature probe adapted to generate second signals related to the temperature of at least a portion of said test chamber; and

a chamber temperature control apparatus comprising:

a controller, operatively coupled to said test chamber and said probes and having an algorithm associated therewith.

6. The humidity control apparatus of Claim 5, wherein said algorithm is adapted to control the temperature of said chamber based at least in part on said first and second signals;

wherein said controller is further adapted to control the temperature of said chamber by: (i) establishing a first temperature for at least a portion of said chamber; (ii) identifying at least one change in said DUT thereafter; (iii) identifying at least one stabilization event in said DUT thereafter; and (iv) adjusting the temperature of said conditioning device based at least in part on said first and second signals and said acts of identifying.

7. The humidity control apparatus of Claim 1, further comprising temperature control apparatus operatively coupled to said chamber and adapted to control the temperature of at least a portion thereof based at least in part on the observance of a temperature stabilization event in a device under test (DUT) disposed within said chamber.

8. The humidity control apparatus of Claim 1, wherein said cooperation to maintain a desired humidity level within said chamber without forming significant amounts of condensation therein comprises delivering the humidified air at a temperature and saturation level that can be supported by an environment within said chamber, thereby significantly eliminating the accumulation of liquid water within the chamber.

9. The humidity control apparatus of Claim 1, wherein condensation is controlled such that it can only substantially occur in said water tank existing outside of the test chamber, thus preventing the condensation of water vapor within the chamber used for conditioning or evaluating the DUT.

10. The humidity control apparatus of Claim 1, wherein said compressor compresses a carrier gas and a carrier gas supply, said supply comprising a re-circulating system with a separate environment that is used to control humidity level.

11. The humidity control apparatus of Claim 10, wherein said carrier gas comprises air.

12. A method of controlling the humidity within a closed chamber without substantial condensation, comprising:

providing a desired humidity level for said chamber;

sensing the actual humidity level within said chamber;

determining whether an increase or decrease in humidity within said chamber is required based at least in part on comparison of said desired and actual levels; and

if the humidity level needs to be decreased, performing at least one of (i) a dry purge process; or (ii) lowering the temperature of a volume from which humid gas is supplied to said chamber, thereby causing any condensation to selectively occur within said volume as opposed to said chamber.

13. The method of Claim 12, wherein said act of providing a humidity level comprises providing a humidity level which varies as a function of time according to a profile.

14. The method of Claim 12, wherein said act of performing a dry purge process comprises using a cryogenic purging apparatus.

15. The method of Claim 12, wherein said act of performing a dry purge process comprises using a desiccant cylinder process.

16. The method of Claim 12, wherein said act of performing at least one of (i) a dry purge process; or (ii) lowering the temperature of a volume from which humid gas is supplied to said chamber, comprises selectively performing both said dry purge process and lowering the temperature of a volume from which humid gas is supplied.

17. A water supply apparatus for use in an environmental conditioning or test system, comprising:

a water tank adapted to contain water therein;
a level control system for maintaining a substantially constant level within said tank;
an aerator adapted to diffuse a carrier gas through the water of said tank, thereby raising the humidity level of the carrier gas output by said apparatus by a prescribed amount and in a predictable fashion; and
a temperature control system to control the tank and water temperature to selectively cause condensation to occur within the tank, as opposed to said conditioning or test system.

18. The apparatus of Claim 17, wherein said environmental conditioning or test system comprises:

a test chamber; and
a compressor operatively coupled between said water tank and said test chamber.

19. The apparatus of Claim 18, wherein said environmental conditioning or test system further comprises a chamber temperature controller, said chamber temperature controller controlling chamber temperature according to the method comprising:

determining the allowable operating range of at least one of said chamber temperature controller and said test chamber;

determining the allowable operating range associated with an object disposed within said test chamber; and

calculating a control setpoint based at least in part on said allowable operating ranges of said at least one of chamber temperature controller and test chamber, and on said object.

20. The apparatus of Claim 19, further comprising providing data related to the temperature of said object; and

wherein said act of determining the allowable operating range associated with an object disposed within said test chamber is based at least in part on said data.

