University of Toronto
Faculty of Applied Science & Engineering
APS112: *Conceptual Design Specification (CDS)*

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Client Name	Grace Shan				
Project Title	Designing a cost-efficient method for humidifying solid wood guitars				
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1.0 Executive Summary

Musical instruments crafted from wood are easily susceptible to fluctuations in temperature and humidity. Extended exposure to low humidity can cause wood to expand and contract causing damage to an instrument. Our client Grace Shan seeks a design to store her guitar collection in optimal humidity levels to safeguard their sound quality. We have identified the gap of this project to be the lack of a guitar storage environment with consistently optimal humidity levels. The need is for an autonomous design that maintains adequate humidity. We are spatially limited to the client's music room, with modifications pertaining to the guitar being out of scope.

The primary function is to generate adequate humidity levels to preserve a guitars' structural integrity and acoustic properties. Our objectives include creating a solution that enables easy accessibility and display of the instruments while being autonomous. Key constraints include a budget of $300 per guitar, design with a minimum lifetime of 3 years and relative humidity levels within the range of 43-55%.

Our service environment consists of three main divisions: the physical environment, which includes natural elements and the furniture in the room; the user environment, the client's parents; and the virtual environment, encompassing internet connectivity and electrical infrastructure. Stakeholders of this project include the client's parents, acquaintances, as well as individuals living in the neighbouring houses.

The idea generation process was conducted with every aspect of the Project Requirements being considered. To foster creativity, we implemented various techniques including the SCAMPER method, brainstorming, blue sky thinking, lateral thinking, and morph charts. This approach allowed us to explore a wide range of possibilities and expand our design space. With 85 ideas generated, we proceeded with several evaluation processes including, a feasibility check, multivoting as well as a graphical decision chart to narrow down our options.

Ultimately, we were left with 3 alternative designs that stood out. Firstly, a whole room humidifier connected to a water supply featuring a UV light to prevent mold growth within the humidifier. Secondly, a glass display cabinet for multiple guitars equipped with an internal humidifying unit. Finally, a room-sealing approach containing a humidifier featuring a UV lamp to maintain optimal humidity levels while preventing microbial growth.

After thorough discussions and the creation of a Pugh chart, we decided to pursue the first design option due to several key objectives not being met in the second and third alternative designs. The selected whole-room humidifier ensures the guitars remain at optimal RH levels, facilitates easy access to the guitars and operates autonomously. Its seamless integration into various spaces, with its proven effectiveness, durability, and reliability, made it the ideal choice.

With pre-existing humidifiers proven not to work for the client, we have based our measures of success on simulations to test our main objectives. Testing if the solution could be left unmonitored for 7 days and preventing microbial growth using several environments with control variables including varying humidity, fluctuating temperature, and addition of mold spores.

To conclude, we are confident that our chosen solution will successfully fulfill all of its functions and objectives. Upon going through our measures of success, our client can rest assured that her guitars will be safely stored in an environment with optimal RH levels.

2.0 Introduction

Grace Shan, a resident of Toronto, ON, Canada, is an avid guitarist with a collection comprising five instruments fashioned from wood and/or pressed plywood. A physical property of wood is that its volume increases with its moisture content, which is dependent on the humidity of the instrument's surroundings [1]. Guitars undergo precise manufacturing processes within controlled humidity environments. Consequently, any fluctuations in the instrument's moisture content can lead to significant deformations that surpass acceptable tolerances, ultimately jeopardizing the integrity, appearance, and performance of the guitar.[2] (Figure 1).

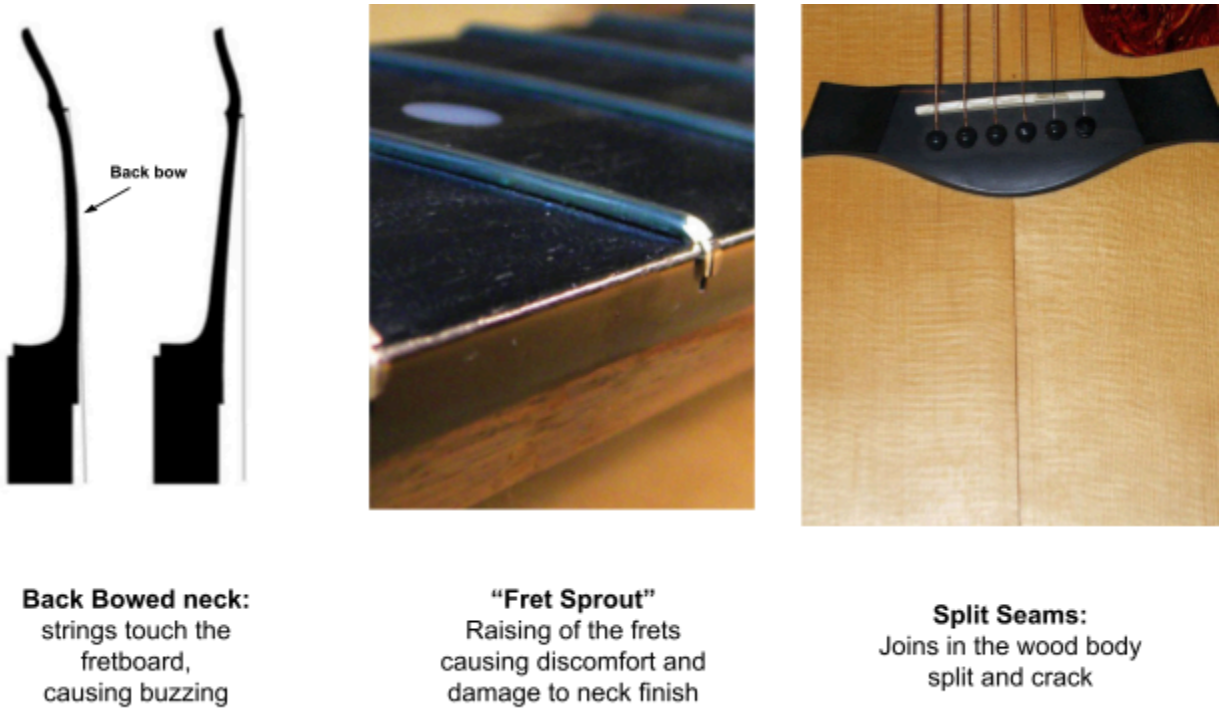


Figure 1. Common 'symptoms' of a dehydrated guitar [2]

