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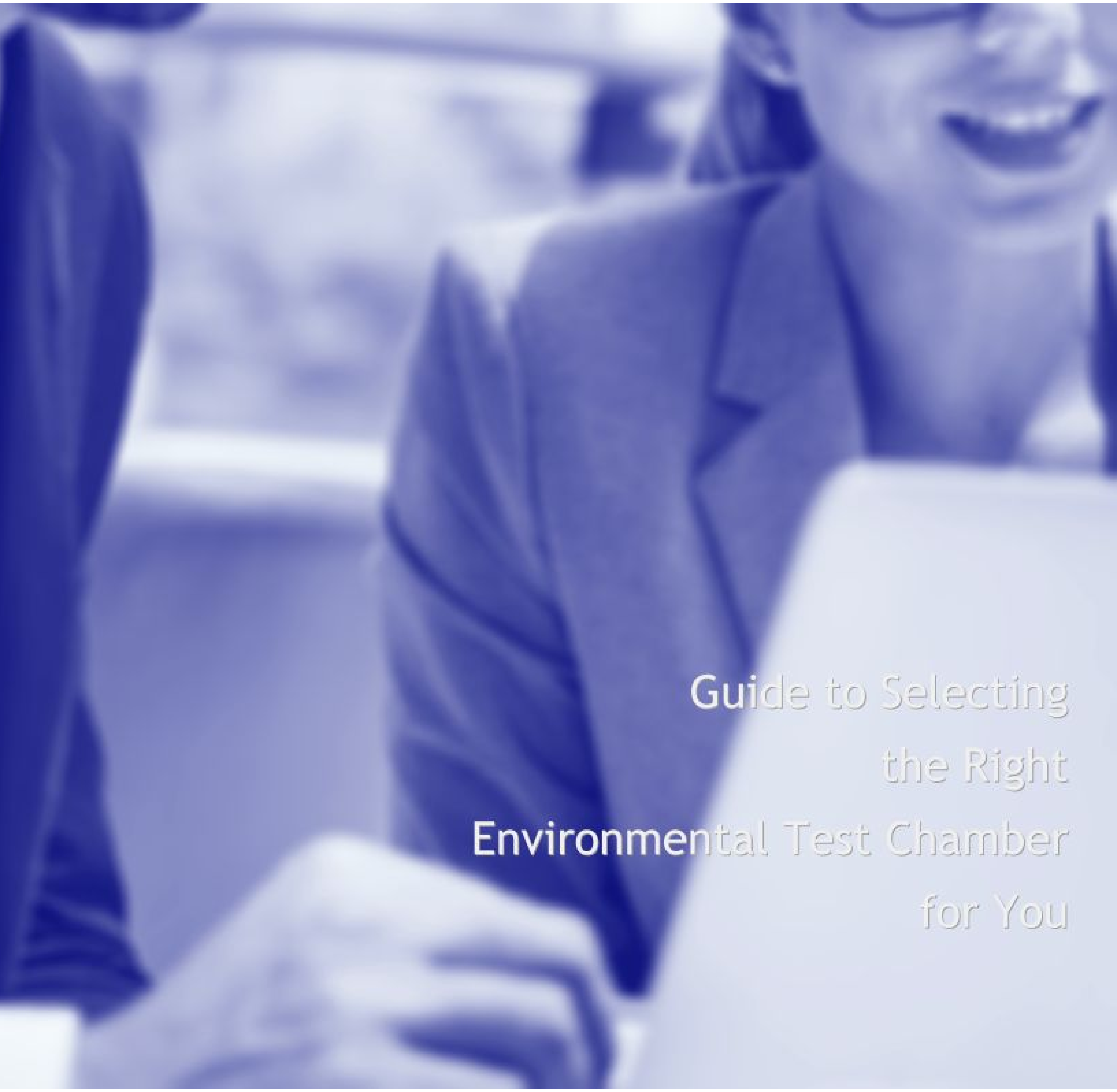

Guide to Selecting the Right Environmental Test Chamber for You

ENVIRONMENTAL TEST CHAMBER

BUYER'S GUIDE: Selecting the Right Environmental Test Chamber for You.

Introduction

Product testing can be expensive. Especially if you need to outsource your testing to a 3rd party. It can consume a majority of the product pre-launch budget. Outsourced testing can be costly but it can also add significant time to your release schedule.

Segway, for example, did an ROI calculation that showed purchasing chambers and a drive- or walk-in environmental chamber for $150,000 provided a break-even return within 18 months. They also found it reduced schedules and allowed for additional tests when needed.

