DESIGN AND FABRICATION OF A COST-EFFECTIVE HUMIDITY CHAMBER FOR CONTROLLED ENVIRONMENT TESTING

BY

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Declaration

"The project submitted herewith is a result of my own investigations. All information that has been obtained from other sources had been fully acknowledged, including the use of generative AI technology. I understand that plagiarism constitutes a breach of university rules and regulations and would be subjected to disciplinary actions"

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Abstract

This project focuses on the design and fabrication of a compact, cost-effective humidity chamber for evaluating solder joint reliability under controlled environmental conditions. Commercial humidity chambers are often expensive and bulky, limiting their accessibility in academic and small-scale research settings. To address this, the project developed a prototype using PVC foam board and low-voltage components such as a 5V humidifier, 12V fan, and thermo-hygrometer. Design selection was guided by tools like the Pugh Matrix, emphasizing portability, ease of fabrication, and material efficiency. The completed chamber successfully maintained internal humidity between 77% and 79%, demonstrating its ability to simulate consistent environmental conditions for small-scale solder testing. The outcome offers a practical solution for low-budget research environments and contributes a functional, scalable tool for studying humidity-related degradation in electronic components, with opportunities for future upgrades through automation and data logging.

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Chapter 1 Introduction

This chapter provides information regarding the study's background, problem statements, objectives, research questions, scope and limitations, and potential benefits. This chapter also presents an outline of how the product will be fabricated.

1.1 Background and Motivations

Humidity chambers play a crucial role in reliability testing across diverse industries such as electronics, automotive, and materials science. In the field of electronics, uncontrolled humidity can lead to significant deviations from desired functionality or even permanent device failure [1]. Solder joints are known to degrade over time when exposed to fluctuating humidity, resulting in problems like interfacial corrosion, delamination, and mechanical failure. As demands for miniaturization and higher packaging densities increase, the need for a reliable and cost-effective humidity testing setup has become more crucial than ever.

Commercially available humidity chambers can be prohibitively expensive, especially for researchers and small-scale manufacturers conducting limited experiments. This has prompted the development of various in-house solutions, ranging from simple setups using common laboratory equipment to more sophisticated custom-built chambers [2][3]. These homemade systems offer a more accessible and flexible approach to humidity testing, allowing for greater control and customization to meet specific experimental requirements.

Additionally, commercially available humidity chambers tend to be large, costly, and limited in their ability to facilitate parallel testing. These chambers may also lack the necessary accommodations for convenient electrical connections, hindering the monitoring of sample performance during environmental testing. To overcome these constraints, researchers have investigated developing custom, affordable humidity chambers that can provide accurate humidity control, support parallel testing, and allow for easy access to samples [2][4].

This research aims to address the disconnect between the need for reliable environmental testing and the availability of accessible testing equipment. By designing and fabricating a compact, cost-effective humidity chamber, this study seeks to provide a practical solution for evaluating solder performance, catering to the requirements of academic and small-scale industrial settings [2][3][4]. Ultimately, the project endeavors to bridge the accessibility gap in environmental testing and deepen the understanding of how humidity affects the reliability of electronic components.

1.2 Problem Statement

A humidity chamber is a controlled device that recreates precise humidity and temperature conditions for testing purposes. It is vital in research and industry, allowing the examination of material durability, electronic component reliability, and product performance under different humidity levels [5]. By mimicking real-world environments, humidity chambers enable researchers to understand how humidity affects various materials and processes, making them crucial tools for quality control and product development.

Recent studies have underscored the importance of controlled environments for testing solder joints and other sensitive materials using humidity chambers [6]. However, most existing chambers are large, expensive, and designed for industrial applications, restricting their accessibility for small-scale research and educational purposes. Researchers often encounter challenges such as high operational costs, complex setups, and limited sample capacity, hindering their ability to conduct frequent and cost-effective testing [7].

To address these challenges, this project aims to develop a cost-effective, miniature humidity chamber that offers essential environmental controls for academic and small-scale testing. By focusing on a compact design, this chamber will provide researchers with an affordable alternative that retains the necessary functionality, facilitating studies on solder performance under controlled conditions. This will also enhance accessibility for students and researchers conducting preliminary experiments without the need for expensive commercial equipment.

1.3 Objectives

This research aims to design and fabricate the humidity chamber to test solder performance under a controlled environment. Further specific objectives are listed as follows:

1. To study the working principles of humidity chambers for controlled
2. To design a humidity chamber with control of humidity level and temperature.
3. To fabricate the humidity chamber according to the proposed design.

1.4 Scope and Limitations of the Research

This research will focus on the design of the humidity chamber solely to evaluate the performance of small-scale electronics, particularly solder joints. Furthermore, the fabrication will focus exclusively on testing the humidity factor. The chamber will also control humidity and temperature within a reasonable range to simulate realistic environmental conditions, without replicating extreme conditions like a high-pressure environment. Due to budget constraints, the research will employ cost-effective materials and sensors that are feasible for a diploma-level project, ensuring affordability without compromising essential functionality.

The research was limited by the project timeline restrictions, which prevented a more in-depth investigation of the effects of humidity on solder performance. As a result, the humidity and temperature control system will be basic, with minimal automation, and it will also accommodate a limited number of samples per test due to the small-scale design of the project.

1.5 Contribution

This project contributes to the field by providing a cost-effective and portable alternative to conventional humidity chambers, which are often expensive and stationary. By developing a home-made humidity chamber, this project enables researchers with limited budgets to conduct experiments that require controlled humidity conditions without compromising functionality.

The significance of this innovation lies in its portability and accessibility. Researchers who face restrictions in accessing their laboratory can bring the chamber to alternative locations, such as their homes, ensuring uninterrupted research progress. This flexibility improves convenience and opens opportunities for experimentation beyond traditional laboratory environments.

Chapter 2 Literature Review

2.1 Introduction to Soldering Technology

There are mainly two types of soldering Technologies used in the semiconductor industry, which are Through Hole Technology (THT) and Surface Mount Technology (SMT).

2.1.1 Through Hole Technology (THT)

Through-Hole Technology (THT) is a method used in electronic assembly where the leads of electronic components are inserted into pre-drilled holes on a Printed Circuit Board (PCB). Once the leads are in place, they are soldered on the opposite side of the board, creating a strong mechanical bond [8]. This technology was widely used way before the invention of Surface-Mount Technology (SMT). This was mainly due to its reliability and the robust connections it provides. THT is used for components that goes through mechanical stress, such as connectors or large components, which makes it an important technology in the electronics industry [9].

Furthermore, another key reason why THT is still popular till this day is its ability to create durable connections. When passing component leads through the drilled holes in the PCB, the solders form a secure bond that holds the components together firmly [10]. This is unlike Surface Mount Technology (SMT) which does not have strong mechanical connections, for applications such as the aerospace and automotive industry, where mechanical connections are crucial for the safety of the users and passengers of the vehicles.

2.1.2 Surface Mount Technology (SMT)

SMT, as the name already suggests, is a technology where components are directly soldered on top of a PCB [8]. This makes it more cost effective compared to THT, as SMT devices can be smaller which takes less spaces. This extra space can then be used to place other components onto the PCB. This means that through SMT, the insides of devices can contain more compact designs and in return reduces the requirement for bigger devices.

In addition, SMT processes can also be automated. This is because since the components are attached directly to the surface of the board, SMT can be constructed with leads that are finer and more closely spaced than what's used in THT [11]. Another reason behind SMT's ability to be automated is because it does not require drilling, which takes additional time and also increases the cost of the products produced [11]. Furthermore, it is also tougher to place the component into the hole and solder at the same time.

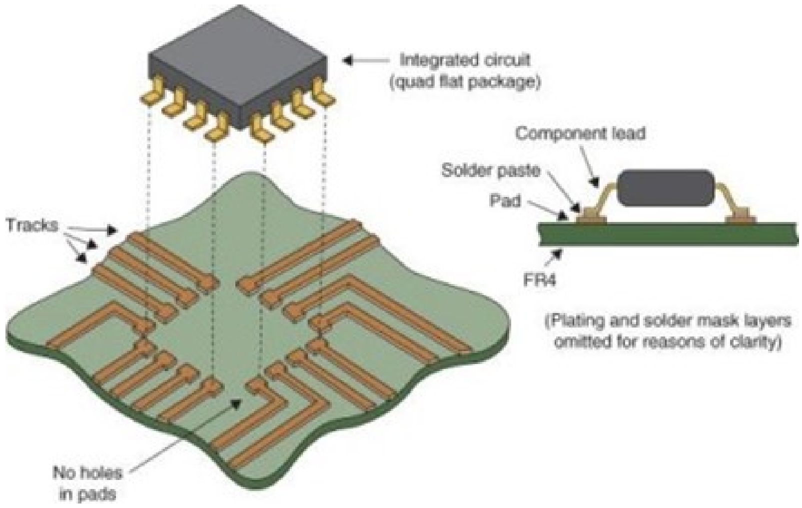

Figure 2-1 An example of SMT being used, where the solder paste can be seen being used to attach the component lead to the pad [11].

2.2 Solder Types

Several types of solder are used in semiconductor packaging, from the commonly used solder SnAgCu, or also known as SAC305 to other commonly used solders such as SnCu and the traditional SnPb.

2.2.1 SAC305

SAC305 stands for Solder Alloy Composition 305, which is one of the most commonly used soldiers in semiconductor packaging today. The reason behind the wide use of this solder is that it is not patented and is lead free, unlike the other types of solders [12]. The contents of SAC305 consists of 96.5%, Sn, 3.0% Ag and 0.5% Cu. The combination of these 3 metals provides SAC305 with relatively good properties such as relatively high melting point, good mechanical properties, and thermal cycling reliability [12].

Despite those excellent properties mentioned earlier, there have been studies that have shown that the presence of silver in SAC305 increases the rate of corrosion, this is due to the presence of Ag3Sn, and the Ag3Sn intermetallics accelerates the dissolution of tin from the β-tin rich matrix into the corrosive medium due to galvanic corrosion mechanism [13]. In addition to that, SAC305 is also an expensive solder due to the presence of silver in its contents which increases the cost of manufacturing products that have this solder [14].