21. The apparatus of Claim 18, further comprising a test chamber temperature controller comprising a temperature control algorithm providing input thereto, and said chamber controller controls temperature of an object within said test chamber according to the method comprising:

providing data related to the internal temperature of said object to said algorithm;

determining the allowable operating range associated with said object based at least in part on said data;

evaluating whether a valid control setpoint can be calculated based at least in part on said allowable operating ranges of at least one of said chamber temperature controller and said test chamber, and said object; and

calculating said valid control setpoint.

22. The humidity control apparatus of Claim 18, further comprising:

a first temperature probe adapted to generate first signals related to the temperature of a device under test (DUT);

a second temperature probe adapted to generate second signals related to the temperature of at least a portion of said test chamber; and

a chamber temperature control apparatus comprising:

a controller, operatively coupled to said test chamber and said probes and having an algorithm associated therewith.

23. The humidity control apparatus of Claim 22, wherein said algorithm is adapted to control the temperature of said chamber based at least in part on said first and second signals;

wherein said chamber controller is further adapted to control the temperature of said chamber by: (i) establishing a first temperature for at least a portion of said chamber; (ii) identifying at least one change in said DUT thereafter; (iii) identifying at least one stabilization event in said DUT thereafter; and (iv) adjusting the temperature of said conditioning device based at least in part on said first and second signals and said acts of identifying.

24. The humidity control apparatus of Claim 18, further comprising chamber temperature control apparatus operatively coupled to said chamber and adapted to control the temperature of at least a portion thereof based at least in part on the observance of a temperature stabilization event in a device under test (DUT) disposed within said chamber.

25. A controller architecture for use in an environmental conditioning or testing system, comprising:

a first temperature controller operatively coupled to a test chamber of said system, said first controller being adapted to algorithmically control the temperature of at least a device under test (DUT) disposed within said chamber; and

a second temperature controller substantially independent temperature controller operatively coupled to a humidity-control water tank of said system;

26. The architecture of Claim 25, further comprising a humidity sensor adapted for sensing at least a portion of the interior volume of the test chamber;

wherein said humidity sensor is in operative communication with said first and second controllers to provide signals thereto, said signals being used by said controllers at least in order to maintain prescribed conditions of humidity and temperature within the chamber.

27. The architecture of Claim 25, further comprising a tank level sensing apparatus operatively coupled to at least one of said first and second controllers, said sensing apparatus adapted to generate a signal relating to the level within said tank, said level relating at least in part to the amount of interaction between water in said tank and a gas diffused therein.

28. The architecture of Claim 27, further comprising a pump operation and speed control apparatus, said control apparatus being operatively coupled to at least one of said first and second controllers and adapted to control at least one of said pump energization and pump speed.

