EXPERIMENTAL STUDY ON THE EFFECTS OF GASEOUS CONTAMINATION ON IT EQUIPMENT

by

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Abstract

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Every company is trying to reduce their carbon footprint in today's world. The data center industry is no different. To reduce the cooling costs and increase the efficiency, air -side economizers are used. Air-side economizers bring in outside ambient cold air to cool the data center equipment. Through this, we can save on cooling costs. The problem relating to air-side economization is that we have no control over the humidity and contamination. Humidity and contamination go hand in hand, as one influence the other. In the past filters have been used to combat contamination but it has proved to be a costly affair as they have to be replaced periodically. According to ASHRAE standards, the filters inside the data center must be MERV 8 filters. The air filters at the inlet for outside air must be MERV 13 [6]. Sulfur bearing gases are one of the main causes of corrosion of IT equipment in data centers. They react with silver and copper in the presence of humidity to cause corrosion. Most of the electronic equipment is built of metals like copper and silver. Due to the corrosion of these metals, the reliability of the equipment reduces drastically. This thesis focusses on experimentally determining the amount of corrosion that occurs when these metals are exposed to a concentrated amount of sulfur dioxide in a controlled atmosphere.

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Chapter 1

Introduction

1.1 Data Centers

A data center is a server farms containing equipment used for storage, processing, managing and exchanging digital information. Storage servers store the digital data; compute data process the information while the network equipment provides the communication. These three components together form IT equipment. The data center provides the computing power to run various softwares used for various sectors in the fields of academia, business, government etc. A data center is located in a building with no windows. A tight environmental control is kept in the building for the optimum performance of data centers. Power conversion equipment is present to facilitate the power needs of the equipment [14].

1.2 Components of a Data Center

Components of a data center are mainly divided into two types; IT infrastructure and physical infrastructure. IT infrastructure consists of components that are involved directly in the process of information exchange and collection. The various components are servers, storage, networking, security, control and software. Physical infrastructure consists of the equipment that is involved in facilitating the optimum performance of a data center. The various components are power supply, security, fire sensors, and air conditioning.

1.2.1 IT Infrastructure

IT infrastructure consists of equipment that facilitates the exchange and storage of digital information and data. The most important component is the server. A typical data center consists of thousands of servers mounted on racks. There are different types of servers present. Servers are selected mainly based on the application, power and space. Another important component is the storage. In today's world, the amount of information to be stored in data centers is enormous. An external storage is used for storage information. The networking elements are the components that are used to connect the various components to complete a network. In the case of data centers security of digital information is of the utmost importance. Security components like firewall, intrusion prevention system and intrusion detection systems are deployed. Control components help in the monitoring and management of information. Software is the applications installed in the servers, which specifically designed for specific industries such as banking etc.

1.2.2 Physical Infrastructure

Physical infrastructure consists of equipment that facilitates the smooth operation and maintenance of data centers. They mainly consist of air conditioning systems, power system, security systems and detection systems. Due to the heavy computing of the servers lots of heat is generated. In order for the servers to perform in an optimum level they must be maintained within a specific range given by ASHRAE [2]. The air conditioning systems help in maintaining this specified range. The power system is the backbone of a data center. It provides power for both the physical and IT infrastructure. Data centers consume lots of electrical energy. Security systems are deployed for security purposes within the data center. Detection systems range from fire detection, fire suppression systems, water detection, and rodent repellant systems.

1.3 Thermal management of Data Center

1.3.1 Introduction to Thermal Management

Enormous amounts of data are stored in data centers. It is safe to say that at least a million data requests per day are being processed by large data centers. Due to this, there is heavy workload on servers and storage devices in the data centers. This causes the storage disks and servers to heat up leading to reliability issues in data center [3].

1.3.2 Basics of Heat Generation in Data Centers

The components of a data center are made up of millions of building blocks of electronics namely transistors, inductors, capacitors and resistors. These are the building blocks of electronics. Current passing through the components of electronics result in power dissipation due to the resistance towards the flow of current. The heat should be dissipated in an orderly manner to avoid reliability issues.

Chapter 2

Introduction to Air-side Economization

2.1 Free Cooling

Data centers employ mechanical systems such as chilled water systems, CRAC cooling systems to provide the cooling needs of a data center. These systems usually comprise of mechanical sub systems like compressors and condensers. These systems make use of the heat exchange between a medium and the servers. In system such as chilled water systems, we employ a liquid coolant, which is made to absorb the heat released by the servers in data center. In air-cooled systems, large amounts of energy are spent in adjusting the CRAC unit to keep the desired temperature in the data center. The CRAC provides chilled air to the racks through the perforated tiles present in the data center. This chilled air passes through the racks and gets heated up. This hot air exits the data center via vents present in the ceilings. It then passes through a heat exchanger and is then used again to chill the racks. Many mechanical sub systems are utilized in ensuring that proper and efficient cooling take place within a data center.

Free Cooling is defined as the cooling technology in which we can cool the data center by using external ambient conditions. Through the use of free cooling we are able to reduce the energy consumed by the cooling system drastically

2.2 Classification of Free Cooling Systems

Free cooling systems are classified based on the medium use to cool the data center. They are mainly classified into two types namely air-side economization and water-side economization. As the name suggest the medium for cooling in the airside economization system is air while in water side it is water

2.3 Energy Consumption in a Data Center

According to the department of energy in United States of America, a typical data center would divide the energy consumption as shown in the figure 2.2. The efficiency as calculated by the department would be around 15%. The packaging density and power dissipation of a data center have increased leading to increase in heat fluxes. This can be clearly seen in the figure 2.1 shown by ASHRAE. The heat load for computing servers has tripled while for storage servers have doubled. This has a direct impact on the hot spots in a data center. As the footprint decreases, we have a direct increase in the number of hot spots in a data center. Air-cooling is a good cooling solution that is deployed in order to keep the temperature in the specified range.

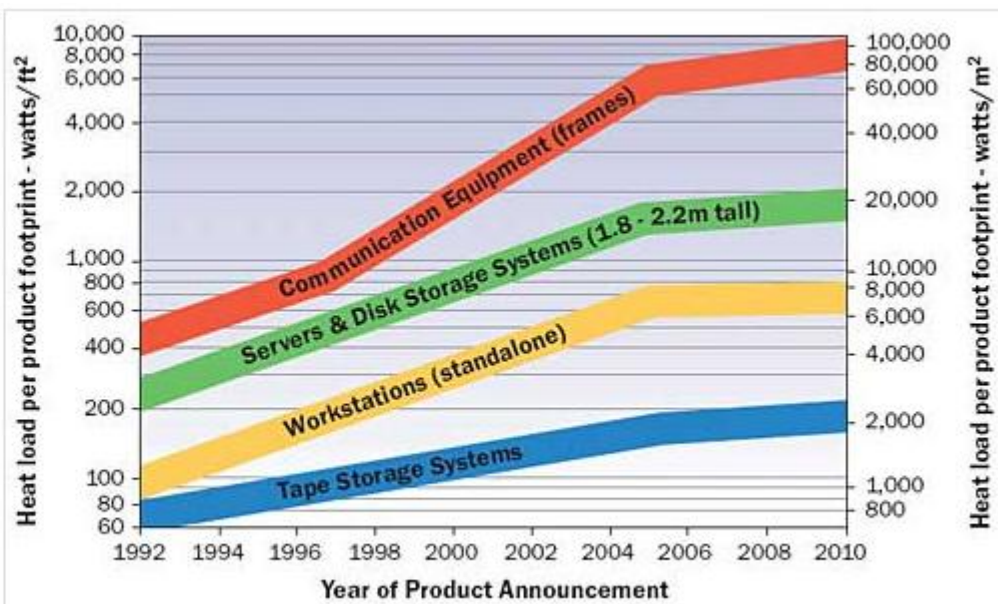

Figure 2.1 Heat load trends [3]

