Beyond the Basics

Expert Tips for Choosing and Maintaining Environmental Chambers

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An environmental chamber is a device that simulates various environmental conditions, such as temperature, humidity, altitude, vibration, dust, etc., to test the performance and reliability of products, materials, or components. Environmental chambers are widely used in various industries, such as aerospace, automotive, electronics, defense, pharmaceuticals, and more.

Choosing the right environmental chamber for your testing needs and keeping it running reliably for years requires careful consideration of several factors. Such factors include the type of chamber, the test application, the performance criteria, the construction quality, the safety features, and the preventive maintenance.

Types of Chambers for Testing

There are many types of environmental chambers that can be utilized for testing, depending on the specific conditions that need to be simulated. Some of the common types are:

- **Temperature and humidity chambers:** These chambers can control the temperature and humidity levels within a specified range, usually from -70°C to +180°C and from 10% to 98% relative humidity.
- **Thermal shock chambers:** These chambers can subject the test specimens to rapid and extreme changes in temperature, either by air or liquid, to evaluate their resistance to thermal stress.
- **Altitude chambers:** These chambers simulate altitudes up to 100,000 feet. The full range temperature can be controlled up to 40,000 feet. Typical applications for altitude chambers are aerospace, aviation, or military products.
- **HALT and HASS chambers:** These chambers apply high levels of stress, such as rapid temperature cycling and 6 degrees of freedom (dof) vibration to accelerate failure of products, identify weak points and improve the design.
- **Settling dust chambers:** These chambers expose the test specimens to dust particles of various sizes and concentrations, to evaluate their resistance to dust ingress and abrasion.
- Vibration chambers: These chambers combine temperature and/or temperature/humidity control with vibration to simulate the effects of transportation, operation, or environmental factors on the products.
- **Other custom-built systems:** These chambers are designed and manufactured to meet the specific requirements of the customers, such as special temperature ranges, humidity levels, test volumes, or test standards.

