

EXPERIMENTAL AND COMPUTATIONAL INVESTIGATION OF THE NEED FOR
AN ACCLIMATION FOR OPERATING IT EQUIPMENT

By

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ABSTRACT

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Acclimation of IT equipment is not only for newly commissioned equipment but are also for the equipment that is already in use. In conventional Data Center, IT Equipment are cooled by traditional cooling methods, but due to increasing serious energy crisis, Data Centers are Free cooled because of the reduced power consumption. Free Cooling a Data Center is, when the outside air conditions are appropriate, they are drawn into the Data Center to cool the Operating IT Equipment. Data Centers uses dampers to control the type of cooling to be used. Due to a rapid change in the temperature and humidity of the outside air at various parts of a day has presented challenges to control the air handler line-ups in a way where they conflict with each other. Which creates a change in condition, where an unnecessary condensation occurs, which results in failure of the equipment. As failures in existing equipment make a huge loss both in company money and time. This study tries to address the issue by studying the several factors that affect acclimation and prioritizing them. The overall goal of this project is to understand the factors that influence the acclimation time and develop a method to find how can one control the air handlers by improving the safeguards and prevent the condensation from occurring inside the data center.

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NOMENCLATURE

v	Velocity (m/s)
m	Mass flow rate (kg/s)
q	Heat load (W)
P	Power (W)
v	Volumetric Flow Rate (cfm)
f	Humidity
T	Temperature of the Room
T_D	Dew Point Temperature
IT	Information Technology
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
DEC	Direct Evaporative Cooling Unit
IEC	Indirect Evaporative Cooling Unit
PUE	Power Utilization Efficiency
DP	Dew Point
DB	Dry Bulb
WB	Wet Bulb
RA	Return air damper

Chapter 1

Introduction

1.1 Data center:

Data center acts as a house to computer systems, telecommunications systems and storage systems. The IT equipment inside a data center is connected to a power supply using cables and wires. The IT equipment is generally arranged on a rack and the racks are placed inside the data center and are connected to the power source. Several IT Equipment are inside a rack and number of racks depend on the size of the data center. Due to the operation of the IT equipment large amount of heat is generated from it, and this heat generated might increase the temperature of a Data Center. Data Centers cannot operate at high temperatures; this might cause of failure of IT equipment due to overheating. To cool the Data center and to remove the hot air, a cooling method is chosen. Various types of cooling are discussed in Chapter 2. Cooling the data center not only removes the heat but also improves the effectiveness of the data center. Before Building a Data Center following design considerations are made.

- Design Programming – Space Planning, Type of cooling and power source is chosen, Technology infrastructure design.
- Modeling Criteria – To find various parameters such as, number of Equipment, size, location, topology, IT floor layouts, power and cooling technology.
- Design Recommendations – PUE (power utilization efficiency), cooling capacities and power required and mechanical and electrical facilities.
- Site Selection
- Environmental control – Air conditioning used to control the temperature and humidity of the room.

Even though there are many factors to be considered while designing a data center, these are the most important factors one must consider before designing a data center.



Fig 1: USC Data Center

1.2 Need for an Acclimation in an operating Data Center:

Since the day data center concept was started there have been huge demand for power supply. The increasing need of power lead to a high PUE (Power Utilization efficiency)

The PUE is defined as the ratio of total energy consumption of the data center to total energy consumed by IT equipment.

$$PUE = \frac{\text{Total Facility Power}}{\text{IT Equipment Power}}$$

To reduce the amount of money spent on the power, some companies started using free cooling. Free cooling is method of cooling the data center or room by blowing the air from the outside. The outside environmental air is passed through a serious of filters and then enters in to the data center, but it can be used only if the temperature and humidity of the outside air is within the operational range of the data center. When this outside is air outside the operational range, there comes the alternative cooling methods. Parasol combines free cooling with a direct-expansion (DX) AC, and embodies a commercial feedback-driven cooling controller that periodically selects the cooling regime. When we switch from one cooling method to other, there might be a need for acclimation. The operational range for a data center specified by ASHRAE is given below.

2008 Classes	2011 Classes	Applications	Information Technology Equipment	Environmental Control
1	A1	Data Center	Enterprise Servers, Storage Products	Tightly Controlled
2	A2		Volume Servers, Storage Products, Personal Computers, Workstations	Some Control
	A3			Some Control, Use of Free Cooling Techniques When Allowable
	A4			Some Control, Near Full-Time Usage Of Free-Cooling Techniques
3	B	Office, Home, Transportable Environment, etc.	Personal Computers, Workstations, Laptops, and Printers	Minimal Control
4	C	Point-of-Sale, Industrial, Factory, etc.	Point-of-Sale Equipment, Ruggedized Controllers, or Computers and PDAs	No Control

Table 1: Data Centers are classification by class

Range	Class	Dry-Bulb Temperature	Humidity Range, Non-Condensing	Maximum Dew Point
Recommended	All A	64.4°F to 80.6°F	41.9°F DP to 60% RH and 59°F DP	59°F
Allowable	A1	59°F to 89.6°F	20% to 80% RH	62.6°F
	A2	50°F to 95°F	20% to 80% RH	69.8°F
	A3	41°F to 104°F	10.4°F DP and 8% RH to 85% RH	75.2°F
	A4	41°F to 113°F	10.4°F DP & 8% RH to 90% RH	75.2°F
	B	41°F to 95°F	8% RH to 80% RH	82.4°F
	C	41°F to 104°F	8% RH to 80% RH	82.4°F

Table 2: Operational range of various classes of Data Center

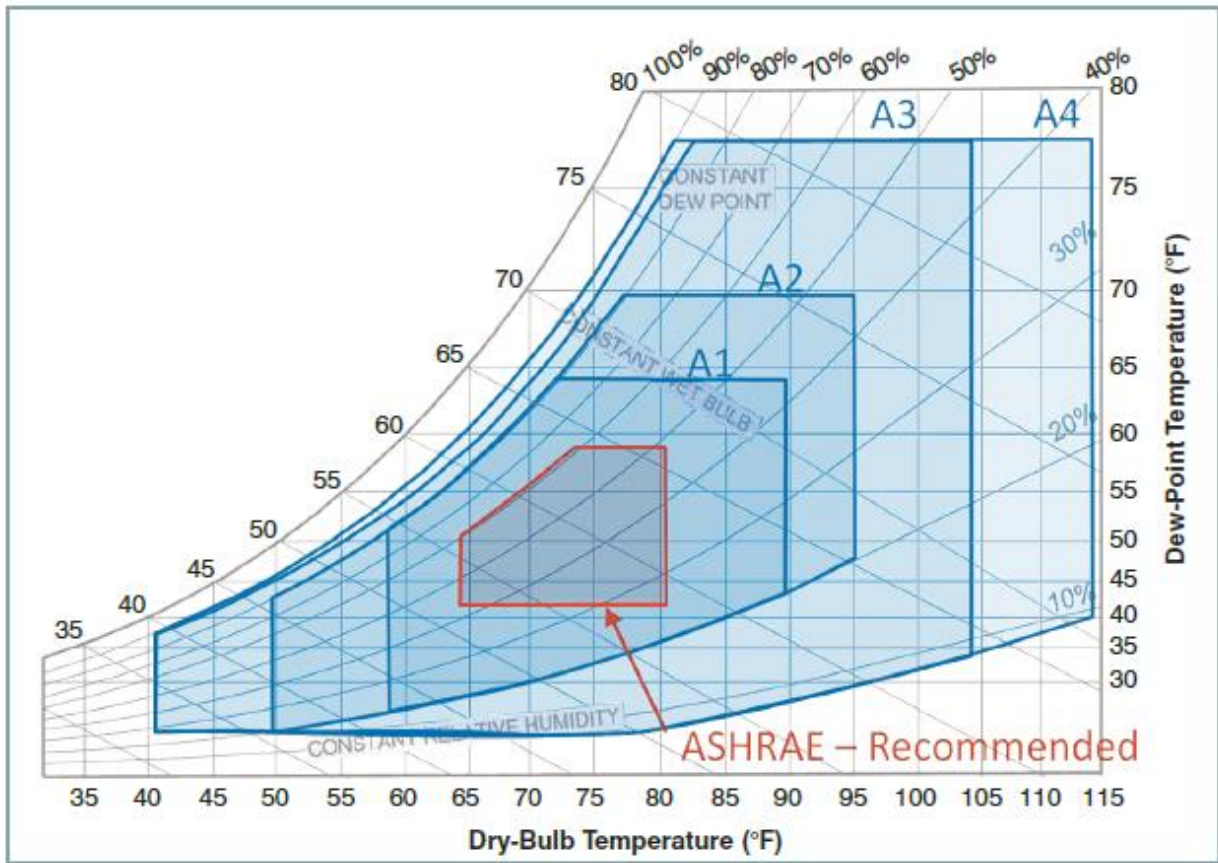


Figure 2: Operating regions shown in ASHRAE's Psychrometric Chart

1.3 Experimental Setup:

The following experiments are conducted in a Thermotron environmental chamber 600 SE 10-10, using DHT22 sensors and Type-T Thermocouple to measure the Humidity and the Temperature inside the chamber, respectively. For the following experiments, HP and Facebook servers were used.

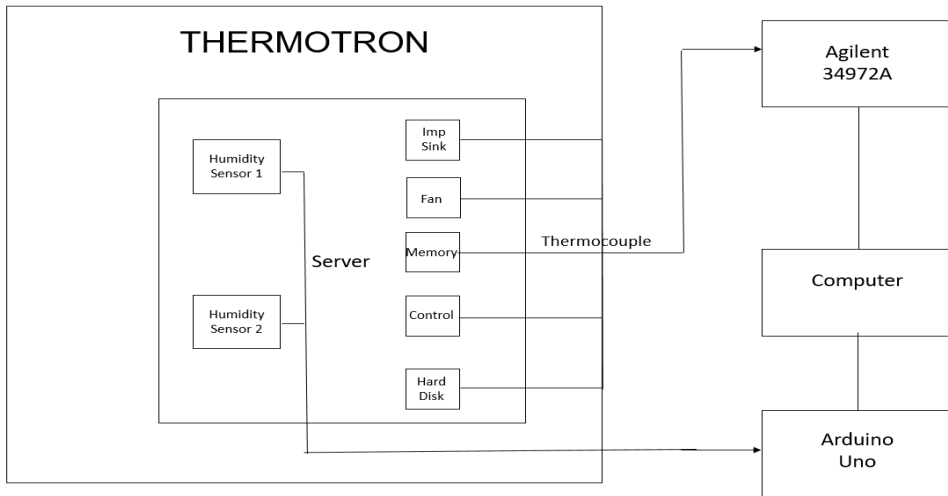


Fig 3: Schematic Diagram of the Experimental Setup

Thermotron 600 SE 10-10:

Thermotron's SE-600 environmental chambers provide the versatility required for today's testing needs. In other words, Thermotron Environmental chamber provides us a chance to change its environment to the user fed values, i.e. user can control the humidity and temperature to values that are needed. In our experiments the servers are kept inside a Thermotron SE 600 Environmental chamber, and the thermocouple and humidity sensors are kept at various locations inside the chamber based the experiment conducted. The table below shows the properties and specifications of a Thermotron Environmental chamber.

Workspace Dimensions—WxDxH:	40 x 26.25 x 34 inches
	102 x 67 x 86 centimeters
Workspace Volume:	20.7 ft ³
	586 L
Temperature Uniformity:	±0.5°C (±0.9°F)
Temperature Range:	-70°C to 180°C
	(-94°F to 356°F)
Temperature Control Tolerance:	0.3°C (0.5°F)

Approx. Shipping Weight:	2,040 lbs.
	925 kg
Move-In Dimensions—WxDxH:	49 x 70 x 83 inches
	124 x 178 x 211 centimeters
Inlet Water Gal / Liters per Minute 24°C / 75°F:	9 / 34
Inlet Water Gal / Liters per Minute 18°C / 65°F:	7.5 / 28
Inlet Water Gal / Liters per Minute 13°C / 55°F:	6 / 23
Inlet Water Gal / Liters per Minute 29°C / 85°F:	16 / 60
Humidity Range:	10 to 98% RH
Humidity Control:	+/- 2.5% RH
Heating Performance in Minutes -65° to 71°C:	9
Heating Performance in Minutes -65° to 180°C:	19
Heating Performance in Minutes -40° to 85°C:	8
Heating Performance in °C/Minute -65° to 71°C:	15.1°C
Heating Performance in °C/Minute -65° to 180°C:	12.8°C
Heating Performance in °C/Minute-40° to 85°C:	15.6°C
Electrical Requirements in Full Load Amps 460 / 3 / 60:	41
Electrical Requirements in Full Load Amps 400 / 3 / 50:	42
Electrical Requirements in Full Load Amps 230 / 3 / 60:	81
Electrical Requirements in Full Load Amps 208 / 3 / 60:	89
Cooling Performance in Minutes 85° to -40°C:	11
Cooling Performance in Minutes 71° to -65°C:	17
Cooling Performance in Minutes 180° to -65°C:	28
Cooling Performance in °C/Minute 85° to -40°C:	11.3°C

Cooling Performance in °C/Minute 71° to -65°C: 8°C

Cooling Performance in °C/Minute 180° to -65°C: 8.7°C

Airflow: 1,000 CFM



Fig 4: Thermotron Environmental Chamber SE600 10-10

Thermocouple

Thermocouple Type	Useful/General Application Range
E*	200-1650°F (95-900°C)
J	200-1400°F (95-760°C)
K*	200-2300°F (95-1260°C)
N	200-2300°F (95-1260°C)
R	1600-2640°F (870-1450°C)
S	1800-2640°F (980-1450°C)
T*	32-660°F (0-350°C)

*Also suitable for cryogenic applications from -328 to 32°F (-200 to 0°C)

Table 3: Types of Thermocouple

A thermocouple is an electrical device consisting of two dissimilar conductors forming electrical junctions at differing temperatures. A thermocouple produces a temperature-dependent voltage as a result of the thermoelectric effect, and this voltage can be interpreted to measure temperature. Thermocouples are a widely-used type of temperature sensor. The Thermocouple is connected to a

computer using Agilent DAQ, to monitor the temperature. The table below shows several types of Thermocouple, based on their temperature range. In our case, Type-T Thermocouple is closer to the range of temperature that we are going to run inside the Thermotron Environmental Chamber.