Ms. Shan recognizes that maintaining specific relative humidity (RH) levels is crucial for the preservation of her guitar collection in the dry winters of her area of residence; however, high humidity levels created by a traditional humidifying unit [3] pose the risk of mould growth within her home. This document reviews the storage conditions of Ms. Shan's guitar collection and synthesizes design requirements, considering guitar preservation and stakeholder concerns.

3.0 Problem Statement

The relative humidity (RH) within the storage space of the client's guitars is presently at a diminished level of around 30% RH [3], posing the risk of adverse effects on the playability and structural integrity of the instrument [1]. This is caused by a combination of low environmental humidity [4] and the use of central heating in the winter. To remedy this, the client requests a design that automatically creates and maintains an environment with the ideal humidity for the guitars, protecting them from dryness through winter. The guitars may be left unattended for up to a week, necessitating the need for self-management of humidity and mold growth. Crucial stakeholders are the client's parents, who should not be tasked with any maintenance of the design. Ms. Shan values both the aesthetics and function of her collection, so the instruments should be displayed and their access should not be impeded.

Therefore, the project's gap, need, and scope are synthesized: The gap is the lack of an ideally humid environment for guitar storage. The need is a self-managing design able to maintain the correct humidity for safe and convenient guitar storage, which simultaneously displays the guitar collection. The scope of this project is spatially limited to the client's music room. Modifications to the guitars are out of scope to maintain their original condition (Appendix A). The design is only intended to store Ms. Shan's current and possible future guitars, not for any other user.

4.0 Service Environment

The design will operate in Ms. Shan's designated music room as the guitar collection, which is considered for design compatibility (Table 2), cannot be relocated to other areas of the apartment [3]. This section is divided into three categories: physical conditions, users, and virtual connectivity.

4.1 Physical Environment

The features and dimensions of the music room are outlined in Figure 2.

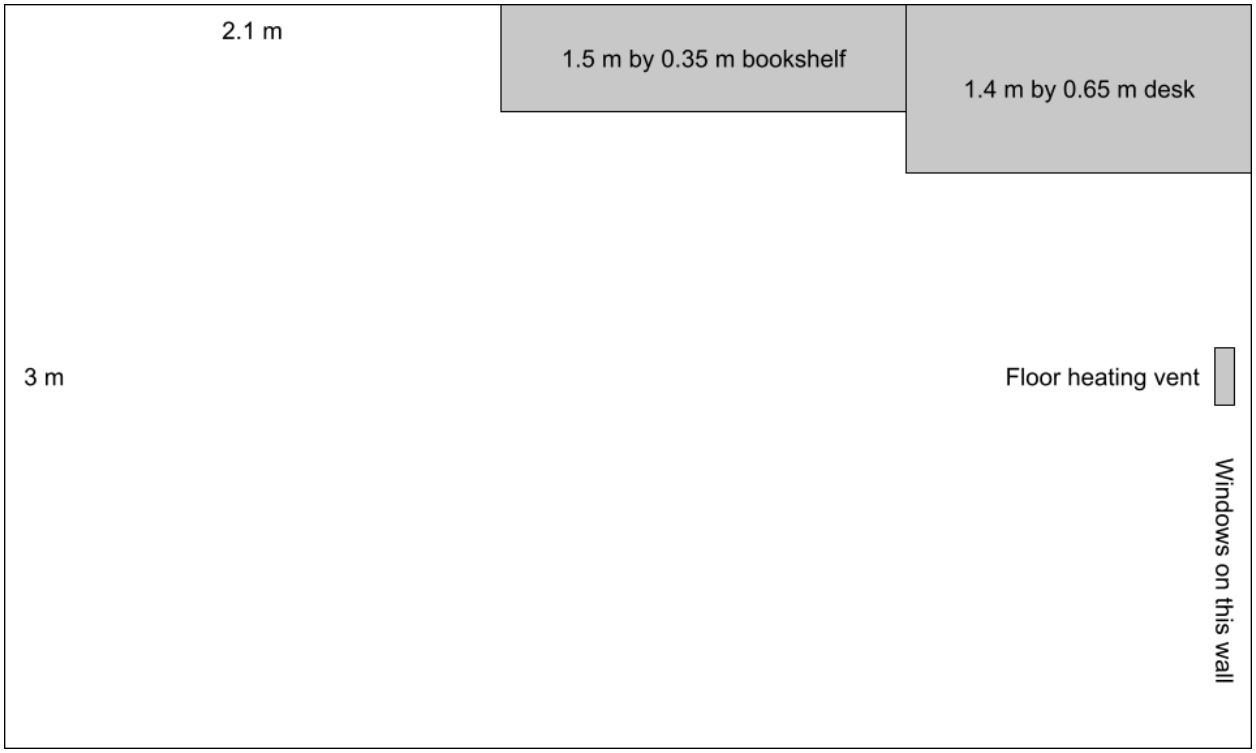


Figure 2. The floor plan & description for the music room provided by the client

Table 1. Client's room dimensions and materials

Dimensions and materials	• Ceiling height is 2.4 meters
	• Materials:
	  ○ Desk and shelf: solid pine
	  ○ Floor: carpet

Temperature, air quality, and humidity (Figures 3 and 4) are important design factors for guitar preservation as outlined in Table 1.