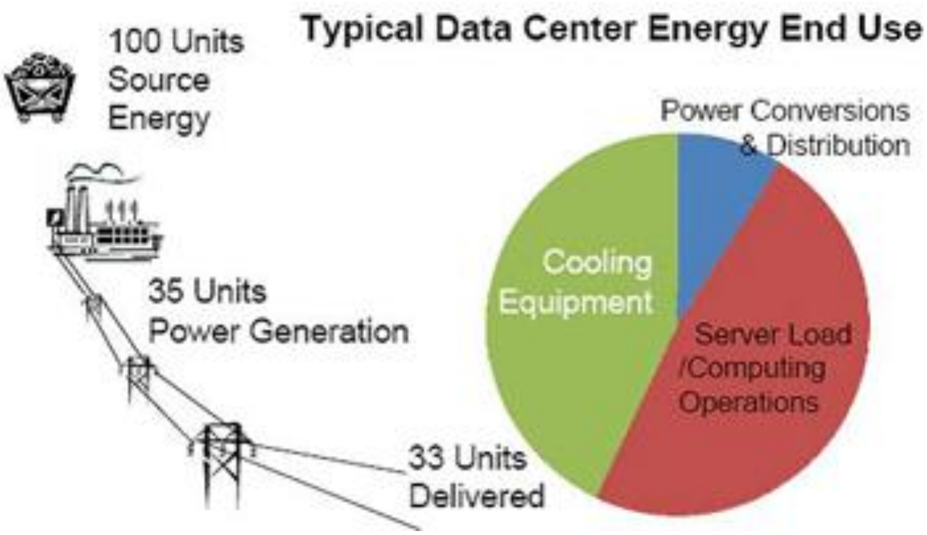

Figure 2.2 Data center energy use [11].

In the figure 2.3, we notice that cooling equipment takes up one third of the energy in a data center. This is further broken down into various components of the cooling system. The figure shows the energy consumption of various components. The pump power is the largest energy consumer followed by the Chiller power. This cooling system is further divided into two types namely IT and faculty. Except the server fans all the other cooling equipment falls under the faculty side

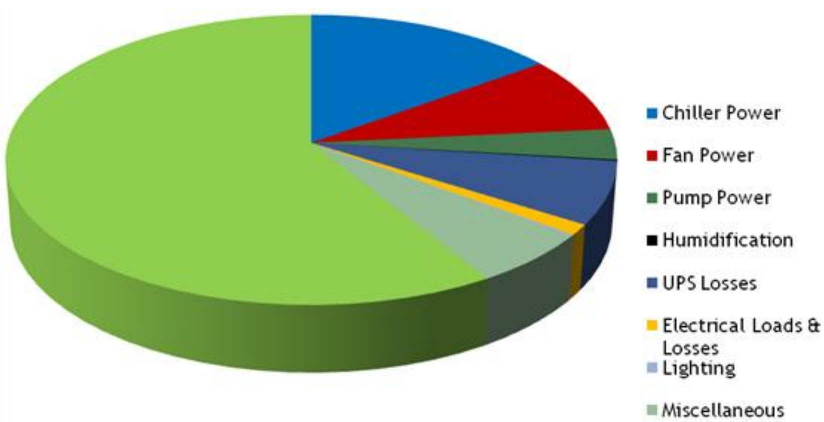

Figure 2.3 Breakdown of cooling energy [10].

2.4 Functioning of an Air-side Economizer

The air-side economizers reduce the usage of expensive mechanical cooling systems by drawing outside air to cool the data center. It is usually a system consisting of dampers, actuators, logic controllers and sensors. The most basic air side economizer is shown in the figure. The outside air damper regulates the amount of air to be drawn into the building. The return air damper regulates the possible amount of air that can be possibly recirculated within the data center. The exhaust air damper regulates the amount of air to be exhausted into the environment. A temperature sensor is placed outside to record and measure the temperature. This temperature is fed to the logic controller, which controls the outside air damper to let the appropriate amount of air into the system.

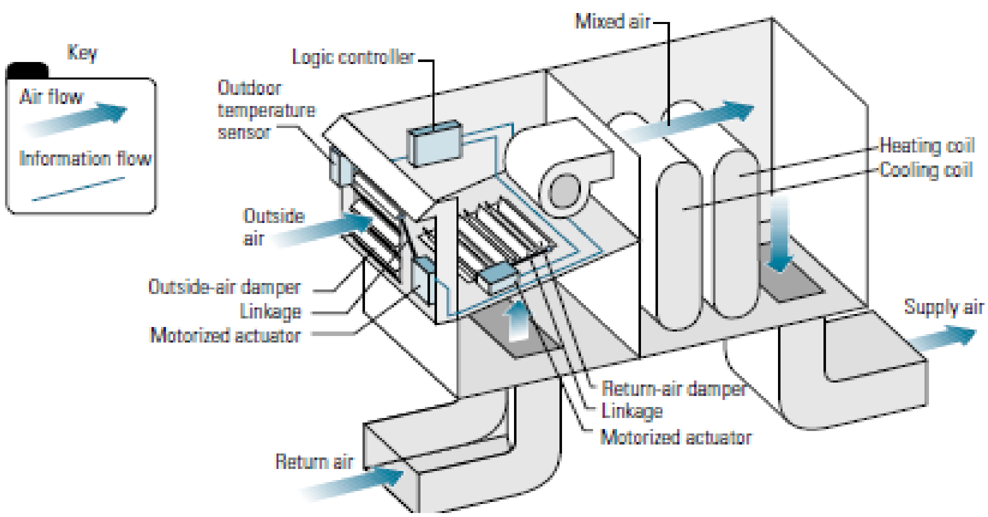

Figure 2.4 Components of air-side economizer [13].

Figure 2.4 shows a schematic of a simple air-side economizer. The HVAC system consists of a cooling tower, condenser, evaporator, and compressor. When the ambient environmental conditions are favorable in terms of temperature and humidity, we let the outside air into the data center through the dampers [13]. The CRAC unit supplies the chilled air to the racks through perforated tiles and is exits through vents present in the walls of the data center. This hot air is passed through a heat exchanger mostly a cooling tower and is recirculated through the CRAC unit.

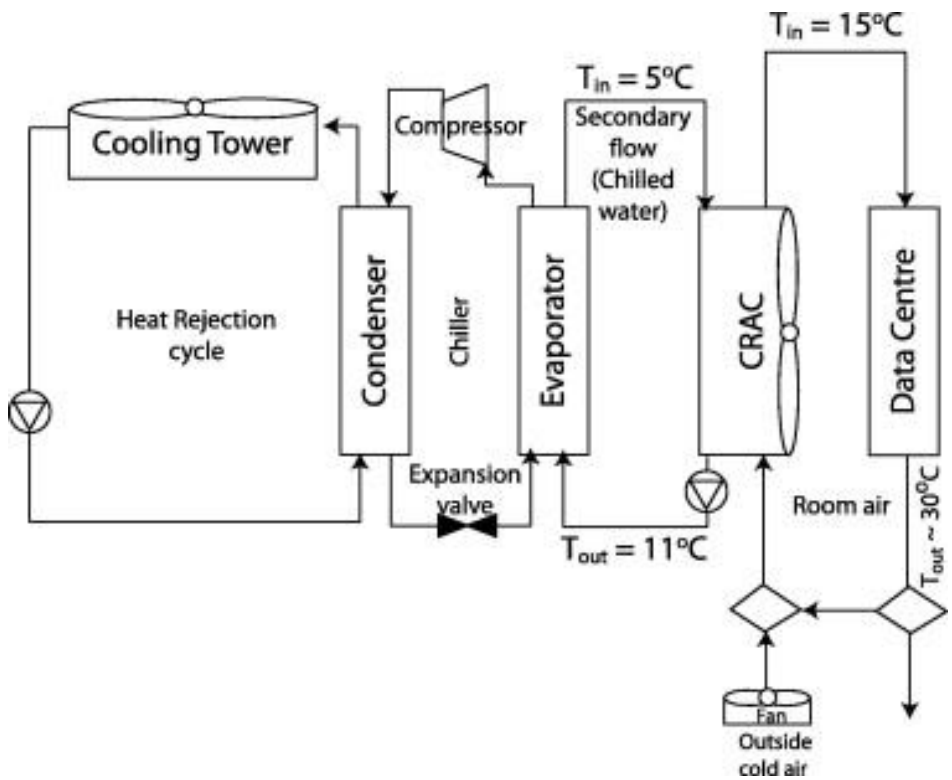

Figure 2.5 Schematic of air-side economizer [4].