DHT22 Sensor:

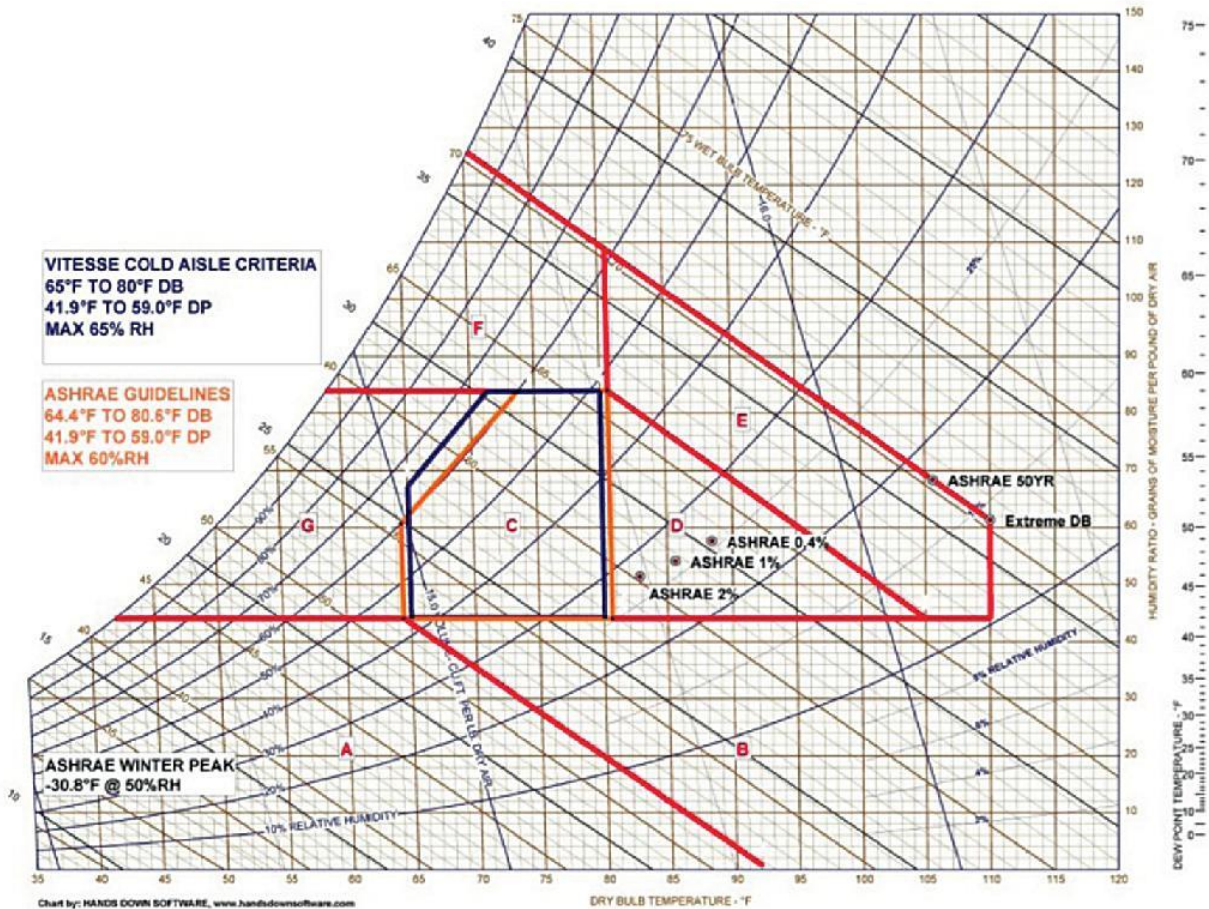


Fig 5: DHT 22 Sensor

The DHT22 is a basic, low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (no analog input pins needed). It is simple to use, but requires careful timing to grab data. The only real downside of this sensor is you can only get new data from it once every 2 seconds, so when using our library, sensor readings can be up to 2 seconds old. DHT 22 sensors along with Arduino Uno Board are used to measure the Humidity.

1.4 Facebook Server:

Facebook server is used in our experiments to check if an acclimation is needed when the cooling is switched from one type cooling to another one. Before starting to conduct experiments on the Facebook Server, the operational ranges of the Facebook server were found out. The ranges of the Facebook server are discussed below.



OUTSIDE AIR OPERATING CONDITIONS

Fig 6: Open Compute Operating Zones shown in the ASHRAE's Psychrometric chart

1. Region A (< 11.1°C DB and < 5.5°C DP): When outside air conditions lie within this region, the target supply air dry bulb temperature is 18.3°C. The outside and return air dampers modulate to mix both airstreams. If required, the EC/H system stages on to provide the necessary humidification for maintaining Dry bulb temperature of the supply air at 12.2°C and the dew point temperature at 5.5°C.
2. Region B (>11.1°C DB and < 5.5°C DP): This region calls for 100% outside air. The return air dampers are completely closed and the outside air dampers are fully open. EC/H stages on to provide the required humidification or cooling. The supply air dry bulb temperature is maintained between 18.3°C and 26.6°C while the dew point temperature is maintained at 5.5°C.

3. Region C ($> 18.3^{\circ}\text{C}$ DB and $> 5.5^{\circ}\text{C}$ DP and $< 26.6^{\circ}\text{C}$ DB and $< 15.0^{\circ}\text{C}$ DP and $< 65\%$ RH): In this region, too, the return air dampers are completely closed and the outside air dampers are fully open. 100% outside air is admitted. The EC/H system remains off, since no evaporative cooling or humidification is required. The outside air is delivered into the data hall “as is” (after filtration).
4. Region D ($> 26.6^{\circ}\text{C}$ DB and $> 5.5^{\circ}\text{C}$ DP and $< 18.9^{\circ}\text{C}$ WB): The economizer is at 100% in this region as well, meaning that outside air is not mixed with return air. EC/H stages on to provide required humidification or cooling. The supply air dry bulb temperature is maintained at 26.6°C while dew point temperature is maintained between 5.5°C and 15°C .
5. Region E ($> 26.6^{\circ}\text{C}$ DB and $> 5.5^{\circ}\text{C}$ DP and $> 18.8^{\circ}\text{C}$ WB): Once more, the dampers modulate to bring in 100% outside air. EC/H stages on to provide the required humidification or cooling. The supply air dry bulb temperature is maintained at 26.6°C while dew point temperature is kept above 15°C .
6. Region F ($< 26.6^{\circ}\text{C}$ DB and $> 15.0^{\circ}\text{C}$ DP and $< 21.2^{\circ}\text{C}$ WB): In this region, the dampers modulate to mix outside air with return air to increase cold aisle temperature as necessary for reducing cold aisle relative humidity to a 65% maximum. The supply air temperature is maintained between 18.3°C and 26.6°C . The dew point temperature is kept above 15°C . The direct evaporation system is bypassed, since no evaporative cooling or humidification is required.
7. Region G ($\{> 18.3^{\circ}\text{C}$ DB and $< 15.0^{\circ}\text{C}$ DP and $> 65\%$ RH} or $\{< 18.3^{\circ}\text{C}$ DB and $> 5.5^{\circ}\text{C}$ DP and $> 65\%$ RH and $< 15.0^{\circ}\text{C}$ DP}): Again, the dampers modulate to mix outside air with return air to increase cold aisle temperature as necessary for reducing cold aisle relative humidity to a 65% maximum. The supply air temperature is maintained above 18.3°C and the dew point temperature is kept below 15°C . The direct evaporation system is bypassed, since no evaporative cooling or humidification is required.
8. Region H (Unacceptable OA conditions): When outside air is inadmissible to the datacenter (such as excessive smoke or dust particulates in the air), the external dampers are shut.

Chapter 2
Types of Cooling

2.1.1 Free Cooling

Free cooling is an economical method of using low external air temperatures to assist in chilling water, which can then be used for industrial processes, or air conditioning systems.

2.1.2 Indirect Evaporative Cooling

With indirect evaporative cooling, a secondary (scavenger) air stream is cooled by water. The cooled secondary air stream goes through a heat exchanger, where it cools the primary air stream. The cooled primary air stream is circulated by a blower.

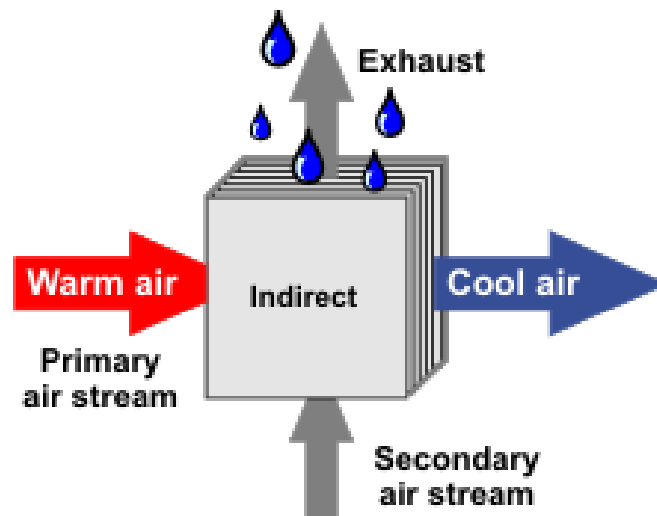


Fig 7: Indirect Evaporative cooling

2.1.3 Indirect Evaporative Cooling/DX Cooling

With indirect evaporative cooling with DX back-up, the primary air stream is cooled first with indirect evaporative cooling. Most of the time, this cools the primary air stream to the desired temperature. When more cooling is required, the supplemental DX module cools the air further to reach the desired temperature.

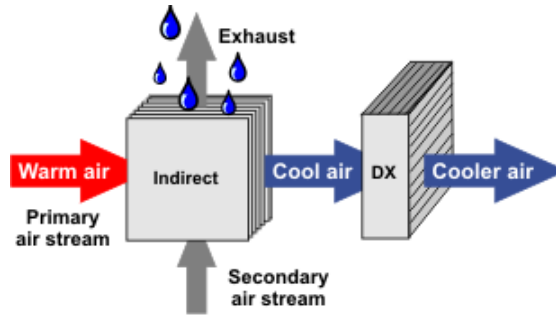


Fig 8: Indirect Evaporative cooling/DX cooling

2.2 Humidity Events

To begin this project, *“Learning Lessons at the Prineville Data Center”-Open Compute Project* by *Veerendra Mulay* 2011 was used as the source of my project.

The list of conditions mentioned above (Region A-H) were used as the operating regions of the Facebook data center. Even though the operating region and condition was well set, they learnt a lot of faced lot of issues and consequences on their way, Due to sudden changes in temperature and humidity of the outside air between day and night have presented them challenges to control the air-handler line-ups. Due to these extreme cases and conditions modulation or fighting occurred which lead to stratification of air streams. Another issue, they faced was an error in the sequence of operation controls that led to complete closure of the outside air dampers, which makes the one-pass airflow system to which made them to recirculate the air over and over. During late June 2011, due to sudden change in the outside air, the demand signal of the economizer started to respond to the changes occurred in the outside air, this made the control sequence demand signal to 0, which completely closed the outside air dampers. As a result, the data center began to recirculate the hot

exhaust air at high temperature and low humidity. The evaporative cooling system reacted to this high temperature and low humidity, it resulted in 100% spraying to maintain the maximum allowed supply temperature and dew point temperature. This made the cold aisle supply temperature to exceed 28C and relative humidity over 95%. The open compute servers that were operating inside the data center started to respond to these extreme changes. Many servers began to reboot and some even automatically shut down due to the power supply unit failure. This High temperature and high humidity supply air caused condensation on the concrete slab flow. Based on further investigation it was found out that the failure in the power supply units was related to the condensation that occurred. On further investigating the failed server by subjecting the server to rapidly changing temperature and humidity conditions in a confined test chamber. The relative humidity was increased to 97% and the temperature was switched from 15C to 30C with a ramp time of 10 minutes. At the end of this experiment, condensation was observed on the non-heated components, but no condensation was formed on the motherboard as it always ran above the dew point temperature. Condensation was also evident on the surfaced of power supply components such as capacitors and inductors.

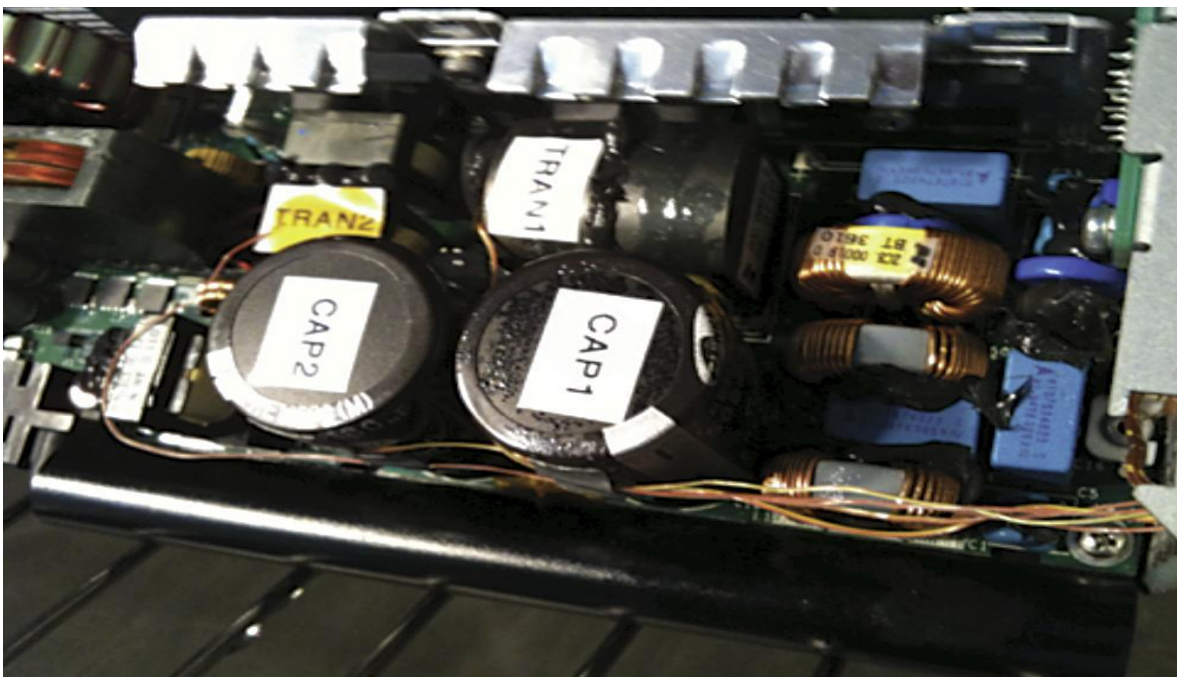


Fig 9: Water Droplets formed on top of the CAP 1



Fig 10: Water Droplets formed on the Chassis

However, on the surface of the capacitor 1, we can see the water droplets formed on the surfaces of these non-heated components. The graph below shows the targeted and actual values of the ambient as well as dew point temperature, the surface of capacitor 1 is also plotted. During the entire test interval, the PCB in the power supply always ran above the dew point temperature and showed no signs of condensation. This was the main motivation for the project.

