FlexStar Environmental Chamber Testing Active Loads at Low Temperatures

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FlexStar environmental chambers are designed to test disc drives to simulate a wide range of environmental conditions. They can range from temperature and humidity in tropical areas, to the high heat in the deserts of Africa, and to freezing cold the at South Pole. These conditions are not easily reproduced in the local environment without an environmental chamber.

Utilization

FlexStar Chambers can test various types of media devices such as standard 3.5” disc drives, CD and DVD devices, 2.5” disc drive, Flash Drives and some of the latest 1" and 1.8” disc drives. We often refer to these various devices as Device Under Test or DUT.

General Construction

The unit has an environmental test section surrounded by refrigeration components, humidity control components, and test electronics. The Chamber’s environmental test section is a highly insulated box with a large insulated door, to allow easy access to the DUTs, and especially built nosepieces to allow a large number of cables to be fed into the environment to enable active tests to be performed on the DUT. There is a single board computer behind every port. The refrigeration components are mainly to the rear or side of the Chambers environmental section. The humidity control components are within the refrigeration area or adjacent to it. Since the unit is designed to drive the temperature to normal extremes, it is designed to collect and drain water that condenses in the system. See the FlexStar Website for a complete list of features, and specifications http://www.flexstar.com/products/envir_chmbr.htm

Basic Operation

To raise the temperature of a DUT, all chambers utilize electrical heaters to generate heat. To cool the DUT, some chambers use a single stage refrigeration system, some use a dual stage or cascade stage refrigeration system. A blower motor and blower wheel are used to move and recirculate the air in the environmental section. To raise the humidity most systems use an atomizer system to blow very fine water particles into the air stream where it quickly turns to water vapor. Other systems use a boiler to generate steam to introduce water vapor into the air stream. To lower the humidity, the chambers employ both refrigeration and dry air purge to remove moisture from the air.

Basic Physics

To heat or cool a load, the system exchanges energy with the surrounding environment by heat flow through a medium. In a FlexStar chamber, the medium is air which contains a mixture of gases, mainly nitrogen, oxygen, water vapor and, various other gases and particles. The rate of heat exchange is determined by the delta in air temperature and the temperature of the DUT, the linear feet per minute of air flow across the surface of the DUT and density of the air.

A phenomenon known as sublimation occurs at freezing temperatures, ice crystals go directly from ice to water vapor without going through the liquid stage, which causes a measurable amount of humidity at freezing. As sublimation occurs, water vapor continues to condense. At some point, the two processes equalize and a constant relative humidity occurs.

The detailed dynamics of heat exchange and water content in the air are complex studies unto themselves. Following, are some topics that can be studied further to get a better understanding of the problem;

For details of the mathematics involved in the thermodynamics,
http://scienceworld.wolfram.com/physics/topics/Thermodynamics.html
http://scienceworld.wolfram.com/physics/HeatConductionEquation.html
http://scienceworld.wolfram.com/physics/NewtonsLawofCooling.html

Water vapor in the air causes condensate at the dew point.
http://ww2010.atmos.uiuc.edu/(Gh)/guides/maps/sfcobs/dwp.rxml/
http://www.faqs.org/faqs/meteorology/temp-dewpoint/

Psychrometric charts are used to calculate the amount of water vapor in the air.
http://www.linric.com/psycpro.htm
http://www.taftan.com/thermodynamics/PSYCHART.HTM

More on sublimation.
http://en.wikipedia.org/wiki/Sublimation_%28physics%29

Refrigeration Operation

To cool a system, heat must be removed. In a FlexStar chamber, heat is removed using refrigerant R-404A, which is a gas under room temperature and normal atmospheric pressure. Cooling is accomplished by moving heat via the refrigerant from a low pressure container known as the evaporator coil to high pressure container known as the condenser coil. A refrigerant compressor is used to suck the gas from the low pressure evaporator coil and compress it into a high pressure hot gas, which then moves into the condenser coil. At the condenser coil, the high pressure gas moves through the coil, cool air is drawn over the condenser coil which removes heat from the gas. As the gas cools, it condenses into a liquid. The condensed refrigerant leaves the condenser coil, and the liquid then flows through distribution tubes to various solenoids and expansion valves. The expansion valves at the evaporator coil allow the liquid refrigerant to expand rapidly or evaporate. As the R404A refrigerant evaporates into a gas, it removes heat form the surrounding area. The expansion valves used in these systems are Thermal Expansion Valves (TEV). These valves use a capillary tube to sense the amount of heat the refrigerant has picked up through the evaporator coil to regulate the flow of the gas.