2.2.2 SnCu

SnCu is another type of lead free solder that is also commonly used. This solder consists of 99.3% Tin (Sn) and 0.7% Copper (Cu). Although it lacks silver, making it more cost-effective than SAC305, it exhibits a higher melting point than traditional SnPb solders, which can be advantageous in certain applications [15]. Despite that, eutectic SnCu alloys have the advantages of a lower melting point than conventional SnCu, together with narrow crystallization temperature range, good fluidity and low tendency of hot cracking and segregation [15]. Furthermore, there also has been research that states that SnCu reveals a modest wetting that appears just adequate for various applications [13].

However, due to the structure of SnCu solders, they are more susceptible to galvanic corrosion due to exposure to relative humidity, RH [16]. Furthermore, through a previous research done by other researchers who tested SnCu solders under polyvinyl chloride fire smoke atmosphere, it was found that the corrosion degree of SnCu solder is highest at 90% RH, whereas the corrosion degree is weaker at 98% RH, which is the saturated RH [16]. The research stated that it may be attributed to the fact that oxygen is difficult to diffuse in a saturated RH solution, and in an unsaturated RH environment, a high RH environment may promote the corrosion of Sn–0.7Cu solder [16].

2.2.3 SnPb

SnPb is one of the traditionally used solders, as it has been used for a long time before the invention of lead free solders. SnPb solder comprises 63% tin and 37% lead. SnPb has advantages in properties such as low melting temperature, affordability and excellent wettability [17]. Despite these advantages, there has been a growing need to replace lead free solders due to the possible harmful effects lead solders can cause. The toxicity of lead has led to countries such as Japan, EU and others to have form laws to gradually prohibit the use of lead in electronic packaging [15]. The toxic fumes produced when soldering in a poorly ventilated room can lead to health effects such as affecting sleep quality and causing digestive disorders [18].

However, SnPb solders are noted for their good corrosion resistance compared to lead-free alternatives like Sn-Ag and Sn-Ag-Cu. This property contributed to their widespread use before environmental concerns led to the restriction of lead in electronics [14]. In addition, lead-free solders can suffer from issues like poorer wettability and higher melting temperatures, which can complicate manufacturing processes and affect the integrity of solder joints under thermal cycling. As regulations continue to evolve, researchers are actively exploring new solder compositions and treatments that maintain the desirable properties of SnPb while addressing environmental concerns.

2.3 Corrosion

Corrosion in semiconductor packaging is a major concern, as it may affect the performance and reliability of an electronic device. Corrosion typically involves the degradation of materials through electrochemical reactions with environmental elements like moisture, oxygen, and contaminants. For semiconductor interconnections, corrosion often manifests as metal oxidation, dendritic growth, and material weakening, which may result in failures in electronic devices.

The main form of corrosion in semiconductor packaging is galvanic corrosion [19]. Galvanic corrosion is a type of electrochemical corrosion that occurs when a potential difference exists between two dissimilar metals in a corrosive medium, creating an electrochemical cell in the presence of moisture [20]. For instance, there was an research that showed that the presence of silver in SAC305 solder alloy increases the rate of corrosion due to the presence of Ag3Sn, which the Ag3Sn intermetallic accelerates the dissolution of tin from the β-tin rich matrix into the corrosive medium due to galvanic corrosion mechanism [13].

Furthermore, corrosion not only deteriorates the physical integrity of interconnections but also increases electrical resistance, which may lead to signal degradations or even complete failure of the device [21]. This issue is especially pertinent in semiconductor packaging because the miniaturization of devices means that even minor corrosion can have major effects on functionality.

Materials like nickel (Ni) and gold (Au) are often used as protective layers in semiconductor packages, but they are still not immune to corrosion, particularly when exposed to harsh environments with high humidity. The increased use of lead-free solders, such as SAC305, introduces additional challenges because the exclusion of lead can make these materials more susceptible to certain types of corrosion, especially in the presence of moisture [13][14].

2.4 Relative Humidity

Relative humidity (RH) significantly affects the corrosion rates of the semiconductor packaging, especially in environments with high moisture levels. RH is a ratio of the humidity ratio of a particular water-air mixture compared to the saturation humidity ratio at a given temperature [22]. The relative humidity can be related to the temperature, as it is directly proportional to each other. As the greater the temperature, the lower the relative humidity. But when RH exceeds a critical threshold, usually above 60%, it significantly accelerates corrosion processes, particularly in materials used for semiconductor interconnections [23].

High relative humidity promotes the formation of electrolytes on the surface of metals, which leads to the activation of electrochemical reactions that cause corrosion [24]. In semiconductor packaging, even small amounts of moisture can seep through cracks or imperfections in protective coatings, which causes these reactions to initiate. Once moisture has infiltrated the packaging, it can degrade metal interconnects and solder joints, causing electrical failures.

Studies have shown that in environments where the relative humidity fluctuates between high and low levels, exacerbates the corrosion process [25]. This is particularly relevant in semiconductor applications where devices may be exposed to varying environmental conditions during their operation. In addition, the geographical location of semiconductor manufacturers or users also impacts the rate of corrosion due to varying humidity levels. In tropical climates, such as in Malaysia, RH levels are consistently high, leading to faster corrosion rates compared to arid regions. Manufacturers must consider environmental conditions when selecting packaging materials due to these reasons.

There are various methods that can be used to mitigate the effects of humidity on corrosion. These include the application of conformal coatings, the use of desiccants in packaging such as silica gel, and the design of hermetically sealed packages to minimise moisture ingress. However, these solutions are not always foolproof, especially when devices are exposed to prolonged periods of high humidity, corrosion can still slowly develop due to the wear and tear of those methods.

2.5 Introduction to the Humidity Chamber

Humidity chambers serve as vital tools in evaluating material performance under controlled environmental conditions, by enabling temperature and relative humidity regulation [26]. This is especially useful in electronics where fluctuations in temperature and humidity can lead to reliability issues. In electronics testing, humidity chambers simulate real-world conditions, allowing researchers to assess how materials and components respond to humidity-induced stress, which can reveal potential issues like interfacial corrosion, delamination, and mechanical failure in solder joints and other sensitive components [3]. This is increasingly important as miniaturization and density in packaging amplify the susceptibility of components to environmental degradation.

High-temperature and high-humidity testing is especially critical in semiconductor packaging, where materials are subjected to prolonged humidity exposure to gauge long-term reliability. Studies have demonstrated that controlled humidity testing helps in understanding how moisture and temperature accelerate corrosion mechanisms, affecting the performance and durability of sensitive materials like printed circuit boards and solder alloys [3][2]. By simulating environments with variable humidity, these chambers help replicate harsh operational conditions that electronic devices may encounter, making them essential in quality control and product validation.

Due to high costs and large sizes, commercially available humidity chambers are often inaccessible to small-scale research facilities and educational institutions [3]. Consequently, the development of custom-built chambers has gained attention as an alternative. These in-house setups can be designed to offer precise humidity and temperature control while remaining compact and cost-effective, bridging the gap for academic and small-scale testing. Overall, such advancements enhance the accessibility of environmental testing, enabling more comprehensive studies on the effects of humidity on material performance and reliability.

2.5.1 Working Principle of Humidity Chamber

A humidity chamber typically consists of several key components, including a heating system, cooling system, humidification system, and dehumidification system, all controlled by a central control panel.

The operation begins when the chamber is sealed and the desired temperature and humidity settings are inputted into the control panel. The heating or cooling system activates to adjust the temperature accordingly; if the temperature exceeds the set point, the cooling system engages, while the heating system activates if the temperature falls below the set point [4]. Simultaneously, the humidification system introduces moisture into the chamber, either through evaporative methods or steam injection, to achieve the required humidity levels. If humidity levels surpass the desired range, the dehumidification system works to remove excess moisture, ensuring that the chamber maintains consistent environmental conditions.

Traditionally, humidity control is achieved by using saturated salt solutions, which maintain a specific relative humidity based on the equilibrium of the salt and water. These solutions either absorb or release moisture to stabilize the humidity in a closed environment, but the resulting humidity is fixed by the specific salt used, so multiple solutions are needed to achieve a range of humidities [4]. Modern, commercially available humidity chambers often employ electronic sensors and control loops to allow for more versatile humidity control, using steam generators and condensers to adjust humidity levels dynamically and precisely and according to needs [4].

Lately, there have been more economical humidity chamber humidity chambers developed by researchers that have utilised other materials to achieve humidity control, such as using aqueous glycerol solutions placed inside the chamber [3]. Others, using dual-relay hygrostat. When the relative humidity falls below or exceeds a threshold, the air inside the chamber will be moistened or dehumidified, respectively. Air moistening is realised with a fan-driven air circuit passing an external humidifier. This humidifier consists of a polypropylene container with deionised water and an ultrasonic mister [26].

2.6 Design Concept Selection

The demand for low-cost testing solutions has led researchers to develop self-fabricated humidity chambers that can offer reliable humidity control using accessible materials. While commercial chambers provide precise control, their high cost and large size often make them impractical for smaller-scale research. Studies have demonstrated that self-made chambers, though generally less precise and robust, can still meet laboratory needs at a fraction of the cost, making them a viable option for budget-conscious researchers [3][2][4][26].

2.6.1 Quality Function Deployment (QFD)

In engineering design, multiple methods exist for evaluating and selecting among design options. Quality Function Deployment (QFD) is widely used to align product characteristics with project requirements, ensuring that final designs meet user needs efficiently. In a study of low-cost environmental testing equipment, QFD helped prioritise factors such as cost, portability, and ease of use—similar to considerations relevant to academic research equipment [27]. This approach ensures that cost-effective designs still meet essential functional criteria.

2.6.2 Pugh Matrix

The Pugh Matrix offers another framework by using a reference standard to compare the strengths and weaknesses of each design, which helps quickly identify trade-offs. In the context of environmental chambers, researchers have noted the usefulness of the Pugh Matrix for highlighting the limitations of simplified designs, particularly in reliability and control capabilities [28]. By assessing different prototypes against a standard, the Pugh Matrix provides a practical, visual tool for making balanced design decisions.

2.6.3 Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is also commonly applied to prioritise criteria in design choices, especially when weighing multiple objectives such as cost, reliability, and control precision. AHP is a structured technique for organizing and solving complex decision-making problems based on mathematics and psychology [29]. By applying pairwise comparisons, researchers can more effectively determine which criteria are most important, leading to a more balanced decision.