2.5 Data Center Cooling through Air-side Economizer

Unlike typical buildings, the data centers must run 24- hours in a day, every day in a year. This causes an immense need in energy not only for the running of IT equipment but also for the cooling of it. Through air -side economizers' data centers draw ambient air from the environment to cool the components. Through this we eliminate the refrigeration cycle from the heat exchanger process[4]. This would save up on energy and cooling costs. Air- side economization is easier said than done. Through the introduction on large quantities of air, we must consider the possibility of the following:

1. The air present in the ambient environment may be a source of contamination to the data center
2. Controlling the humidity becomes a task
3. Additional expenditure is required to modify the data center to support air- side economization.

Sometimes it is observed that the temperature of the air in the environment is less hot than the air through the exhaust. It would be more economical to cool this air instead of the exhaust air. We can also reduce the temperature of the outside air by humidifying it. Through humidification, we can reduce the temperature of the air and bring the humidity level to an acceptable range as specified by ASHRAE [4]. The following figure is a schematic showing air filters, mixing chambers and humidifiers

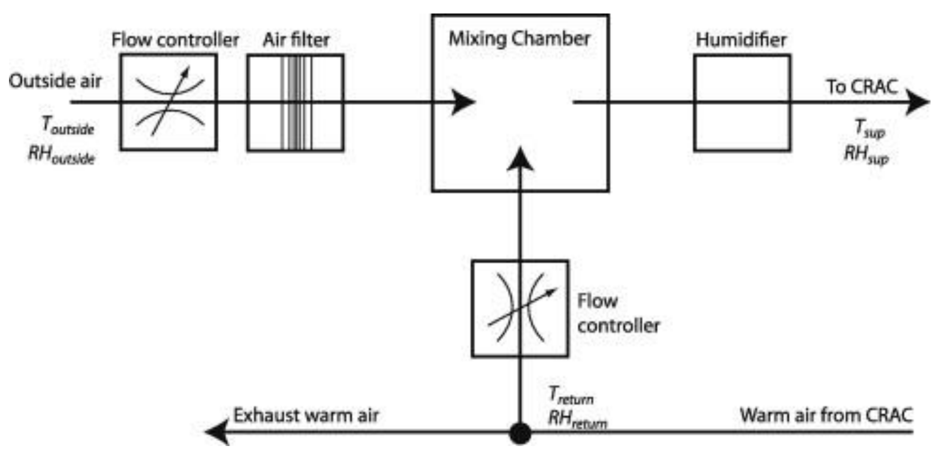

Figure 2.6 Air flow through an air side economizer [4].

2.6 Air-side Free Cooling Maps

ASHRAE updated the thermal guidelines for data centers in the year 2011. The allowable and recommended guidelines have been expanded thus the air side free cooling maps have been updated. According to these updated maps, around 70% of North America can implement air-side economizers for every hour if the temperatures are occasionally allowed to go until 35^0C. If the changes in the equipment are finalized and implemented, the amount of percentage shoots up to 90%. This is possible because these equipment work on the new A3 range as specified by ASHRAE [2].

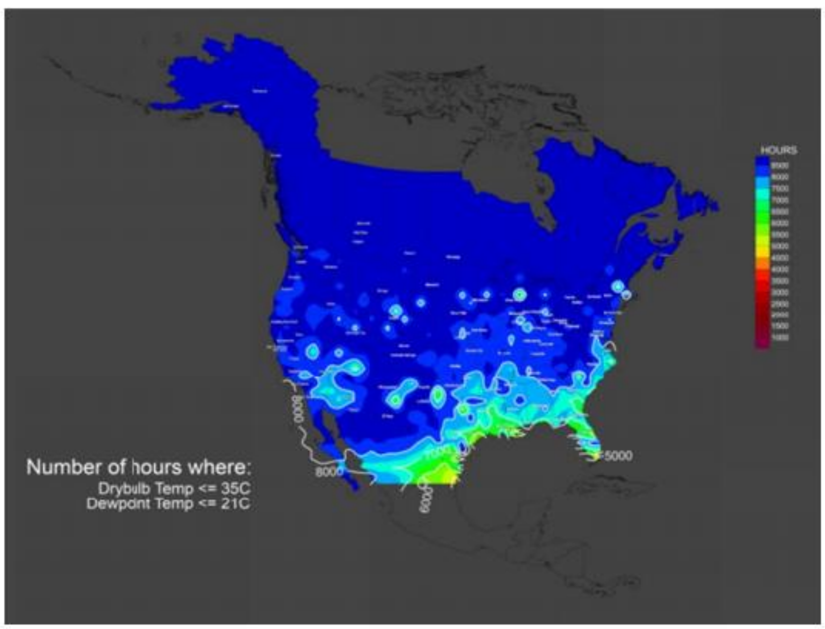

Figure 2.7 Map showing air-side economization in ASHRAE allowable A2 Range [9].

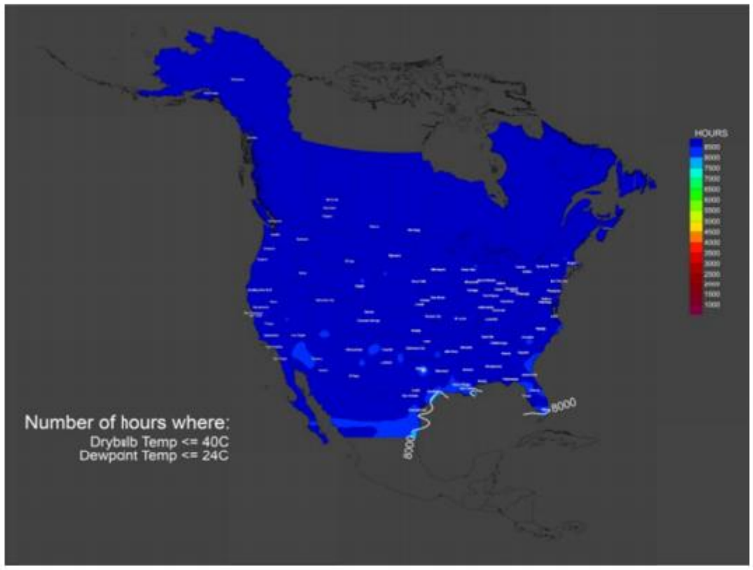

Figure 2.8 Map showing air-side economization in ASHRAE allowable A3 range [9]

Chapter 3

Psychometric Charts and their Importance

3.1 Influence of Environment

Different cooling technologies are implemented based on the conditions of the environment of a particular location. If the surrounding ambient temperature of a particular location is in the range of 18^0C to 27^0C, it would be wastage of resources to install and use cooling technologies. On the contrary, if the ambient surrounding temperature is above 27^0C we have to use cooling technologies as air side economizers wouldn't be able to provide the necessary cooling [5]. Thus, we conclude that the sudy of temperature profile and its history is of importance in determining the criteria for selection of cooling technology.

The different environmental classes for datacom facility according to ASHRAE datacom series will be discussed in this chapter.

3.2 Types of Telecom Environment

Telecommunication environments are broadly classified into three categories, namely:

Class A1: It is the type of data center where the environmental parameters are tightly controlled. These environmental parameters include temperature, relative humidity, dew point etc. Usually storage servers and enterprise products are the products designed for this data center

Class A2: It is usually an IT space or a laboratory environment where we have some control over the environmental parameters. These environmental parameters include temperature, dew point and relative humidity. In this class we mostly see personal workstations, volume servers and storage products.

Class A3/A4: It is usually an IT space or a laboratory environment where we have some control over the environmental parameters. These environmental parameters include temperature, dew point and relative humidity. In this class, we mostly see personal workstations, volume servers and storage products.

Class B: It is usually an office space, home or a transportable environment with less control over the environmental parameters. Usually the environmental parameter in this case is temperature. The products in this type of class are usually personal computers, workstations, printers and laptops

Class C: It is usually factory environment or an industrial environment with decent heating and ventilation systems. The products in this class are PDA's and controllers [2].

Table 3.1 Different Classes with Environmental control [2].