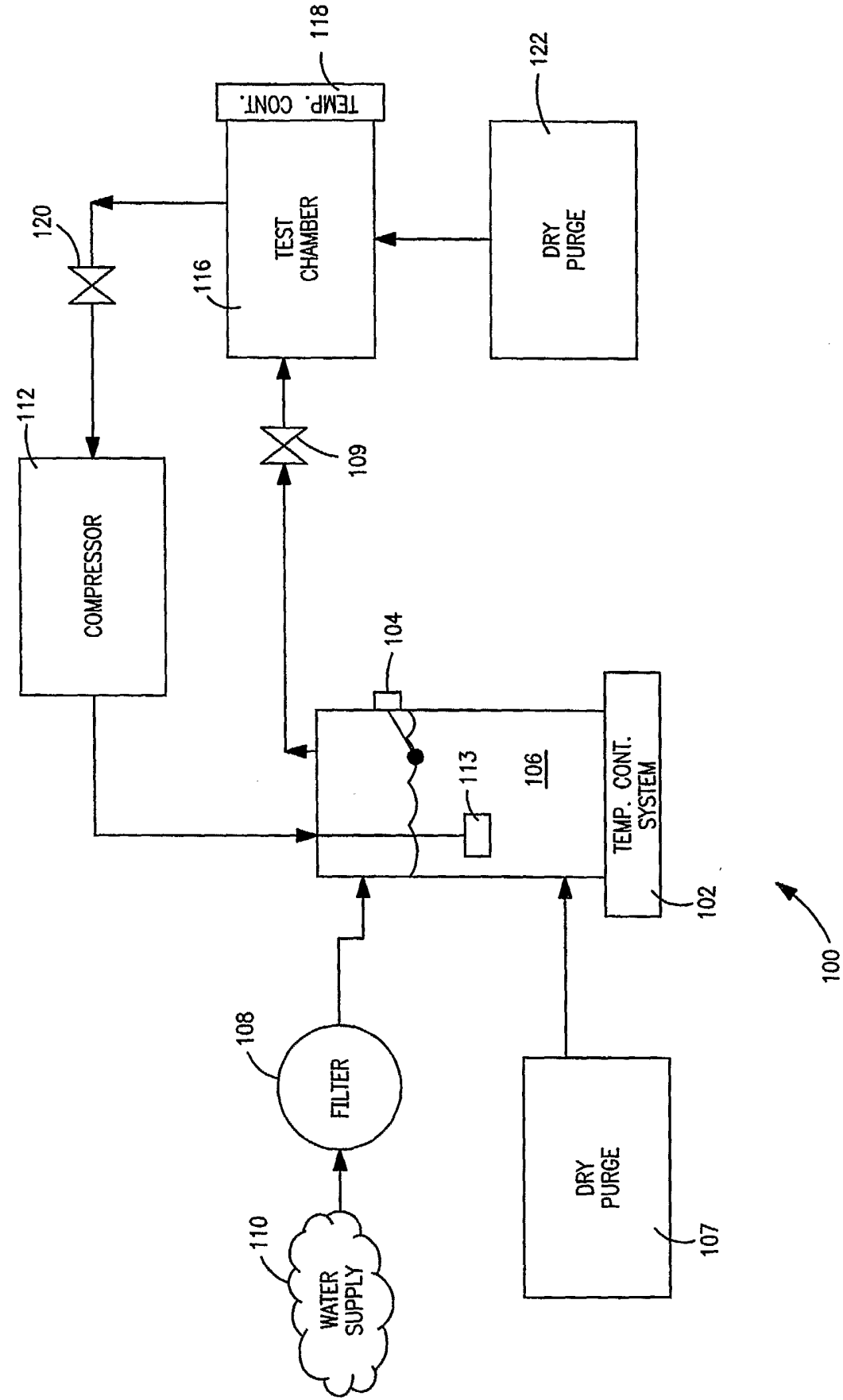
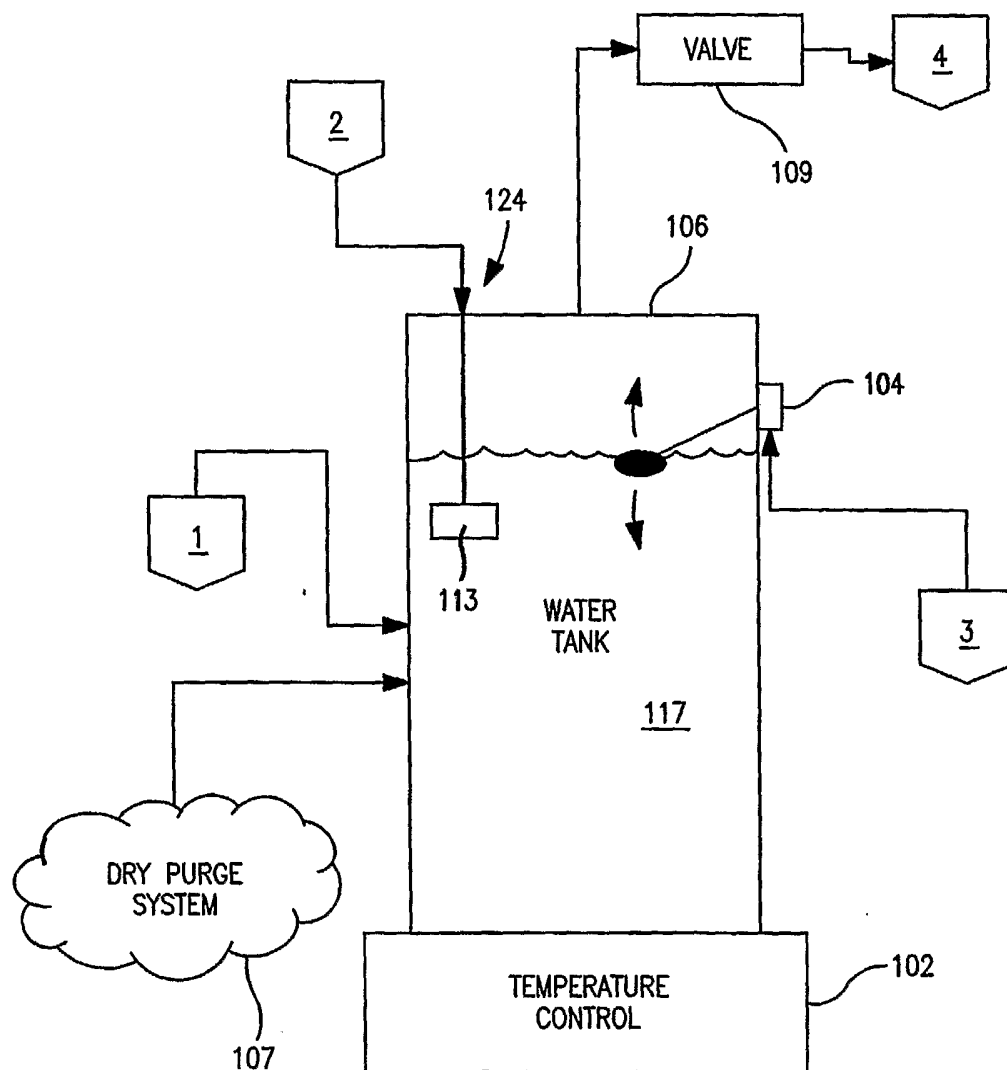