Table 2. Aerial conditions

Temperature:

Consistent around 23-24 °C [3]

Humidity:

Indoor:

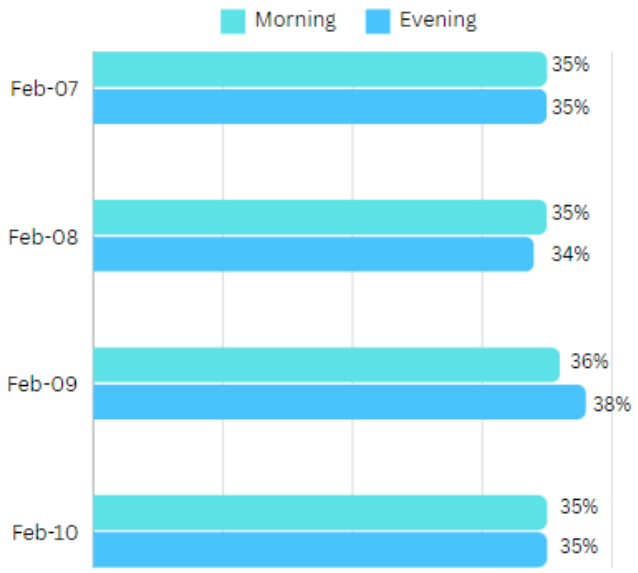


Figure 3. Humidity levels of the music room for week of February 07- February 10

Outdoor:

Month	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24
Maximum Humidity	100	100	100	100	100	100	100	100	100	100	100	100	100
Mean of Min/Max	74	72	67	57	63	71	72	69	74	69	82	80	74
Minimum	39	29	26	16	21	35	38	24	40	35	39	54	43

Figure 4. Monthly data for relative humidity levels in Toronto for 2023-2024 [4]

Air quality:

Windows are opened at least once a day, therefore air quality is similar to outdoor, at Air Quality Health Index value (AQHI) between 2-4. [5]

Table 3. Detailed Guitar and equipment Information

Hollow-bodied			Solid-bodied	
Taylor GS-Mini [6]	Yamaha guitar [7]	Classical guitar [8]	Epiphone SG [9]	Epiphone LP [10]
				
Solid wood	Laminate	Laminate	Solid wood	Solid wood
Scale Length: 23-1/2" **Body Length:** 17 5/8" **Body Width:** 14 3/8" **Body Depth:** 4 7/16" **Neck Width:** 1-11/16" **Scale Length:** 23-1/2" **Gross weight:** 1.8 Kg [11]	**Spruce** **Scale Length:** 648 mm (25 1/2") **Body Length:** 512 mm (20 1/8") **Body Width:** 400 mm (15 3/4") **Body Depth:** 100-125 mm (3 15/16"-4 15/16") **Weight:** 2.2 Kg [11]	**Dimensions:** 20.32 × 35.56 × 45.72 cm **Weight:** 5.76 kg [11]	**Mahogany** **Scale length:** 24.75" / 628.65mm **Country of origin:** China **Gross Weight:** 3.1 Kg [11]	**Mahogany** **Scale length:** 24.75" / 628.65mm **Nut width:** 1.68" / 42.672mm **Weight:** 4.3 Kg [11]

4.2 User environment

The client, Grace Shan, is the primary user of the guitar collection.
There are no pets or animals in the residence.
Ms. Shan's parents live permanently in the residence and visit the room for regular cleaning. (Appendix A)

4.3 Virtual Environment

Internet connection is available (Appendix A).
Electrical power is available (120V, 240V) [13]

5.0 Stakeholders

The proposed humidifying solution may impact stakeholders other than Ms. Shan, as summarized in Table 4 below:

Table 4. Stakeholders and Corresponding Impact

Stakeholder Group	Stakeholder	Interest and Impact
Other Residents	Ms. Shan's parents	● The apartment is primarily occupied by her parents. ● May use the guitar room or may choose to undergo regular cleaning etc
Guitar Users	Ms. Shan's Acquaintances	● Ms. Shan may wish to bring or provide access to any of her acquaintances to the guitar room. ● May be impacted by humidity levels, use of chemicals or changes to air quality
Neighbours	Individuals living in neighbouring houses.	● Neighbouring units may be impacted by noise or other disturbances from the design.

6.0 Detailed Requirements

Requirements for the guitar humidification design were developed through the analysis of the client statement and meeting. Supplementary secondary research was conducted to help develop quantitative metrics for the functions, objects, and constraints of the design.

6.1 Functions

This section articulates the essential functions that the humidification system must fulfill, derived through the Black Box method (see Appendix B). Figure 5 depicts both primary and secondary functions for reference.

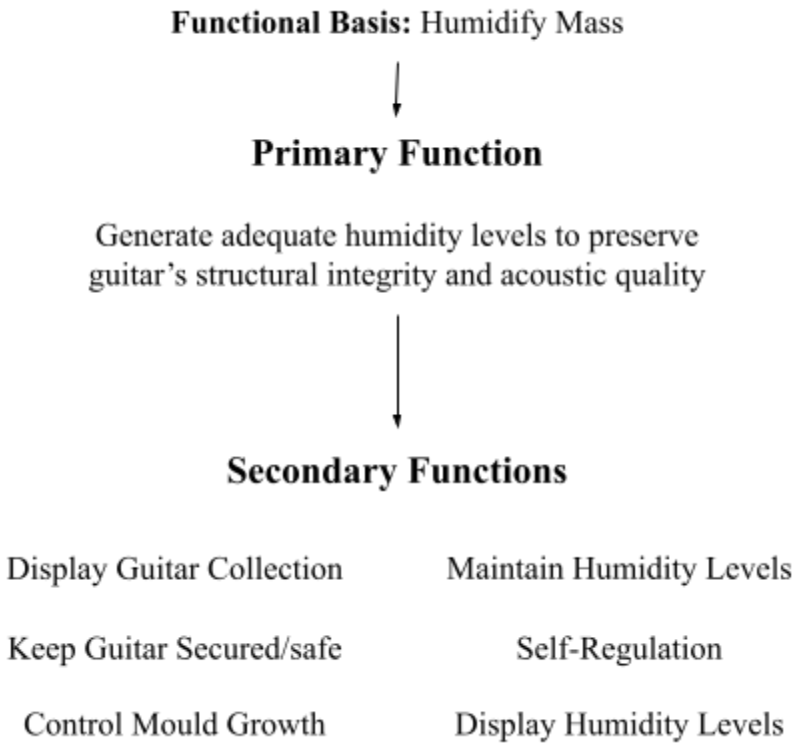


Figure 5. This figure describes the functional basis, primary function, and secondary functions of the project.