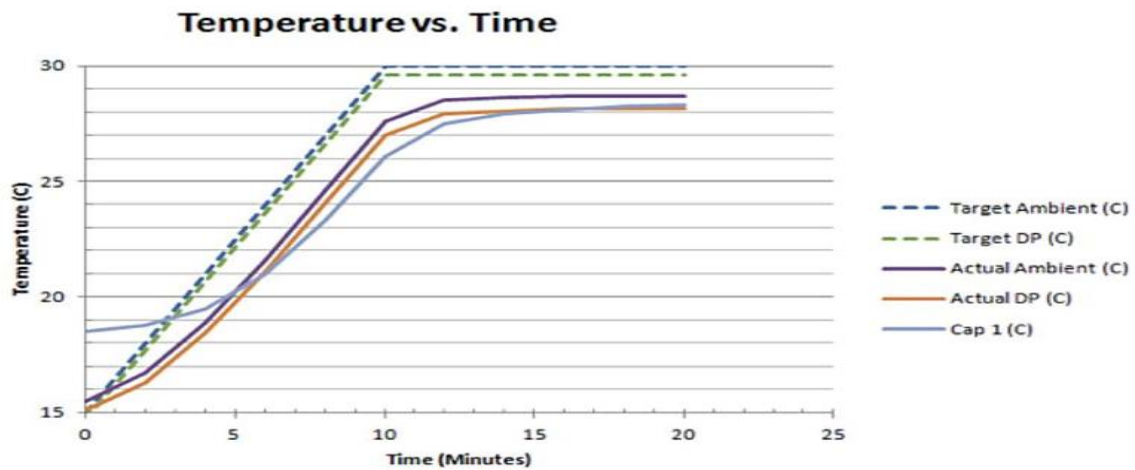


Fig 11: Plot shows the Temperature and Dew Point plotted against the time

Chapter 3

Experimental Work

3.1 Spatial Variation of Humidity

As discussed in the Introduction, a Thermotron Environmental chamber is used. Here the server is kept inside the Thermotron SE 600 10-10. To measure the temperature and Humidity inside the environmental chamber, a DHT 22 sensor is used. Before we can start proceeding with the experiments, we need to know how accurate these DHT 22 Sensors are and how to they vary spatially. Initially, 5 DHT 22 sensors were used, each sensor was placed at random locations as shown in the image below. Here the Thermotron is set to the following values, at a constant temperature, humidity was varied constantly over time. Initially the chamber was set to 30% RH for an hour and then ramped up to 40% RH with 10 minutes as the ramp time and kept in this condition for an hour and later with 10 minutes as the ramp time, it is now switched to 50%RH and maintained for an hour.

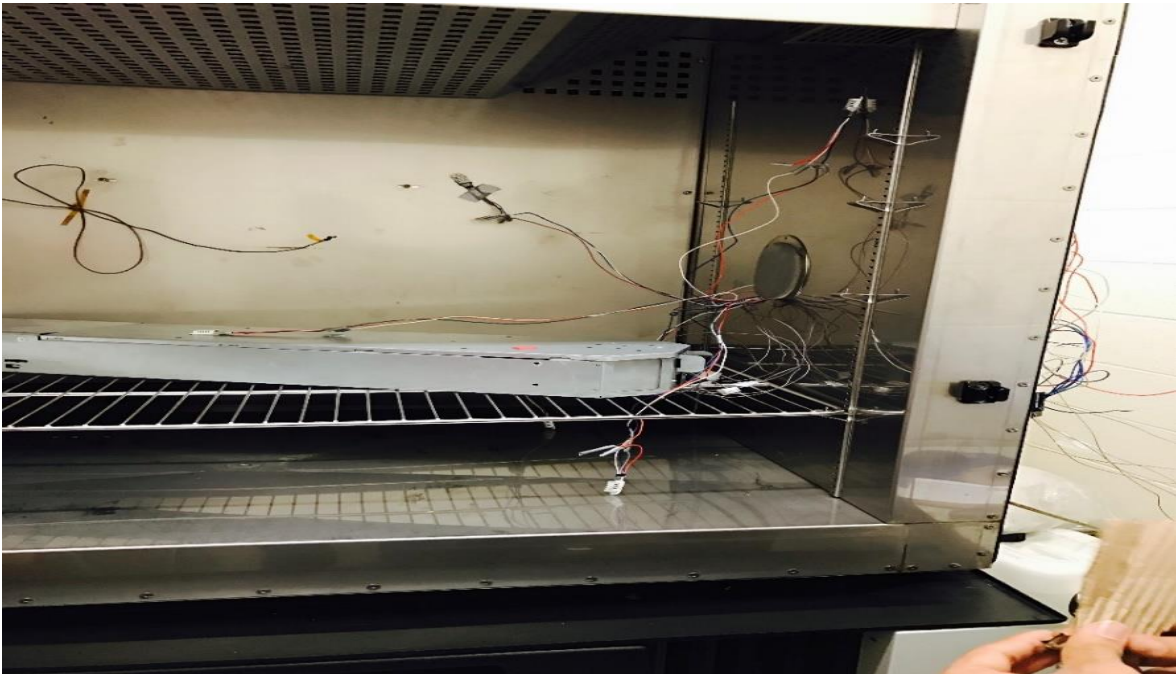


Fig 12: Humidity sensors placed at different location inside a Thermotron environmental chamber

After the completion of this experiment the data were collected and graph were plotted (variation of Humidity with time).

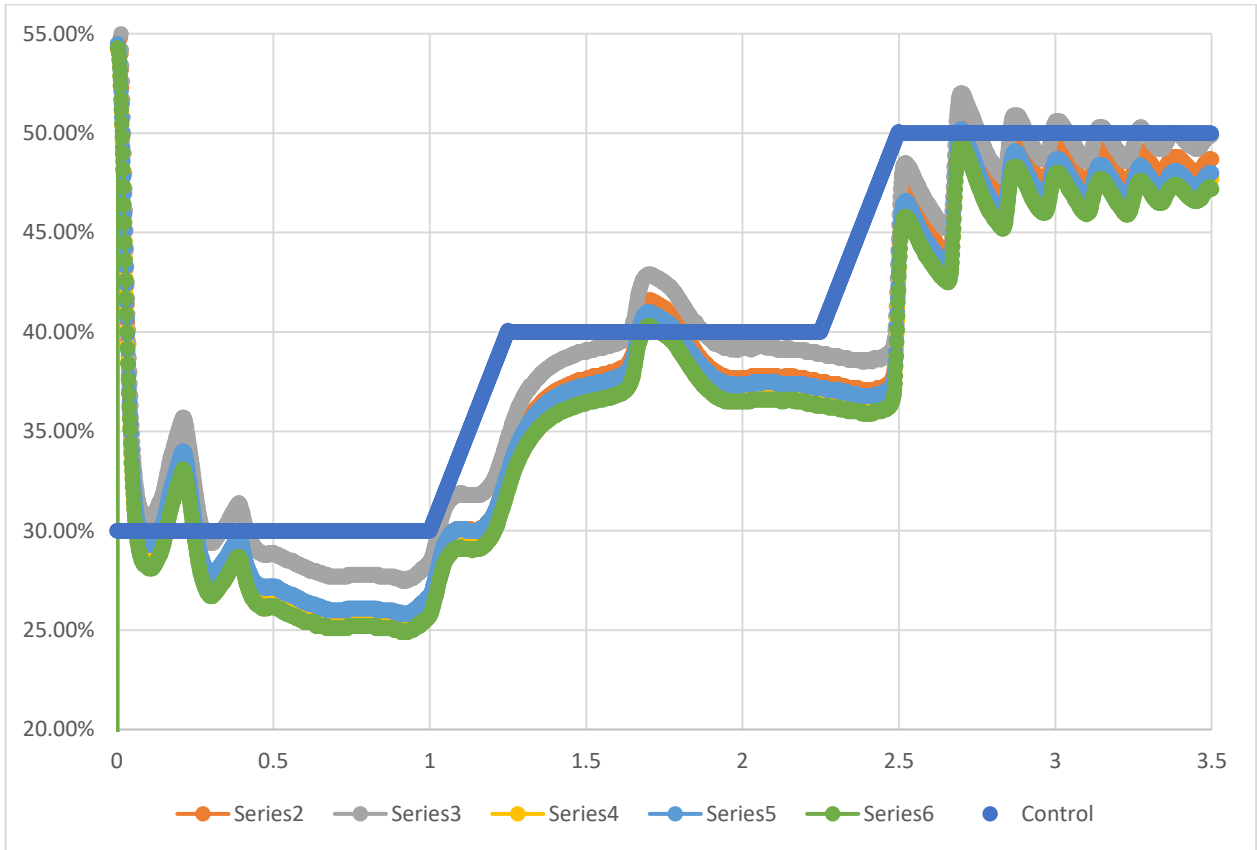


Fig 13: Humidity values plotted against time

From the results obtained it is now clear that, how accurate each sensor is and how do they vary spatially. The Dark blue line in here is the set values(Control) and colored lines show how much they differ from the set value.

3.2 Methodology and Approach:

As discussed earlier in the Introduction section, an Open Compute Facebook server is used in this case, and two DHT 22 sensors are used. One is placed near the fan and the other one as the control and this DHT 22 sensor in return is connected to the Arduino Board and then connected to the System. The schematic diagram shows the methodology of the experiment.

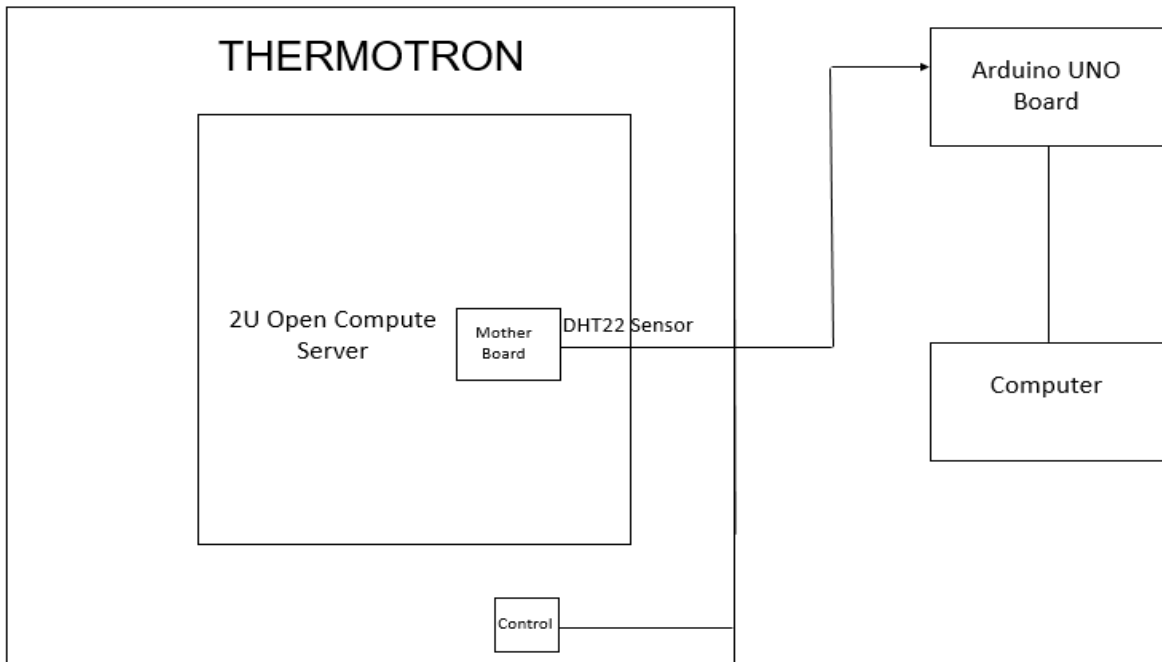
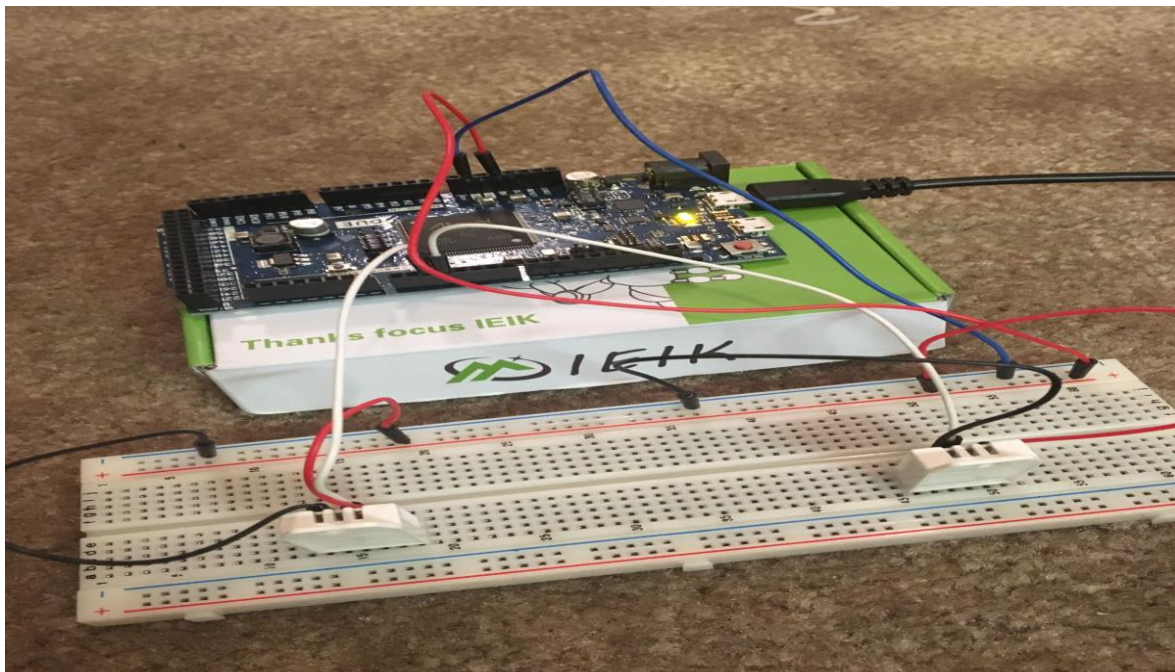


Fig 14 & 15: Schematic Diagram of experimental setup & Arduino Board connected with sensors



3.3 Experimental work

Before we even proceed with any other experiment, it is better to do the experiment with known values and result. As, discussed in the Literature Review a work done by Veerendra Mulay, the condition where he happened to see water droplets, was used. So, the Initial Temperature was kept at 15C and 50% RH for 2 hours and with a ramp time of 10 mins it is now switched to 30C and 97% RH and this condition is maintained for 2 hours. The image below shows the arrangement of 2U Open Compute Facebook server inside the Thermotron Chamber, in this case the server is kept in OFF state.