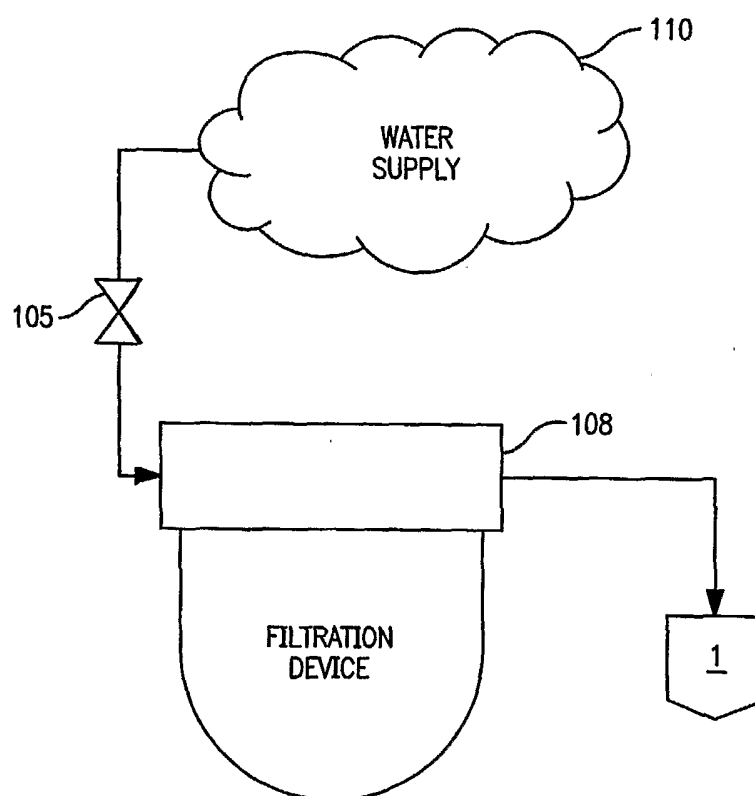