6.2 Objectives

Objectives were synthesized using Ms. Shan's client statement and benchmarking of previous design attempts for this problem and ordered using pairwise comparison (Table 5 and Appendix C).

Table 5. Design objectives, goals, metrics and justification

Objective	**Goal** Design should:	**Metric**	**Justification**
Functionality			
Humidity Level	• Always be within 50%-53% RH	Relative Humidity Level	Requirement from client. [3]
Convenience & Monitoring	• Be capable of unmonitored function for more than 7 days • **Not** exceed 40 dBA [15] while running to not disturb neighbouring residents.	Days Db	Design will be left unmonitored for a number of days, and shouldn't disturb other residents. [3]
Mold Growth	• Prevents microbial growth within the humidifier for at least 7 days	Days	Previous issue brought up by client [3]
Accessibility	• Take less than 1 minute or less than 3 steps to access the guitars. • **Not** be stored in cases or require tools.	Minutes Number of Steps	Requirement from client, for ease of use. [3]
Durability	• Last longer than 3 years without replacement. [3]	Years	Requirement from client [3]
Budget			
Cost	• Cost less than $90 to maintain throughout the winter. [3]	Dollars	Requirement from client [3]

6.3 Constraints

The following Table 6 lists restrictions that must not be violated in the design using information given in the client statement [3] and client meeting notes (Appendix A).

Table 6. Metric-based constraints and justifications

Constraints *Design must (be):*	**Justification**
Automatic: operate without human intervention for 7 consecutive days	Design will be left unattended for multiple days at a time [3]
Maintain **43% to 55% RH** for guitars at all times	Guitar relative humidity requirement [3]
Maintain **20-25 degrees Celsius** temperature	Acceptable temperature range for guitar storage [3]
Maximum of **$300/guitar** humidified	Client budget restriction [3]
Minimum lifetime of **3 years**	Acceptable design lifetime indicated by client [3]
Entire body of guitar must be **visible**	Client request for aesthetic purposes [3]
Contained within a **single room**	Client request for guarantee of provided operating conditions [3]
Must not mar guitar surfaces at points of physical contact.	Must not **damage** guitars [3]
Must not raise water activity of any materials in the surrounding room over 0.65	Must not increase risk of mold growth. [3][16]

7.0 Generation, Selection and Description of Alternative Designs

Our idea generation and selection process aimed to first produce a diverse initial design space, and use systematic selection methods to avoid confirmation and/or other bias in our chosen design.

7.1 Idea Generation

The ideation process (Figure 6) was initiated by tasking each team member to generate 25 unique ideas, to benefit from individual thinking's enhanced brainstorming ability [18]. After consolidating all the brainstormed ideas and removing duplicates, the team applied SCAMPER to the ideas to expand and diversify the solution space, seeking additional means to satisfy the project requirements. At this point, the team reached 85 ideas (Appendix E).

Some ideas were, a wall-mounted device that monitors the entire room environment and sounds an alarm when necessary, a smart guitar case with a moisture control feature, and a glass display that maintains a constant humidity level. We tried to combine usefulness and style; we took inspiration from food preservation techniques and museums. For instance, a climate room that can house an entire collection using museum archival techniques, or guitar strings that can be kept at constant moisture levels using silica gels, which are used in the food and beverage industry to control moisture.

Creative tools such as the Morph Chart (Appendix F) and SCAMPER (Appendix G) were then used collaboratively to create 68 solutions that satisfy most of the secondary functions, that is, display the guitar collection, keep them secured, control mould growth, maintain humidity levels, is self-regulating and displays the humidity levels.

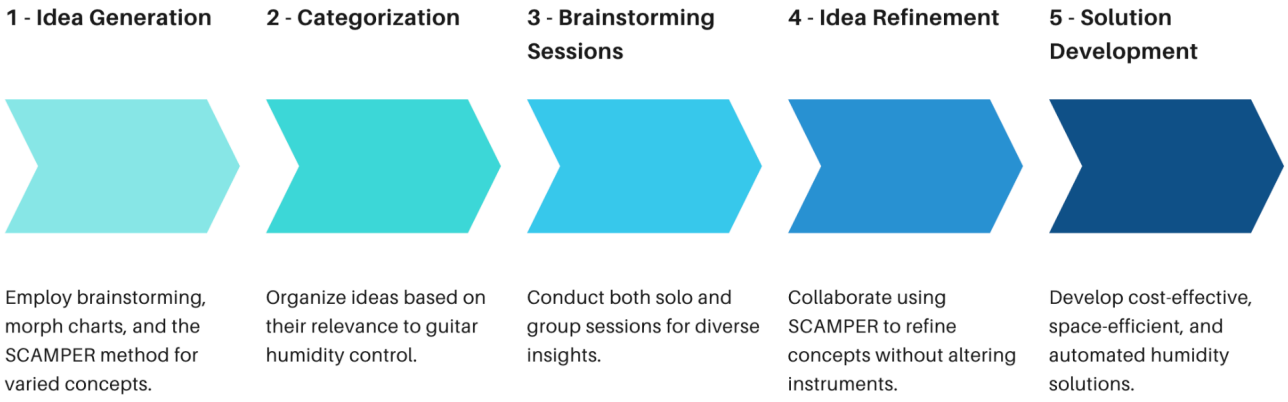


Figure 6. Flow Chart explaining the Idea Generation process

7.2 Alternative Design Selection

The idea selection process utilized structured and justifiable decision making tools to ensure an alternative design selection free of bias. Each idea was run through a feasibility check based on its ability to create the design within a $300 budget, narrowing down ideas to 35 by eliminating any solution that is infeasible based on approximate cost of the materials used in the designs.