2011 Classes	2008 Classes	Applications	IT Equipment	Environmental Control
A1	1	Data center	Enterprise servers, Storage servers	Tightly controlled
A2	2	Data Center	Volume servers, workstations	Some control
A3	NA	Data Center	Personal computers, workstations	Some control
A4	NA	Data Center	Workstations, volume servers	Some control
B	3	Office, home, etc	Laptops , printers	Minimal control
C	4	industrial, factory, etc	Point of sale, controllers, PDA'S	No control

Table 3.2 Different Classes with their respective ranges [2].

Classes	Dry bulb temperature (^0c)	Humidity range non conducting	Maximum dew point (^0c)	Maximum elevation (m)	Maximum rate of change $(^0c/hr)$
A1	15 to 32	20% to 80% RH	17	3050	5/20
A2	10 to 35	20% to 80% RH	21	3050	5/20
A3	5 to 40	-12^0c DP & 8% to 80% RH	24	3050	5/20
A4	5 to 45	-12^0c DP & 8% to 80% RH	24	3050	5/20
B	5 to 35	8% to 80% RH	28	3050	NA
C	5 to 40	8% to 80% RH	28	3050	NA

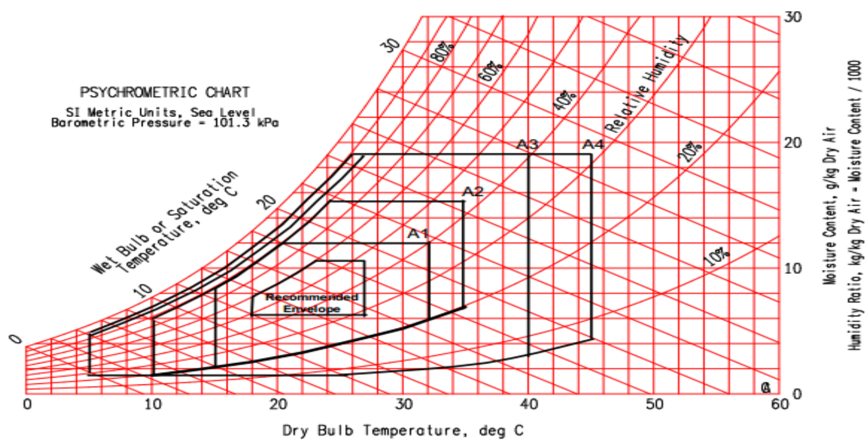

Figure 3.1 Recommended operating conditions [2]

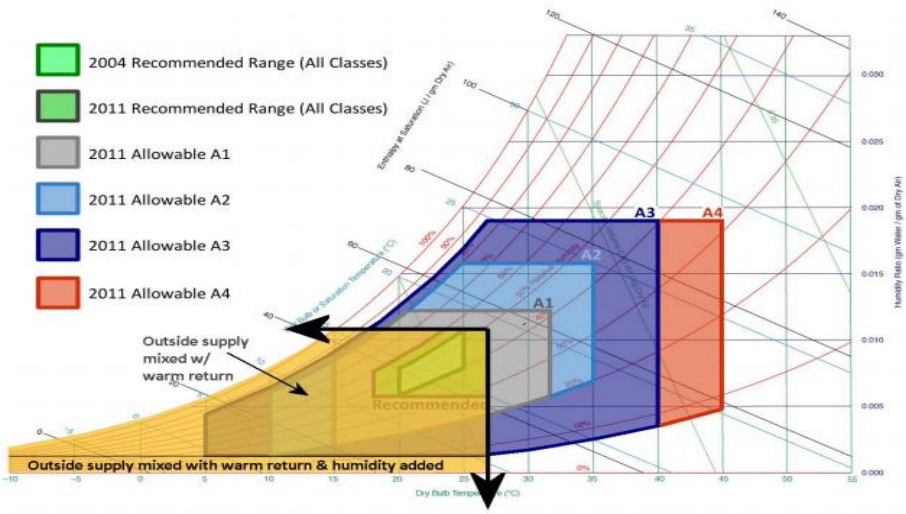

Figure 3.2 ASHRAE ranges [9]

The network devices used in data centers mostly are classified in the 1st and 2nd category. The recommended range is shown in figure 3.1

According to the ASHRAE datacom thermal guidelines the recommended envelope remains the same as shown in 2008. The Class A3 has been expanded to 5^0C to 40^0C. A notable change is that the moisture range has also been expanded from8% relative humidity and -12^0C dew point to 85% Relative humidity. The class A4 has been further expanded. The moisture range now extends up to 90% Relative humidity. The recommended envelope is the limits under which IT equipment would be most reliable while achieving energy efficiency

Chapter 4

Contamination in Data Centers

4.1 Introduction to Contamination in Data Centers

ASHRAE community published environmental guidelines for datacom equipment in 2011. This increases the operating range of data centers reducing energy consumption. There has been a recent increase in the hardware related failures in data centers. After careful analysis, we have found out that contamination is the main cause of these hardware failures. Due to contamination many equipment in the data center get corroded and reduce the reliability of electronic equipment present in that data center.

The electric signals travel faster due to the reduction of the sizes of the transistor. This overall affects the size of the electronic equipment present in data centers. As the size of electronic equipment decreases, the following happens

1. There is an increase in the packaging density of the equipment, as a result the heat load per unit area increases. The airflow is increased to cool the equipment. This leaves the equipment exposed to more contaminants present in the air causing a higher risk of failures
2. The sealing of components may vary due to the packing densities which further increases exposure to contamination and moisture
3. Electrical short-circuiting may occur due to spacing of PCB's
4. The effects of corrosion increase as their size reduce [6].

4.2 Corrosion due to Contamination

Corrosion is defined as the chemical product formed between the base metal and contaminants. It is usually the products formed when chemical reactions occur between water vapor, contaminants and the metal. These reactions are adversely effected by relative humidity and heat. Rapid fluctuations in relative humidity and heat cause pools of condensation to form. These pools of condensation react with contaminants becoming electrolytes. These electrolytes are the fundamental reason for electroplating. The base metal may be affected in various ways. A new layer may form on the metal due to corrosion of a layer of metal would deplete. This change in the metal affects the integrity of the equipment. It also forms insulating layers, which can cause thermal failures [1]. Corrosion may happen in disk drives, which may cause loss of valuable information. It may also occur on printed circuit boards and edge connectors causing fluctuations in electrical current.

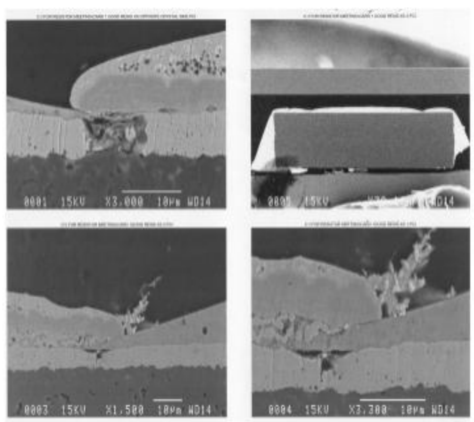

Figure 4.1 Silver sulfide formation due to sulfur bearing gases [6].

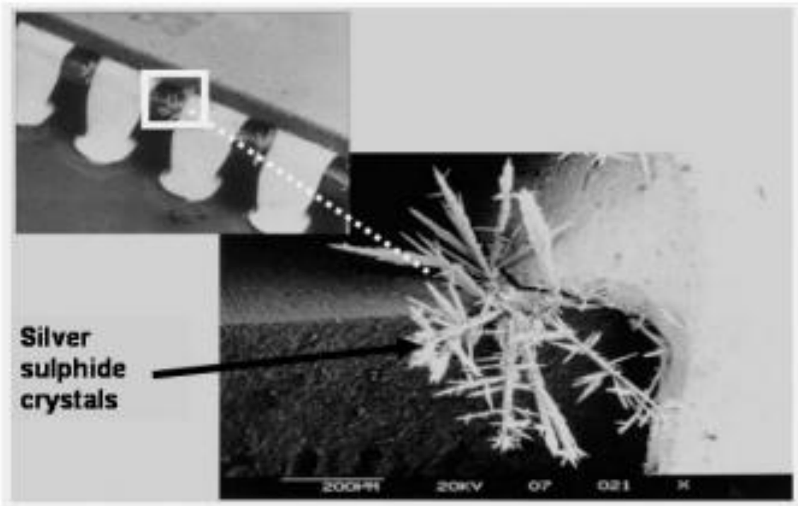

Figure 4.2 Silver sulfide on silver palladium [6].