With 3rd party testing rates of $1,500 per day, it's easy to see the ROI of buying a chamber for in-house testing purposes. Having the ability to test in-house allows for additional testing when confronted with test results that are not conclusive or definitive. Product testing pales in comparison to the cost of a recall.

The likelihood of a product recall today versus five years ago is significantly higher. Today's consumer advocates and regulators have better detection tools and stricter safety rules which mean that problems that once went undetected are now spotted more often and traced back to their source. There is a mind boggling number of products the Consumer Products Safety Commission watches over, with an average of one recall per day. The numerous FDA recalls include methods in which food is packaged and shipped. Recalls.gov, a collaborative effort of seven US Government agencies, admits there are many more recalls that are not being listed.

Clearly, there are benefits to using outside test houses, like engineers to help develop test protocols and identify failure reasons and fixes.

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However, when you are developing new to market items your in-house team is likely to be the best group of experts, and in today's fast paced marketplace, waiting for scheduled time for testing over many iterations can mean not being first to market.

Purchasing a chamber is a capital expense, and can be time-consuming if you do not plan your purchase needs. Let this guide help you make the best purchasing decision. At the end of this guide, you will find a helpful buyer's checklist to assist you along the way.

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Determine your testing requirements

As dictated by governing boards, industry standards, or consumer expectations

Your company has developed a new product, and now you need to select an environmental test chamber to test it and make sure the product will perform as expected. The product must be tested at various temperature and humidity conditions to ensure its quality and reliability. Where do you start? What will determine your selection criteria?

Development Testing

If you are testing in R&D, consider how the different elements can be tested to shorten the development time by identifying the shortcomings of components. Environmental test chambers feature precise temperature and humidity control to create repeatable climate conditions. The most common tests run are for product shelf life, accelerated life testing/reliability testing (ALT/HALT testing), and stability and package testing. These tests can be run using temperature for thermal cycling and humidity to find weak points. By identifying defects products can be redesigned, or stress limits can be identified to meet or set product performance expectations.

The automobile industry has a quasi scenario where they have many safety requirements via government regulations that specify the quality or safety expectations for the consumer. However, as the electric vehicle segment has grown, manufacturers created their own overseeing body to set standards based on how the battery market is changing. Therefore, they have created their own testing and performance expectations and communicated these openly to consumers.

In the United States, consumers know when their milk will expire through required date stamping implemented by the FDA. However, most consumer products do not have expiration dates, and companies are left to self-govern themselves.

Additionally, industries have their own test specifications that are self-regulated through organizations or adhere to government regulations under applications like light exposure, corrosion, military standard testing, temperature evaluation studies, electronic component burn-in, plant growth, and insect rearing just to name a few.

Production Testing

> In the semiconductor industry, manufacturers, like Analog Devices, HASS test every product the comes off the production line since the application of the devices are used in medical systems, scientific instruments, and communication devices.

During production companies choose to sample test products from batches or lots, or they may choose to test every product that comes off the line with highly accelerated stress screening (HASS testing). This form of testing involves pushing the product to its identified stress limits determined by the HALT testing in the development phase. HASS testing is important because it will likely identify improper manufacturing processes. There is the chance that product fails during manufacturing due to unreliable components that could have been identified in HALT testing. It is common practice to test products that contain Lithium Ion batteries during production. Automated external defibrillators (AED's), flight recording devices, mobile/cell phones, and many more products are tested during production. Finding defects during manufacturing is much more costly and more difficult to identify where the failures are occurring, so it is beneficial to put more time and resources into development. Customer expectation will determine the need for batch sampling or total production testing, as this varies by industry.

In-house vs. Outsourced Testing

While some companies rely on external test labs to do all their testing, most companies that perform a simple return on investment (ROI) analysis show cost savings by bringing environmental testing in house. Along with the cost savings, companies are also realizing the customization, freedom and time savings of purchasing their own test chamber equipment. Many companies, even smaller and startups, have not only experienced a financial return on investment but have also experienced how much easier an in house environmental chamber is to manage. When testing occurs in-house, engineers can test often, when, and whatever they want. Companies like Apple, Segway, and Zoll have experienced these benefits along with positive ROI.

Choosing Chamber Size

As mentioned in the previous section, determining the tests to be run is the first step because different tests have different ratio requirements for the load-to-empty space volume.

Choosing a correct chamber size depends on the application and your available floor space. The suggested ratio is about 1:3 between product volume and the working volume of the chamber. ⅓ product to ⅔ empty space around the product ensures adequate airflow to the test sample and makes sure your test is conducted properly. Items that allow for airflow (such as a computer chassis with plenty of air vents) can take up a larger percentage of the test volume.