Fig 16: Open Compute Server Kept inside a Thermotron environmental chamber

Based on the results obtained from the experiment, the data were plotted on a graph. Here the based on the temperature and the Humidity, Dew Point is calculated. To calculate the Dew Point, the following formula is used. From these values a graph is plotted against the time.

$$T_D = \left(\frac{f}{100} \right)^{\frac{1}{5}} (112 + 0.9T) + 0.1T - 112$$

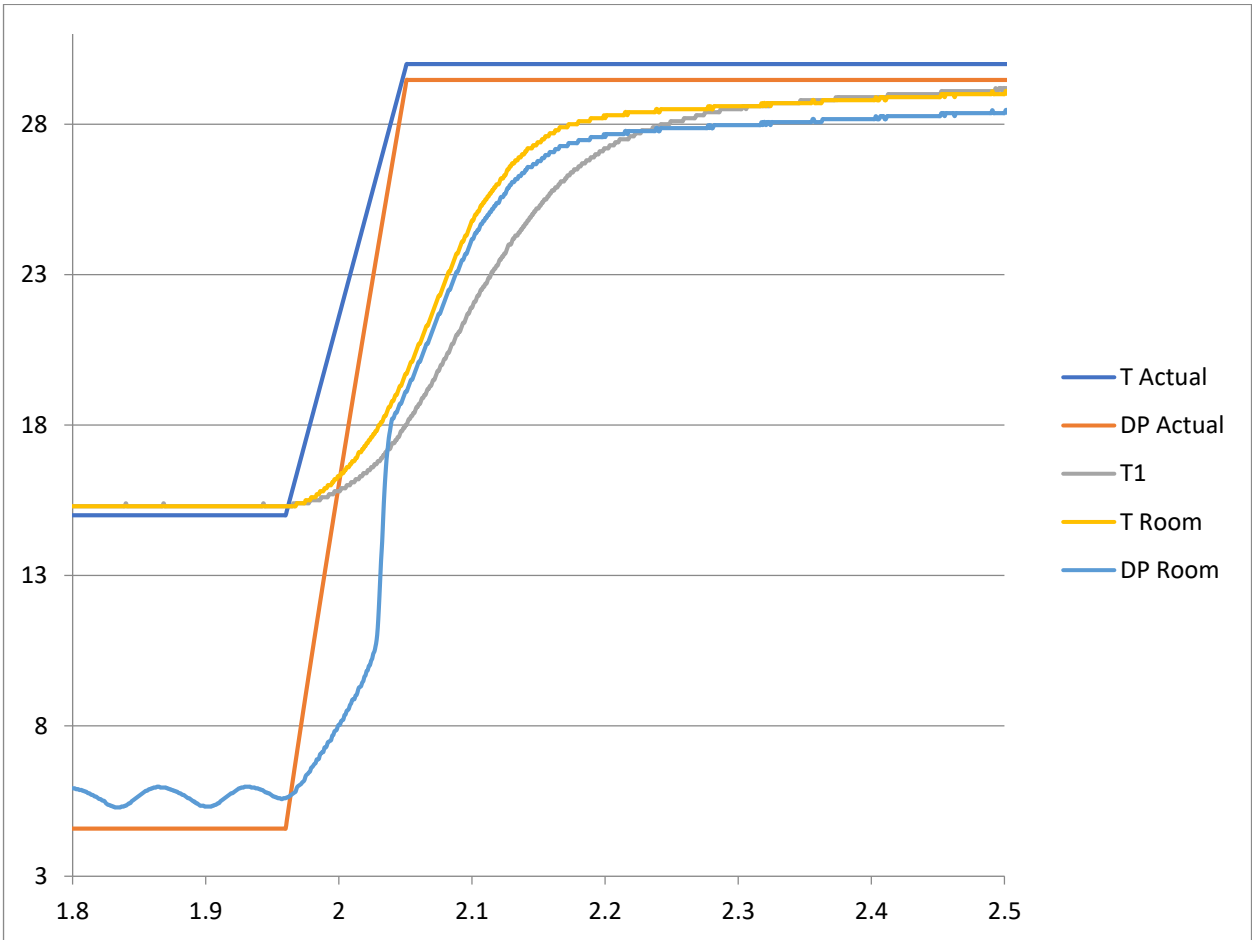


Fig 17: Temperature and Dew Point plotted with time, for 15C TO 30C at 97% RH

From the Graph it is clear that, the dew point of the room crosses the temperature within the server. So, there might be chances of condensation formation inside the server and water droplets were visually seen inside the server.

3.3.1 ASHRAE Recommended:

Based on the ASHRAE's regulations, the recommended values for a Data center is between 18C to 27C with a constant humidity of 60% RH. To check how the server responds within the ASHRAE's recommended values, the same 2U server was used in OFF state. Here the server was kept a

constant humidity of 60% RH and initially was at 18C for 2 hours and with a ramp time of 10 minute, it is now switched to 27C and maintained in this condition for another 2 hours. Based on the results obtained from the experiment, the data were plotted on a graph. Here the based on the temperature and the Humidity, Dew Point is calculated. From these values a graph is plotted against the time.

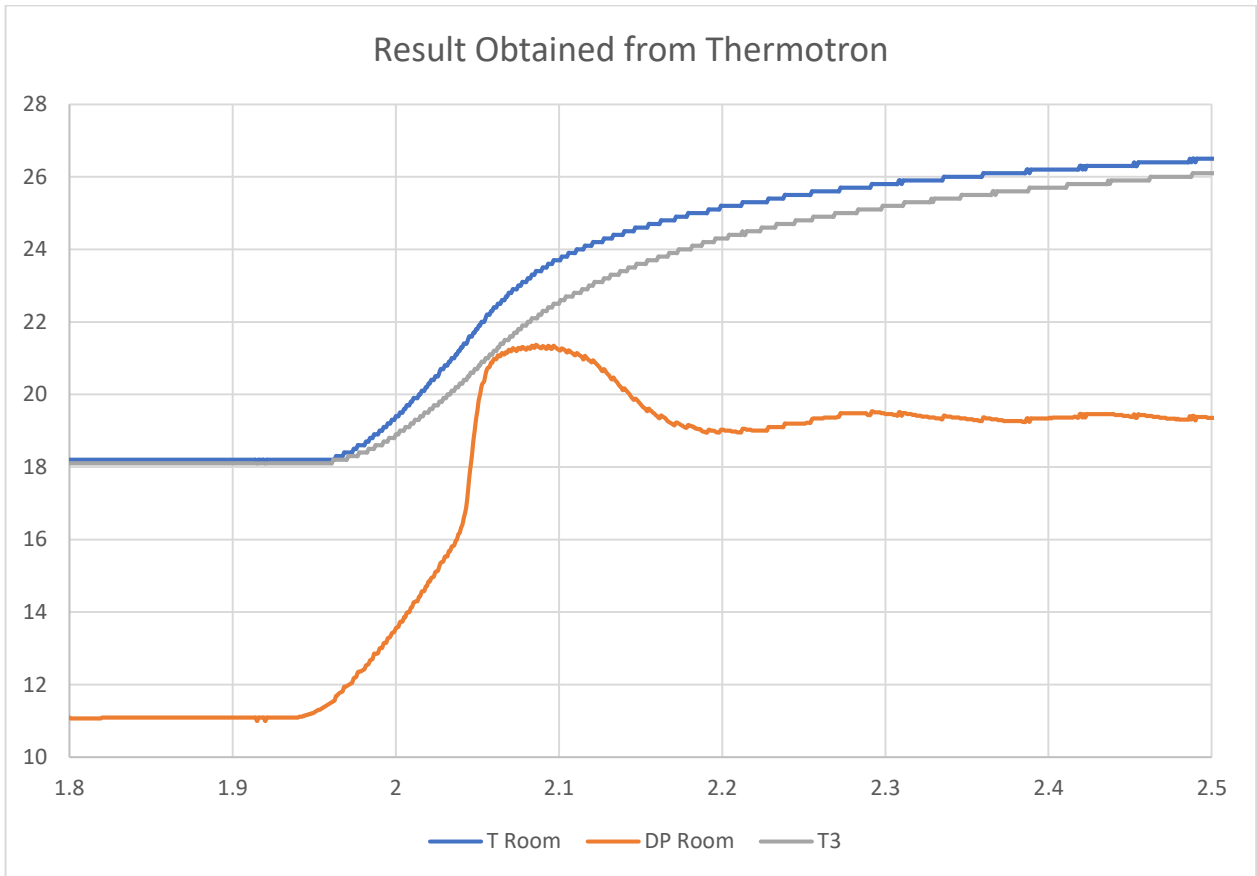


Fig 18: Temperature and Dew Point plotted with time, for ASHRAE's Recommended values

From the Graph it is clear that, the dew point of the room is closer to the temperature within the server, but it never crossed it. So, there is no condensation formation within the server and no water droplets were seen.

3.3.2 Test Cases:

Case 1:

To evaluate the worst-case scenarios, ASHRAE's A4 condition was chosen. Here the Humidity was set at 8% RH and the temperature was maintained initially at 5C for 2 hours and with a ramp time of 10 mins the condition now is switched to 18C and 90%RH and maintained for 2 hours. Based on the data obtained from the DHT 22 sensors dew point for the room is calculated, from these values a graph is plotted against the time. In this case, the server was kept OFF.

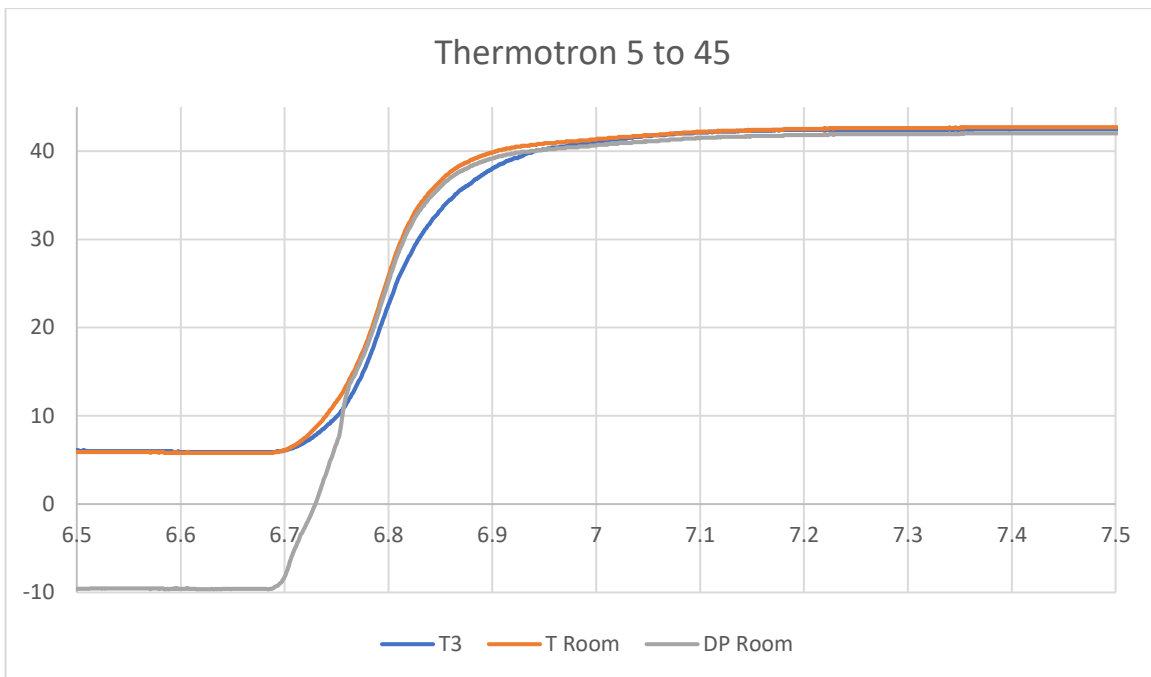


Fig 19: Temperature and Dew Point plotted with time, for ASHRAE's A4 region

From this graph, we can see that, the Dew Point of the Room crosses the temperature within the server. So, there are chances of condensation formation within the server and visually water droplets were seen.

Case 2:

Here to find the condensation formation with the server at different condition a set of experiments were conducted on the server. In all the cases the humidity was set constant to check at what rate does the condensation occur within the server. Here the Humidity was set at 50% RH and the temperature was maintained initially at 15C for 2 hours and with a ramp time of 10 mins the condition now is switched to 18C and maintained for 2 hours. Based on the data obtained from the DHT 22 sensors dew point for the room is calculated, from these values a graph is plotted against the time. In all the cases the server was kept OFF.

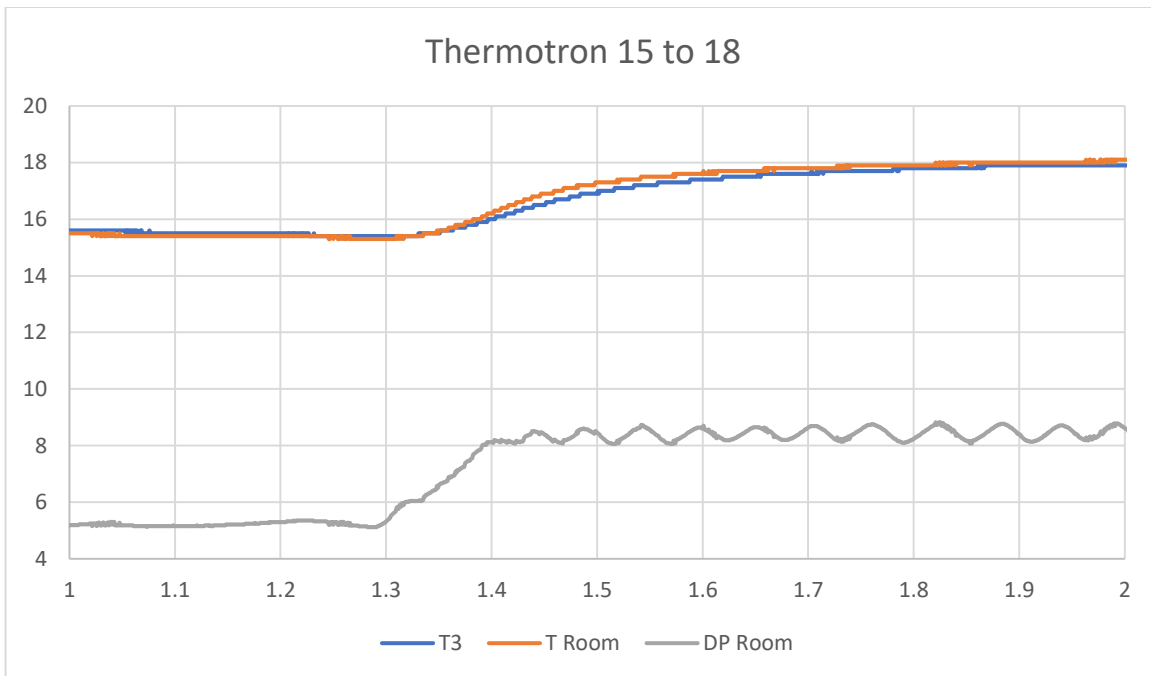


Fig 20: Temperature and Dew Point plotted with time, for 15C to 18C

From this graph, we can see a significant difference between the Dew Point of the Room and the temperature within the server. So, there could be no chances of condensation formation within the server and visually no water droplets were seen.