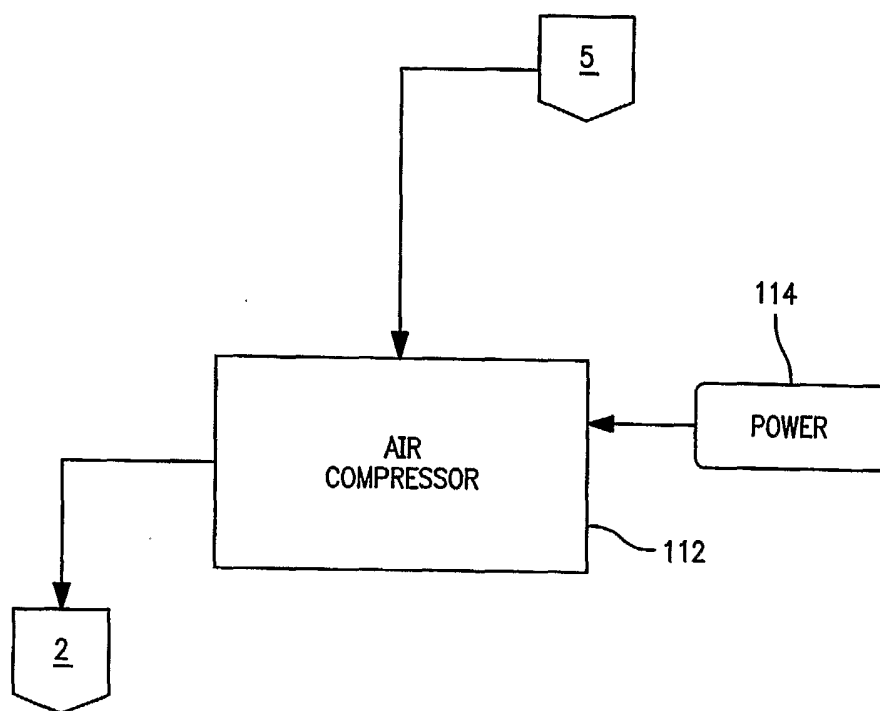
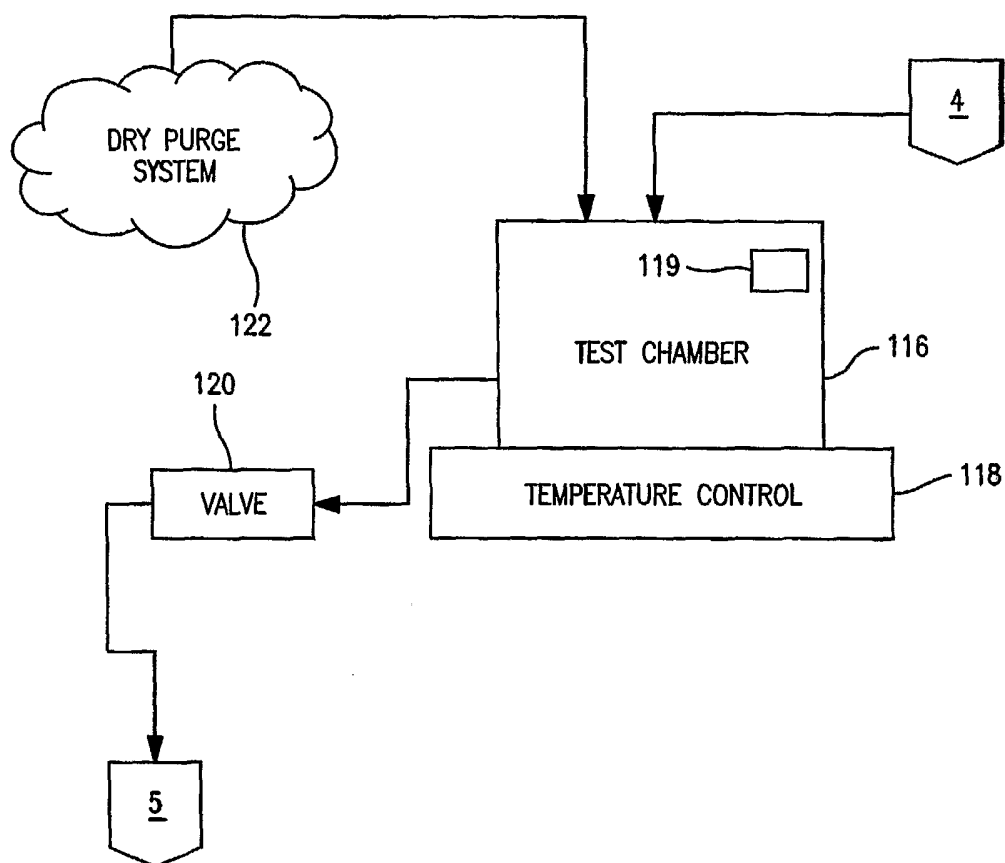