Externally, consider that these machines create a lot of heat, and with test cycling up and down the temperature spectrum, the chambers themselves require good air circulation. Some units will require up to three feet (or more) of clearance in all directions to work properly.

Depending on whether the test product is a live load, a larger chamber may be needed to dissipate heat produced by the test subject, adversely affecting the chamber's pull down times or humidity system.

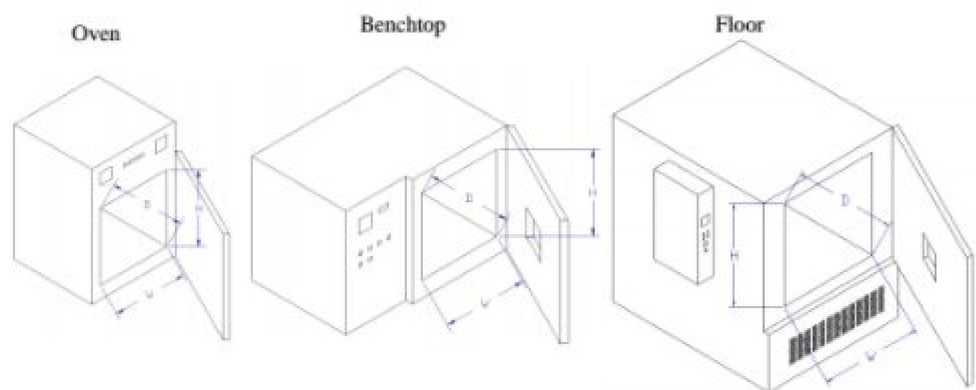
Sand, dust, and high altitude chambers do not need a 1:3 ratio of product volume and empty space. The air speed inside the chamber is already very high for the products and makes a 1:3 ratio unnecessary. These chambers should be just slightly bigger than your test product.

Volumes in Depth

Chambers are used in a wide variety of applications and come in many sizes. The most common volumes produced by chamber manufacturers range in size from small units of 0.5 ft^3 to 64 ft^3 (14 to 1812 liters) to walk-in rooms averaging 1,122.6 ft^3 (31,788.5 l), or even drive-in units that fit as many as six cars. The selection seems endless and requires additional criteria before your decision can be made.

Space and Mobility

Environmental chambers can be generalized into three categories: oven, benchtop, and floor models. Ovens take the least amount of space because they do not include humidity or refrigeration and are typically used as a stability unit without constant temperature cycles. Benchtop and floors models perform similarly, but offer different flexibility in space requirements and mobility needs. Let your operational and laboratory requirements dictate your benchtop or floor style needs.



Before deciding which chamber is best, consider where the unit will be located in the lab. Will it be a shared unit, and need to move to different areas? Maybe your lab has a hub and spoke arrangement with the testing space centralized for all users. Be sure to include discussions with R&D, manufacturing, and operations to better understand the multiple perspectives with regards to performance and facility requirements.

Choosing Temperature Characteristics

Types of Cooling Systems

How cold do you need to be? Across manufacturers, you will find two types of cooling systems: single-stage and cascade (two stage) systems. The first, single-stage compressor refrigeration system, supports temperatures as low as-37˚C (-35˚F) and conforms to both commercial and military standards for low-temperature tests. For temperatures below -37˚C, a cascade refrigeration system should be used, and can generally support temperatures as low as -73˚C (-100˚F). The low temperatures obtained with cascade systems occur when two separate, closed refrigerant circuits run concurrently, but each uses dedicated refrigerant and its own compressor.

Low maintenance. The way that mechanical refrigeration systems are designed is critical. Check to see that it is a self-contained system. Choosing a unit that is a hermetically or semi-hermetically sealed unit will make operation and maintenance an easier process.

Air cooled or water cooled? This might be an easy decision: With water cooled condensers, the chamber requires a dedicated conditioned waterline. All chambers can be air or water cooled however water cooled units will lower the temperature in the chamber workspace faster than an air cooled chamber.

Condenser Comparison	Air Cooled	Water Cooled
Heat rejection	Positive heat rejection	Little to no heat rejection
Energy efficiency	Less efficient	More efficient
Footprint	Larger space requirement	Smaller space requirement
Pull-down times	Slower rate	Faster rate
Purchase price	Less costly for small units	Less costly for large units
Installation	Easy	Must supply conditioned water cooling loops

Cooling Systems: LN^2 and CO^2 Boosts

The Liquid nitrogen and carbon dioxide cooling systems include an attached storage vessel of either liquid, which is injected into the conditioned airflow area of the chamber, known as the plenum. These liquids evaporate into gas on contact with the inside air of the chamber. CO^2 can lower the chamber's internal temperature rapidly to -73˚C (-100˚F) while LN^2 can quickly lower temperatures to a cryogenic temperature of -185˚C (-300˚F.) LN^2 and CO^2 boost kits for mechanical refrigeration systems decrease the temperature and total time for a system to cool down and act as a back up to the mechanical refrigeration system if it fails.