The feasibility check was followed by Multivoting which shrunk the design space to 20 ideas (Appendix H), where individual members voted based on:

a) Constraints that limit physical dimensions to within the room, visibility of the guitars, ensuring consistent RH level.
b) Functional efficacy of the humidification system: ability to generate humidity autonomously.
c) Objectives: being able to access the guitars in less than a minute, prevention of mold growth for at least 7 days, and durability of the design.

The 20 highest-voted ideas were then evaluated in reference to one another using a graphical decision chart (Figure.7) based on the two main objectives, mold prevention, and convenience and monitoring (as determined in the Pairwise Comparison Chart (Appendix C). Through the graphical decision chart, each idea received a 0-20 rating based on how well it satisfied these objectives as shown in Appendix I. The three designs closest to the top right corner (i.e. which best satisfy both of the objectives in question) were chosen as the 3 alternative designs.

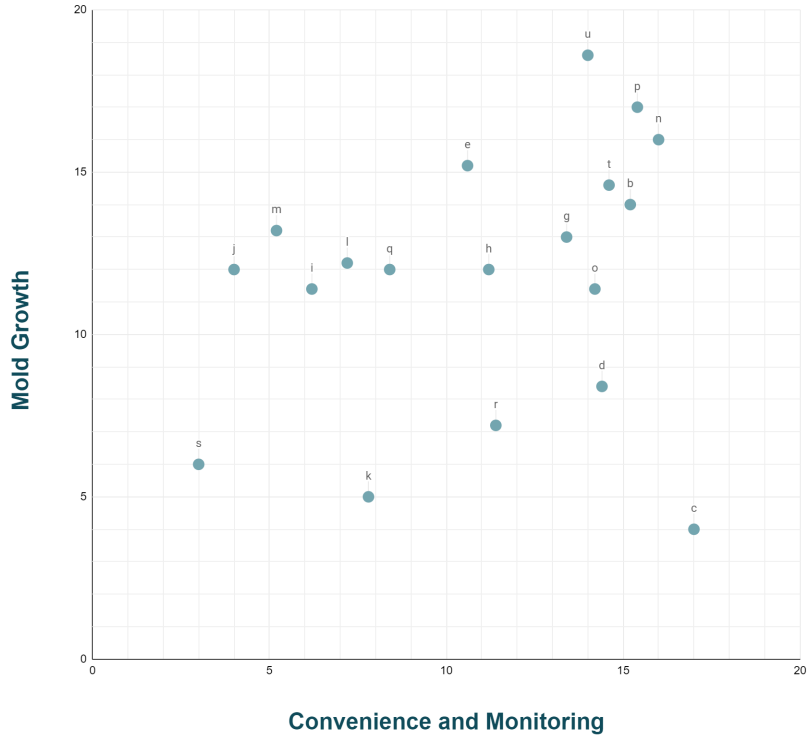


Figure 7. The scatter plot represents ideas and the scale to which they satisfy the top two objectives.

7.3 Alternative Design Descriptions

This section provides an in-depth description of all of our 3 alternative designs. Each design consists of a written description, a conceptual sketch, an objective evaluation table, and a list of benefits and drawbacks to each design.

7.3.1 Alternative Design A: Waterline-fed humidifier

A whole room humidifier taking the form of a floating shelf is connected to the home water supply. A small reservoir made of copper (Appendix J) holds water for the ultrasonic atomizer, which generates the humidity. The reservoir is refilled when the water level drops, activating the conductive level sensor. An electronic controller reads input from a hygrometer near the guitar stands and regulates the atomizer to maintain the correct humidity level by compensating for the rate of humidity leaving the room (Table 7). The design is visually described in figure 8 below.