2.7 Challenges in Using Commercial Humidity Chambers.

The use of commercial humidity chambers presents several significant challenges that researchers and manufacturers must consider. One of the most pressing issues is the high overall cost, often exceeding $30,000 USD [26]. This substantial financial burden can be attributed to various factors, including the manufacturing costs associated with the intricate technology used in these chambers and the ongoing maintenance expenses required to ensure their optimal performance. These costs can be particularly prohibitive for smaller research institutions or companies with limited budgets, potentially hindering their ability to conduct essential humidity-related experiments.

Furthermore, the complexity of these commercial units can lead to additional challenges, such as the need for specialised training for personnel to operate and maintain the equipment properly. This training can further escalate the overall investment required, as it necessitates time and resources that may not be readily available [26].

In response to these challenges, there has been research done that has produced smaller, lighter and more portable humidity chambers compared to commercial humidity chambers [26]. These innovative designs aim to provide a more cost-effective alternative without compromising on performance. By utilizing advanced materials and streamlined engineering processes, these new models can offer a range of humidity control options in a compact form factor, making them more accessible to a broader range of users.

2.8 Summary of Literature Review

In conclusion, the humidity chamber serves as a vital tool in evaluating the impact of environmental conditions, particularly relative humidity, on semiconductor packaging materials. It allows for controlled testing of how different packaging materials, such as SAC305 and SnCu, respond to varying humidity levels, simulating real-world conditions where moisture can lead to corrosion and affect component reliability. By subjecting samples to accelerated humidity exposure, the chamber facilitates the identification of critical relative humidity thresholds that significantly influence corrosion rates, as well as the examination of the effectiveness of protective measures such as coatings and sealing. The use of a humidity chamber is integral to understanding the underlying mechanisms of humidity-induced corrosion and plays a crucial role in the development of more durable and reliable semiconductor packages, ensuring better performance in high-humidity environments.

Chapter 3 Prototyping

Following the insights gathered from the literature review, this chapter focuses on the practical development of the humidity chamber. It covers the overall design process, key considerations in selecting materials and components, and the step-by-step fabrication of the prototype. The aim was to translate the theoretical concepts and requirements identified earlier into a functional, cost-effective, and user-friendly humidity chamber suitable for small-scale testing.

3.1 Process Flow of Research

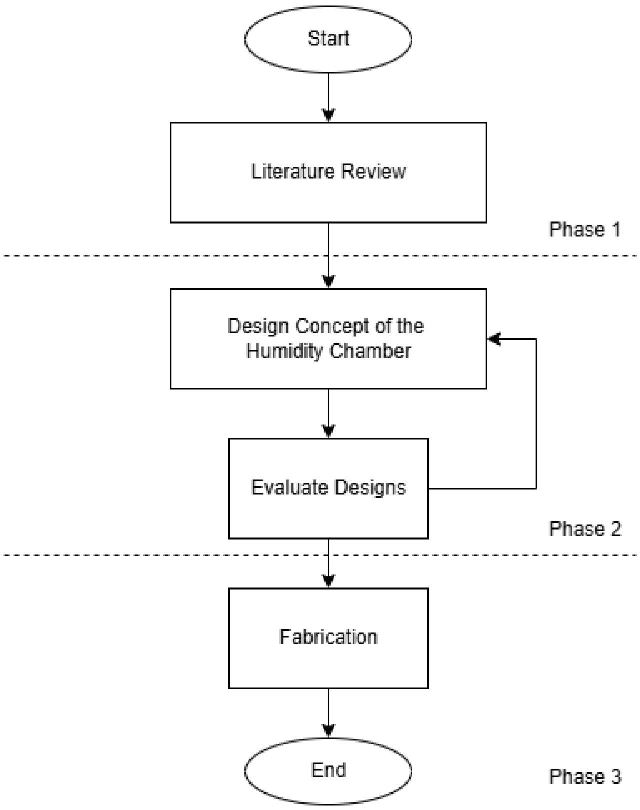

Figure 3-1 Process flow of research.

A detailed timeline of the research activities is presented in the Gantt chart (Appendix A).

3.2 Consideration of Impacts towards Society, Legal, Health and Compliance

Designing and fabricating the humidity chamber required thoughtful consideration of safety, health, societal, and regulatory factors. Basic precautions were taken to ensure the safe use of the chamber, including the selection of low-voltage electrical components, reliable humidity control, and proper air circulation to prevent excessive condensation buildup. The chamber was constructed using non-toxic materials such as PVC foam board and lightweight components, ensuring it would be safe for handling and experimental use.

Although the project was conducted on a small scale, attention was given to basic regulatory principles related to environmental testing equipment, including maintaining stable temperature and humidity conditions within the chamber. The design prioritised user-friendliness and ease of maintenance, allowing students or researchers to operate the system safely without requiring specialised training. This promotes accessibility for educational and research activities while maintaining safe operational practices.

Sustainability was considered within the limitations of available resources. PVC foam board was chosen for its durability, ease of fabrication, and low material wastage, although it is not the most environmentally sustainable material. Nevertheless, its reusability for multiple prototyping purposes helps minimise overall environmental impact. Furthermore, the chamber was designed to operate efficiently with low-power components, reducing its energy consumption during use.

Throughout the construction and material selection process, ethical procurement practices were observed to ensure that materials and components were sourced responsibly. The chamber is intended solely for legitimate research and educational purposes, upholding principles of responsible scientific inquiry, academic integrity, and environmental responsibility wherever practical.

3.2.1 Contribution to Sustainable Development Goals (SDGs)

This project aligns with several United Nations Sustainable Development Goals (SDGs). Firstly, by developing an affordable and accessible humidity chamber, the project supports SDG 4: Quality Education, enabling students and researchers with limited resources to conduct essential environmental testing. Secondly, the project's emphasis on innovative, cost-effective design and fabrication contributes to SDG 9: Industry, Innovation, and Infrastructure, fostering technological advancement and encouraging sustainable engineering practices. Lastly, through efficient material use, low-power component selection, and minimizing waste during fabrication, the project addresses SDG 12: Responsible Consumption and Production, promoting environmental responsibility throughout the product's life cycle.

3.3 Concept and Design of Humidity Chamber

3.3.1 Humidity Chamber Design 1

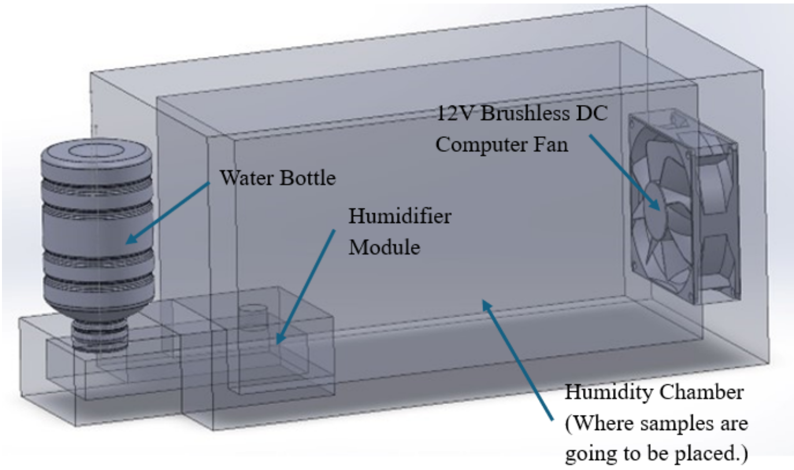

Figure 3-2 Humidity Chamber Design 1.

Figure 3-2 shows the first conceptual design of the humidity chamber. This design has more intricate parts compared to the second design shown in Figure 3-7. This design features a upside down bottle, which allows water to flow down into a humidifier module which sprays mist into the chamber. The mist is then circulated throughout the chamber using a fan.

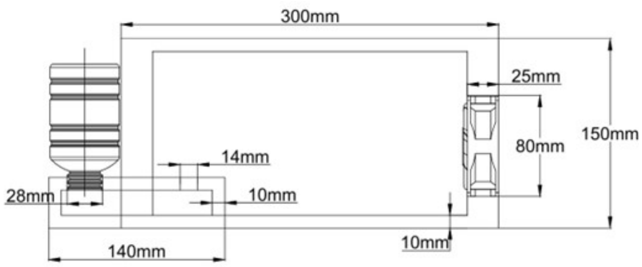

Figure 3-3 The front view of humidity chamber design 1, with dimensions.

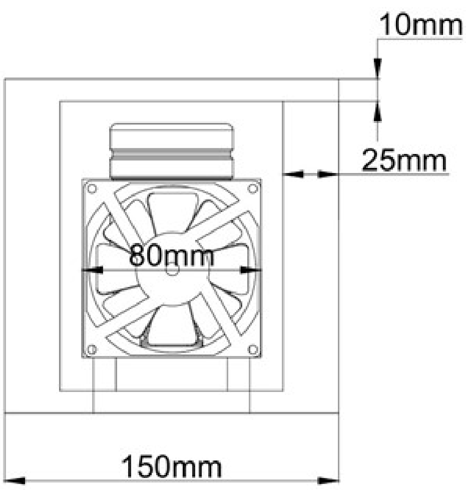

Figure 3-4 The right view of humidity chamber design 1, with dimensions.

3.3.2 Humidity Chamber Design 2

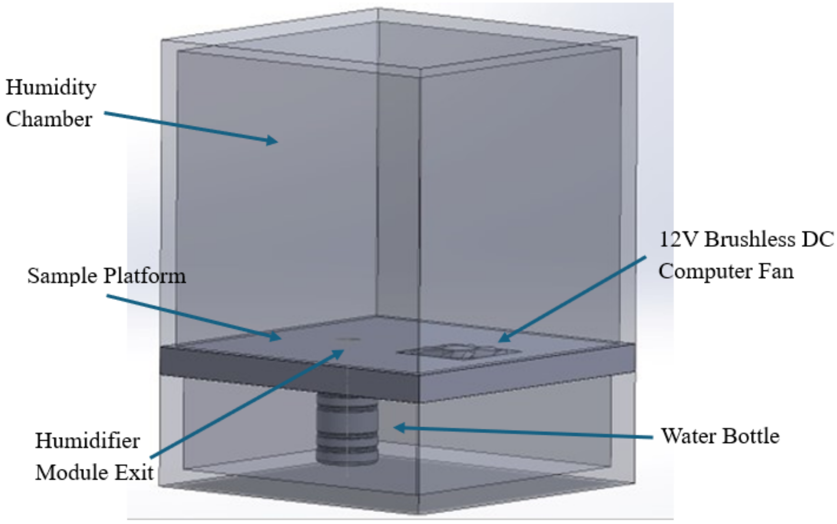

Figure 3-5 Humidity Chamber Design 2.