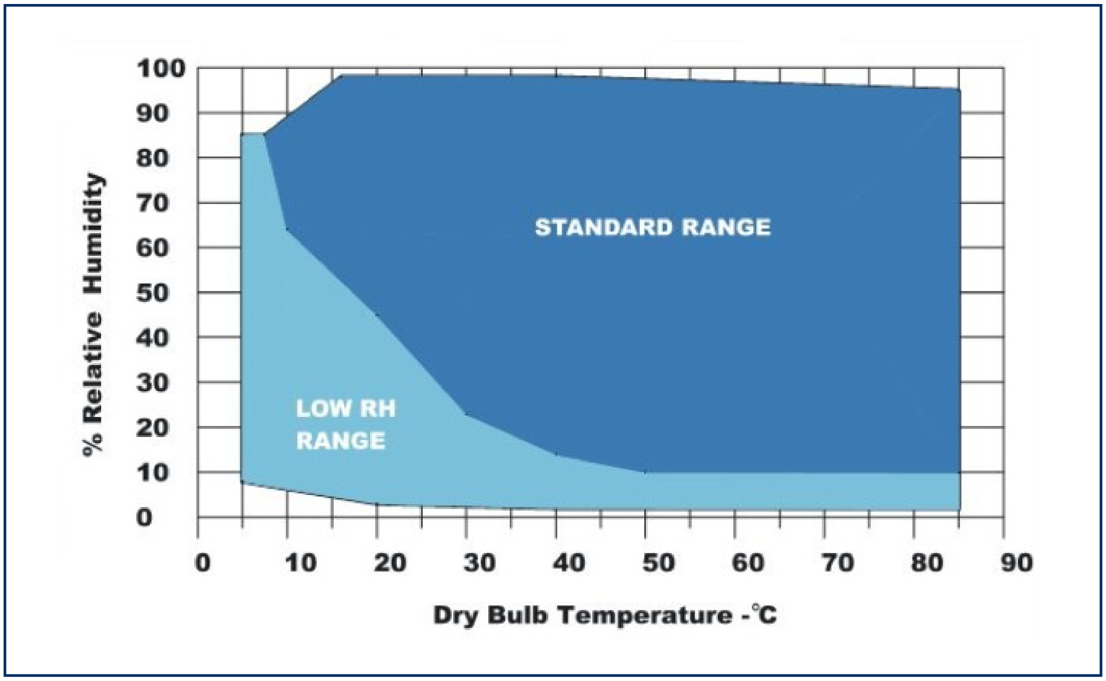
Defining the Test Application

Before selecting an environmental chamber, it is important to define the test application clearly and accurately to ensure that the chamber can meet the performance criteria and test objectives. Some of the key information that needs to be provided are:

- **What is being tested?** The weight, size, heat load, construction materials, and configuration of the test specimens affect the required chamber size and performance specifications.
- **Is the test specimen powered?** The electrical, mechanical, or chemical power of the test product, as well as the timing and duration of the power will determine the safety features of the chamber along with the cooling capacity needed to maintain product temperature.
- **Is the test specimen hazardous?** The potential risks of flammable, explosive, or toxic materials or vapors need to be considered and mitigated by appropriate safety measures.
- **What is the temperature range?** The minimum and maximum temperatures that need to be achieved and maintained in the chamber, as well as the current and future test needs, affect the choice of the refrigeration system and the cooling method.
- **What is the required ramp rate?** The speed of the temperature change, as well as the frequency and duration of the change, affect the refrigeration capacity and the cost of the chamber.
- **Is the required temperature change average or linear? What is the difference?** Average change rates differ from linear change rates. An average change rate might be very fast during the initial transition and then become slower as the temperature gets colder since the compressor capacity is lower. Linear change rates are accomplished by holding back refrigeration capacity early in the ramp and overpowering the system with very high capacity late in the ramp. For example, a 1 HP system used for average change rates might need 5 HP for linear change rates over the same temperature range. A linear transition changes the same degree/per minute across the entire range. The most common is an average change rate but be sure to ask and clarify the change rate with your chamber manufacturer. There is a significant difference in design, performance, and price for linear temperature change rate requirements.
- **Is humidity required?** The minimum and maximum humidity levels that need to be achieved and maintained in the chamber, as well as the ability to control humidity during transitions and with live loads, affect the choice of the humidification system and the water supply. To achieve lower humidity levels down to 5% RH most manufacturers offer a low RH package. It normally includes a dry air purge system and refrigeration valves to allow the refrigerated coil to go below freezing. However, the dry air purge helps to offset this by maintaining a positive pressure in the chamber and sublimating some of the accumulating frost from the coil.
- **Are there any special requirements?** The test standards, facility or corporate standards, explosion resistance, available utilities, move-in restrictions, installation, start-up, and training needs affect the customization and the service of the chamber.

Humidity Systems

The standard controllable temperature/humidity range for most manufacturers is 8˚C (46°F) to 85˚C (185°F) with 10% to 98% RH, limited by a 7˚C (44˚F) dew point. Since the amount of moisture varies at every temperature, the chamber manufacturers use dew point to describe the RH limitation. The best way to understand this is to refer to the graph below. If you follow the bottom line of the standard range section of the graph, those temperatures and humidities represent the 7˚C dew point. For example, the lowest humidity level achievable at 20˚C is 43% RH with a dew point very near the 7˚C lower limit. At 50˚C the chamber will be able to achieve 10% RH. The chamber must be operated within the limits set by the manufacturer. Damage to the refrigeration system can occur if points outside of the standard range are attempted.