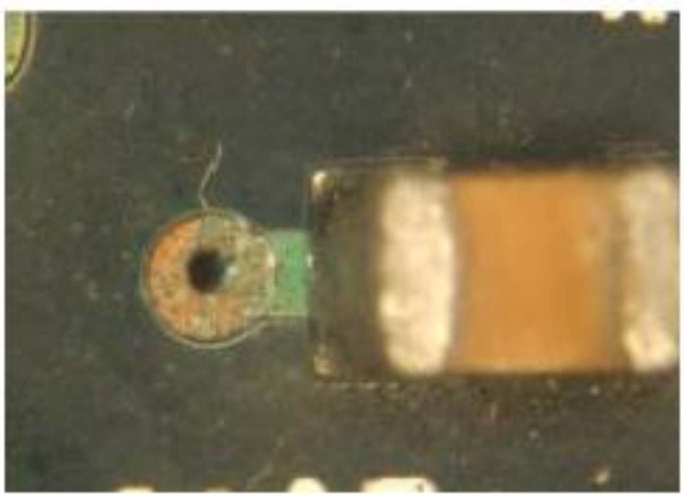

Figure 4.3 Plated hole corrosion due to magnesium chloride [6]

4.3 Particulate Contamination

The particulate contamination is usually classified into dust and salt. Dust enters into the data center even regardless of the filtration systems present. It causes mechanical, chemical and electrical failures. Dust may accumulate in a particular region blocking air, may settle on interfaces causing disturbances and may cause deformation of certain electronic equipment. In the presence of heat and moisture, dust may cause corrosion in certain electronic equipment. It may also cause short circuits and changes in impedances. Dust is usually corrosive when its deliquescent humidity is lower than that of a data center. Deliquescent humidity is defined as the relative humidity at which it contains enough moisture to promote corrosion. When the deliquescent humidity is lower dust, become wet dust causing corrosion in data centers. Dust promotes ion migration, which increases chances of corrosions in data centers. Another important particulate corrosion is zinc whiskers. These whiskers may be present in floor tiles or floor cables. Zinc flakes are one of the most dangerous particulate contaminant. It causes galvanic corrosion when it meets metal present in the IT equipment. Zinc flakes have to be periodically checked by flashing light under the tiles. These whiskers settle on electronic equipment causing changes in electrical conductivity causing thermal and electrical fluctuations. Data centers are kept clean following ISO class 8 standards shown in the figure below.

Table 4.1 ISO 14644 classes with particle concentration [6]

ISO CLASS	>0.1µm	>0.2µm	>0.3µm	>0.5µm	>1µm	>5µm
Class 1	10	2				
Class 2	100	24	10	4		
Class 3	1000	237	102	35	8	
Class 4	10000	2370	1020	352	83	
Class 5	100000	23700	10200	3520	832	29
Class 6	100000	237000	102000	35200	8320	293
Class-7				352000	83200	2930
Class-8				3520000	832000	29300
Class 9					8320000	293000

Particulate contamination is present in the environment in the form of dust and particles displaced in air. These particles are present due to environmental condition such as storms, tornados or by fabricated machines, improper burning of fossil fuels, industrial discharge. Particulate contamination is not limited to the ambient air present outside the data center; sometimes dust and particulate contamination effervesce for the clothes of the data center employee. In order to avoid this, special suit must be worn when entering the data center

4.3.1 Air Filtration (Particulate Contamination)

According to ASHRAE standards the data center room must be kept to ISO class 8 standards [6]. When using air- side economizers the air entering the data center must be filtered by MERV 13 filters and the air circulating the data center must be MERV 8 filters. The downside of using these filters is that they are expensive to replace. The life expectancy of these filters is small so they must be changed periodically. Usually these filters are made of organic substances like cellulose

Table 4.2 MERV filters [12].

MERV Rating	Efficiency	Particle Size	Applications	Filter Type
1-4	<20%	>10 µm	Residential Light Commerical Equipment Fiber Glass Polypanel	Permanent Metal Foam
5-8	<20-60%	3-10µm	Commercial Industrial	Pleated Filters Tackfied
9-12	40-85%	1-3µm	Commercial Telecommunications Industrial	Best Pleated Rigid Box Rigid Cell Bag
13-16	70-98%	0.3-1µm	Clean rooms	Hepa

4.4 Gaseous Contamination

In the context of contamination, we have classified gases into three categories namely acidic, caustic and oxidizing gases. Acidic gases usually cause more amount of corrosion in IT equipment. They are usually sulfur bearing gases and chlorine. The caustic gases such as ammonia and oxidizing gases such as ozone also cause corrosion but relatively low when compared to acidic gases. These gases are present in the atmosphere due to the burning of fossil fuels, industry discharge, pollution and volcanic eruptions. In the case of air-side economizers the ambient air is used to cool the data center. This ambient air contains gaseous and particulate contamination. Gaseous contamination isn't limited to ambient air present outside the data center, Sometimes printer discharges, cleaning supplies and cigarette smoke also cause corrosion within the data center.

4.4.1 Air Filtration (Gaseous Contamination)

The most common method for filtration of gaseous contamination is the use of gas phase air filters. These filters can be divided based on filtration techniques namely adsorption and chemical reaction. Adsorption is the process by which particles are bound to a particular surface. The binding is weak compared to other processes. The most common material used for adsorption is activated carbon and silica gel. The activated carbon is effective due to large surface area and porosity. The other method is making the gaseous contamination react chemically with a substance to get harmless by products. The efficiency of these filters is up to 95%.

4.4.2 Contamination Measurement Techniques

The two standard methods of measuring contamination in a data center namely direct gas measurement and reactivity monitoring [7]. The above-mentioned methods are both real time measuring methods. The direct gas measurement systems use gas-monitoring equipment. Reactivity monitoring uses special corrosion coupons to measure the amount of corrosion. These coupons are kept in the data center for a period of one month. The standard is defined by the amount of corrosion layer formed on the coupons. The three metal coupons used are copper, and gold. Copper has its drawbacks, as it is overly sensitive towards relative humidity and insensitive towards chlorine gas. Chlorine is extremely corrosive to many metals used in IT equipment [6]. In order to measure corrosion more accurately silver and gold coupons are also included in the reactivity monitoring.

4.4.3 Gaseous Corrosive Levels

According to ASHRAE standards, the data center severity levels are classified into 4 classes. G1 is the most mild where the copper corrosion is below 300Å. G2 environment is classified when the corrosion rate us below 1000 Å.G3 environment is classified when the copper reactivity is less than 2000 Å. The harshest environment GX is classified when the copper corrosion is greater than 2000 Å.

Table 4.3 Environmental Classification [6].

Severity level	Environmental description	Copper reactivity level	Environmental Reliability
G1	Mild	<300	Corrosion not a factor
G2	Moderate	<1000	Corrosion may be a factor
G3	Harsh	<2000	High Probability of corrosive attack
GX	Severe	>2000	On specially designed and packaged equipment would be able to survive

Through the literature search, we have found out most common gases present in the atmosphere that may cause corrosion. A table is calculated showing the list of gaseous contaminants and their harmful effects on IT equipment. These gases enter into the data center through the air side economizers are hamper the electronic equipment present in it

Table 4.4 Common pollutant gases [8].

Pollutant Gas	Typical outdoor range (µg/m^3)	Typical Indoor range (µg/m^3)	Rationale for Selection
SO_2	3-185	1-40	Major Pollutant. Known to attack various metals
NO_2	20-160	3-60	Major pollutant know to attack Ferrous metals
H_2s	1-36	0.2-1	Stress corrosion accelerator.
O_3	10-90	7-65	Major pollutant degrades polymers
HCl	0.3-5	0.08-0.3	Destabilizes passive films by lattice impregnation
Cl_2	Less than 5% Cl_2 Levels	0.004-0.015	Destabilizes passive films

4.5 Copper Corrosion

Previous tests performed by Muller had indicated the types of films that may form on the copper due to corrosion. The films were composed of copper oxide (Cu_2O), copper sulfide (Cu_2S) and an unknown film (Cu-unk). The copper corrosion is would be the thickness of the thin film individually if present alone. If more than one film was present the thickness would be added [1].