The second humidity chamber design, shown in Figure 3-5 features a simple water bottle with a humidifier module (generates mist) located on the tip of the water bottle. Similar to Figure 3-2, the fan also helps to circulate the mist so that the mist reaches around the entire chamber. This is important so that the humidity in the chamber is the same at different parts of the chamber.

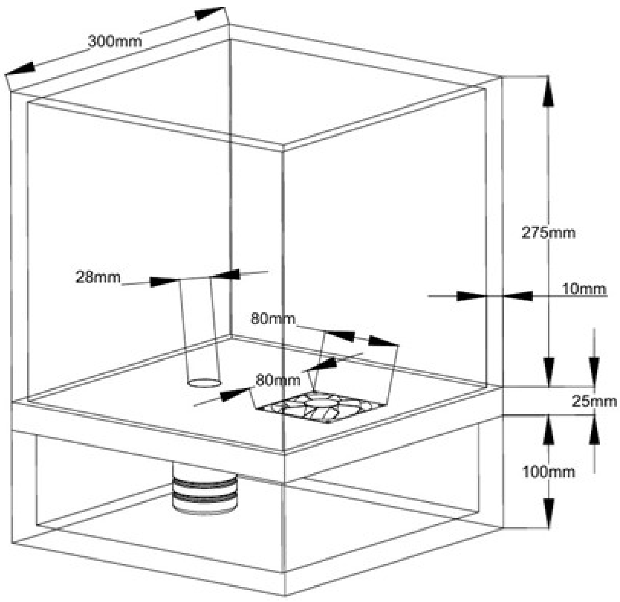

Figure 3-6 The full view of humidity chamber design 2, with dimensions.

3.4 Design selection by using Pugh Matrix

Table 3-1 Pugh Matrix Evaluation Table

Criteria	**Weight**	**Datum (Commercial Humidity Chamber)**	**Design 1 Rating**	**Design 1 Score**	**Design 2 Rating**	**Design 2 Score**
Cheap	5	0	+1	5	+1	5
Humidity Precision	4	0	-1	-4	-1	-4
Easy to Place Sample	4	0	-1	-4	-1	-4
Portable	4	0	0	0	+1	4
Easy to Fabricate	5	0	0	0	+1	5
Durability	3	0	+1	3	0	0
Ease of Use	4	0	0	0	+1	4
Total Score				**0**		**10**

Scores for each humidity chamber designs were calculated using the formula below:

$$Weight\ X\ Rating \qquad \text{Equation 3-1}$$

Each criterion is assign a weight based on its importance to the project. Design 2 scores higher because both humidifier and dehumidifier are at the bottom, optimizing space and making it easier to maintain a compact form. Design 1 places the components on the sides, which may make the chamber slightly bulkier, and more difficult for a person to move it around.

3.4.1 Summary of Design Selection

This evaluation aimed to identify the most suitable humidity chamber design for academic and small-scale testing applications, emphasizing cost-effectiveness, portability, and ease of fabrication. Using the Commercial Humidity Chamber as the datum (baseline), Design 1 and Design 2 were evaluated across multiple criteria, including cost, humidity precision, weight, and ease of use. Although design 1 achieved a total score of 0, it reflects strengths in affordability, sample placement ease, and durability. However, it did not show significant improvements in portability or ease of fabrication, which limits its flexibility for varied testing environments.

Design 2, with a total score of 10, outperformed the Commercial Chamber and Design 1 in several key areas, particularly portability, ease of fabrication, and overall ease of use. This design is also lightweight and cost-effective, making it a practical choice for environments requiring flexibility and frequent sample handling. Although Design 2 shares the same limitation as Design 1 in terms of humidity precision, it offers enhanced adaptability and user-friendliness, aligning well with the project's goal of creating a low-cost, accessible solution for humidity testing.

In conclusion, Design 2 is the preferred choice, balancing affordability and functionality, and providing a reliable option for controlled humidity testing in educational and small-scale research settings.

3.5 Finalised Design of Humidity Chamber

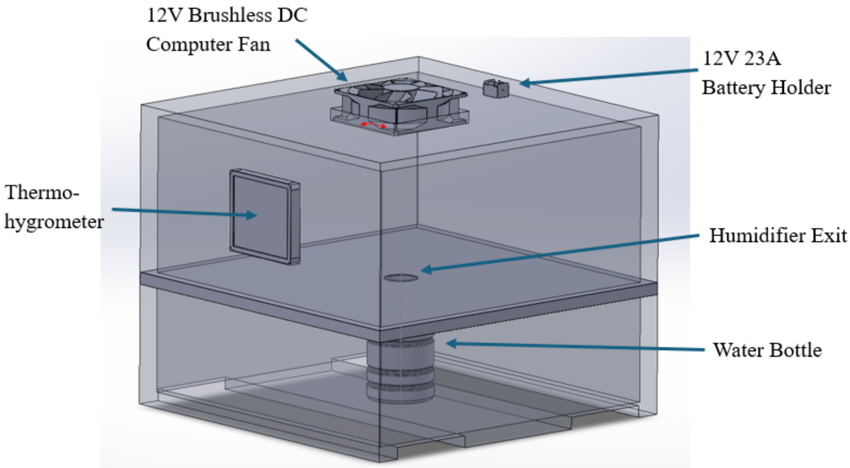

Figure 3-7 Overall view of the finalized humidity chamber design. *(Note: Transparent parts are shown for visualization purposes only; these components are not transparent in the actual prototype.)*

3.5.1 Updated Design Overview

The updated humidity chamber design (shown in Figure 3-7) includes several new components to enhance its functionality. A thermo-hygrometer is mounted on the upper left side of the chamber, allowing users to monitor the temperature and humidity without opening the enclosure. A computer fan is installed at the top for air circulation and is powered by an 12V 23A battery, with its holder located on the right side of the fan.

At the bottom of the chamber, a bottle houses a humidifier module powered by a 5V power bank. The base holding the bottle has also been modified to save materials and allow a more easy excess to components at the bottom. Additionally, the humidifier's top and bottom parts are detachable and held together using magnetic strips, allowing for easy removal and reassembly during refilling or maintenance.

Furthermore, the height of the chamber was reduced from 270 mm to 140 mm to minimize material usage and improve portability without compromising internal functionality, as the components that are usually tested in the humidity chamber are small.

3.5.2 Final SolidWorks and AutoCad Drawings

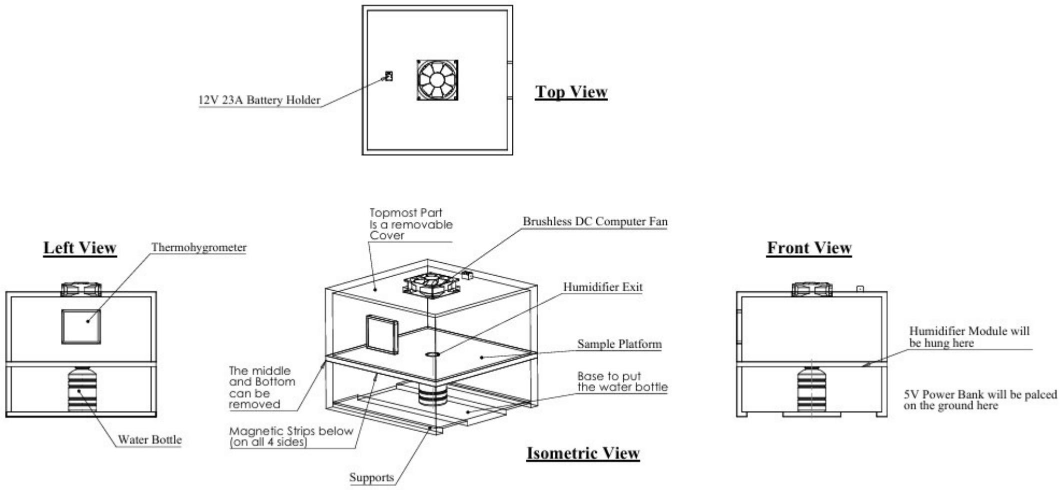

Figure 3-8 Final Solidworks Drawing with Descriptions.

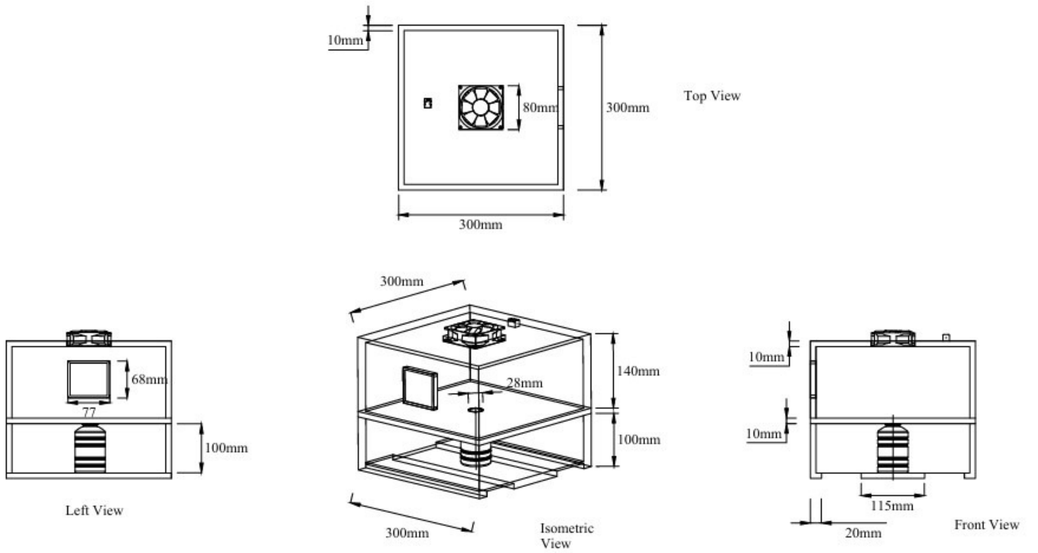

Figure 3-9 Final Solidworks to AutoCad Drawing with Dimensions.