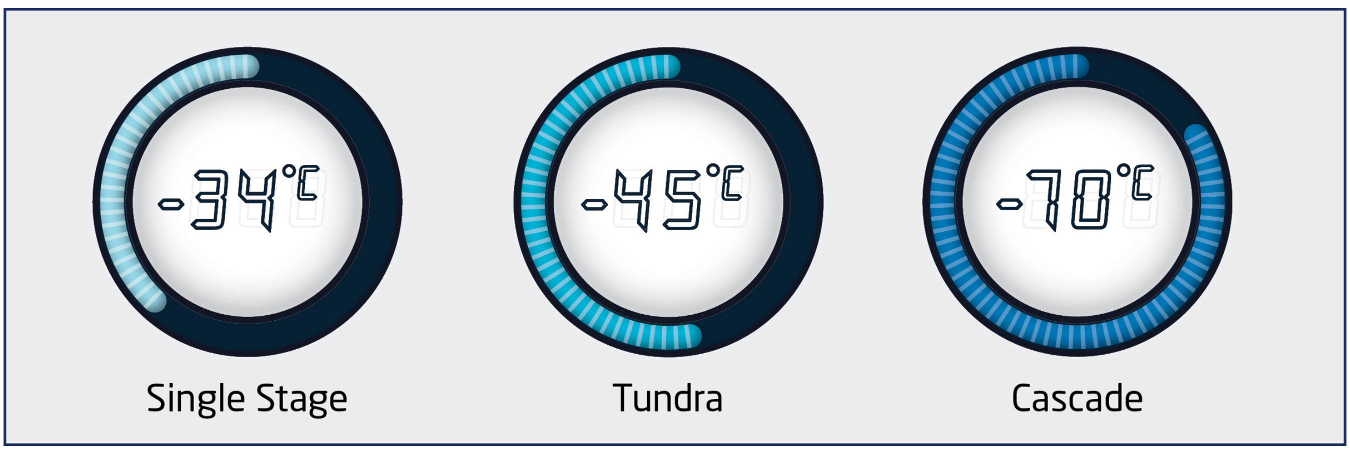
There are various types of humidity systems used on test chambers today such as a water bath, boiler/steam generator, and atomizing system with a combination of a steam generator and atomizing system that may be used in conjunction for very specific applications involving testing products that generate a lot of heat.

- **Water Pan:** Very stable, but slow response
- **Boiler:** This is standard on most CSZ chambers. This system provides the ability to attain 98% humidity and has a large capacity to work in all chamber sizes.
- **Atomizer:** This system sprays very fine drops of water into the air stream. The advantage of this system is that it provides good control with live loads. CSZ typically uses this type of humidity system on reach-in chambers for devices under test that generate over 2000 watts.

Refrigeration Options

One of the most critical components of an environmental chamber is the refrigeration system, which is responsible for cooling the chamber and maintaining the desired temperature. There are different types of refrigeration systems, depending on the temperature range and the ramp rate required for the test. Some of the common types are:

- **Single stage:** Single-stage refrigeration systems typically can pull the temperature in the chamber down to - 34˚C (-30˚F). Some manufacturers rate their single-stage systems down to -40˚C (-40˚F). However, due to the refrigerant used there is very little cooling capacity available at -40˚C and can be difficult to achieve. For continuous operation at -40˚C and below most manufacturers recommend a cascade refrigeration system.
- **Tundra®:** The Tundra refrigeration system is a patented, single-stage refrigeration system that can efficiently cool the chamber down to -45˚C (-50˚F). It utilizes a common refrigerant and can operate continuously at -40˚C. Since most low temperature environmental testing is done at -40˚C, it is a good alternative to buying a cascade system. It uses less energy (up to 40% less) and is less complex than a cascade system. There are also fewer parts compared to the cascade system which means lower maintenance & utility costs over time. At warmer temperatures, this system can also handle large live load conditions generated from testing electronics.
- **Cascade:** Cascade refrigeration systems have two separate refrigeration systems working to cool the chamber down to an ultimate low of -70˚C (-94˚F) and -84˚C (-120˚F) on industrial freezer models. The first stage refrigeration system cools and condenses the refrigerant in the second stage. The second stage refrigerant flows through an evaporator located in the chamber which cools the air. These systems can become very complex depending on your application.
- **Expendable refrigerants:** Expendable refrigerants are liquid/gases that can be injected directly into the space being cooled or into fin coil heat exchangers. As the liquid enters the chamber (directly or through a fin coil) it absorbs heat and flashes to a gas. The gas is then vented out of the chamber and should be ducted outdoors. The two most popular refrigerants are liquid nitrogen (LN2) and liquid carbon dioxide (CO2). Cryogenic temperatures down to - 184˚C (-300˚F) can be achieved with LN2. CO2 on the other hand can only achieve temperature down to -60˚C (-76˚F). Both gases are environmentally safe and can be vented to the atmosphere. Note: the gases must be vented outdoors. These gases displace oxygen and asphyxia can occur if the chamber is not properly vented.