If either LN^2 or CO^2 is used, the chamber must be housed in a well-ventilated room, as the oxygen content of the air is diluted with use of the liquid refrigerant. Both compounds are natural components of air, however constant use can dilute the oxygen content of a room to dangerous levels. If your facility already pipes the gases in, then your facility's ventilation system most likely already vents to the outside directly. Bottled gas can be brought in however, consumption could be high and, again, the room must be vented to the outside to ensure the safety of personnel working in the surrounding area.

Environmental Safety

Today, environmentally-friendly HFC refrigerant and CFC-free insulation are utilized by most reputable test chamber manufacturers. Check with your manufacturer as the use of environmentally-friendly chemicals is not a requirement, but moving toward these refrigerants aligns with the International Paris Climate Agreement.

Temperature Change Rate

Temperature cycling is a method used in many different HALT and HASS tests; therefore the temperature change rate of an environmental test chamber will be important when determining which chamber to purchase. Variables that affect the pull-down time and ramp up time of a chamber include the chamber size, ambient room temperature, clearance around the chamber, temperature range, and the power of heating and refrigeration systems.

Typically, the larger the chamber, and the more extreme the temperature range, the longer it will take the chamber to reach the maximum (ramp-up) or minimum (pull-down) temperature. Usually, a more powerful heating and refrigeration system will be used for larger chambers to keep these larger chambers' change rates consistent with smaller chambers within the same series.

Another factor that can affect the pull-down time is whether the refrigeration system is water or air cooled. Water cooled systems typically improve the pull-down time to the minimum temperature opposed to an air cooled system of the same size.

Depending on the temperature range and size, some chambers will take up to two hours to reach the maximum temperature. For example, for a test chamber to reach 538°C (1000°F) an 8 ft^3 chamber can take up to two hours, while a smaller chamber will take one hour. Likewise, a chamber can take up to an hour to reach its lower limit. When CO^2 or LN^2 boosts are added a test chamber will reach -65°C (-85°F) in 15-60 minutes. A time savings of many minutes per cycle, equating to shorter testing periods of sometimes 10 hours (based on 40 cycles).

Usually, chamber manufacturers will have options to improve the chamber ramp-up and pull-down times with more powerful heating and/or a refrigeration unit with more horsepower.

Air Circulation

How air moves around the product and workspace is extremely important in environmental testing. As discussed in the Choosing Chamber Size section, the general rule of thumb is that only ⅓ of the internal space be used for product. This is to ensure that the conditioned air can flow evenly through the workspace. If many smaller products are being tested, it is best to spread the products evenly throughout the chamber to maximize air flow circulation. When selecting a chamber order fully adjustable shelves, so you can freely arrange products throughout the chamber.

Choosing Humidity Systems

Types of Humidity Systems

Vapor Generator. The vapor generator is a closed steam generator sized to fit any chamber. With the advantage of quick steam generation, diligent maintenance is required as sediment builds up in the bottom of the generator making occasional cleaning necessary.

In the situation where large live loads are being tested, steam from vapor generators may create problems with icing on the refrigeration coils. Increasing the space ratio of the product to working volume by using a larger chamber is recommended.

Immersion Water Pan. The water pan system consists of an open water pan with an immersed heater that generates steam. It is a simple system that generates steam slowly and will build up sediment in the bottom of the pan over time.

Atomizing. Mainly used in salt spray chambers, an atomizing nozzle creates fog inside the chamber and requires a constant water supply.

Humidity Range

The humidity range for most chambers is 20% to 98%, ±2% RH (Relative Humidity.) The range can usually be lowered to 5% RH by adding a dry air purge system. In the system, dry air from an outside supply line is added to the air conditioning area, and can then be managed through its controller.

Whenever water is introduced to a mechanical system, regular maintenance will be required. Across the test chamber industry, you will find that chambers require demineralized/deionized water with a typical resistivity of .05-1MΩ/cm. It is likely that your facility's tap water supply does not conform to this standard. Therefore, facility water will need to be conditioned, or you will need to purchase water from an outside source. Demineralizer systems coupled with filtration are often an option offered to protect chambers internally. Care must be taken when installing these systems as, over time, deionized water will corrode and eventually destroy the internal workings of a chamber. Damage begins inside the pipes, so by the time the naked eye can see the damage, the entire piping system must be reconstructed.