3.5.3 Technical Specifications

- Power Supply: 12V for DC fan; 5V for humidifier module
- Humidity Range: 77% – 79%
- Dimensions:
  - Overall Chamber: 300 mm × 300 mm × 250 mm
  - Main Chamber: 300 mm × 300 mm × 140 mm (Top section where humidity is controlled and samples are placed)
- Chamber Wall Material: PVC Foam Board
  - Sufficient Insulation, helps maintain a stable temperature inside the chamber.

3.5.4 Working Principles of System Components

The walls of the humidity chamber were constructed using PVC foam board, which provides sufficient insulation. This helps maintain a stable temperature inside the chamber, which is important because temperature is inversely proportional to relative humidity. As temperature increases, relative humidity decreases, and vice versa.

Silica gel is placed on the chamber's sample platform, acting as a desiccant to help manage and control the humidity levels. Silica gel has a high surface area, allowing it to adsorb moisture from the air, preventing excess humidity buildup in areas of the chamber that could cause unwanted condensation or affect the experimental conditions. This ensures that the chamber's relative humidity remains stable and within the desired range, avoiding fluctuations that could impact the experiment.

Humidity is introduced into the chamber using a 5V battery-powered humidifier module, which generates mist through ultrasonic atomization. The module contains a piezoelectric transducer which is a small ceramic disc that vibrates at an ultrasonic frequency (typically around 1.7 MHz) [30]. These vibrations create high-frequency pressure waves that break the water from the 10mm-tall water bottle into fine droplets, creating a cool mist. This mist is then dispersed evenly throughout the chamber, helping to regulate the humidity without changing the temperature. A battery-powered computer fan helps to distribute the mist evenly across the chamber, ensuring that the humidity remains consistent at all points inside the chamber.

3.6 Apparatus and Materials

The apparatus and materials used are:

1. Air humidifier Mist maker module with an on/off button.

Figure 3-10 Humidifier Module with a on/off button.

2. 100mm height bottle

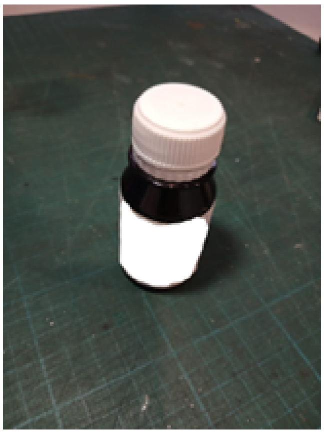

Figure 3-11 100mm height bottle.

3. 5V Power Bank

Figure 3-12 5V Power Bank.

4. Glue gun

Figure 3-13 Glue Gun.

5. PVC Foam Board

Figure 3-14 PVC Foam Board.

6. Magnetic Strip

Figure 3-15 Magnetic Strip.

7. 12V 23A Battery and Connector

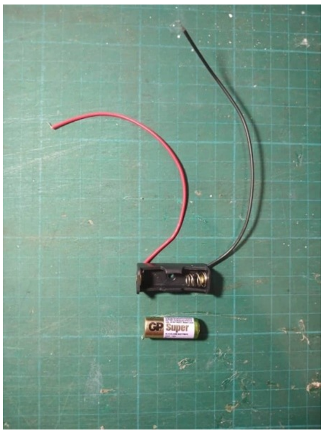

Figure 3-16 12V 23A battery and Connector.

8. 12V Brushless DC Fan

Figure 3-17 12V Brushless DC Fan.

9. Thermo-hygrometer

Figure 3-18 Thermo-hygrometer.

10. Silica Gel

Figure 3-19 Silica Gel.

3.7 Procedure

3.7.1 Initial Assembly

Step 1: Cutting and Preparation of Foam Board

The A2-sized PVC foam board (10 mm thick) was selected as the primary material for constructing the chamber. The board was marked using a pencil and a ruler according to the following dimensions:

- 300 mm × 300 mm (×2 pcs): Used for the top cover and the sample platform.
- 300 mm × 140 mm (×4 pcs): Used for the vertical chamber walls. Each 300 mm edge was reduced by 10 mm to ensure a proper 300 mm × 100 mm outer box dimension after assembly.
- 115 mm × 300 mm (×1 pc): Designed to support the humidifier bottle at the bottom section of the chamber (In the storage chamber).
- 20 mm × 300 mm (×2 pcs): Served as stabilizers to reinforce the base structure.
- 300 mm × 100 mm (×4 pcs): Used to form the walls of the storage chamber. Each 300 mm edge was again reduced by 10 mm to ensure a proper 300 mm × 300 mm outer box dimension after assembly.

After marking, the PVC boards were cut using a box cutter to ensure clean and accurate edges. The marking and cutting process are shown in Figure 3-20 to Figure 3-24.

Figure 3-20 Marking one of the PVC foam boards with dimensions using a pencil and ruler.

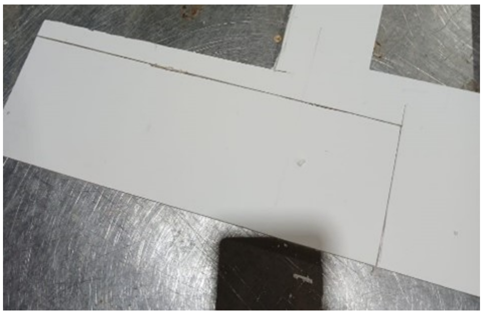
Figure 3-21 Close-up of a PVC foam board with dimension lines sketched using pencil.


Figure 3-22 Cutting the board with a box cutter, guided by a ruler to maintain straight lines.


Figure 3-23 A selection of the finished cut pieces.

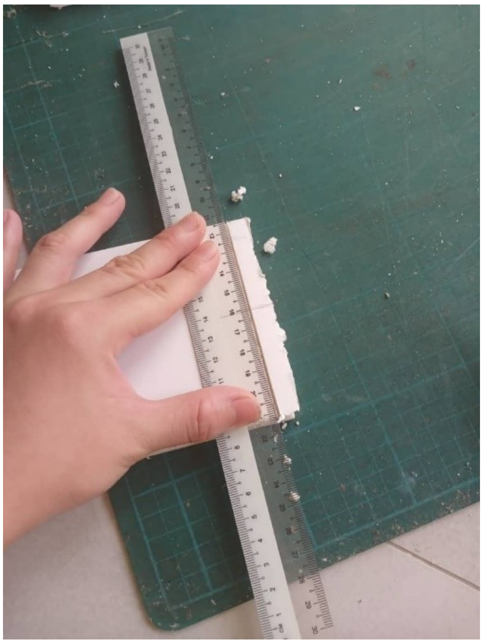

Figure 3-24 Trimming 10 mm from the 300 mm edge of a 300 mm × 100 mm piece for size adjustment.

Before assembly, each 300 mm × 100 mm piece was trimmed on one edge and arranged in a clockwise layout to verify orientation. This step ensured that all trimmed edges aligned correctly when forming the base structure.

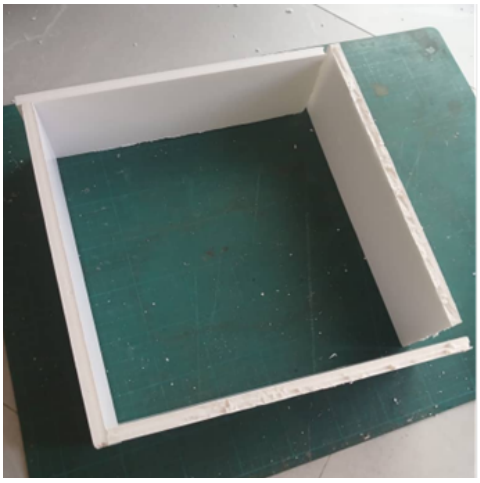

Figure 3-25 Four 300 × 100 mm PVC foam board pieces after a 10 mm edge reduction, arranged clockwise starting with the left piece (trimmed edge on top), then the top piece (trimmed edge on right), the right piece (trimmed edge on bottom), and the bottom piece (trimmed edge on left).

Step 2: Chamber Assembly

After all pieces were cut, a glue gun was used to assemble the chamber walls. Glue was applied to each edge, and pieces were held in position until bonded. A ruler was used to ensure all sides were aligned and that the overall base remained within the 300 mm × 300 mm dimensions.

Figure 3-26 Glue gun being used to glue two board pieces together.

Figure 3-27 The pieces with glue being glued together.

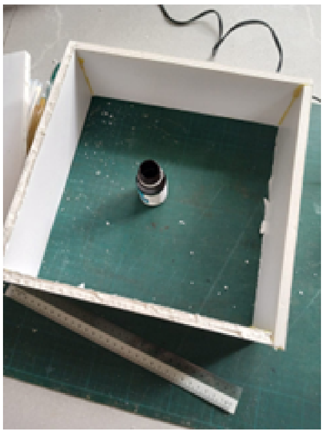

Figure 3-28 The glued pieces placed next to a ruler and on a cutting board to ensure that overall base size was still 300 mm x 300 mm.

Figure 3-29 The chamber base placed on top to visualize how the bottom part of the chamber will look.

A hole was marked and cut in the center of the middle base (sample platform) by tracing the mist outlet of the humidifier module. This was done to ensure the mist outlet fits properly.

Figure 3-30 A hole sketched on the base before cutting.

Then, the mist outlet was fit into the cut hole.

Figure 3-31 The mist outlet fitted properly into the hole.

The humidifier module was then connected to a 5V power bank via a USB to micro-USB cable. The humidifier was tested, and the mist output was confirmed.

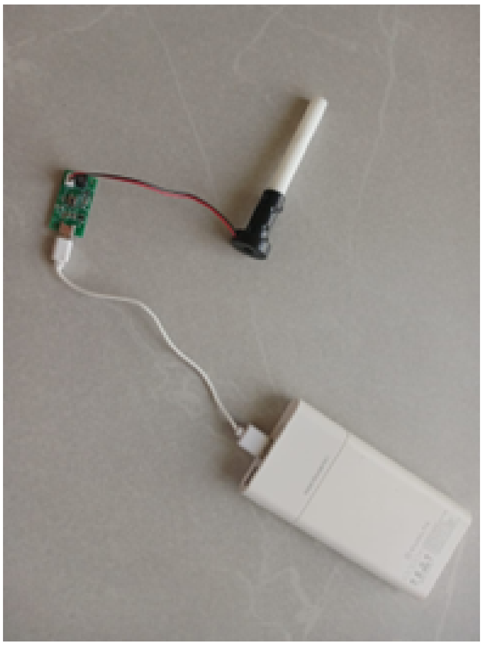

Figure 3-32 The humidifier module connected to the 5V power bank.