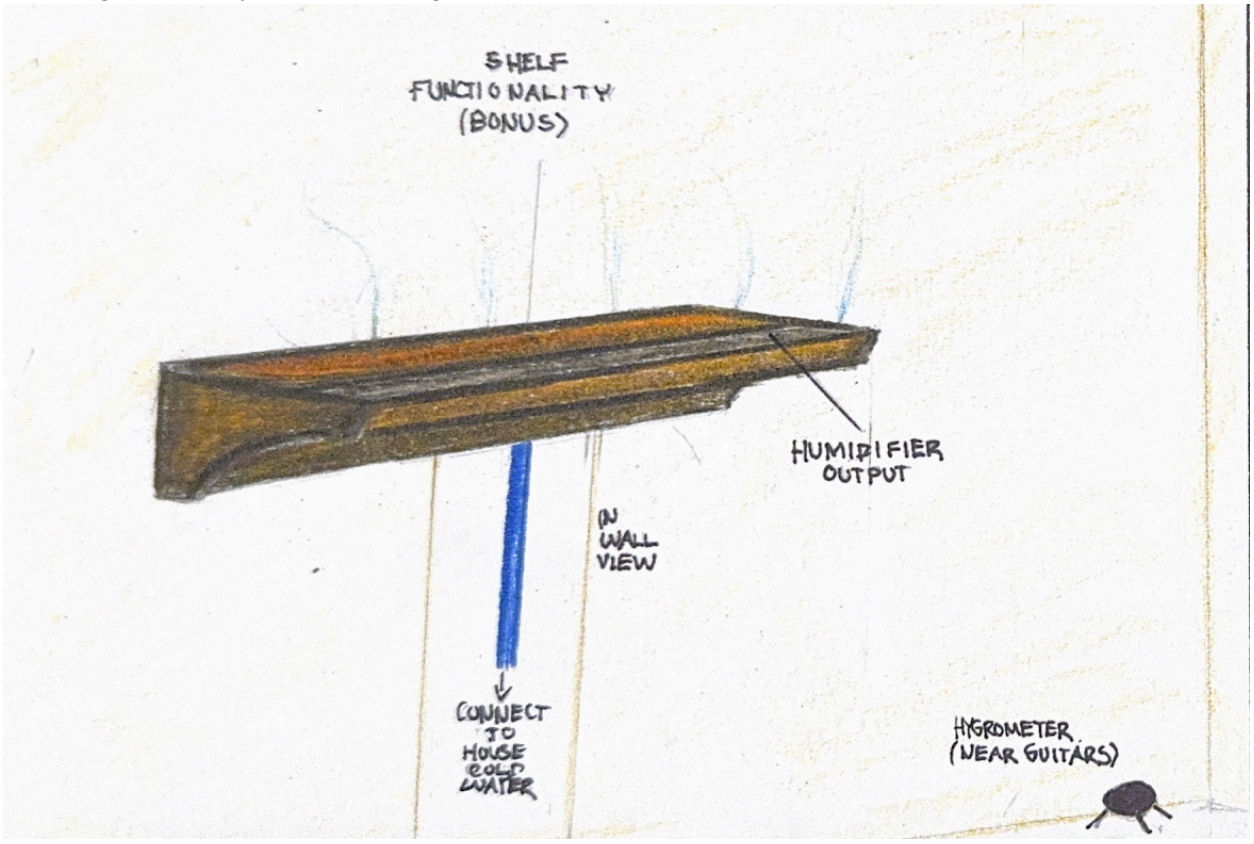


Figure 8: Alternative Design A

Table 7. Evaluation of Design A

Objective	Method/degree of Achievement
Humidity Level	Target levels, in playing and in storage
Convenience & Monitoring	Time between refills: N/A (self-filling) Self-monitors humidity levels
Mold Growth	Mitigated by copper construction [20]
Accessibility	Very easy to access, guitars on open stands owned by client
Durability	Few moving parts, 2-5 years [19]
Cost	~ $375 (Appendix K)

Notable benefits of this design include:

- Constant humidity, even while playing
- No refilling

Drawbacks of this design include:

- More complicated installation (requires plumbing)

7.3.2 Alternative Design B: Humidified Display Cabinet

Humidity is generated by an ultrasonic atomizer connected to a 6-litre water tank humidifier made of copper within its base (Appendix J). An electronic controller reads input from a hygrometer inside the cabinet and regulates the atomizer to maintain the correct humidity level. The cabinet provides isolation from airflow so that the system can run longer without refill. The glass panels and integrated lighting allow the guitars to be displayed. The humidifier will continue to run while the glass doors are open (consuming water at a faster rate), providing humidity to the room while the guitar is being played, so that the guitar's environment is always within the target humidity (Table 8). The design is visually described in figure 9 below.