Cycle Times

Humidity systems have factors that influence cycle times: the type of humidity system, temperature of the chamber, and humidity set point. All affect the time it takes a chamber to reach its set point. When contacting manufacturers, ask for more details on humidity cycle times to understand how your product will affect test chamber performance.

%RH versus Temperature

Electronic Sensor Measurement. Chambers made today are typically equipped with electronic relative humidity sensors as a standard feature. If the understanding of relative humidity in relation to temperature is important, then take time to discuss with manufacturers your product and needs to monitor humidity and temperature levels.

There are many electronic sensors on the market today and the technology is changing fast. Although there is no one perfect electronic sensor for all needs, there are several that can be offered to suit your needs. As humidity moves close to 100% sensors can have a difficult time with accuracy.

The same goes for scenarios where test products release gases when exposed to heat and moisture. When the gases come in contact with typical electronic sensors, the gases stick to the sensor surface, blocking the probe’s ability to get an accurate reading. Special sensors can replace standard probes that will separate the residues from the gases released in the chamber.

When a chamber cycles from high to low temperatures while humidity remains constant, ask for “warmed sensors” to stop condensation from building up on the sensor and giving inaccurate readings. It may be better to resort to old school methods: wet-bulb and dry bulb temperature readings.

Dry Bulb-Wet Bulb Measurement. Before electronic sensors were available, engineers and scientists used this method to determine percent relative humidity and temperature.

Dry bulb measurement is the way that most people measure temperature. Holding a temperature probe tip (aka the bulb) and allowing air to pass by.

Wet bulb measurement is a process in which the tip of the probe is wrapped in wet muslin. This temperature reading will be lower and coupled with the evaporation of the muslin will determine the humidity in the air. When the humidity is at 100%, the dry bulb and wet bulb will be the same temperature: complete saturation. Applying the dry bulb and wet bulb temperatures on a psychrometric chart will indicate the humidity level. Many companies still choose to use this method because they are consistently running environmental tests at high humidity levels. Of course, the psychrometric chart is not an algorithm and as the probe bulbs collect temperature readings the relative humidity is calculated automatically. It is worth mentioning that wet bulb measurements loose accuracy during low humidity testing conditions. Achieving measurements no longer occurs using charts with manual calculations, digital controllers perform the calculations internally and adjustments can be made from there. A deeper controller discussion can be found in the Controls and Sensors section.

Achieving Low Humidity. Desiccant dehumidifiers allow you to operate a chamber at low humidity levels, beyond the ability of refrigeration system evaporators. If you require low temperature/low humidity conditioning in your chamber, make sure to check the maintenance required for the dryer. Look for compressed air dryers that circulate the wet air through a series of drying agent substances or a drying wheel, and then recirculate clean dry air into the chamber workspace. Take time to understand the maintenance needed to operate the dehumidifiers as each has pros and cons and the offerings are diverse across chamber manufacturers.

Controlling and Monitoring Humidity

Most modern test chambers feature microprocessor-based controllers with computer communications, autotune, solid state RH sensors, and stainless steel temperature probes with LED, LCD, or touch LCD displays of temperature and RH during operation, showing both process and set point values.

Components and Materials

Construction Materials

When purchasing a chamber it is important to select a chamber that will last. It is not unusual for a well-maintained chamber to last for two decades. Ensure your chamber has a long life by making sure the materials used to construct your chamber are high quality and durable. For smaller chambers, under 8 ft^3, confirm the internal chamber is at least 304-grade stainless steel, and depending on the size of the chamber, is an adequate thickness of at least 18-gauge stainless steel for the interior walls. Larger chambers need at least 18-gauge stainless steel to ensure adequate durability.

Construction Method

Internal Workspace. The internal walls of a chamber should be seam welded. Heli Arc or TIG welding is preferred to reduce the chance of leaks from inside the chamber to the external components. Some chambers use riveted wall assembly which will leak heat and humidity into the electrical components of the chamber.

Door. Ensure the door to the chamber workspace is fitted with a silicone-type gasket to ensure chamber conditions do not leak through the door. Silicone gaskets are able to sustain their structure high and low-temperature conditions. This is especially important when CO^2 or LN^2 is used because other materials easily disintegrate when exposed to low temperatures.

Exterior. The outer body of the chamber should be welded heavy gauge cold rolled steel. Cold rolled steel is 20% harder than other steel, and when finished will be truer to shape, durability, and tolerance; qualities that are all important factors when subjecting machines to high and low temperatures and various humidity levels.