4.6 Silver Corrosion

Previous tests performed by Muller had indicated the types of films that may form on the silver due to corrosion. The films were composed of silver oxide (Ag_2O), silver sulfide (Ag_2S), silver chloride (AgCl) and an unknown film (Ag-unk). The silver corrosion is would be the thickness of the thin film individually if present alone. If more than one film was present the thickness would be added [1].

Chapter 5

Experimental Setup

5.1 Test Rig Setup

For the following test we use the test rig chamber provided by Purafil. The test chamber is designed with mixing manifolds and diffuser plate for even flow of gases in the chamber. The chamber is made up of polycarbonate-Lexan. Polycarbonate Lexan is chosen as it has thermo formability making it a good air tight product. The cables for the sensors can be passed into the chamber by drilling holes in the chamber. Polycarbonate Lexan is relatively easy materials for drilling holes. The test rig dimensions are 12” long by 5”wide by 11” high. The thickness of the chamber is 0.25 Inches.

Figure 5.1 Test Chamber

5.2 Copper and Silver Coupons

As discussed earlier the corrosion coupons provided by IBM were used for this experiment. These coupons are made up of copper and silver material. The silver and copper film formation is an indication of the corrosiveness of the environment. These coupons are placed on the coupon chamber within the test rig. These coupons are sealed in an airtight container so that they do not undergo the process of corrosion when not in use.

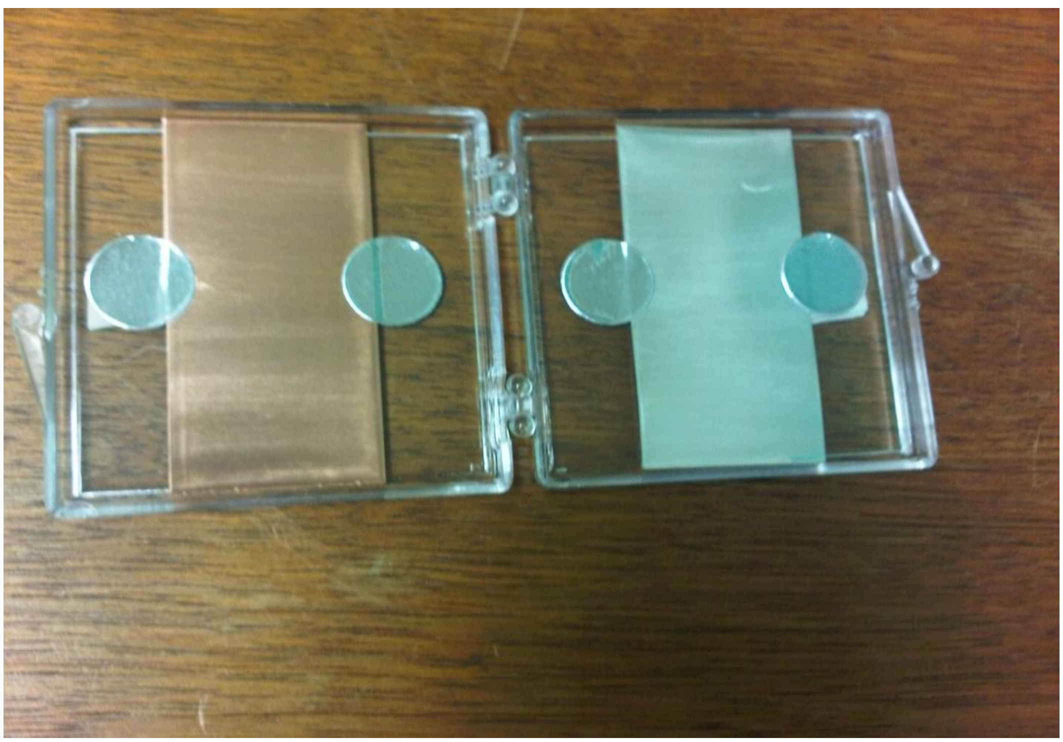

Figure 5.2 Copper and silver coupons

5.3 Data Hub

The data hub is the main link between the sensors present in the chamber and the laptop. It is manufactured by iButton link Technologies. It consists of (5) 1-wire busses of which 1 are internal and the other 4 are external. It is designed to work efficiently with both short and long Ethernet cables. The firmware present in the data hub is adaptive and it adjusts automatically according to the network parameters. The four ports in the data hub can be used individually or together. It provides +12V and +5V on the cable as the 1 wire bus.

Figure 5.3 ibuttonlink data hub

5.4 Corrosion Sensor

The corrosion sensor used for this experiment is manufactured by ibuttonLink. It consists of two ports. The corrosion sensitivity is 1A a day and has a life span of 2 years. It consists of very thin metal layers which are deposited on silicon. The film thickness is fabricated such that is smaller than the width and length so that only film thickness causes change in resistance. In this corrosion sensor, the layers are arranged in the order of increasing thickness so that we can get good sensitivity as well as good life span for the sensors. The sensor works on the principle of resistance measurement. When corrosive layers form on the metal the resistivity changes, as they are not conductive. This change in resistance is converted to thickness of the film/ Taking the thickness of the film over a certain period we get the corrosion rate. Wheatstone bridge is used for internal detection electronics in the sensor. The data received is stored using IBM's Measurement and management technologies. This technology can be used for a holistic approach in the study of atmospheric conditions in a data center [15].

Figure 5.4 Corrosion sensor

5.5 Relative Humidity and Corrosion Sensor

The relative humidity and temperature sensor is fabricated by ibuttonlink. The sensors consists of two ports namely the Port 1 and Port 2. The humidity will be reported in the ranges between 0.8VDC to 4.07VDC. The zero humidity is represented by 0.8VDC while 100% humidity is represented by 4.07VDC. The power supply must be constantly above 4VDC the ideal being 5 VDC [15].

Figure 5.5 Relative humidity and temperature sensor

5.6 Differential Pressure and Temperature Sensor

The differential pressure and humidity sensor is fabricated by ibuttonlink. This particular sensor incorporated the Omron flow sensor model D6F-P0010A. It is deployed as a pressure sensor or an air flow sensor [15]. There is a provision to place a output barb at any location through tubing. This makes it easier to measure pressure differential inside the chamber and outside the chamber. It also reports the temperature.