The power bank was then placed outside the chamber before switching it on the humidifier to visualize the flow of the mist coming out of the chamber.

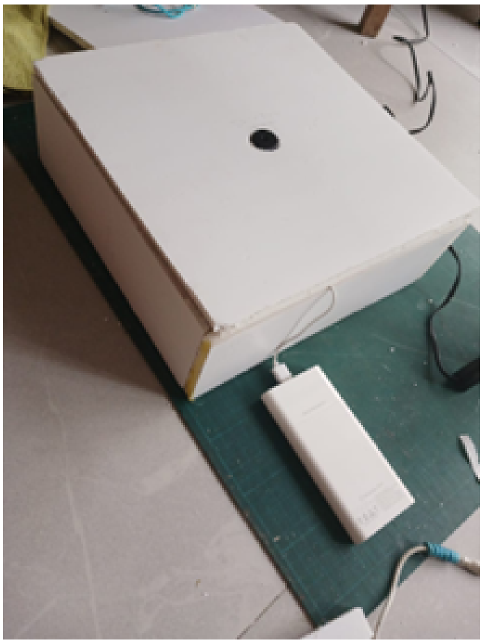

Figure 3-33 The power bank placed outside the humidifier module.

Next, the 115 mm x 300 mm base which will hold the bottle that supplies water to the humidifier module and the chamber's 20 mm x 300 mm support was glued to the bottom of the chamber.

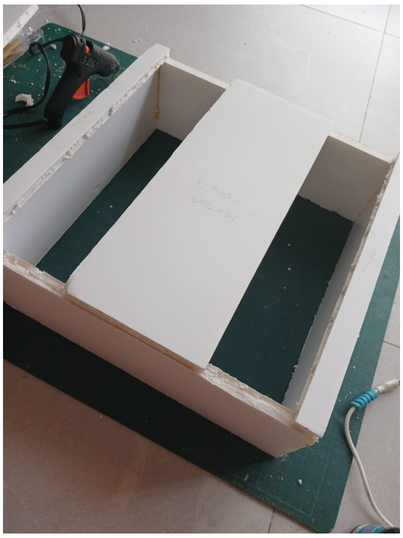

Figure 3-34 Chamber base and support glued to the bottom.

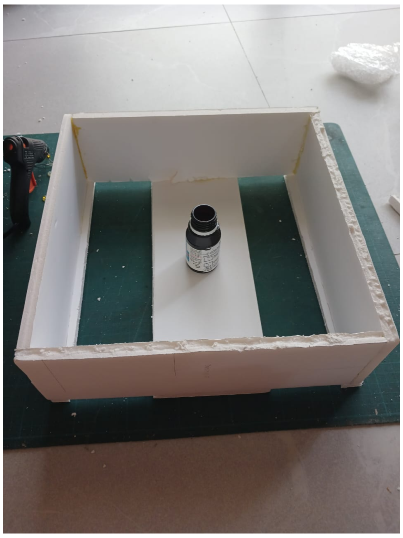

Figure 3-35 The 10 mm bottle placed to visualize the chamber base size.

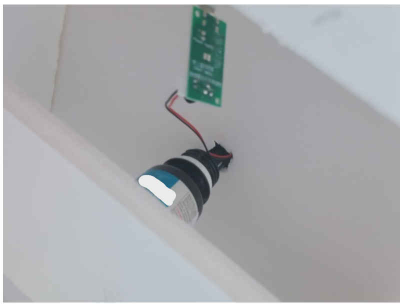

Figure 3-36 The top chamber and the humidifier placed back.

Subsequently, magnetic strips was attached to the bottom sides of the sample platform and the top sides of the storage chamber walls.

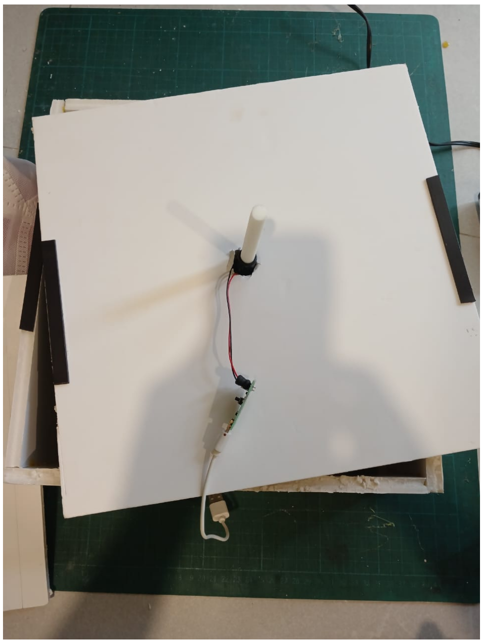

Figure 3-37 Magnetic strips attached.

The thermo-hygrometer was installed by first tracing its outline onto a 290 mm × 140 mm foam board. The cutout was made using a box cutter, and the sensor was carefully fixed into place to allow easy humidity and temperature monitoring.

With the bottom storage chamber completed, one 290 mm × 140 mm foam board was selected and traced with a pencil to outline the placement of the thermo-hygrometer, ensuring a precise fit. The board was then cut using a box cutter, and the thermo-hygrometer was securely fixed into the opening.

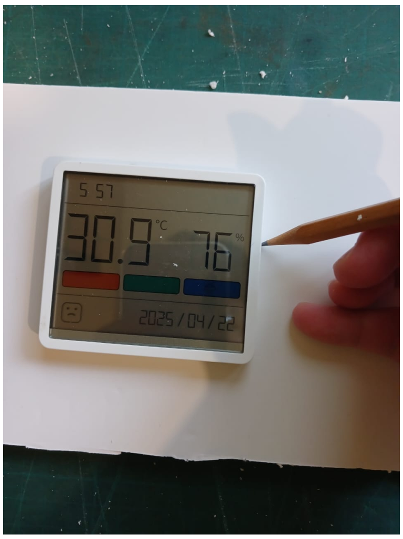

Figure 3-38 The thermo-hygrometer traced using a pencil on the 290 mm x 140 mm foam board.

Figure 3-39 The outline being cut with a box cutter.

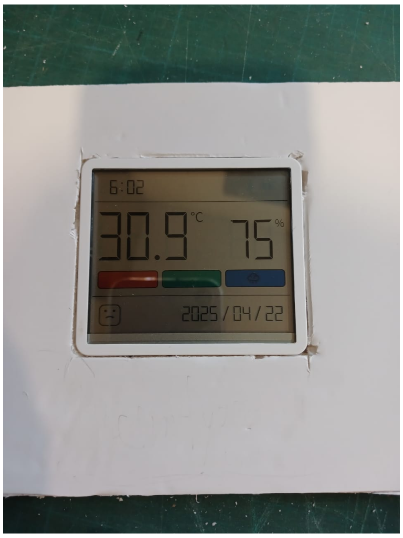

Figure 3-40 The thermo-hygrometer fixed in position.

The assembly continued with the gluing of the main chamber walls. The 290 mm × 140 mm panels were glued onto the 300 mm × 300 mm sample base to form the chamber walls.

Figure 3-41 The main chamber walls glued onto the base.

With the walls cut, a 300 mm x 300 mm cover was traced with a pencil to outline the placement of the 12V brushless DC computer fan, ensuring a precise fit.

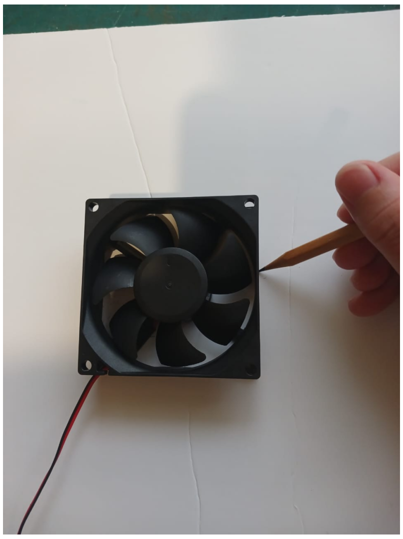

Figure 3-42 The computer fan being traced with a pencil.

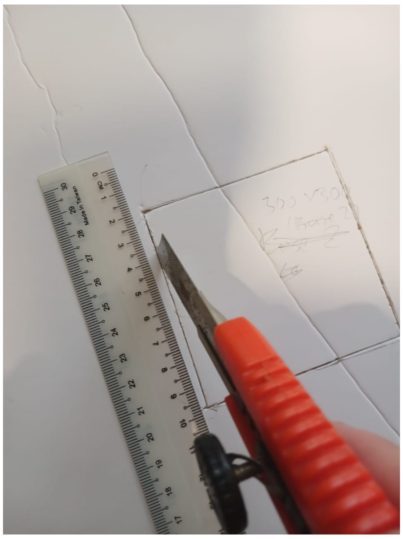

Figure 3-43 The outline of the fan being cut with a box cutter.

The fan was connected to the 12V 23A battery holder and then secured into the designated opening. Once installed, the fan was tested to ensure proper operation.

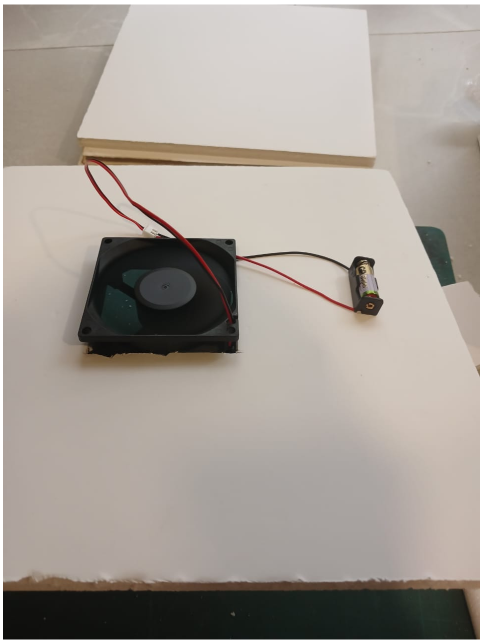

Figure 3-44 The 12V 23A battery holder connected to the fan.