Case 3:

Here the Humidity was set at 50% RH and the temperature was maintained initially at 15C for 2 hours and with a ramp time of 10 mins the condition now is switched to 25C and maintained for 2 hours. Based on the data obtained from the DHT 22 sensors dew point for the room is calculated, from these values a graph is plotted against the time.

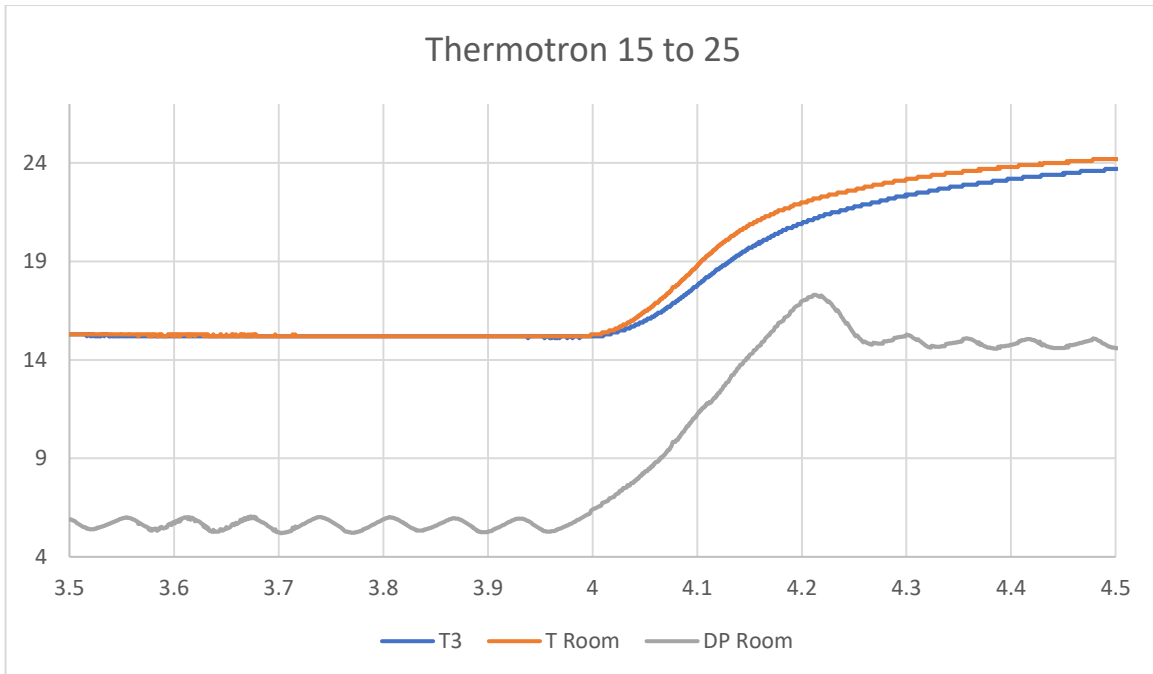


Fig 21: Temperature and Dew Point plotted with time, for 15C to 25C

From this graph, we can see a significant difference between the Dew Point of the Room and the temperature within the server. So, there could be no chances of condensation formation within the server and visually no water droplets were seen.

Case 4:

Here the Humidity was set at 50% RH and the temperature was maintained initially at 15C for 2 hours and with a ramp time of 10 mins the condition now is switched to 30C and maintained for 2 hours. Based on the data obtained from the DHT 22 sensors dew point for the room is calculated, from these values a graph is plotted against the time.

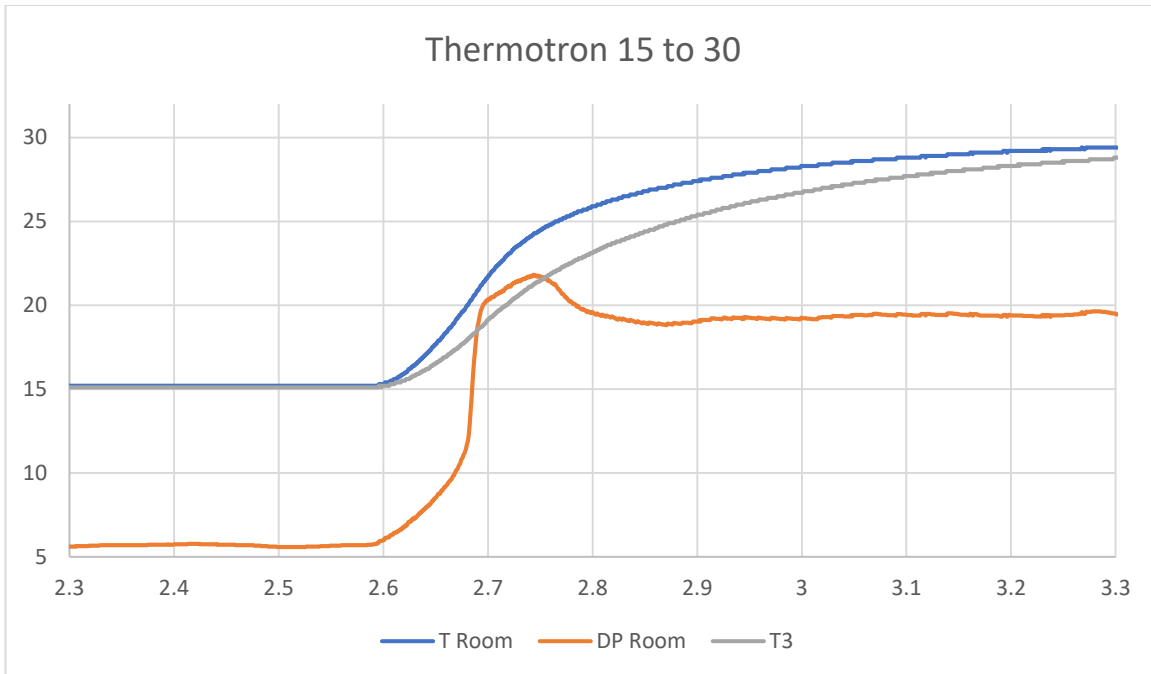


Fig 22: Temperature and Dew Point plotted with time, for 15C to 30C

From this graph, we can see that, the Dew Point of the Room crosses the temperature within the server. So, there are chances of condensation formation within the server and visually water droplets were seen.

On comparing these results, there occurs no condensation when it is switched from 15C to 25C, but it occurred when switched from 15C to 30C at constant humidity. So, there might be chances of condensation formation within the server when switched at 15C/10minutes as the ramp time. To investigate this in detail, experiments were conducted for the values in between 25C to 30C. The Images below shows the comparison for 2U server at the mother board and at the Fan when switched from 15C to 25C and 15C to 30C.

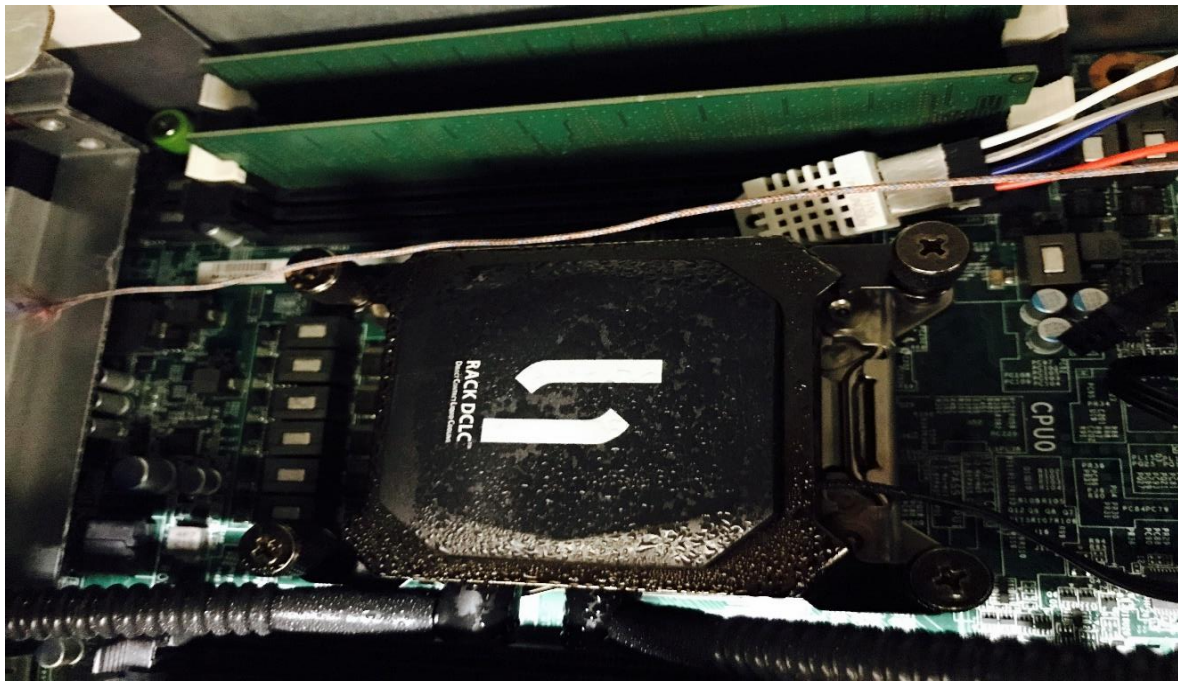
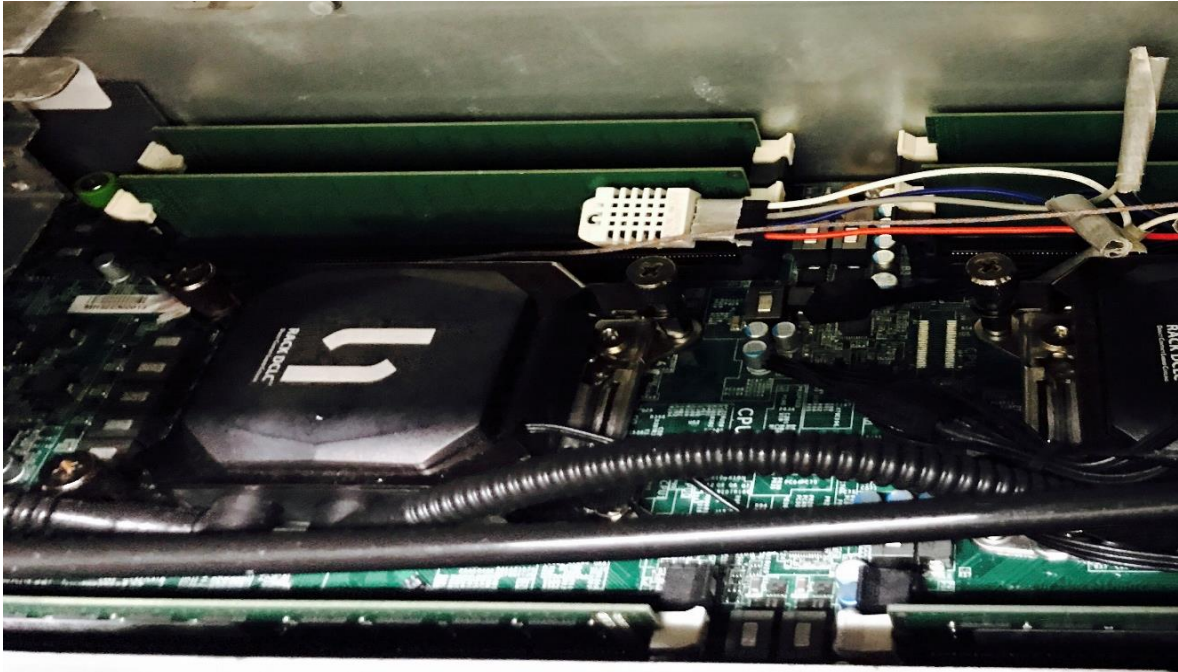


Fig 23 & 24: Image of the mother board at 15C to 25C (Top) and 15 to 30C (Bottom)

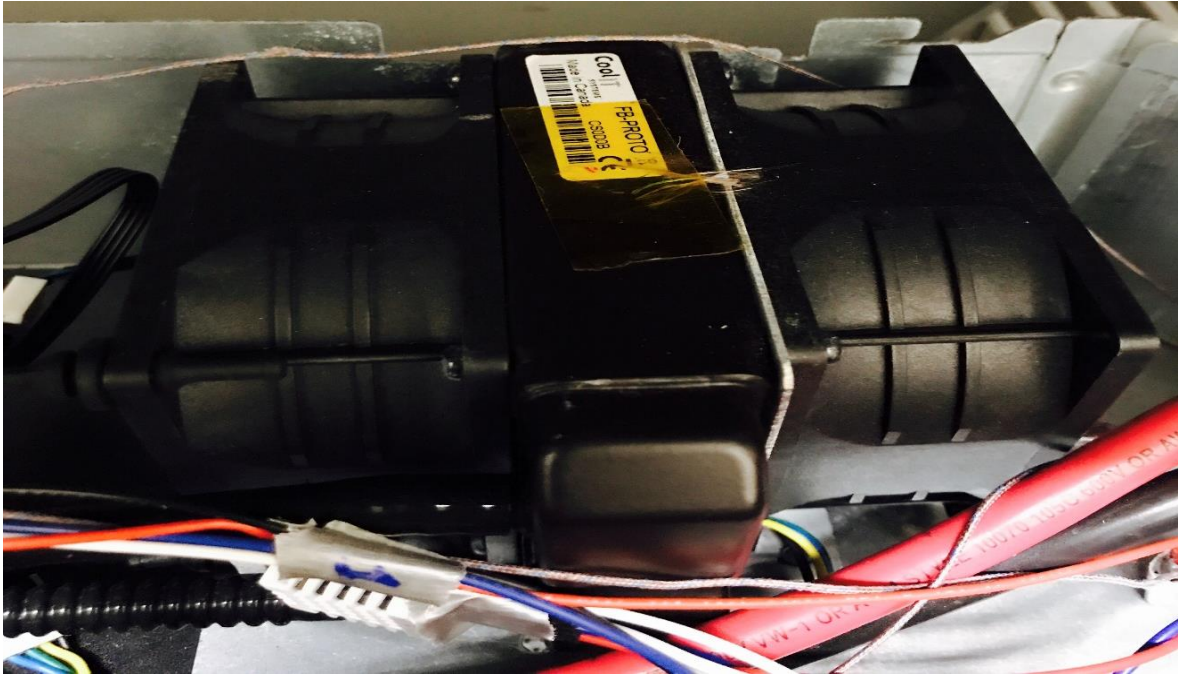


Fig 25 & 26: Image of the fan at 15C to 25C (Top) and 15 to 30C (Bottom)

Case 5:

Here the Humidity was set at 50% RH and the temperature was maintained initially at 15C for 2 hours and with a ramp time of 10 mins the condition now is switched to 26C and maintained for 2 hours. Based on the data obtained from the DHT 22 sensors dew point for the room is calculated, from these values a graph is plotted against the time. In all the cases the server was kept OFF.