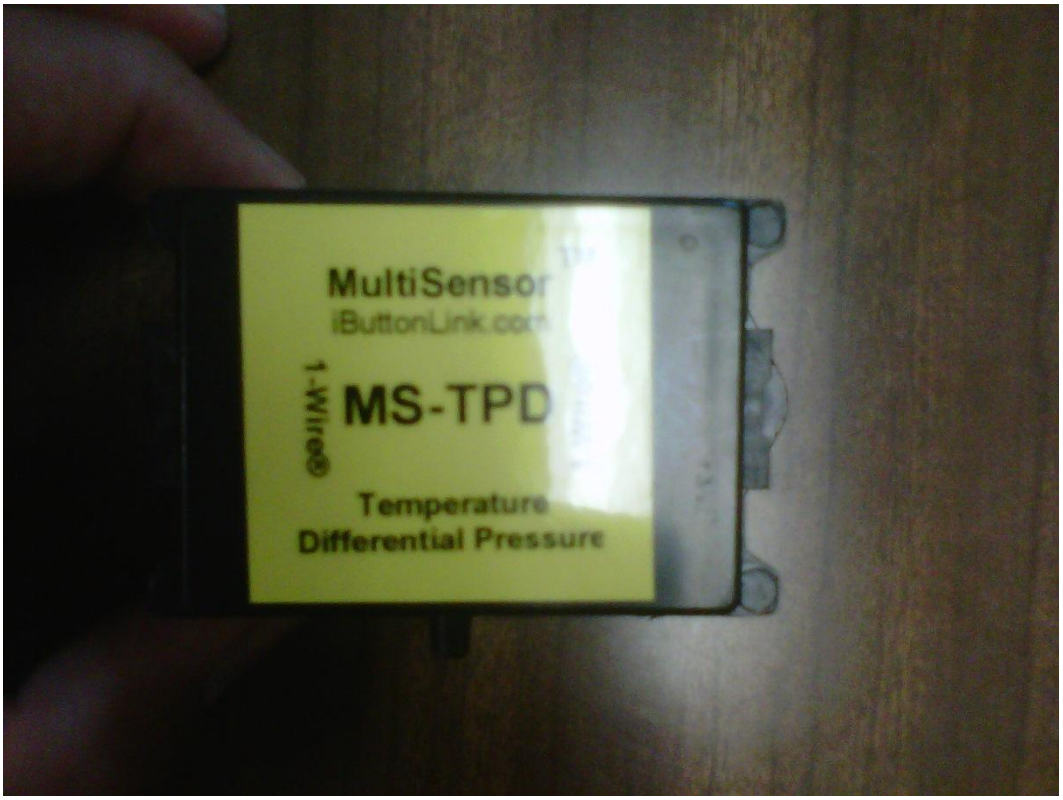

Figure 5.6 Differential pressure and temperature sensor

5.7 Sulfur Dioxide Gas

Sulfur dioxide one of the most common gases that cause corrosion in IT equipment. In this experiment, we intend to use sulfur dioxide as the test gas. The cylinder has a CGA of 660 and was purchased for Praxair. The gas mixture is a pre mixture containing 375 parts per million of sulfur dioxide in nitrogen.

Figure 5.7 Sulfur dioxide gas

5.8 Regulator

The regulator has a CGA of AS 660. This regulator is corrosive resistant as the gases used are corrosive. The pressure range is between 0-60Psgi. This particular regulator was chosen because of its corrosion resistive properties and compatibility with the cylinder provided by Praxair. The regulator is very sensitive and was cleaned ultrasonically so that we do not get any other contaminants in the chamber.

Figure 5.8 Two-step non-corrosive regulator

5.9 Humidifier

A humidifier is used to keep the relative humidity at a constant range between 60-70% RH. The contain gels that would absorb the moisture if the relative humidity was above the specified limit. On the other hand, they would release moisture when it is below the required limit.

Figure 5.9 Humidifier

5.10 Ethernet Cables

Standard Ethernet cables are used to connect the sensors to data hub and the data hub to the laptop. These Ethernet cables vary in lengths with respect to where they are used.

5.11 Teflon Piping

Teflon piping is used to transport the gas from the regulator into the test chamber. Teflon is used as it works in the pressure range we have selected and it has corrosion resistive properties.

5.12 Lantronix Software

In order for the hub to function properly and get the required readings, we must assign a different IP address. This is done by using the Lantronix device installer V 4.3 software created by Lantronix cooperation. Through this assigned IP address, we are able to communicate with the MMT hub.

5.13 Test Procedure

Due to the hazardous nature of this experiment it was carried out in MESTEX Inc. MESTEX is a very famous HVAC company located in Dallas. The test chamber is placed inside an indirect evaporative unit in order to flush out all the sulfur dioxide when the experiment is completed. The sulfur dioxide is a heavy gas so it tends to sit in the chamber. The cylinder is placed in a dolly and is safely restrained using a chain to meet the safety conditions. For better safety, the threads in the regulator are covered with Teflon tape for minimizing leakages through it. The hose fastener is attached so that the hose is fastened safely avoiding any injuries.

Figure 5.10 Cylinder safely strapped to ensure safety

The cables are connected to the sensors through the holes present in the cover of the test rig. The humidifier is placed in the test rig. The test rig is sealed using Teflon tape to prevent any leakages during the course of the experiment. A sample reading of the sensors is taken to make sure everything is in order. The corrosion coupons are placed carefully in the chamber. They are placed near the corrosion sensor so that we are able to get relative reading.

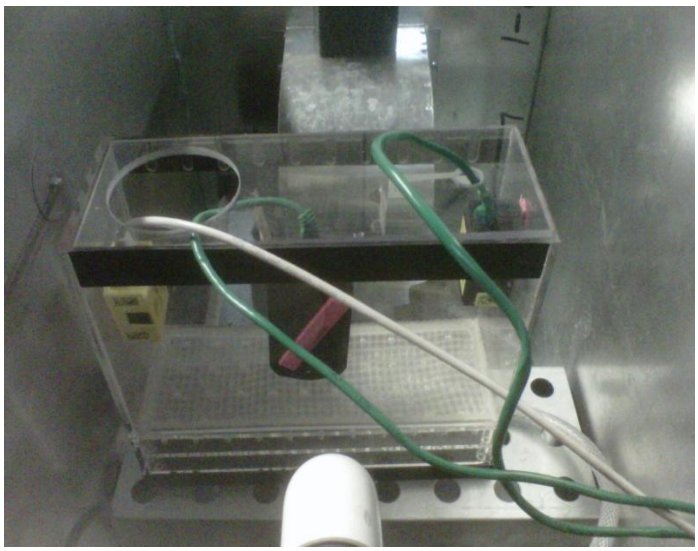

Figure 5.11 Cable arrangement

After all the sensors have been checked, the gas is introduced into the test chamber. It is introduced at a steady rate of 0.1 PSI. We want to introduce the gas into the chamber gradually so that the gas doesn't flood the chamber causing excessive leakages and pressure. Readings are taken every five minutes to check the amount of corrosion, relative humidity, temperature and differential pressure.

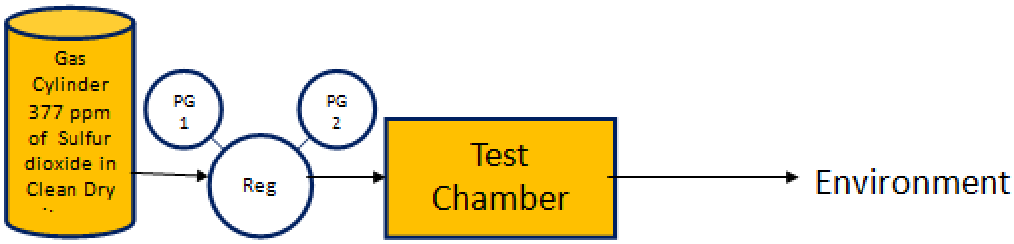

Figure 5.12 Schematic of test setup

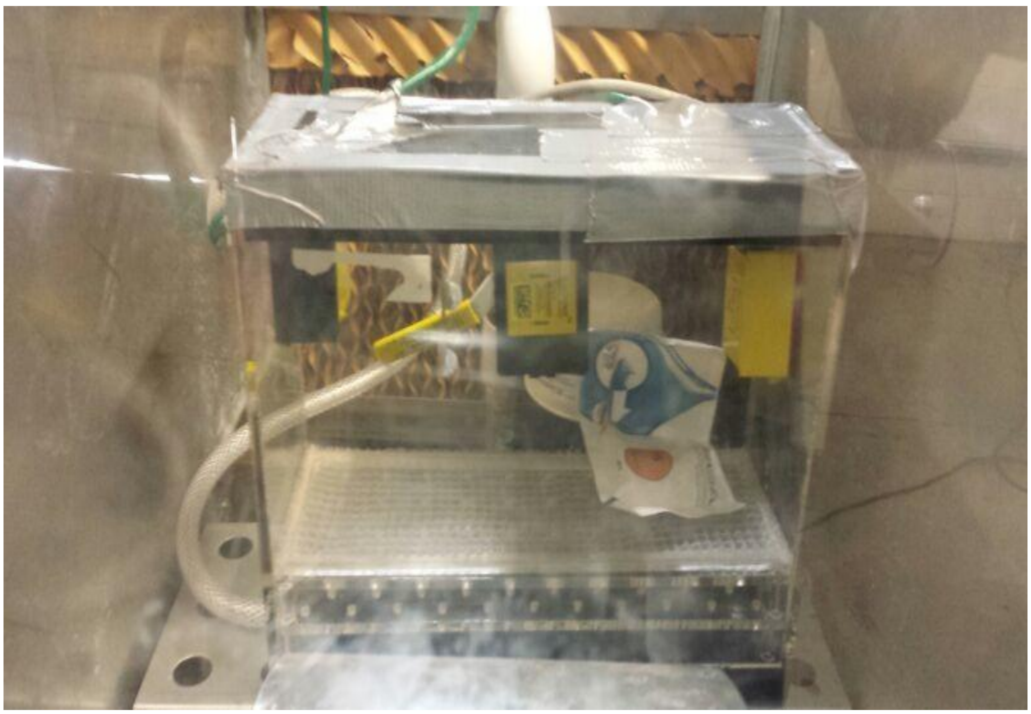

Figure 5.13 Test rig setup

5.14 Result, Conclusion and Result

5.14.1 Result and Discussion

After plotting the graphs between relative humidity and conductive resistance of the corrosion sensors we realize that the corrosion rate is increasing at a steady pace. The dips in the graph are due to the introduction of the sulfur dioxide and nitrogen gas. Through this we infer that when the gas is injected into the chamber the relative humidity drops drastically. After analyzing the gel present in the humidifier we can clearly say that the coupons had reacted with sulfur dioxide and not any other compound. Error readings were recorded during the course of the experiment. Figure shows conductive resistance plotted against relative humidity with errors.