Figure 3-45 The computer fan placed into position and tested.

The humidity chamber was now fully assembled and ready for testing.

Figure 3-46 The fully assembled humidity chamber.

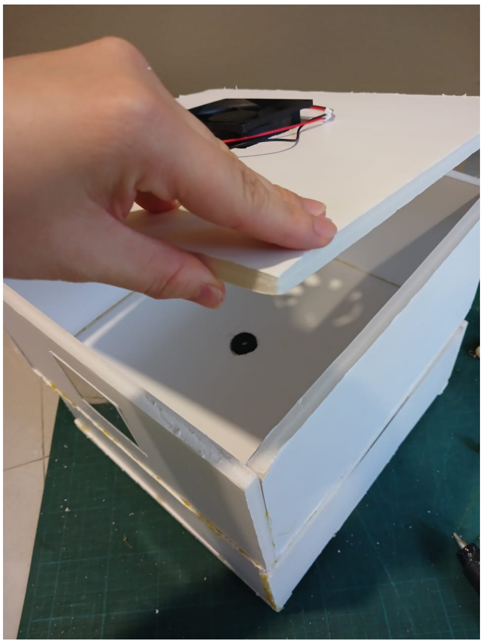

Figure 3-47 The inside of the humidity chamber when the cover has been lifted.

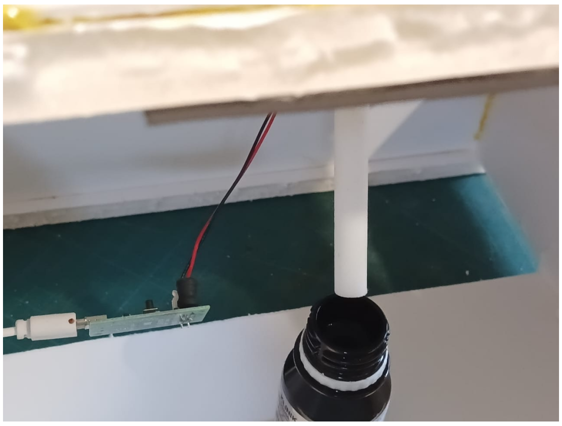
Figure 3-48 The storage area at the bottom when the top chamber was detached.

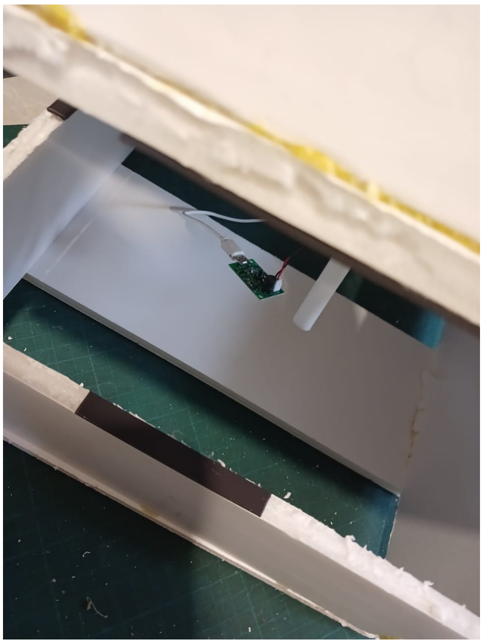
Figure 3-49 The storage area without the bottle.

3.7.2 Testing

The first test was conducted before assembling the main chamber's walls.

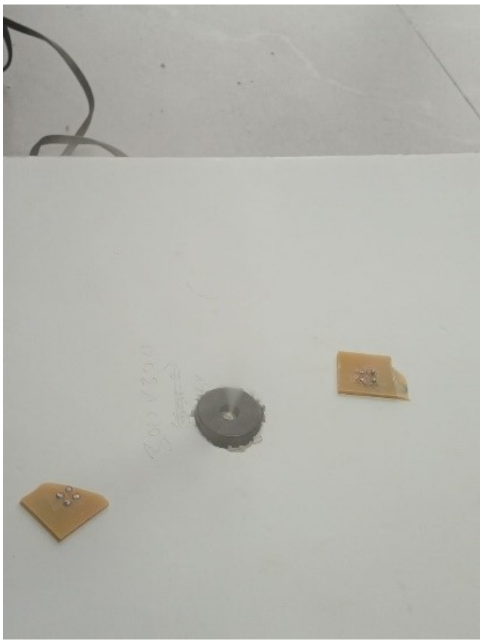

Figure 3-50 The humidifier working with the example samples next to it.

This test was performed to ensure that the humidifier functioned correctly and that the mist output was sufficient to create the desired environmental conditions for the samples.

The second test was carried out after the humidity chamber was fully assembled.

Figure 3-51 The humidifier working with samples next to it.

Silica gel, which helps regulate humidity by absorbing excess moisture from the air, was placed on the platform along with example samples typically tested in a humidity chamber. After placing the samples, the cover was reattached to enclose the chamber, and the humidifier module was switched on. During this test, the 12V brushless DC fan was also activated to ensure even distribution and regulation of humidity inside the chamber.

The temperature and humidity inside the chamber were read on the thermo-hygrometer and recorded.

Chapter 4 Results and Discussion

This chapter presents and discusses the results of the low-cost and efficient humidity chamber.

4.1 Results

Total Cost of the Humidity Chamber:

Table 4-1 Costs of materials used for the humidity chamber

Material	Price Per Item (RM)	No. of Items	Price (RM)	Source
Thermo-hygrometer	69.70	1	69.70	Shopee.com
Humidifier Module	2	1	2.00	Shopee.com
12V Brushless DC Computer Fan	7.72	1	7.72	Shopee.com
PVC Foam Board	8.50	4	34.00	Shopee.com
Magnetic Strip	3.15	1	3.15	Shopee.com
12V 23A Battery	1.80	2	3.60	Shopee.com
12V 23A Battery Holder	0.98	1	0.98	Shopee.com
Total Price			121.15	

Humidity and temperature read by the thermo-hygrometer inside the Chamber:

Table 4-2 Humidity and temperature inside the chamber

Time Lapse after Switching the Chamber's Humidifier and Fan (Minutes)	Temperature (°C)	Humidity (%)
1	30.7	77
3	30.8	77
14	30.5	79
18	30.6	79
38	30.4	79
39	30.5	79
Average	30.58	78.33

Weight of the humidity chamber: The chamber weighs approximately 450g.

4.2 Discussion

The results presented in Table 4-2 show that the prototype for the homemade humidity chamber was able to maintain a stable and high-humidity environment. The average humidity inside the chamber was recorded at 78.33 percent, while the average temperature remained around 30.58 degrees Celsius. From the first minute of operation, the humidity reached 77 percent and stayed within the range of 77 to 79 percent throughout the entire 39-minute test duration. This indicates that the combination of the humidifier module and the 12V brushless DC fan worked efficiently to generate and distribute moisture within the enclosed space.

The quick response in humidity rise within the first few minutes suggests that mist was effectively diffused inside the chamber. This is important for applications that require rapid humidity stabilization. The consistency of both temperature and humidity readings also suggests that the chamber had minimal air leakage and good insulation, aided by the tight assembly of the PVC foam boards.

The temperature remained fairly stable, with values ranging from 30.4 to 30.8 degrees Celsius. These minor fluctuations could be due to the surrounding ambient conditions or slight heat emissions from the electronic components, such as the fan and power sources. However, these effects were minimal and did not significantly affect the overall environment inside the chamber.

While the chamber performed well during short-term testing, there are some limitations to consider. The system lacks a feedback mechanism or control system to automatically regulate humidity and temperature. As a result, in environments where external conditions fluctuate, manual monitoring and adjustment would be required. Another limitation is the short testing duration of only 39 minutes, due to the limited capacity of the 12V 23A batteries used to power the 12V computer fan in this prototype. These batteries deplete quickly and are not suitable for prolonged operation. However, given that this chamber was developed as a functional prototype to demonstrate proof of concept, the use of these batteries was a practical and cost-effective choice. For future improvements and extended testing, a more stable and rechargeable power supply would be recommended.

Additionally, the current setup does not allow for adjustable humidity settings. This limits its flexibility in situations that require precise control of humidity levels for specific materials or experiments. Future improvements could include integrating a microcontroller with sensors and a relay system to create a closed-loop control system.

Despite its limitations, the prototype humidity chamber successfully fulfills its intended purpose as a cost-effective and functional solution for basic humidity testing. With a total material cost of only RM121.15, it offers a highly affordable alternative to commercial humidity chambers. One of its most notable advantages is its lightweight construction, weighing just 450 grams. This makes the humidity chamber extremely portable and easy to handle, suitable for use in academic research, small laboratories, or hobbyist projects where humidity control is necessary but budget constraints exist. Together, its affordability and portability highlight the chamber's practicality for environments that require simple, low-cost, and reliable humidity control.

4.3 Challenges and Troubleshooting

During the fabrication and testing process, several minor challenges were encountered that required logical troubleshooting:

- Glue Gun Drying Too Quickly and Assembly Mistakes: During the assembly of the chamber walls, the hot glue from the glue gun dried too quickly before the foam board panels were properly aligned. In some cases, attempts to reposition the pieces after partial bonding caused tearing of the foam surface. This affected the structural integrity and finish of the chamber. To resolve this, damaged pieces were replaced with new foam boards, and the gluing process was adjusted by applying glue to smaller sections at a time and assembling more quickly and carefully to avoid misalignment.
- Humidifier Not Producing Mist: During initial testing, the humidifier module powered on, but no mist was produced. After checking the wiring and power supply, it was discovered that the internal cotton wick was completely dry. Since the module relies on the cotton being saturated to produce mist, the wick was removed and soaked in clean water for a few minutes before being reinserted. After doing so, the humidifier functioned normally.
- Mist Leakage from Humidifier Port: After installing the humidifier module, slight mist leakage was observed around the cutout. The opening was checked, and the issue was resolved by re-cutting the hole for a tighter fit and using hot glue to seal the gaps.
- Misalignment of PVC Boards: During the early stages of gluing, some PVC board edges did not align perfectly, affecting the overall dimensions. This was corrected by sanding down the overlapping edges and reinforcing the joints with additional glue.