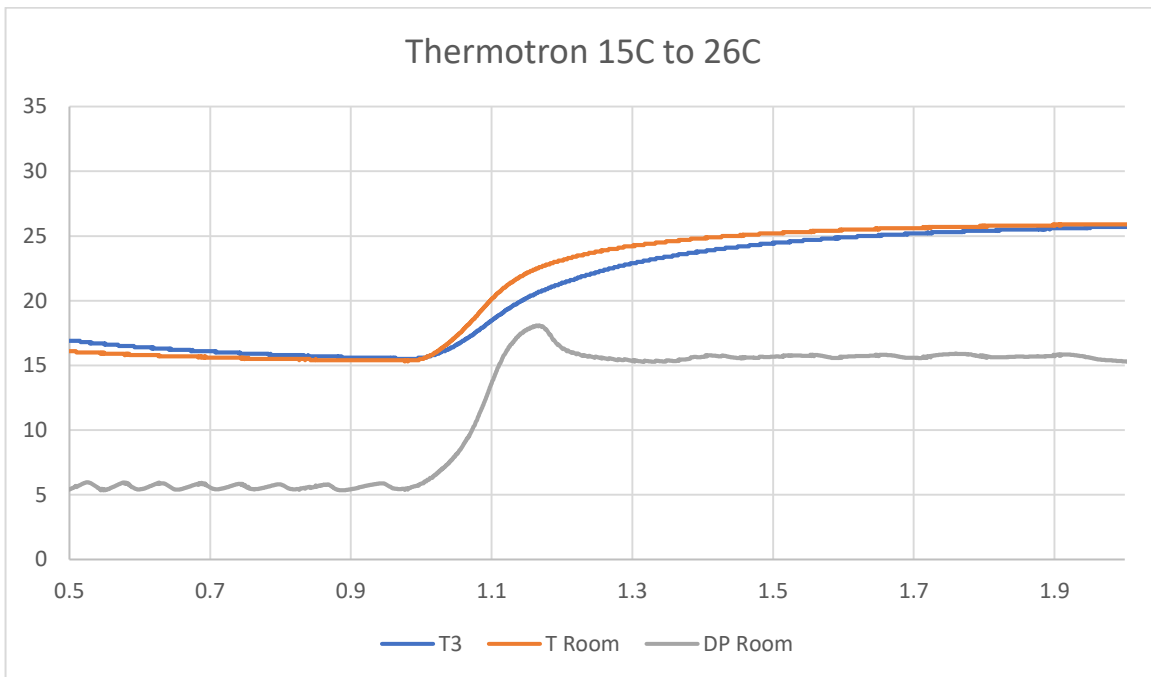


Fig 27: Temperature and Dew Point plotted with time, for 15C to 26C

From this graph, we can see a significant difference between the Dew Point of the Room and the temperature within the server. So, there could be no chances of condensation formation within the server and visually no water droplets were seen.

Case 6:

Here the Humidity was set at 50% RH and the temperature was maintained initially at 15C for 2 hours and with a ramp time of 10 mins the condition now is switched to 27C and maintained for 2 hours. Based on the data obtained from the DHT 22 sensors dew point for the room is calculated, from these values a graph is plotted against the time. In all the cases the server was kept OFF.

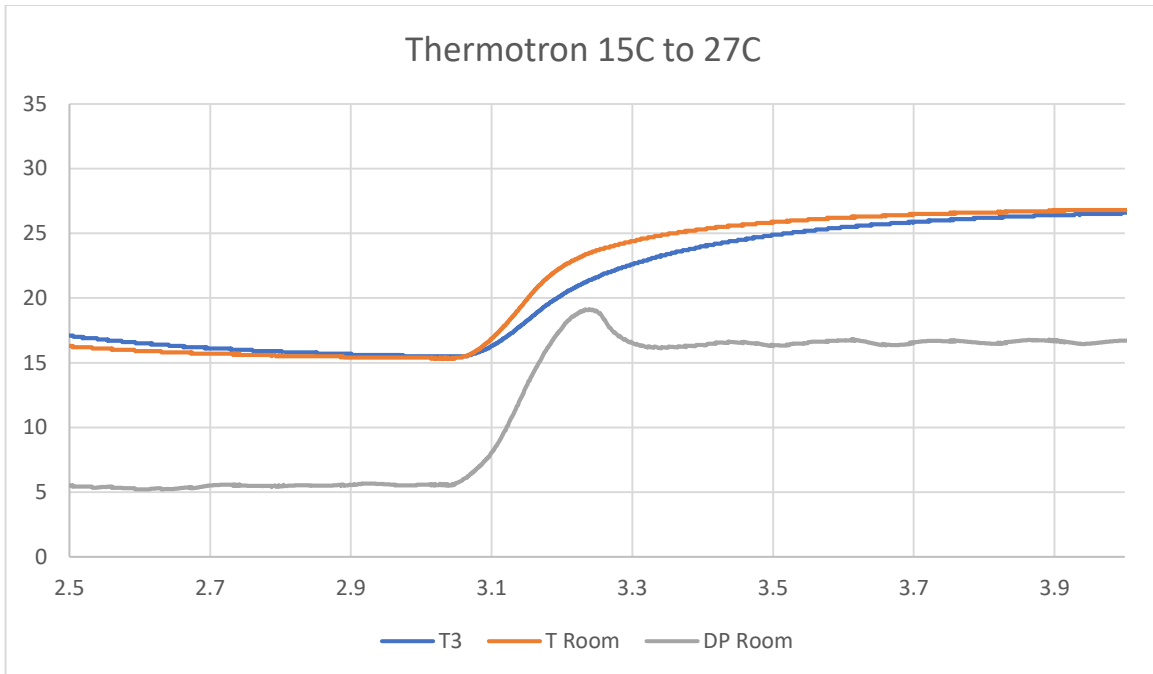


Fig 28: Temperature and Dew Point plotted with time, for 15C to 27C

From this graph, we can see a significant difference between the Dew Point of the Room and the temperature within the server. So, there could be no chances of condensation formation within the server and visually no water droplets were seen.

Case 7:

Here the Humidity was set at 50% RH and the temperature was maintained initially at 15C for 2 hours and with a ramp time of 10 mins the condition now is switched to 28C and maintained for 2 hours. Based on the data obtained from the DHT 22 sensors dew point for the room is calculated, from these values a graph is plotted against the time. In all the cases the server was kept OFF.

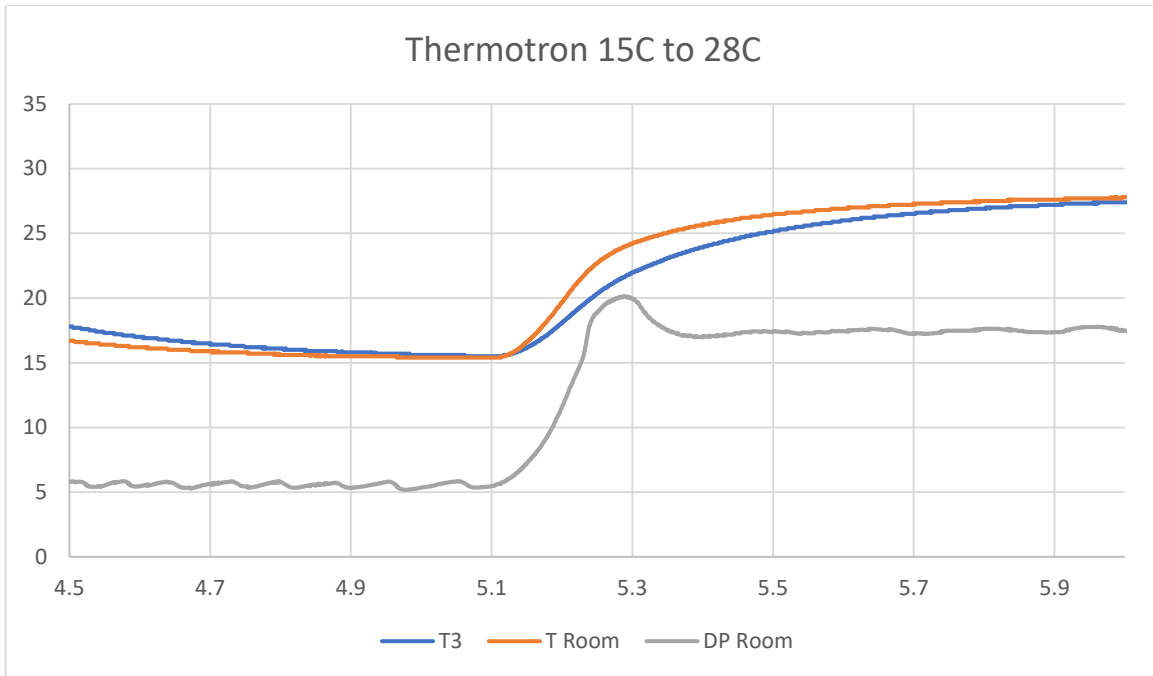


Fig 29: Temperature and Dew Point plotted with time, for 15C to 28C

From this graph, we can see a significant difference between the Dew Point of the Room and the temperature within the server. So, there could be no chances of condensation formation within the server and visually no water droplets were seen.

Case 8:

Here the Humidity was set at 50% RH and the temperature was maintained initially at 15C for 2 hours and with a ramp time of 10 mins the condition now is switched to 29C and maintained for 2 hours. Based on the data obtained from the DHT 22 sensors dew point for the room is calculated, from these values a graph is plotted against the time. In all the cases the server was kept OFF.

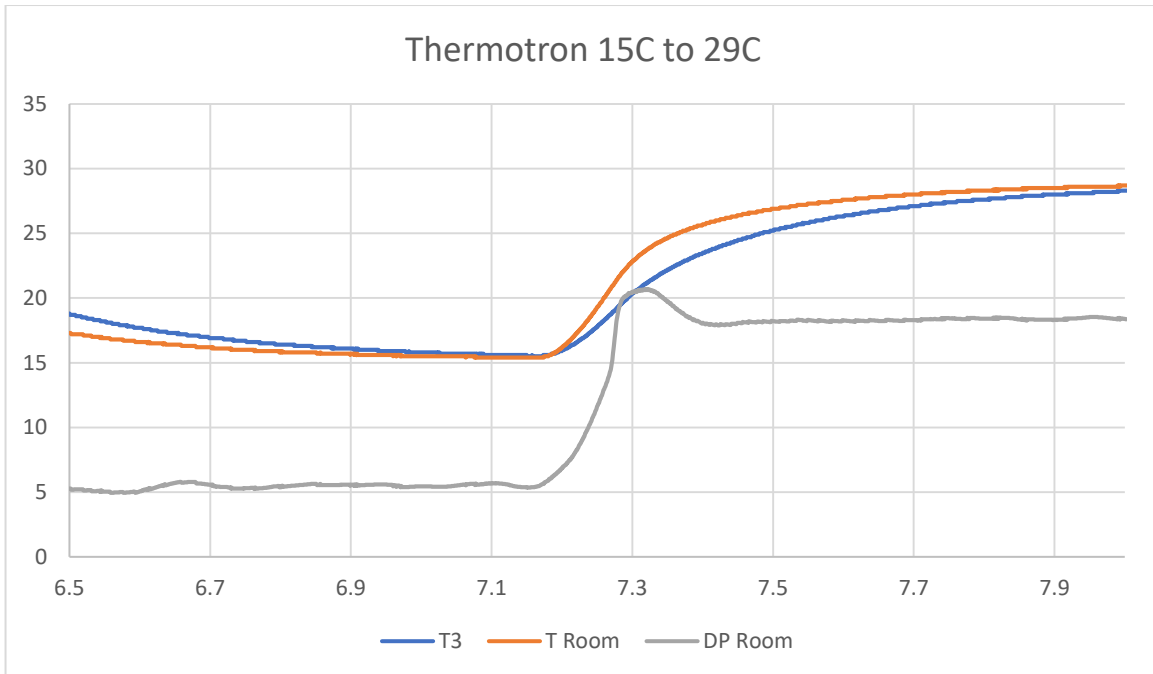


Fig 30: Temperature and Dew Point plotted with time, for 15C to 29C

From this graph, we can see that, the Dew Point of the Room crosses the temperature within the server. So, there are chances of condensation formation within the server and visually water droplets were seen.

On comparing these results, in case 7 and Case 8, there occurs no condensation when it is switched from 15C to 28C, but it occurred when switched from 15C to 29C at constant humidity. So, there might be chances of condensation formation within the server when switched at 14C/10minutes as the ramp time.

Chapter 4

Transient Model

4.1 CFD Modelling

To Verify the results obtained from the experiments conducted in Thermotron Environmental Chamber, a CFD analysis is done. 6SigmaRoom was the most suitable CFD tool that we found for this case. Here using the 6SigmaRoom a transient model was developed. Here a room was created based on the dimensions with that of the Environmental chamber. $W * D * H = 102 * 67 * 86$ centimeters, a 2 Ton AC unit was used for cooling and a 2U-500W server was used in all the cases. Here the server was placed just like that in the Thermotron Environmental Chamber, but the only difference is that in here the server was kept on. Here same way, two sensors were used one to check the Temperature and Humidity within the server and the other one was kept as the control i.e. to measure the temperature and humidity within the room and yellow color ball or sensor shows the humidity control sensor, used to control the Humidity within the room i.e. to keep them in control the humidity of the air coming out from the ACU. The Images below shows the screenshot took from the 6SigmaRoom, how the server is placed inside the chamber.