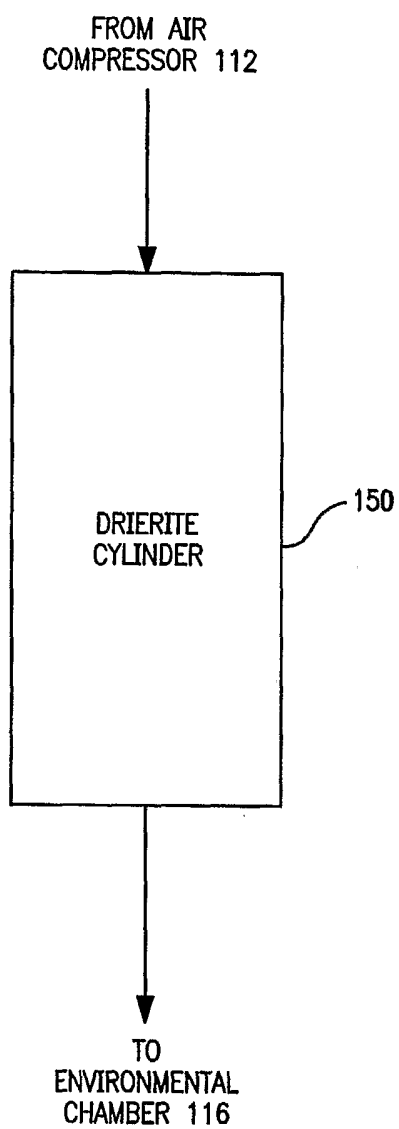
FIG. 1

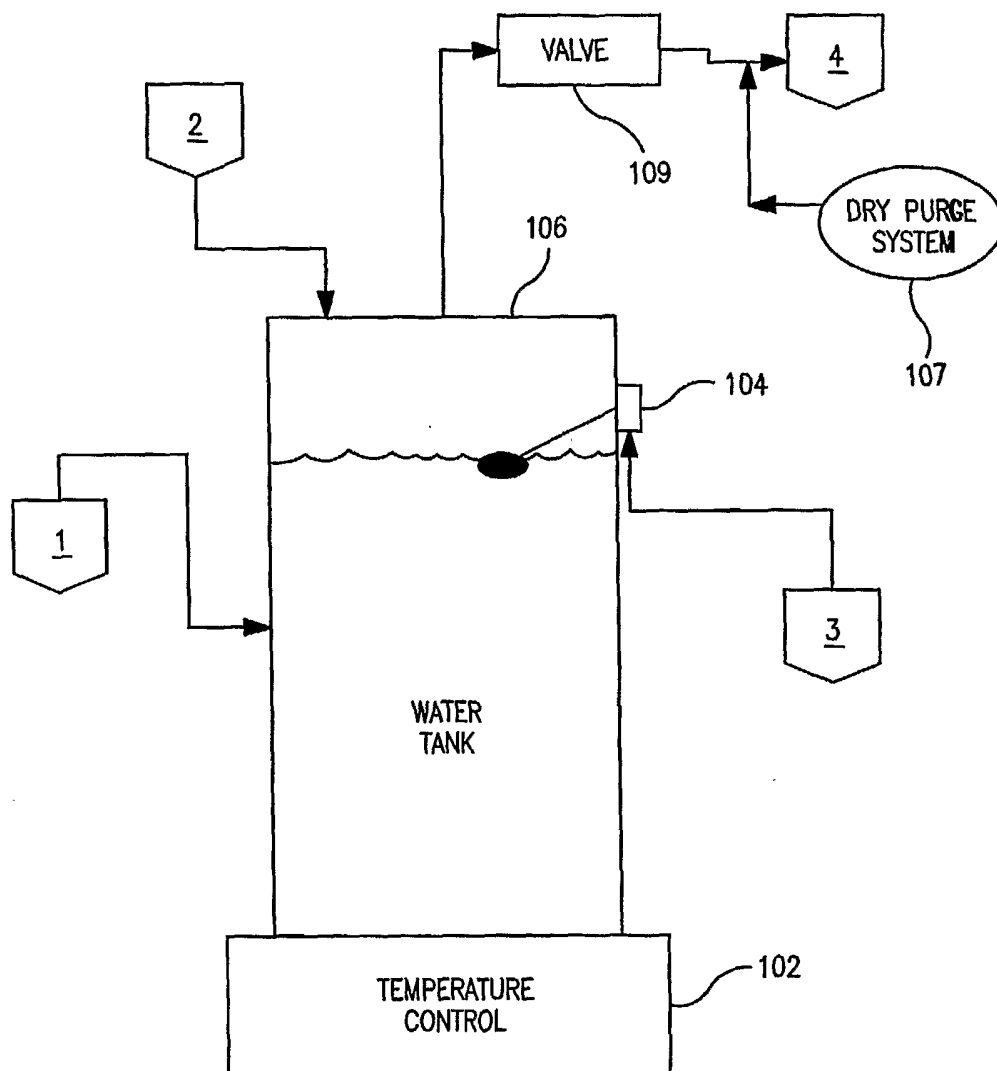