To control condensation, the unit has a wet/frozen coil. In the humidity mode, this device normally operates colder than the evaporator coil, and otherwise known as the main cooling coil. Much of the water will condense on this wet coil and drain out the bottom of the system through the drain pipe.

Specific Operations

The entire system is controlled from a desktop computer system via an easy to use graphical user interface. In FlexStar chambers, a dual channel temperature/humidity controller is used to maintain precise temperature and humidity levels. The controller events are used to turn five different functions ON or OFF. They are EVENTS 1-5, which are Conditioning System, Humidity, Auxiliary Cooling, Purge, and Power Supplies (i.e. the FlexStar Electronics). The FlexStar Host software tells the controller which events to turn ON or OFF. The Host software controls the EVENTS to provide optimum performance of the chamber. It does this by turning events ON and OFF, based on the actual temperature of the oven and if the humidity is above or below the set point. There are limitations, which are discussed later.

NOTE: Component numbers vary somewhat between different machine levels and types.

Heating and full range cooling to -34C on the 30/60E, -40C on the 30C, is enabled when EVENT1, the conditioning system is turned ON. The controller will heat the chamber when it turns ON the heat output and turn on the air heater via 1SSR. The controller will cool the chamber by turning ON the cool output by de-energizing the bypass solenoid 9SOL via CR2, and opening the cooling solenoid 1SOL providing refrigeration to TEV-50.

The full range cooling is limited when EVENT2 the humidity mode is turned ON. EVENT2 energizes CR5 which switches TEV-50 via 1SOL to TEV-H50 via H1-SOL.

Humidify Mode is enabled when EVENT2 is ON and the controller turns ON the humidify output which turn on the water control solenoid W3-SOL via CR3.

Normal dehumidify mode is enabled when EVENT2 is ON and the controller turns ON the dehumidify output, which activates the wet coil via solenoid H11-SOL and CR4 being turned ON. The wet coil operates at 5C.

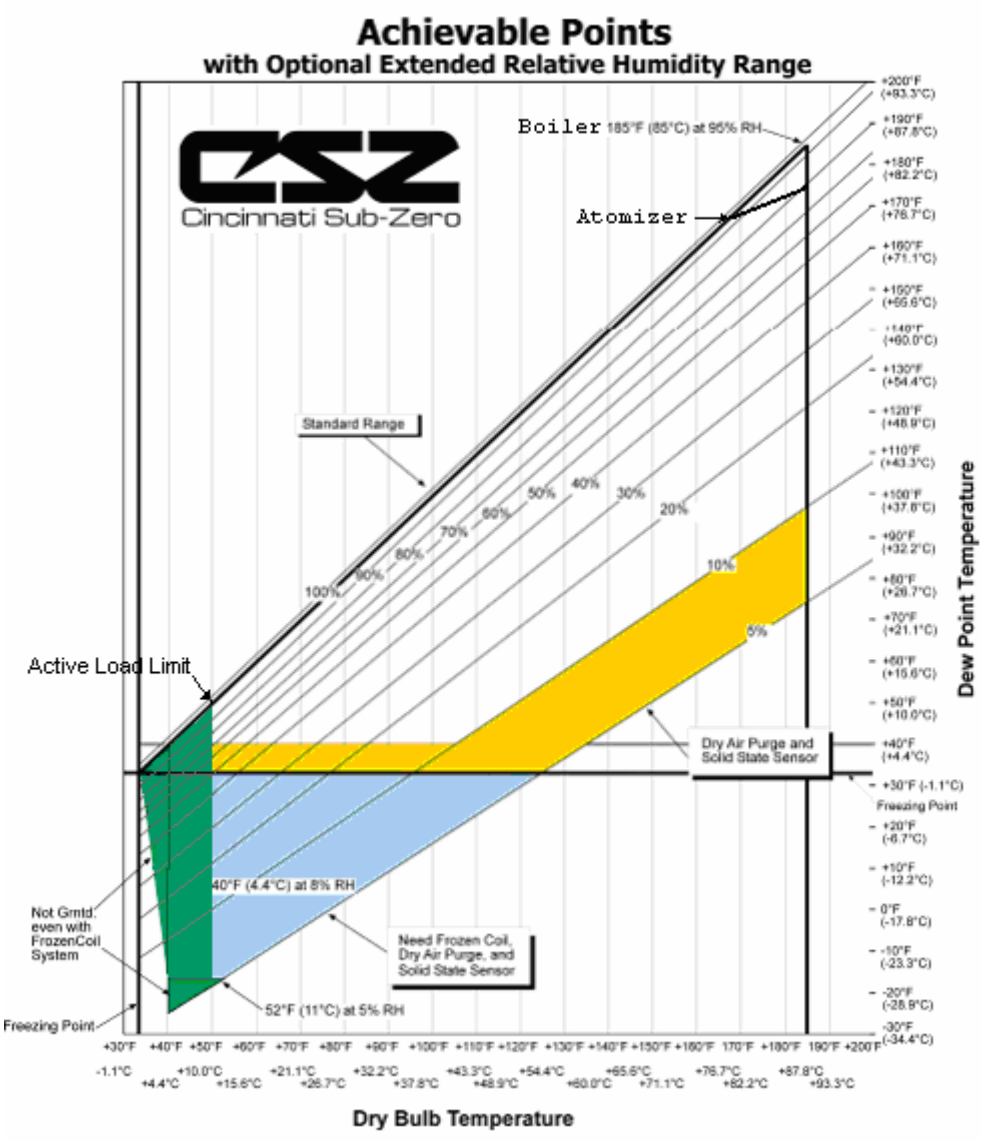
The unit will be in Low RH mode when EVENT4 is ON and the controller turns ON the dehumidify output. EVENT4 energizes 4CREA, which turns on the regenerative air dryer 1AD, A1-SOL, H12-SOL, and 4CRE. A1-SOL enables dry air to flow through the low flow meter of 25cc/minute. 4CRE switches the wet coil to frozen mode via switching TEV-H23 via H11-SOL to TEV-H31 via H13-SOL. In low RH mode the Frozen Coil will operate at -29C.