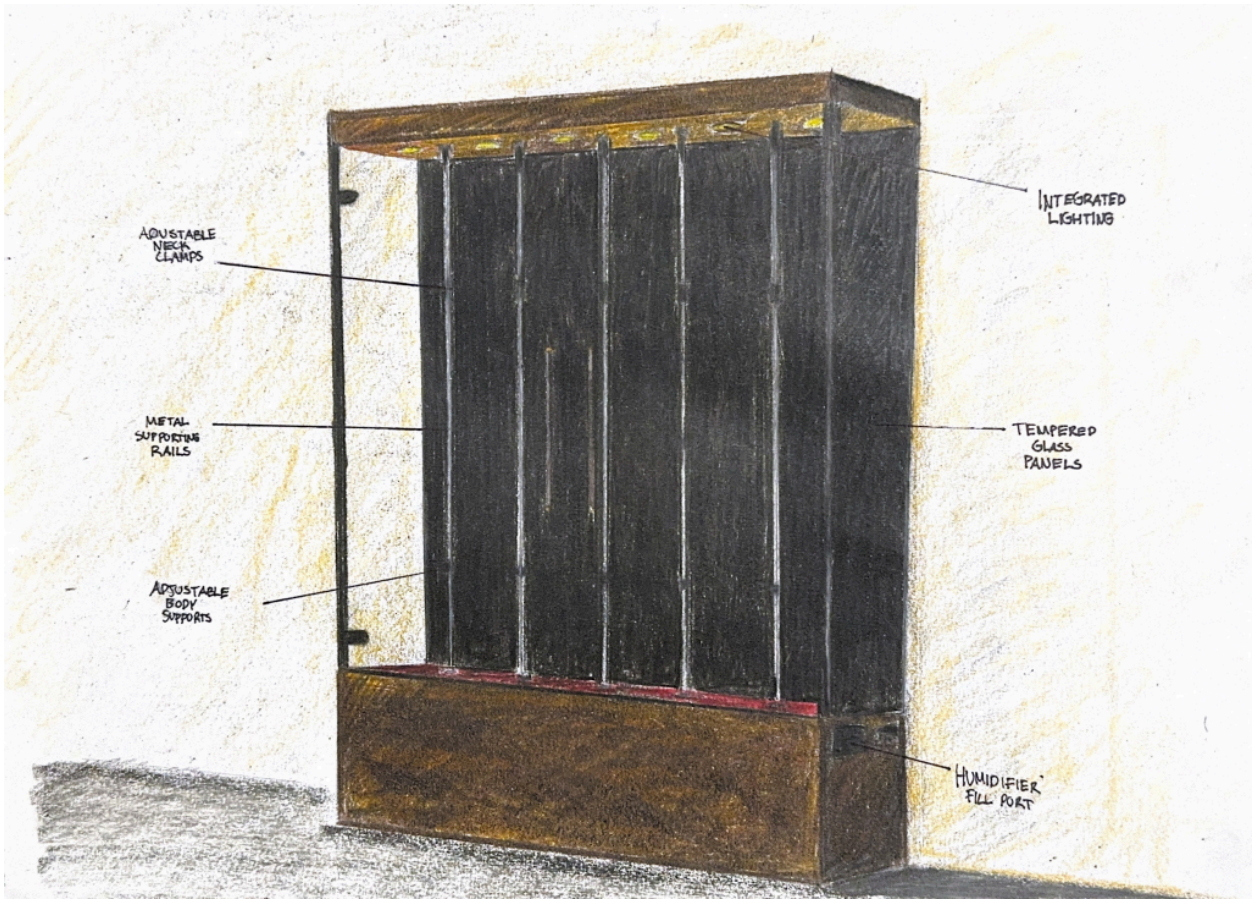


Figure 9: Alternative Design B

Table 8. Evaluation of Design B

Objective	Method/degree of Achievement
Humidity Level	Target levels while in storage, 30% RH (ambient) while playing
Convenience & Monitoring	- Time between refills: >2 weeks (Appendix K) - Self-monitors humidity levels
Mold Growth	Mitigated by copper construction [20]
Accessibility	Need to open cabinet doors and remove from a hanger in the cabinet (still relatively easy)
Durability	2-5 years [19]
Cost	~$400 (Appendix K)

Notable benefits of this design include:
- Aesthetic qualities
- Protection from dust
- Longer lasting between refills

Drawbacks of this design include:
- Higher cost
- Requirement of water refill every 2 weeks (Appendix K)

7.3.3 Alternative Design C: Vapor isolation for humidity retention

Humidity is generated by an ultrasonic atomizer with a 6-litre reservoir made of copper. Waterproofing membrane is applied to the walls and ceiling, caulk seals interfaces between the floor and walls and walls and ceiling, and a rubber door sweep is installed, to reduce the amount of moisture leaving the room. An electronic controller reads input from a hygrometer near the guitar stands and regulates the atomizer to maintain the correct humidity level (Table 9). The design is visually described in figure 10 below:

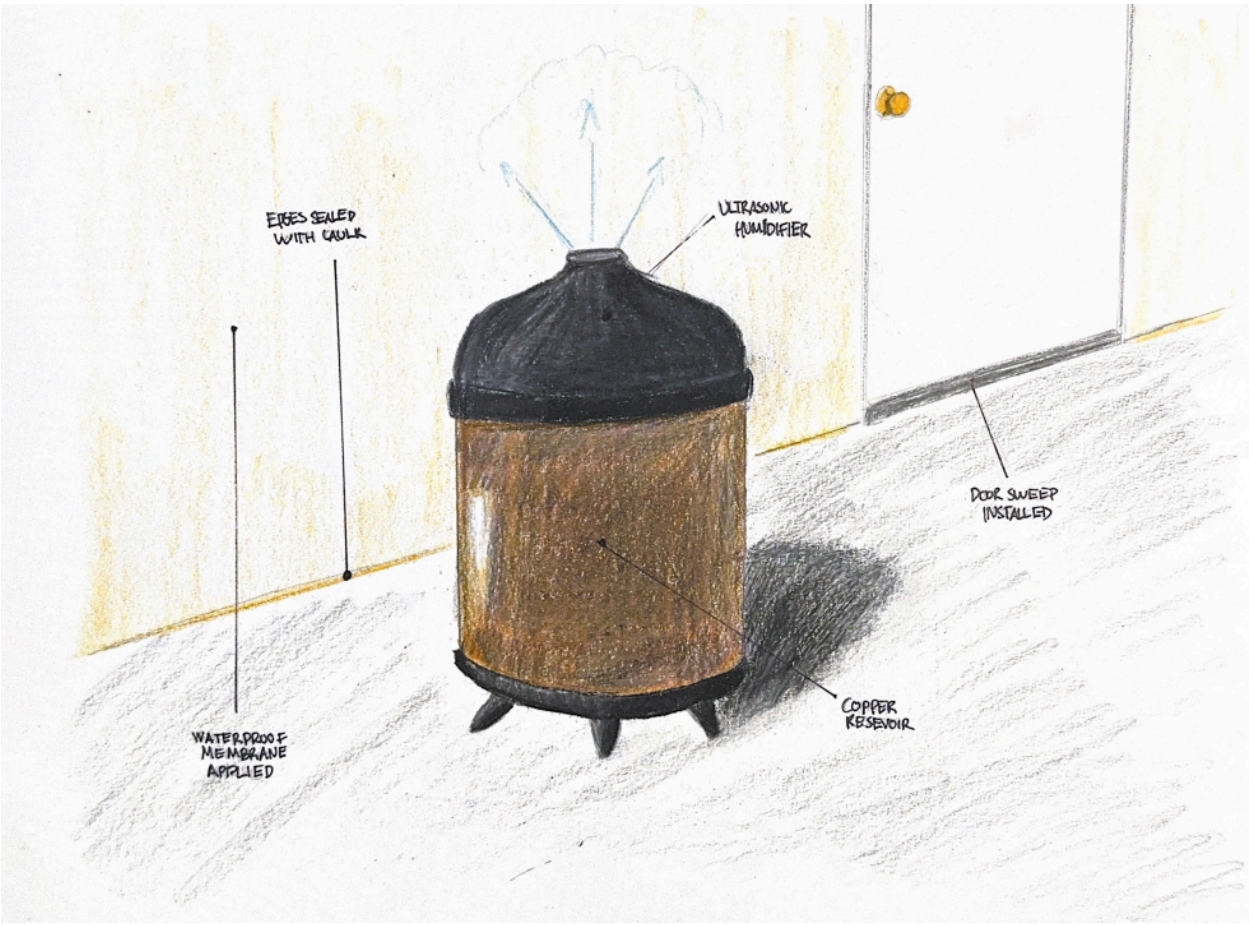


Figure 10: Alternative Design C

Table 9. Evaluation of Design C

Objective	Method/degree of Achievement
Humidity Level	Target humidity in storage and while playing.
Convenience & Monitoring	- Time between refills >1 week (Appendix K) - Self-monitors humidity levels
Mold Growth	Mitigated by copper construction [20]
Accessibility	Very easy to access, guitars on open stands
Durability	2-5 years [19]
Cost	~300 (Appendix K)

Notable benefits of this design include:

- Plumbing-free installation

Drawbacks of this design include:

- Requirement of water refill every 1 week (Appendix K)

8.0 Proposed Conceptual Design Specification

To identify a solution that satisfies every function and fulfills the main objectives we utilized a Pugh chart (Table 10.) using humidipaks as a datum since it was the most effective out of the solutions the client has tried before. This is proven since it is stated in the client statement [3] to have the least amount of problems.