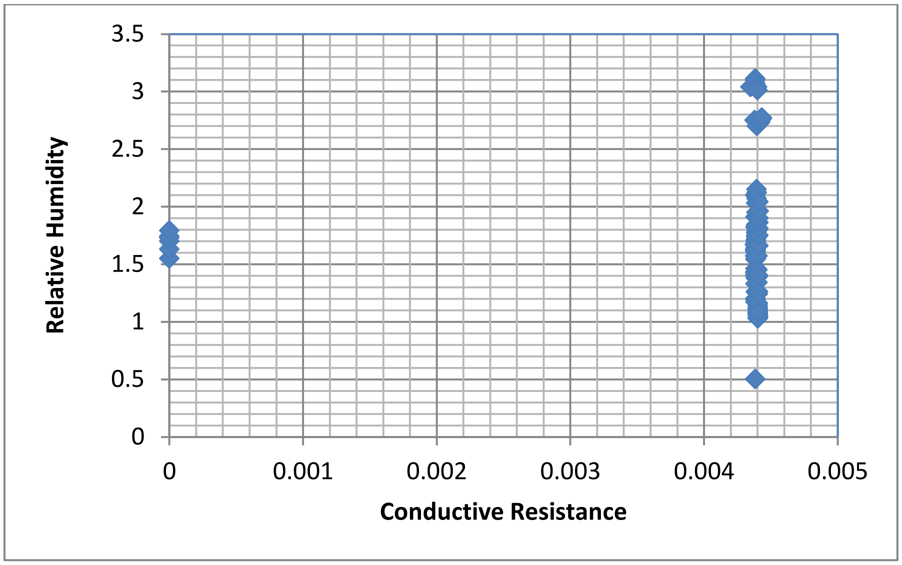

Figure 5.14 Relative humidity Vs. Conductive resistance (including errors)

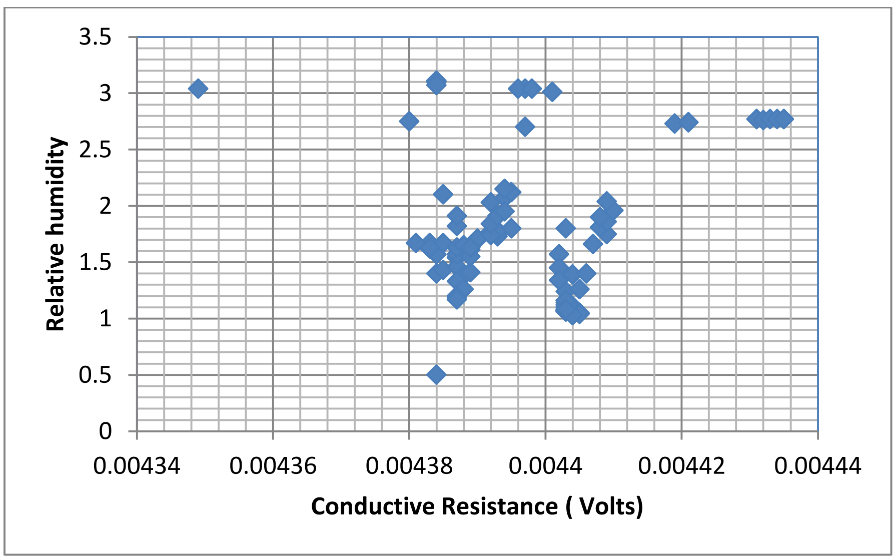

Figure 5.15 Relative humidity Vs. Conductive resistance (excluding errors)

We get the graph shown in figure when we used the data supplied to us by IBM Corporation. This gives us an idea of how the conductive resistance relates to the corrosion thickness. In this experiment we are in the range below 1V. If the coupons and the corrosion sensors were to be exposed to the sulfur dioxide gas for extended period of time we would eventually cross the range of 1V.

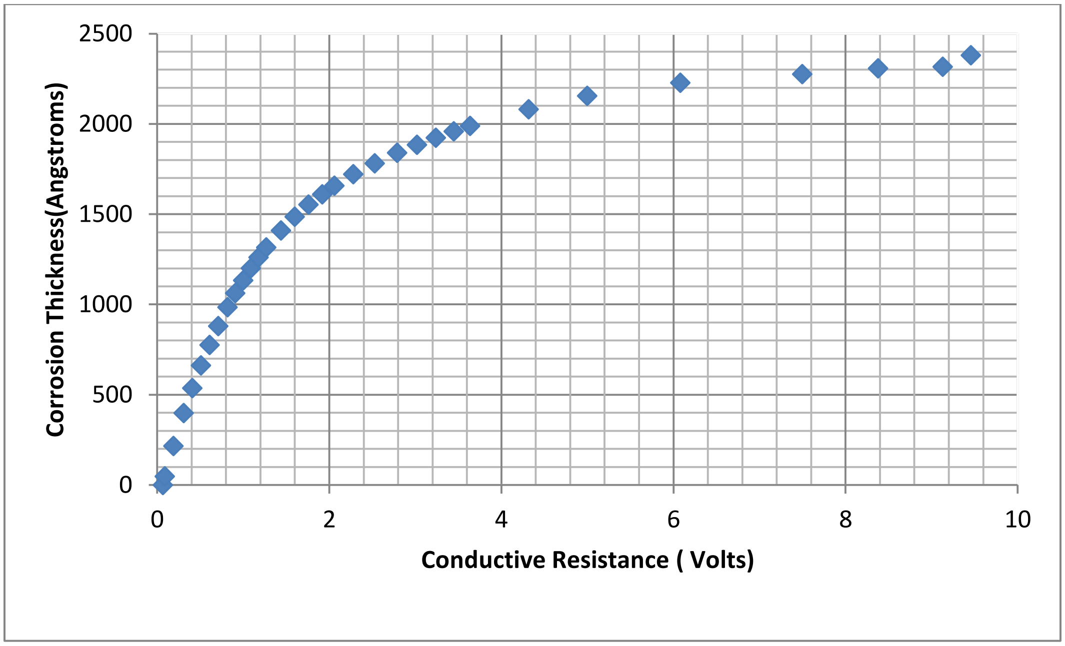

Figure 5.16 Conductive resistance Vs. Corrosion thickness

5.14.2 Conclusion

It is concluded that the silver and copper coupons placed in the test chamber were corroded due to their exposure to sulfur dioxide and sulfur dioxide alone. The relative humidity drastically reduces due to the introduction of sulfur dioxide. This is due to the fact that the mixture of sulfur dioxide and nitrogen absorb the moisture present in the test rig. A steady increase in the conductive resistance values shows us that corrosion is taking place at a steady rate.

5.14.3 Future Work

A bubbler could be used to cover the humidity drop during the introduction of the gas. Through this we can keep the relative humidity at a steady rate and measure the corrosion more accurately. Other gases like ozone; nitrogen dioxide etc. can be used instead of sulfur dioxide to quantify corrosion.

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Biographical Information

Rahul Raghunathan graduated with Bachelors in Mechanical Engineering from Jawaharlal Nehru Technological University, India in May 2011. He decided to pursue masters in mechanical engineering and joined Electronic MEMS and Nano electronics system packaging center at University of Texas at Arlington. During his time in the University of Texas at Arlington. He received the mechanical and aerospace scholarship. He had gained valuable industrial experience when he worked on his thesis at MESTEX Corporation located at Dallas