These challenges were addressed through simple yet effective troubleshooting methods, showing that the prototype design is adaptable and can be improved with minimal adjustments.

Chapter 5 Conclusion

This project set out to address the need for an affordable and portable humidity chamber to test solder reliability under controlled environmental conditions. In Chapter 1, the background, motivations, and objectives were clearly established, highlighting the limitations of commercial humidity chambers in terms of cost, size, and accessibility, especially in academic or small-scale research environments.

Chapter 2 provided a detailed literature review covering soldering technologies, various solder alloys (SAC305, SnCu, SnPb), corrosion mechanisms, and the impact of relative humidity on material degradation. This chapter also introduced existing designs and challenges of commercial humidity chambers, supporting the need for a more accessible alternative.

In Chapter 3, the research moved into the prototyping phase, where two design concepts were evaluated using the Pugh Matrix. The second design was selected and developed into a functional prototype using cost-effective materials. Detailed procedures for assembly, design drawings, and considerations for sustainability, safety, and usability were thoroughly documented.

Chapter 4 presented the results and discussion, showing that the prototype chamber successfully maintained stable humidity levels between 77%–79% and proved suitable for testing solder under controlled conditions. The discussion also reflected on practical challenges encountered during fabrication and testing, such as power supply management and material fitment.

Overall, this project successfully met its objectives by producing a working prototype that is practical, portable, and low-cost. It contributes to greater accessibility in environmental testing and serves as a foundation for future improvements, such as adding a micro-controller for humidity control and enhanced data monitoring features. This project also reflects sustainable design principles, supporting educational access and responsible innovation in line with selected UN Sustainable Development Goals.

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Appendices

Appendix A: Gantt Chart

The Gantt chart below illustrates the planned activities, timeline, and milestones for the project.

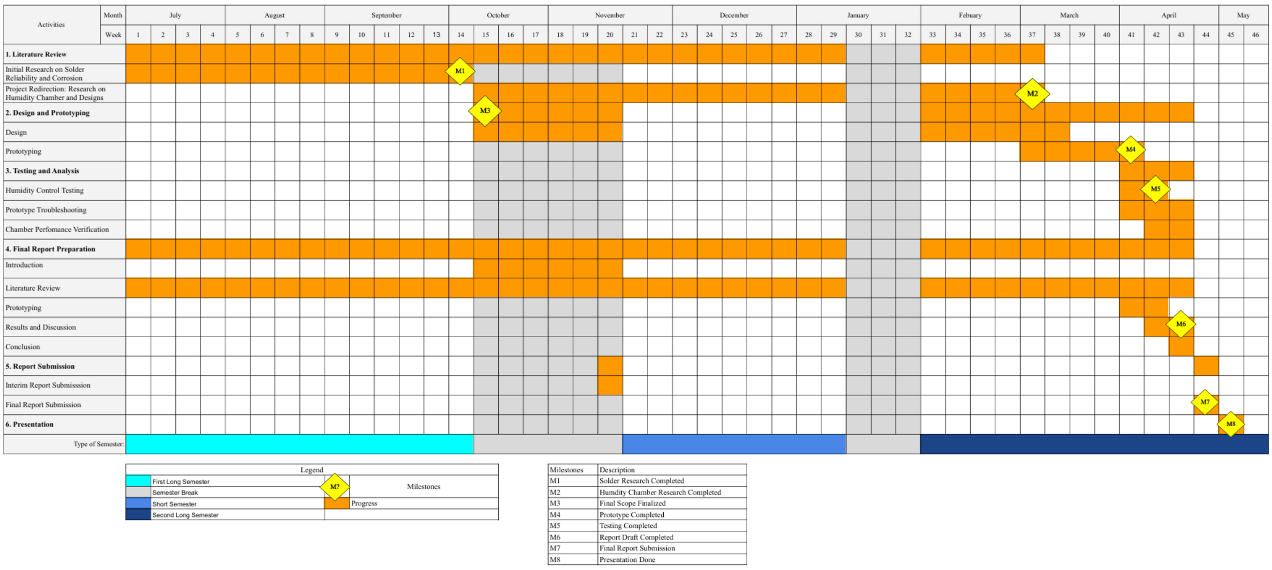

Figure A-1 Final Gantt Chart Showing Project Activities and Milestones. For full view, see: `https://docs.google.com/spreadsheets/d/1KAhZza4zvHO4ub5CSyyLJDlGdfvSx3YiSmgTqzmJpGk/edit?usp=sharing`

Appendix B: Panel Recommendation Form

Final Year Project Viva Panel Recommendation

FYP1 Viva Date: 6/05/2025
Student Name: LIM TZE ZHEN (Based on resubmission report)
Supervisor Name: Dr Intan Fatihah Binti Ahmad
Moderator Name: Dr Seow Boon Loo
Approved Project Title: DESIGN AND FABRICATION OF A COST-EFFECTIVE HUMIDITY CHAMBER FOR CONTROLLED ENVIRONMENT TESTING

Moderator			**Supervisor + Student**		
Observation	Constructive Recommendations with consideration of student's ability and time constraint	Signature	Agree/ Partially Agree/ Disagree	Justification	Signature
Change of project titles and contents	The first submission does not show design works, comments given and feedback to the department. Suggested to add in design of experiment but the supervisor and student decided to change the titles and objective, student has redo and resubmitted the report.		agree	The department has suggested only adding the design of the experiment to the report. However, in order to avoid any problems in future, we decided to change the titles and the objectives. The student has also redone and resubmitted the report.	
Typo errors	Some typo errors have been highlighted in the report returned. Figure 3-1 to be revised.		agree	All the highlighted typo errors will be checked and corrected.	
Figures	All figures need to be labelled for explanation purpose. Eg: Figure 3-2.		agree	All figures will be labelled for explanatory purposes.	
Errors in Pugh Matrix Table 3.4	The weightage given but not used		agree	The weightage assigned to each criterion was indeed used in the evaluation process. In the Pugh Matrix table provided, each design alternative was rated qualitatively relative to the datum	

Figure B-2 Panel Recommendation Form

Final Year Project Viva Panel Recommendation

				(commercial humidity chamber) using a scale of +1 (better), 0 (same), and -1 (worse). These ratings were then multiplied by the corresponding weights assigned to each criterion to produce a weighted score. The total score for each design was calculated as the sum of these weighted scores, allowing criteria with higher importance (such as cost and ease of fabrication) to contribute more significantly to the final evaluation. To improve clarity, I will revise the table to clearly label the weighted scores and explicitly show the formula used (Rating × Weight), ensuring that the application of the weightage is transparent and well-documented.	
References	Some of the references are journal paper, the hyperlink can be removed. Eg Ref [4][7] etc		agree	noted	

* Supervisor decision is final
* Students are required to display this form as a presentation slide in their FYP2 final presentation.
* Attach this document together with FYP logbook for final submission

Figure B-3 Panel Recommendation Form

Appendix C: Logbook

Diploma Final Year Project | Project Log-book | Doc no:DPRJLOGBOOKv1

Student Name : Lim Tze Zhen
Programme (Group) : DMGY2S3
Name of supervisor : Dr. Intan Fatihah Binti Ahmad
Student ID : 23WGD09693
Project Title : Design and Fabrication of a Cost-Effective Humidity Chamber for Controlled Environment Testing

Date of Meeting	Time and Duration	Venue	Statement of the Progress Achieved	Monitoring of Laboratory Work (minimum three physical/remote lab visits per semester by supervisor)	Action Required	Appointment of Next Meeting	Confirmed by Supervisor
24/10/ 2025	3 – 4pm	Online	- Discussed FYP interim report resubmission and change of project title to "Design and Fabrication of Humidity Chamber."		- To resubmit interim report with new title.	20/2/2025	Intan
20/02/ 2025	4 – 4.30pm	Q307	- Discussed new component list, and confirmed materials selection (humidifier, PVC foam board, fan).		- Source components and prepare for assembly.	26/2/2025	Intan
26/02/ 2025	2 – 4pm	N103	- Sketched and cut out the sizes of the foam board.	Yes	- To continue with the assembly of the chamber	7/03/2025	Intan

Figure C-4 Logbook done during the project

Diploma Final Year Project | Project Log-book | Doc no:DPRJLOGBOOKv1

Date of Meeting	Time and Duration	Venue	Statement of the Progress Achieved	Monitoring of Laboratory Work (minimum three physical/remote lab visits per semester by supervisor)	Action Required	Appointment of Next Meeting	Confirmed by Supervisor
07/03/ 2025	2 – 4pm	Home	- Assembled foam board walls using glue gun and supports. Installed base fan opening.		- Prepare humidifier mounting	12/03/2025	Intan
12/03/ 2025	2 – 4pm	N103	- Completed partial chamber assembly. Checked fit for humidifier and hygrometer.	Yes	- Finish full chamber assembly and perform dry run.	17/03/2025	Intan
17/03/ 2025	2 – 3pm	M102 (After Class)	- Supervisor reviewed progress on Chapter 3 and advised on technical write-up flow.	Yes	- Update Chapter 3 with technical descriptions.	21/03/2025	Intan
21/03/ 2025	2 – 4pm	Home	- Installed DC fan and humidifier. Completed full assembly of chamber.	Yes (Lab work reviewed)	- Start full testing and data collection.	1/04/2025	Intan

Figure C-5 Logbook done during the project

Diploma Final Year Project | Project Log-book | Doc no:DPRJLOGBOOKv1

Date of Meeting	Time and Duration	Venue	Statement of the Progress Achieved	Monitoring of Laboratory Work (minimum three physical/remote lab visits per semester by supervisor)	Action Required	Appointment of Next Meeting	Confirmed by Supervisor
1/04/2025	2 – 4pm	Home	- Performed humidity tests using hygrometer. Recorded 77–79% RH in enclosed chamber.		- Analyze data and draft Chapter 4.	17/04/2025	Antan
17/04/2025	4 – 5pm	Q307 (After Lecture)	- Final review of testing setup. Discussed test results and interpretation.		- Complete Chapter 4 and draft conclusion.	28/04/2025	Antan
28/4/2025	2 – 3pm	M102 (After Class)	- Reviewed full draft report. Supervisor gave final comments on formatting and flow.		- Finalize report and prepare for presentation.		Antan

Figure C-6 Logbook done during the project