Air-Cooled vs. Water-Cooled Chamber

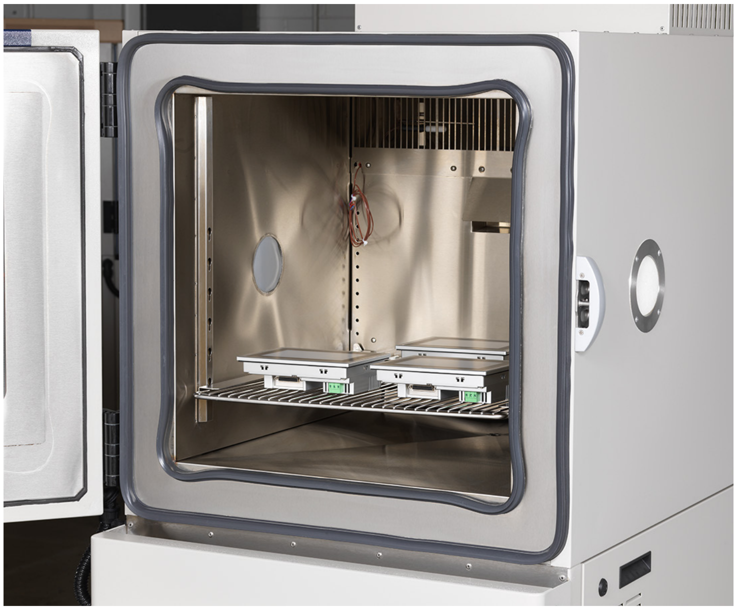
The refrigeration system removes heat from the product and the air which lowers the temperature in the chamber. The heat is moved through the refrigeration system and rejected at the condenser. There are two choices when it comes to condensers, air-cooled or water-cooled.

Most smaller size chambers include air-cooled condensers as standard. The only utility connection required is power (non-humidity units). This is very convenient for moving a chamber from one area to another. The larger the compressor on the chamber the more heat is rejected into the room so most chambers that are 6 horsepower or lower use air-cooled condensers. Chambers with refrigeration systems 6 horsepower or over are typically water-cooled chambers. If your facility has process water that is pumped throughout the building and is routed to a cooling tower / dry cooler, a water-cooled chamber may be installed.

Construction Differences

The construction quality of an environmental chamber affects its durability, reliability, and performance. Even though most chambers have painted exteriors and stainless-steel liners, there are differences in the details that can make a big difference in the long term. Some of the questions to ask the supplier are:

- **Are the seams welded, pop-riveted, or screwed together?** Welded seams are stronger, more durable, and more resistant to leaks than pop-riveted or screwed seams. Robotically welded seams provide even more quality and reliability.
- **How are ports installed?** Welded, silicone with multiple pieces or other. Welded and some epoxy/sealant methods are best.
- **What type of humidity sensing device is used?** The wet wick humidity method requires many more components and has cloth socks. These cloths can collect calcified water and dirt so they must be replaced often to maintain accuracy. Electronic sensors are very reliable and require little maintenance.
- **How are copper tubes passed through a stainless steel chamber?** The main cooling coil (evaporator) in the chamber has copper tubes connected to the refrigeration system. Those tubes must pass through the stainless-steel chamber wall. If the copper can contact a sharp edge of the stainless, a refrigerant leak could happen.