Applying powder coated finishes adds long-term protection against rust and corrosion as compared to wet painted finishes.

Machine Components. Ensure quality workmanship by applying national standards organizations' requirements to the wiring which should conform to NEC (National Electrical Code). Refrigeration systems should be in accordance with ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) guidelines.

Insulation. To maintain thermal integrity, the walls and doors of the chamber should be high density, low "K" factor, non-settling fiberglass or mineral wool. These products are fire retardant, non-corrosive, and thoroughly health and safety tested.

Controls and Sensors

Control

On/Off Only. Very few modern chambers are sold with only an on/off control. These are included because there are still many labs that have 25-30-year-old chambers running. These companies have maintained impeccable preventative maintenance on their machines and they continue to operate effectively. Oftentimes these chambers will have aftermarket digital monitors tracking the sensors and recording data. If your chamber is still operating, there are chamber manufacturers that will retrofit your chamber with current electronics packages to rig your 20th-century chamber with today's technology.

Digital PID. With today's technology, PID Controllers can be operated digitally, and there are many choices in the marketplace. Watlow is a recognized leader in the industry for accuracy and reliability, and the following is based on their product line.

Digital controllers in their simplest form allow you to manually create set points and adjust the settings for one control loop. Errors and

Disruptions are managed using soft buttons from the controller. This form of controller allows for basic operations for the new user and straight-forward testing applications.

The next level of digital controller is an LCD character display controller which adds a variety of control options and is more complex. Control occurs two ways, manually at the controller with soft button activation, or by uploading profiles. There are multiple control loop options, either as a single channel or dual channel, with a set number of inputs and outputs. Watlow offers the F4, which has guided setup easy access to alarm and set point values and includes an on-board user manual.

The most recent advances in controllers include high-resolution, graphical, touch-screen displays that are menu-driven, and comes with software that allows you to create your own profiles using code or bricks. The display allows for easy navigation, but the multiple forms of inputs of control loops makes the system more complex. Watlow's F4T product also includes a data logging capability with multiple methods for data transfer.

Sensors

Quality matters, so consider having digital set point controllers with displays that allow for linearization and tracking between the display and sensor temperature. These sensors should be resistance temperature detectors (RTD) 100 ohm platinum sensors, as they offer the most accuracy and provides excellent stability and repeatability.

Data Collection

Window. Looking through a window is the most basic of data collection, but is sometimes the only option. So, do not forget the value of seeing your product in action as it moves through test cycles.

Internal Light with External Switch. If you ordered the window, you should also order a light to go with it. Consider internal lights for larger chambers, so test engineers can see what they're working on. It beats using a flashlight, and it frees up their two hands to work safely.

IEEE-488 Computer Interface. A general purpose interface bus (GPIB) allows for 1 Mbyte/second maximum data transfer rate. Data is transferred digitally 1 byte at a time. The method allows for the transfer of data between a PID controller and computer. This protocol and method of communication is dated compared with modern communication methods.

Circular Chart Recording. Digital chart recorders offer real-time data collection and documents the test process. The chart recorder can be connected directly to the PID controller or independent sensors. Examples of the recorders are chosen from Honeywell, a reputable instrumentation provider. Honeywell's Truline products allow up to four channels that monitor process variables, up to two PIDs to allow for configuration to the exact control action needed, and Modbus communications to allow for an external interface.

Electronic Data Recorder. These recorders typically collect data from up to 12 inputs in continuous and batch data in a digital format, so it can be downloaded into a spreadsheet for analysis. Newer technology also offers similar data collection with a touchscreen option for quicker visualization of the data. The Honeywell EZ Trend controller allows you to go paperless, replacing the 100mm paper strips and circular chart recorders. The secure digital format eliminates transposing errors. The data is encrypted and can only be read using proprietary Honeywell software to ensure data integrity. The touchscreen version is the Honeywell Minitrend controller Touch Panel Control.

Controller and Data Management Merge. The AES|XChange is

Associated Environmental Systems' data logging dashboard designed to work hand in hand with your environmental test chamber. Built to operate universally on stable and accurate Watlow controllers, AES|XChange is also available for retrofit with any brand of environmental chamber system. The retrofit box easily connects by RS232 cable and is networked via Ethernet.

The AES|XChange controller is designed to make your entire testing experience easier, you can run profiles stored on the controller, add a layer of security to your test chamber, and log up to eight years of data.