Limitations

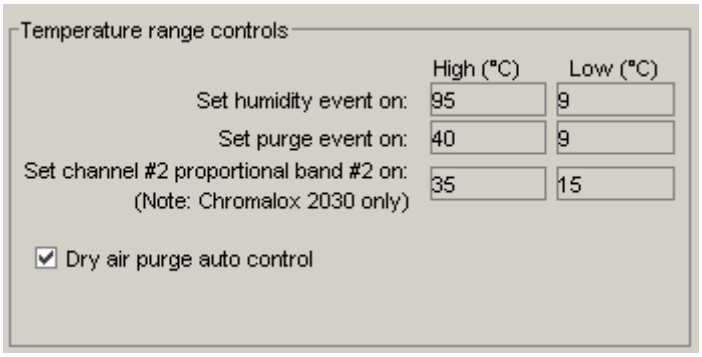
Water freezes at 0C/32F, when the water vapor condenses out of the air it freezes to the surface it contacts. Ice forms by reducing the relative humidity too quickly or maintaining a high humidity level at low temperature where the temperature of the refrigeration components operate below freezing.

The wet/Frozen coil is designed to remove water vapor from the air at very low temperatures. As the coil becomes covered with ice, it loses its ability to remove water vapor at very cold temperatures. When it is completely covered with ice, there is no passage for air between the fins or coils. When this happens, it has lost nearly all its ability to remove water vapor. Therefore, this chamber feature is effective for a limited time period which depends on the set-point temperature, relative humidity level being maintained and the quality of the regenerative air dryer.

The average disc drive consumes about 15 watts during operation, so a 30E chamber that presents a 450 watt active load on the refrigeration system, and a 60E is about 900 watt. The FlexStar chambers, based on the fixed air flow in the system; when operating at low temperatures below 10C/50F require the air medium to be about 8-9 degrees C colder than the DUT to maintain a set temperature. The evaporator coil will be very near freezing, about 1C/34F. If the system tries to maintain an Active Load at a temperature lower than 10C and at a higher humidity level than naturally occurs at these temperatures, the evaporator coil will become covered with ice. When the evaporator coil becomes completely covered with ice, the surface area to cool the air is greatly reduced. The reduced surface area limits the ability to cool the Active Load, thus the air temperature in the chamber rises above the set-point, and the unit will not maintain temperature.



The Temperature Range Control in the Perseus software was recently changed to prevent the Evaporator coil or main cooling coil from becoming iced over. This will ensure the unit will maintain the set point temperature. Unfortunately this change requires the humidity mode to be turned off when the temperature goes below 9C.



The refrigeration systems are capable of cooling an active loaded environment to -26C non-cascade or -32C cascade, provided the humidity EVENT2 is OFF.

Often forgotten Maintenance

The Dry air purge unit contains a Regenerative air dryer. This device uses desiccant beads to remove water vapor from the air. The beads have a limited life, which is dependent on usage and the water vapor content that is being removed. In a properly maintained facility the average chamber can expect the desiccant to last 2-3 year. There is a clear Moisture Indicator between the two Desiccant Towers. On a new unit the color is dark blue. As the quality of the desiccant degrades the color gets lighter and lighter until it turns to white. The Desiccant Towers and Moisture Indicator should be replaced when the color turns to **light blue**, or the entire regenerative air dryer should be replaced.