**FIG. 1a**

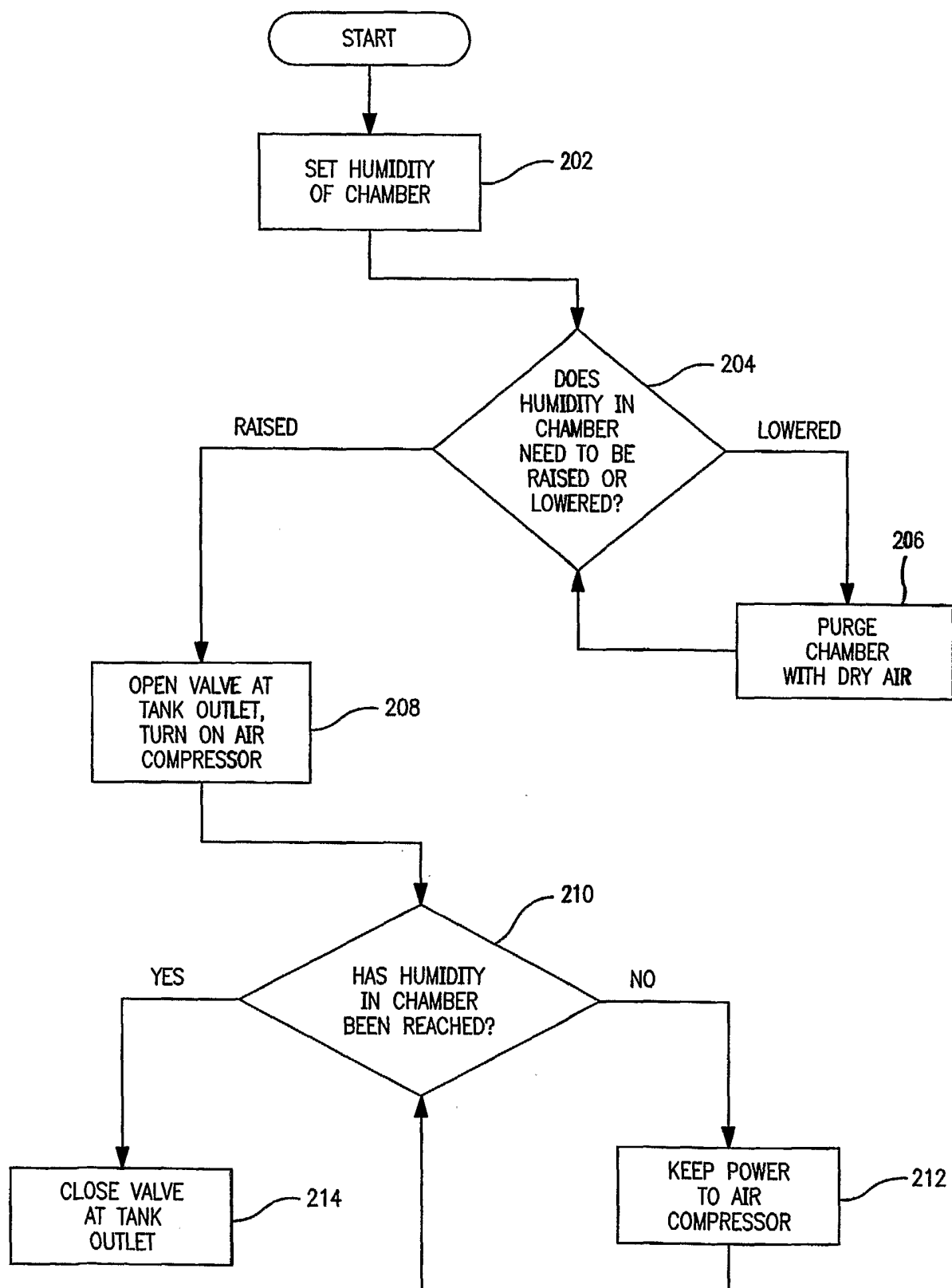
**FIG. 1b**

**FIG. 1c**

**FIG. 1d**