When running profiles with AES|XChange, the user can run, pause, and completely stop the profile in current operation. The home screen can be managed at the chamber from the touchscreen or can be accessed remotely from a desktop, laptop or tablet device. While monitoring up to 24 inputs, On the home screen, a widget displays the name of the profile, the current step being performed, the location of the step in the sequence, what the step is doing, and how much time is remaining for that step.

Data logging with AES|XChange is an absolute breeze. The user can control how many inputs are being logged as well as the frequency at which they are logged. It also monitors data from the chamber outputs creating a log. The log of process cycles allows for easier diagnosis if the test chamber has difficulty achieving desired conditions.

AES|XChange has a built-in graph for archived data and can sort and display data by date range. Adjusting the graph resolution controls how many points the graph can plot. Users can also adjust the color of each series for a completely custom graph. Now you can view your data as a whole, or zoom-in to a particular control loop, making analysis much easier. Data is easily downloaded at the completion of testing in either CSV or TSV files for permanent records.

Securely network your chambers throughout your organization using

Ethernet, JSON, API, and Python scripts and individually control user access with six levels of interaction. Depending on the user's security level, AES|XChange can lock out the chamber to ensure the profile is run to completion, without interruption.

Safety

High-Temperature Failsafe Controls. There are multiple types of temperature failsafes available. The most common that is generally standard with all manufacturers is the mechanical failsafe.The mechanical failsafe ensures that a product will stay within the set point in case of a malfunction of the primary controller.

Mechanical Failsafe Heat Fuse. A safety mechanism used in heating devices to provide failsafe overheating protection. This should be a last resort protection and not a standalone protection. A heat fuse or thermal fuse, will interrupt the flow of electricity to the heaters and shut it down if it reaches a certain temperature.

Digital High Temp Limit Failsafe. Most manufacturers will factory set a digital high temp limit failsafe preventing the heaters from running out of control. As the user, you may dial this down to create your own high-temperature limit. A digital set temperature safety that will shut down the test chamber if it goes over a certain temperature.

Programmable High and Low Temp Safety Indicator. Once you know your product's fail points, you can set the chamber to test up to that set point and set a safety indicator, so the chamber does not beyond the high and low points. This will ensure you are not causing product failures during production testing.

Noise Reduction Package. If employees will be working in close proximity, you can add a sound-deadening foam to the mechanical portion of the unit to lower the noise output from the chamber.

Alternative Power Requirements. When you look for chambers on manufacturers' websites, you may find one power option or multiple power options to choose from. Power requirements are determined by your facility's output. Check with your facility for the best power needs. If multiple chambers or other power draining units are in use at the same time, the load on the facility might be too high. Check with a qualified electrical engineer to determine your capacity.

Conclusion

Chambers come with many features both standard and optional. Planning ahead of time will make the capital expenditure process easier and free up your valuable time. Use the following checklist on the next page to help guide you through your decision-making path.

Buyer’s Checklist

- ❏ Determine the test to perform during development
- ❏ Determine the tests to perform during production
- ❏ Understand the product size requirements
    - ❏ Length, width, height, density
    - ❏ Number being tested at one time
- ❏ Identify performance parameters from operation, R&D, and manufacturers
    - ❏ Understand the hooking up requirements
    - ❏ Understand facility size requirements
    - ❏ Understand facility electrical requirements
    - ❏ What are your networking requirements?
    - ❏ Understand optimal footprint and space requirements
    - ❏ Understand ambient room temperature in test space
    - ❏ Understand facility water availability and quality
    - ❏ Initializing and running start up
    - ❏ How will training staff occur?
- ❏ Product testing
    - ❏ When will the product need to be handled?
    - ❏ Will you need to observe the product visually?
    - ❏ Will light be needed inside the chamber?
    - ❏ Will light or other surrounding condition impact the chamber operation or the efficiency of the controlled room?
- ❏ What is the product’s required life expectancy?
- ❏ What is the required amount of user control and programming
- ❏ What are the calibration requirements for installation and ongoing use?
- ❏ Are there other workflow and process considerations?
- ❏ Is it necessary to measure RH over the entire temperature operating range of a given chamber?
- ❏ Will condensation ever form within the chamber?
- ❏ Will unusual or aggressive gases be present within the chamber?
- ❏ Will the chamber run near 100% RH for extended periods of time?
- ❏ Will the chamber run at low temperatures and low humidity?

NOTES:

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Appendix

A Primer for PID

Introduction

If you are new to PID then this is a primer to help you make choices regarding digital controller devices in the marketplace.

Consider life before automation. Say a steam train needs to be at a certain temperature to keeps its speed. The engineer needs to add fuel to the burner every time the temperature drops below a designated level. The temperature gauge changes and this give feedback to the operator as to what to do next. The feedback from the process is a control loop. This control loop, many years ago, was manual and an employee would be assigned to watch the gauge to make the required adjustments to keep the process operating at the desired level.