Safety Features

Some tests may involve hazardous, flammable materials or vapors that can pose a risk of fire or explosion in the chamber. Therefore, it is essential to understand the hazards of the test specimens and to establish them clearly to ensure that the chamber is equipped with appropriate safety features. Some of the safety features that may be required are:

- **Gas monitors:** These devices can detect the presence and concentration of flammable or toxic gases in the chamber, and trigger alarms, interlocks, or ventilation systems to prevent or mitigate the hazards.
- **Non-sparking fan blades:** These blades are made of materials that do not produce sparks when they contact other materials, such as aluminum or plastic, to reduce the risk of ignition in the chamber.
- **Temperature-limited heaters:** These heaters are equipped with temperature sensors attached to the heaters. The heater surface temperature is limited to prevent them from exceeding the auto-ignition temperature of the test specimens.
- **Ambient air blower:** This device can provide air exchanges in the chamber after the detection of gases or the deployment of fire suppression systems, to dilute or remove the hazardous substances.
- **Per the National Electric Code (NFPA 70) there are two classes of explosion-proof test chambers:** Division 1 and Division 2. The difference between the two is that in Division 1, combustion is possible at any stage in the test, while in Division 2, combustion is only a possibility when a failure occurs.

Preventive Maintenance

To keep an environmental chamber running reliably for years, it is important to perform regular preventive maintenance, such as checking, cleaning, replacing, or adjusting the various components of the chamber. The chamber's data tag provides the model number, serial number, refrigerant type, refrigerant charge, and other information used for troubleshooting and service.

Some of the components that need to be maintained include:

- **Refrigerant charge:** This is the amount of refrigerant in the system, which affects the cooling capacity and efficiency of the chamber. The refrigerant charge can be checked by observing the static pressure and/or the liquid sight glass.
- **Evaporator and heater:** These are the devices that cool and heat the chamber, respectively. They need to be checked for cleanliness, damage, corrosion, or leaks and cleaned or replaced as needed.
- **Humidifier:** This is the device that adds moisture to the chamber to control the humidity level. It needs to be checked for scale, corrosion, or leaks and cleaned or replaced as needed. The water supply for the humidifier should be deionized or reverse osmosis water, with a resistivity between 0.05 and 2 MΩ, to prevent mineral deposits and contamination.
- **Dehumidify coil:** This is the device that removes moisture from the chamber to control the humidity level. It needs to be checked for cleanliness, damage, or leaks, and cleaned or replaced as needed.
- **Chamber drain:** This is the outlet that drains the condensate from the chamber. It needs to be checked for clogs, leaks, or corrosion, and cleaned or replaced as needed.
- **Demineralizer Humidity Filter:** Check and replace the filter when the color changes to a brown or rust color.
- **Air-Cooled Condenser:** Chambers that utilize an air-cooled condenser should be cleaned to remove dirt and ensure proper reliability.

It is recommended to be consistent with the periodic checks, have baseline information for the chamber, such as pull-down times and humidity data, and keep good records of the preventive maintenance and repairs.

A reliable and experienced service provider can ensure that the chamber is installed, maintained, and repaired properly and promptly.

Summary

An environmental chamber is a valuable tool for testing the performance and reliability of products, materials, and components under various environmental conditions. Choosing the right environmental chamber for your testing needs and keeping it running reliably requires careful consideration of several factors. These factors include the type of chamber, the test application, the performance criteria, the construction quality, the safety features, and the preventive maintenance. For more information, please contact sales@cszproducts.com or visit www.cszproducts.com.