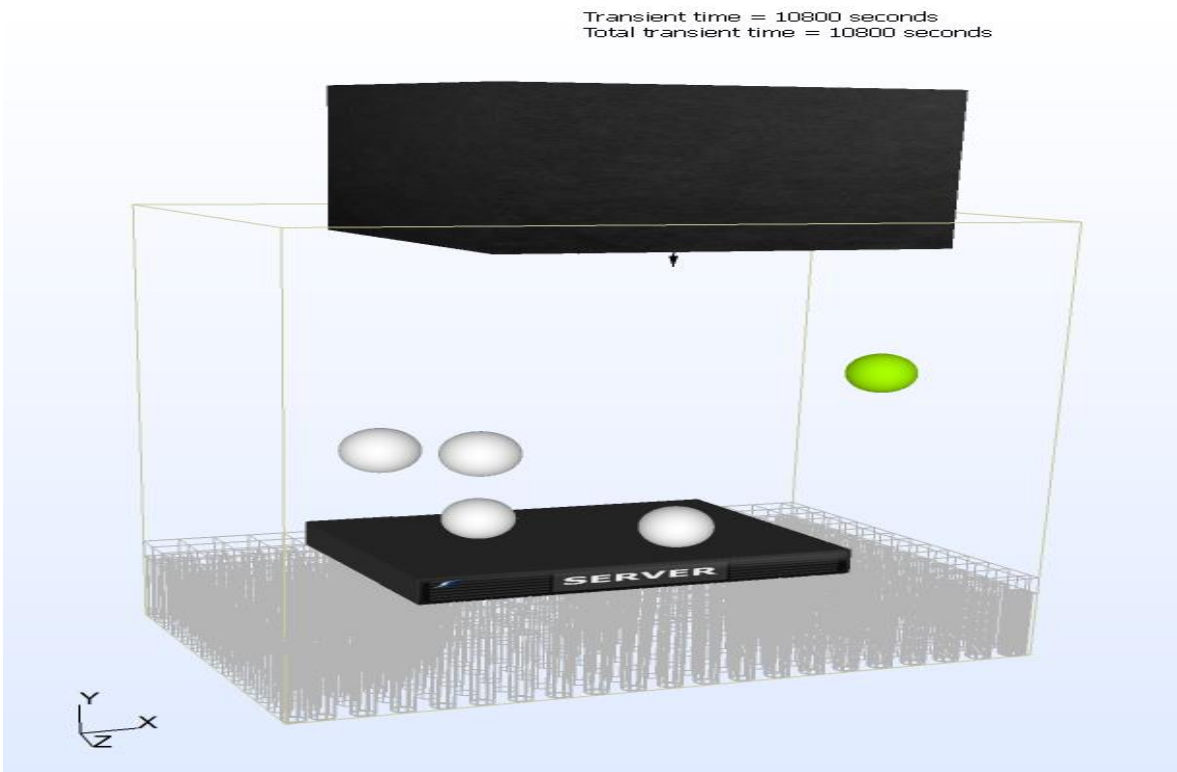
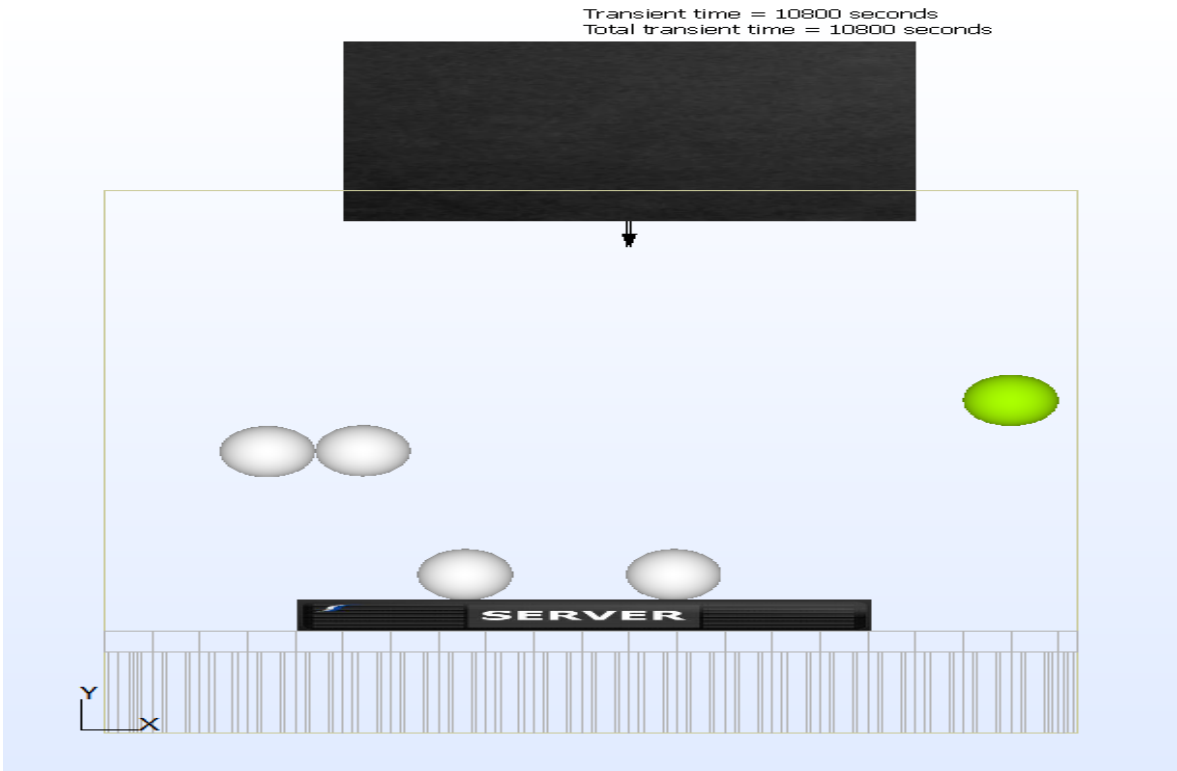


Fig 31: Model Developed using 6SigmaRoom

4.2 Experimental work

As we said earlier experiments are conducted on the 6SigmaRoom is just to compare the results obtained from the Thermotron chamber. Before we even proceed with any other experiment, it is better to do the experiment with known values and result. As, discussed in the Literature Review a work done by Veerendra Mulay, the condition where he happened to see water droplets, was used. So, the Initial Temperature was kept at 15C and 50% RH for 2 hours and with a ramp time of 10 mins it is now switched to 30C and 97% RH and this condition is maintained for 2 hours. In this case, the server is kept in ON state. Based on the results obtained from the experiment, the data were plotted on a graph. Here the based on the temperature and the Humidity, Dew Point is calculated. To calculate the Dew Point, the following formula is used. From these values a graph is plotted against the time.

$$T_D = \left(\frac{f}{100} \right)^{\frac{1}{5}} (112 + 0.9T) + 0.1T - 112$$

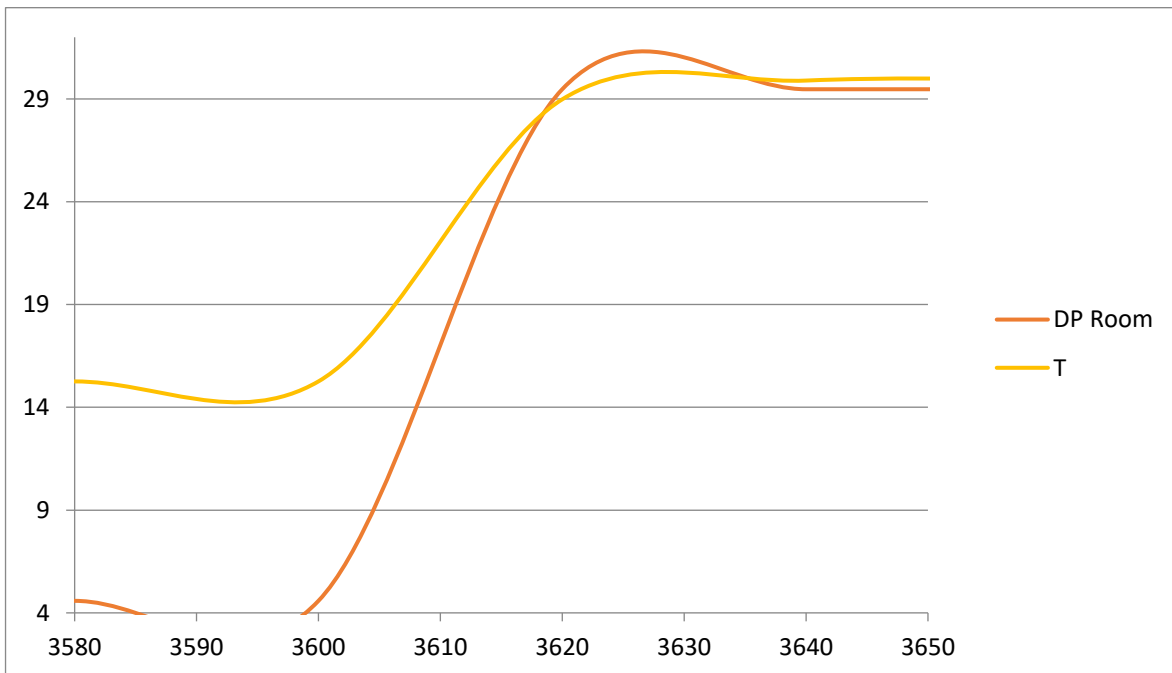


Fig 32: Temperature and Dew Point plotted with time, for 15C to 30C at 97%RH

From the Graph it is clear that, the dew point of the room crosses the temperature within the server. So, there might be chances of condensation formation inside the server.

ASHRAE Recommended:

Based on the ASHRAE's regulations, the recommended values for a Data center is between 18C to 27C with a constant humidity of 60% RH. To check how the server responds within the ASHRAE's recommended values, the same 2U server was used in ON state. Here the server was kept a constant humidity of 60% RH and initially was at 18C for 2 hours and with a ramp time of 10 minute, it is now switched to 27C and maintained in this condition for another 2 hours. Based on the results obtained from the experiment, the data were plotted on a graph. Here the based on the temperature and the Humidity, Dew Point is calculated. From these values a graph is plotted against the time.

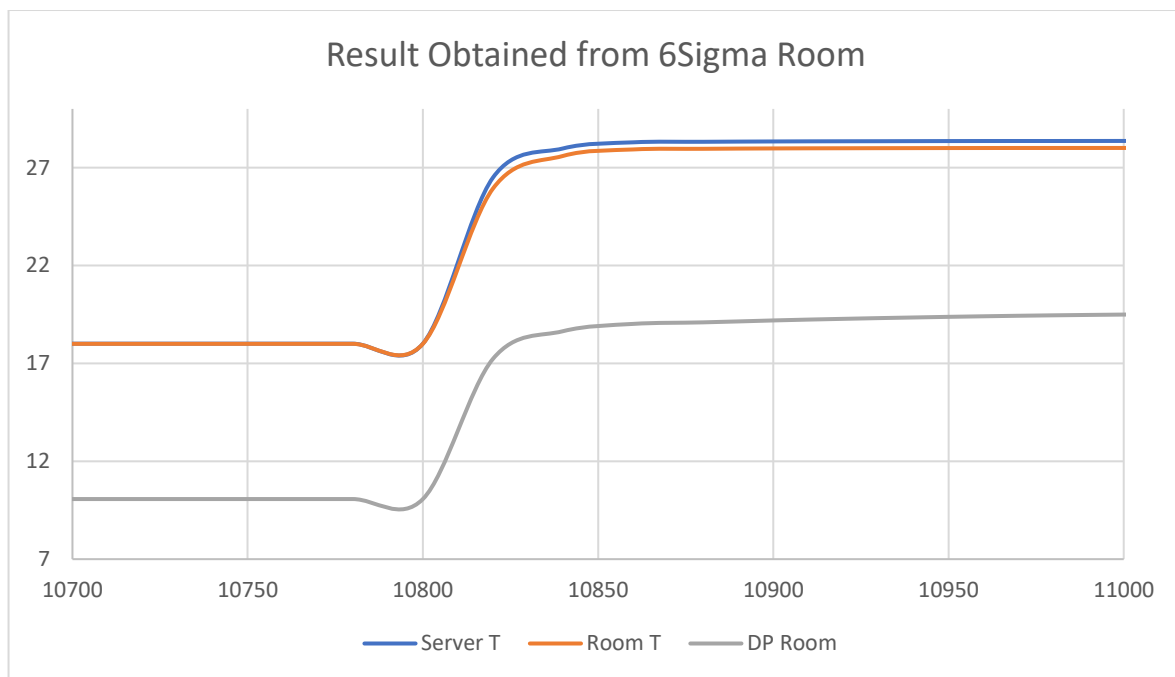


Fig 33: Temperature and Dew Point plotted with time, for ASHRAE's recommended

From the Graph it is clear that, the dew point of the room is closer to the temperature within the server, but it never crossed it. So, there is no condensation formation within the server.

4.3 Test Cases:

Case 1:

To evaluate the worst-case scenarios, ASHRAE's A4 condition was chosen. Here the Humidity was set at 8% RH and the temperature was maintained initially at 5C for 2 hours and with a ramp time of 10 mins the condition now is switched to 18C and 90%RH and maintained for 2 hours. Based on the data obtained from the DHT 22 sensors dew point for the room is calculated, from these values a graph is plotted against the time. In this case, the server was kept ON.

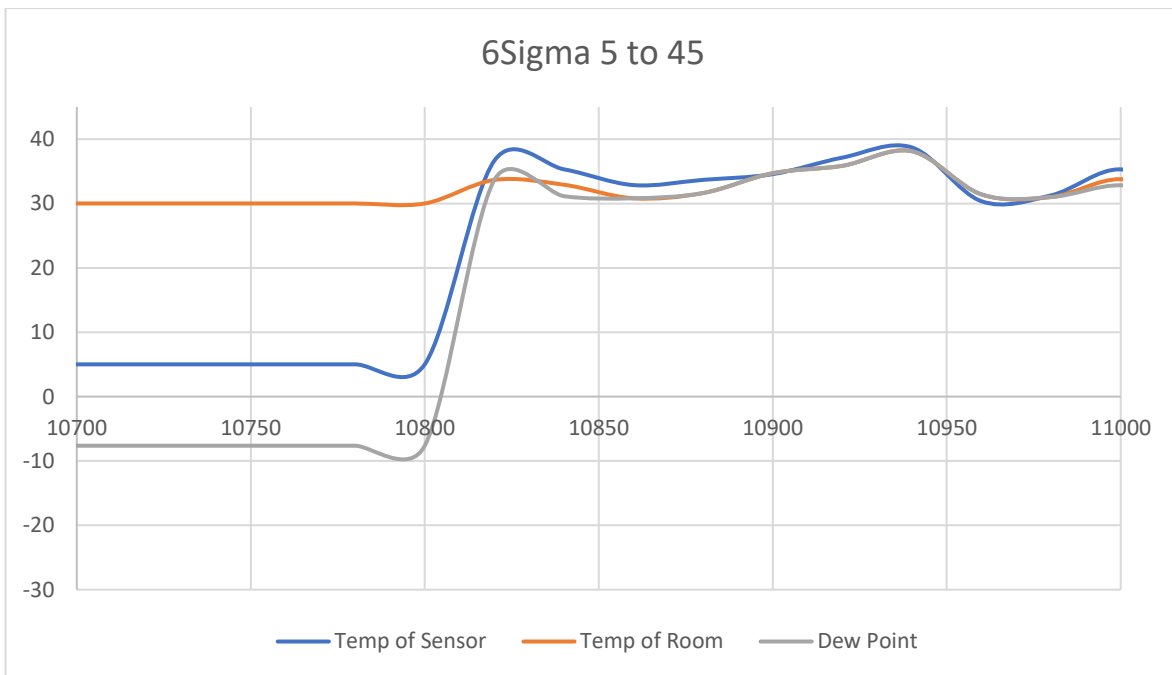


Fig 34: Temperature and Dew Point plotted with time, for ASHRAE's A4

From this graph, we can see that, the Dew Point of the Room crosses the temperature within the server. So, there are chances of condensation formation within the server.