Example

Today, the control feedback loop is automated, and virtually any chamber you purchase will have some version of a PID controller as a standard feature. Think of your car's cruise control mechanism. A control device is connected to the fuel valve, a controller is available to set to a certain point, and a measurement device is connected to create a feedback loop. The driver enters the desired speed (aka ***set point***). The measurement device obtains the speed and sends a signal for more or less fuel if the process is running below or above the set speed. The difference between the two signals (measurement feedback and set point) is called the ***Error***. Based on the Error, a signal will be sent to the control valve to keep the speed at the correct set point. This signaling back and forth, ***feedback loop***, is closed and will keep repeating until changed in any of the three ways:

Integral, the driver taps on the brakes resetting the controller to 0. ***Derivative***, the driver moves the set point to a higher rate (increasing speed) or lower rate (decreasing speed). ***Proportionally***, imagine the cruise control had another button that could allow you to set the speed you wanted to attain as a percentage to the complete measurement, so if your odometer reads 120 mph as its top set point you could would dial in 50% to give feedback to the control process to add fuel until the measurement device reaches 60 mph. In any situation, the feedback loop continues its closed process until further instructions from the operator.

In a PID controller, each of the three modes reacts differently to an Error. The amount each control mode reacts can be tuned or adjusted in the settings.

Proportional Control Mode

The Proportional adjustable setting is called ***Controller Gain***. Increasing the adjustable setting will create a proportional Controller Gain, so if the Error is big, the Controller Gain will also be big. The bigger the Error the larger the Controller Gain will be. However, this can cause great amounts of fluctuation as the Error and Controller Gain can easily swing in opposite directions creating an oscillating effect. If the Controller Gain is set too low, it will not respond to Errors or set point changes.

Measuring Proportional. Do not be confused between ***Proportional Controller*** and ***Proportional Band***, as the setting are not the same and must be handled slightly differently in terms of measurement.

There are deficiencies in using a P-only controller. As in the case of the Controller Gain and Error being wildly oscillating, eventually the Controller Gain will catch up to balance out the Error and they will come closer together. However, they will often balance below the set point, and the operator will need to enter a ***bias*** entry until the Controller Gain reaches set point. The typical method is from switching to manual mode until the set point and Controller Gain are in sync and then resetting the controller.

Integral Control Mode

The need to perform this manual override created the Integral Controller Mode. This mode counteracts the false balance between the Controller Gain and Error by continuously making incremental changes to the controller output until the Error level reaches zero. This Integral change is able to occur fast for large Errors and slow for small Errors. Again there are controller pitfalls with Integral adjustments, set for too long and the controller will be sluggish but set too short and the control loop will begin to swing back and forth around the set point and become unstable.

Measuring Integral. Most Integral Controllers are measured in minutes, but some are in measured in seconds. This is measured by ***Integral Gains*** repeated in cycles per minute or per second.

Derivative Control Mode

This mode is not used often in controlling processes but can make a control loop move a little faster than just PI Controller adjustments alone. The derivative mode setting is called ***Derivative Time*** and based on the rate the Error changes. If the Error changes fast the Derivative Time will change fast. If the Error is zero the Derivative Time is zero. Issues arise when the Derivative Time is too long and again, wild movements above and below the set point will occur and the control loop will run unstable.

Measuring Derivative. The adjustable action of a Derivative Controller can also be measured in minutes or seconds.

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PID Mode

Commonly called the ***PID controller***, its output consists of the sum of the proportional, integral, and derivative control actions. The interactive use of all three modes together provides more control action sooner than the methodologies described earlier, and shortens the time it takes to return to set point.

This primer is a summary of Jacques Smuts blog post and book, *Process Control for Practitioners*.

Resources

http://www.ul.com/newsroom/pressreleases/ul-announces-availability-of-ul-certification-for-hoverboards/

http://www.weather.gov/source/zhu/ZHU_Training_Page/definitions/dry_wet_bulb_definition/dry_wet_bulb.html

http://www.sensorsmag.com/components/choosing-a-humidity-sensor-a-review-three-technologies

http://www.vaisala.com/Vaisala%20Documents/Application%20notes/Measuring_RH_in_test_chambers.pdf

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http://blog.opticontrols.com/archives/344

http://www.omega.com/techref/overview-of-ieee.html

http://www.omega.com/prodinfo/rtd.html

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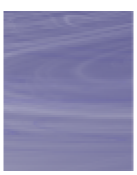

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