**FIG. 1e**

**FIG. 1f**

**FIG. 2**

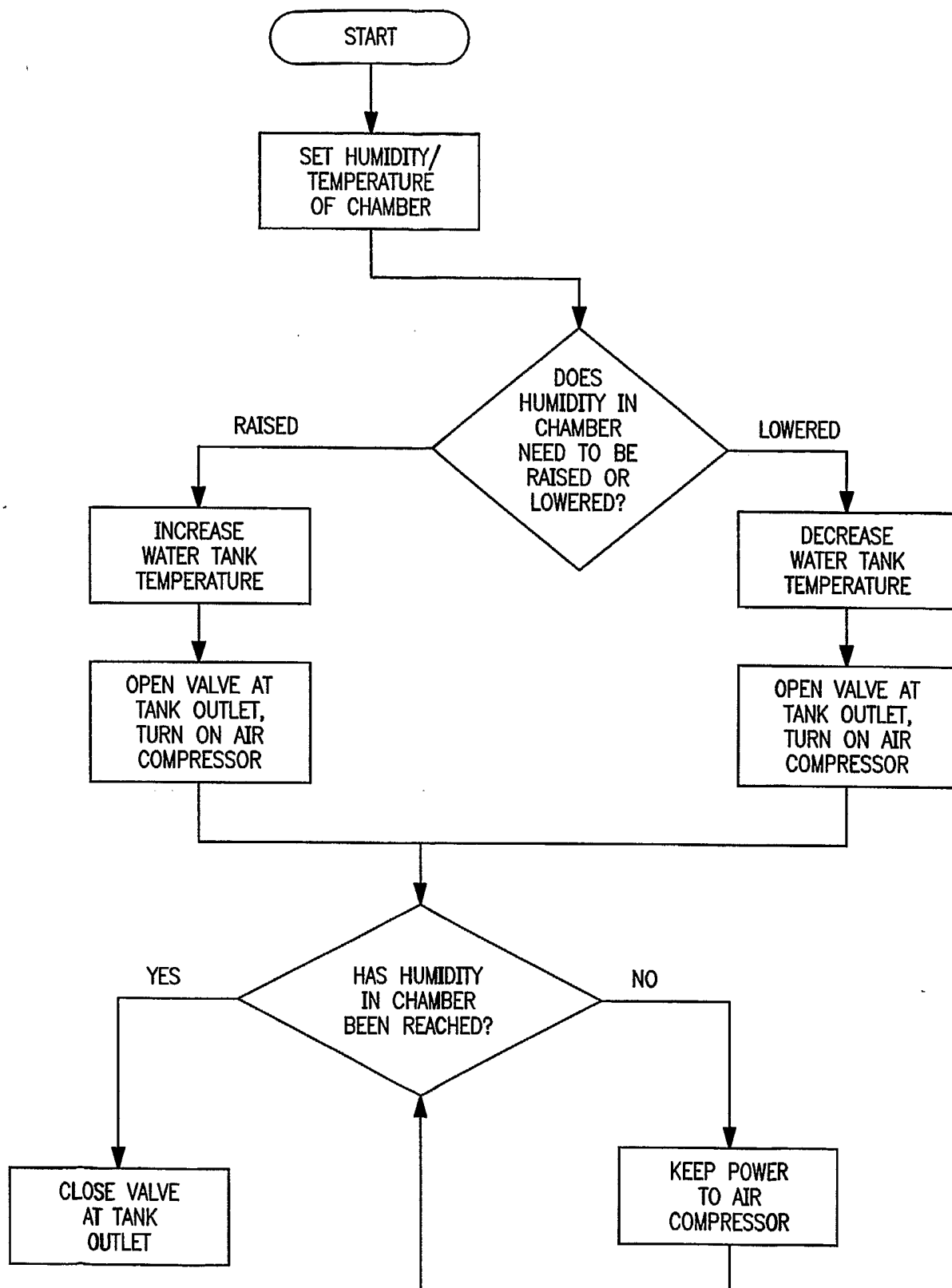


FIG. 2a