Case 2:

Here to find the condensation formation with the server at different condition a set of experiments were conducted on the server. In all the cases the humidity was set constant to check at what rate does the condensation occur within the server. Here the Humidity was set at 50% RH and the temperature was maintained initially at 15C for 2 hours and with a ramp time of 10 mins the condition now is switched to 18C and maintained for 2 hours. Based on the data obtained from the DHT 22 sensors dew point for the room is calculated, from these values a graph is plotted against the time. In all the cases the server was kept OFF.

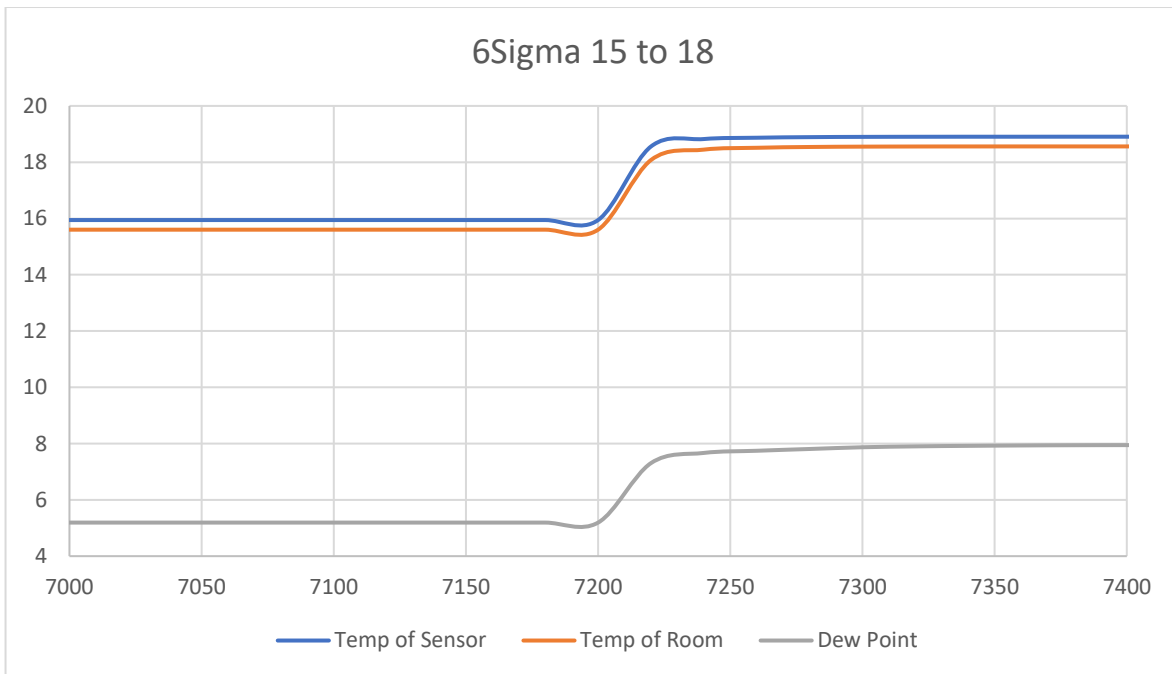


Fig 35: Temperature and Dew Point plotted with time, for 15C to 18C

From this graph, we can see a significant difference between the Dew Point of the Room and the temperature within the server. So, there could be no chances of condensation formation within the server.

Case 3:

Here the Humidity was set at 50% RH and the temperature was maintained initially at 15C for 2 hours and with a ramp time of 10 mins the condition now is switched to 25C and maintained for 2 hours. Based on the data obtained from the DHT 22 sensors dew point for the room is calculated, from these values a graph is plotted against the time.

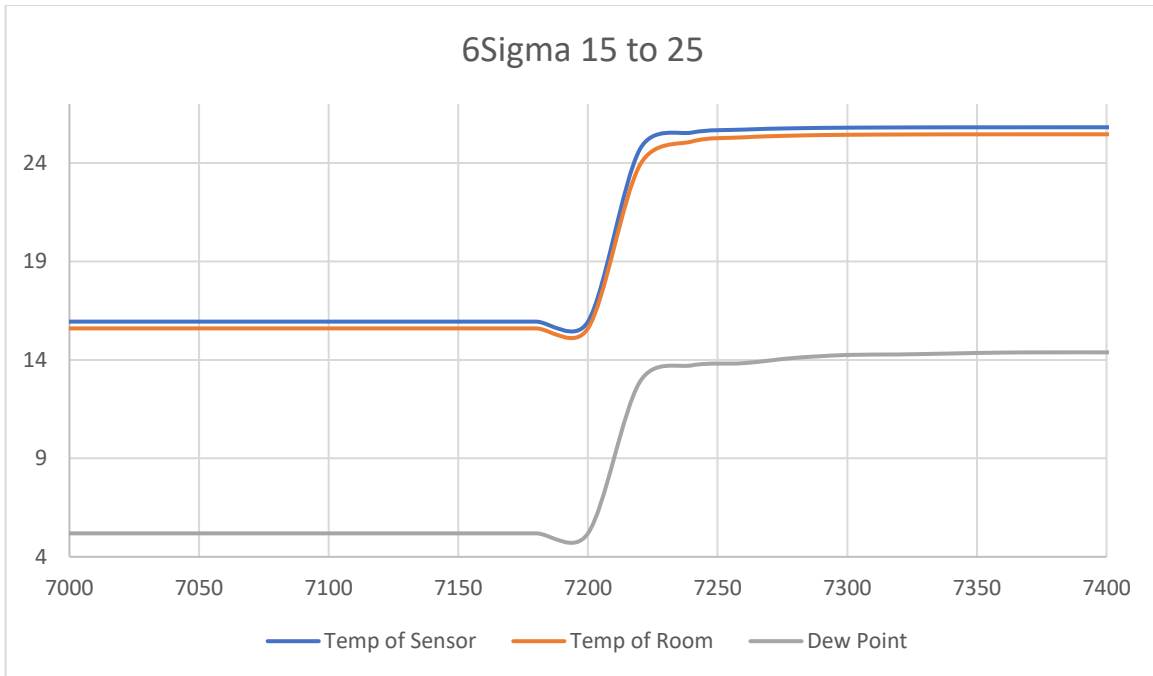


Fig 36: Temperature and Dew Point plotted with time, for 15C to 25C

From this graph, we can see a significant difference between the Dew Point of the Room and the temperature within the server. So, there could be no chances of condensation formation within the server.

Case 4:

Here the Humidity was set at 50% RH and the temperature was maintained initially at 15C for 2 hours and with a ramp time of 10 mins the condition now is switched to 30C and maintained for 2 hours. Based on the data obtained from the DHT 22 sensors dew point for the room is calculated, from these values a graph is plotted against the time.

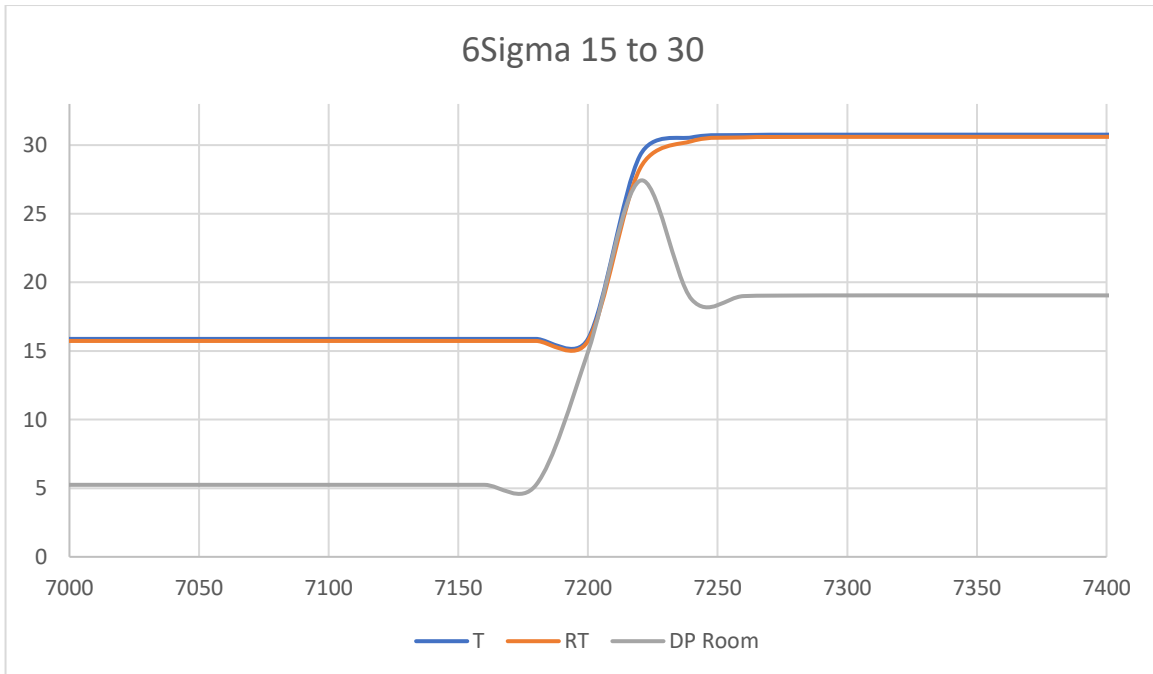


Fig 37: Temperature and Dew Point plotted with time, for 15C to 30C

From this graph, we can see that, the Dew Point of the Room crosses the temperature within the server. So, there are chances of condensation formation within the server.

On comparing these results, there occurs no condensation when it is switched from 15C to 25C, but it occurred when switched from 15C to 30C at constant humidity. So, there might be chances of condensation formation within the server when switched at 15C/10minutes as the ramp time. To investigate this in detail, experiments were conducted for the values in between 25C to 30C. So, the result obtained from the Environmental Chamber is closer to that of the 6SigmaRoom, even though

the server was kept ON here. As only one 2U-500W server is used, the heat generated will not affect the temperature within the room or the server.

Case 5:

To Check the final case scenario, what happens when the server is switched from 15C to 29C an experiment was conducted on the 6SigmaRoom, to check is there is any condensation formation within the room. So initially the Room was kept in 50%RH and the temperature was kept at 15C for 2 hours and with a ramp time of 10 minutes it is now switched to 29C. In this case server was kept ON. Based on the results and data obtained from the room the values were imported to the Excel and graphs are now plotted for the temperature within server and the Dew point of the room against the time.

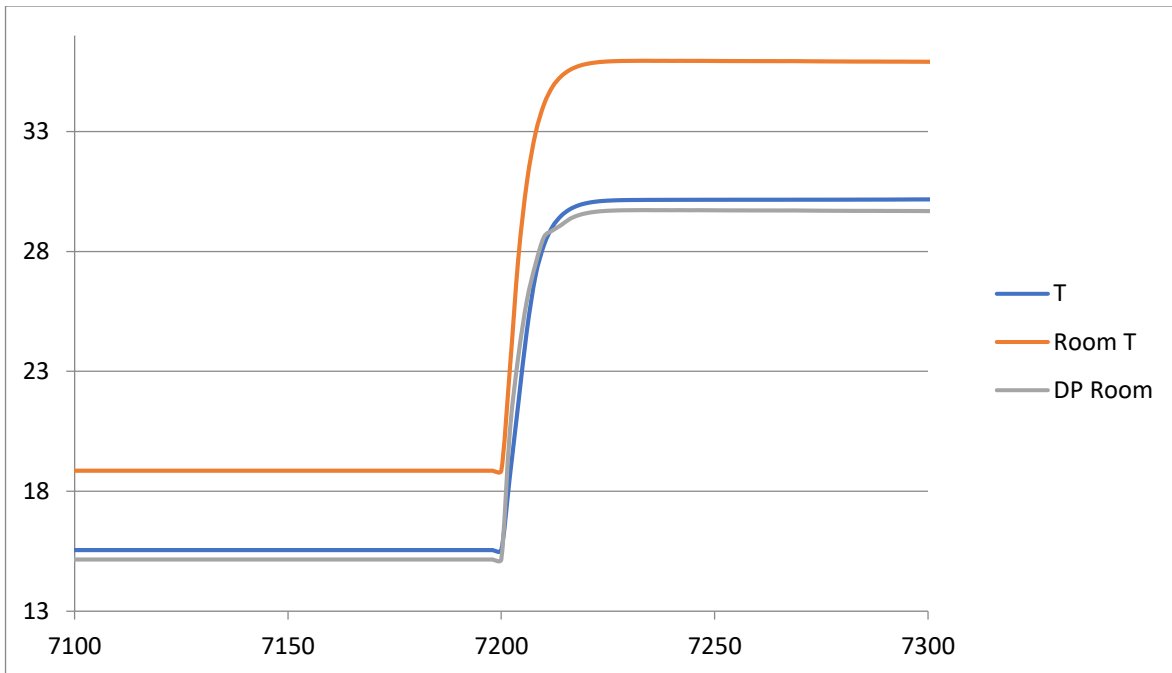


Fig 38: Temperature and Dew Point plotted with time, for 15C to 29C

From the graph, we can see that, when the temperature is switched from 15C to 29C at a constant humidity of 50% RH, condensation has occurred. This result is compared with that of the Thermotron

as well. It is now, pretty much clear that at an increase of 14C within 10 minutes, regardless of the humidity, there might chances of condensation within the server. Even though, there may be no signs of condensation at the heat components of the server, there might be clear sign of condensation on top of the non-heated components.

Chapter 5:

Conclusion

Based on the experiments conducted on the Thermotron Environmental Chamber and 6SigmaRoom, there are few conditions that should be considerations when one switched from one type of cooling to another type cooling in an operating Data Center. From the experiments that were, the following conclusion were made.

It is always not advisable to operate Data Center at high humidity. Based on the experiment conducted based on the ASHRAE's A4 condition, at high humidity range, the dew point of room is increased as it is a factor of Humidity and Temperature. This makes dew point to exceed the temperature within the server which causes condensation.

Even at fixed humidity, when switching temperature rapidly may cause condensation to occur. From the set of experiments conducted it is clear that, when a Data center is switched from 15C to 29C at constant humidity that is whenever there is an increase in temperature over 1.3C a minute there might be definite chance of condensation formation within the server. As it was visually seen and experimentally found out.

From the experiment conducted based on the ASHRAE's recommended values that is between 18C to 27C at constant relative humidity of 60% RH, no condensation occurred and visually no water droplets were seen, even in the non-heated components. So, it recommended to maintain the Data Center always between, 18C to 27C at relative humidity of 60% RH.

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BIOGRAPHICAL INFORMATION

Ramesh Prasanna Manohar (Feb 23rd, 1994) is from Chennai, India. He completed his Bachelors in Mechanical Engineering from Anna University in May 2015. He joined the University of Texas at Arlington in Spring 2016 for Master of Science in Mechanical Engineering. He joined EMNSPC team in summer 2015 and started working on various projects.

His primary research includes Experimental and Computational Investigation of Need for an Acclimation in an Operating Data center.

Ramesh Prasanna Manohar Graduated from the University of Texas at Arlington on May 19th, 2016.