Table 10. Pugh Chart

Objectives	Datum. Humidipaks	A. Waterline-fed Humidifier	B. Humidified Display Cabinet	C. Vapor Isolation for Humidity Retention
Accessibility	S	+1	+1	+1
Humidity Level (consistency in maintaining RH)	S	+1	+1	+1
Convenience and Monitoring	S	+2	+1	0
Sum	**0**	**+4**	**+3**	**+2**

The analysis reveals that alternative design A, the Waterline-fed humidifier (figure 11), is the most effective solution. Since all the solutions prevent mold growth through the use of copper reservoirs (Appendix K), this objective is not considered in the pugh chart for comparison. However, the alternatives require major changes to the room as well as more monitoring.

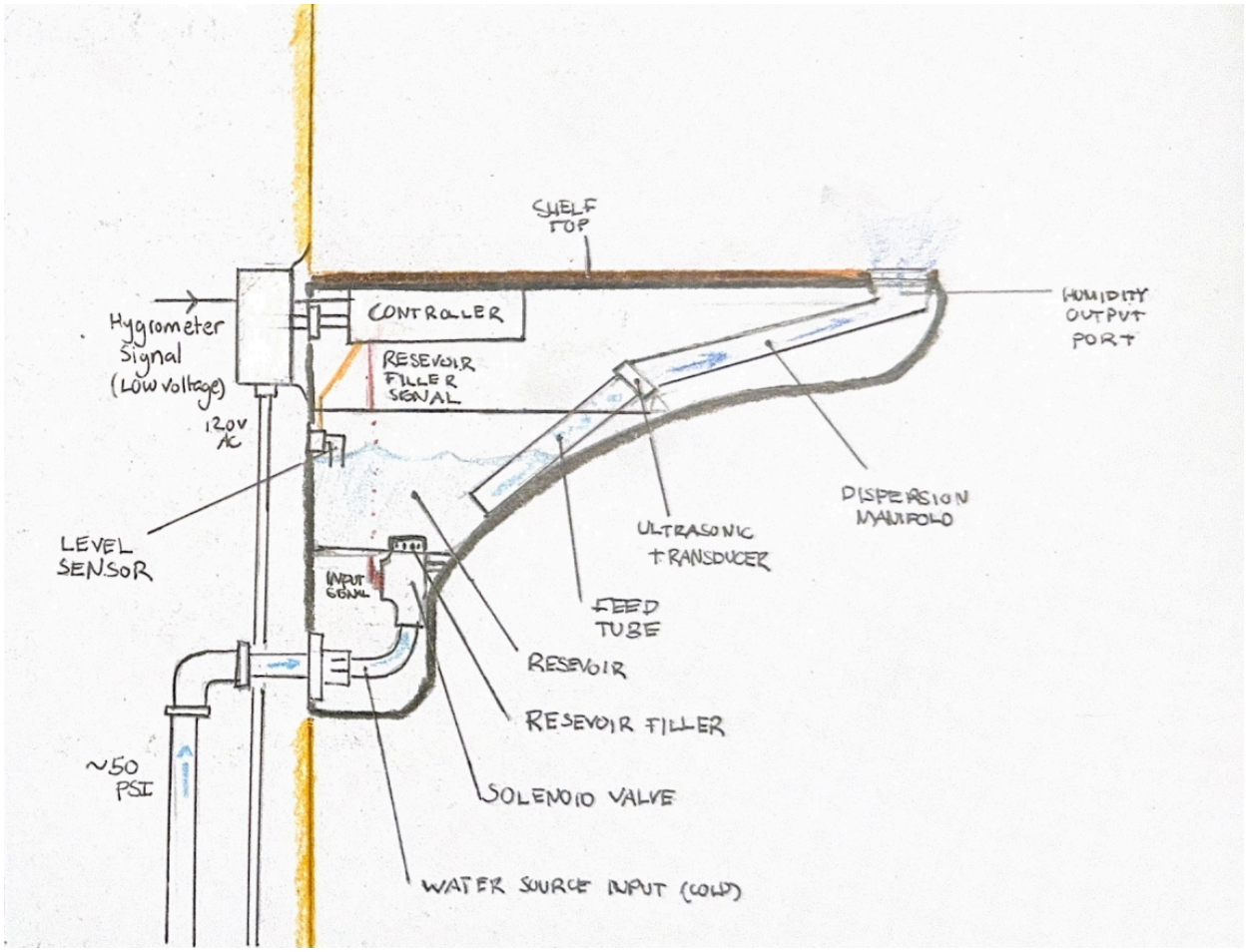


Figure 11: Waterline-fed humidifier: detailed cross section

The waterline-fed humidifier solution ensures the guitars remain consistently stored in an environment with the optimal RH levels, even when being played. Additionally since it is connected to a water source, water is automatically refilled into the humidifier, instituting less maintenance required through not having to refill the tank. This design facilitates easy access to the guitars because the client can display them anywhere within the room using the guitar stands she already owns and can operate autonomously while having minimal impact on the room's layout. Because this solution modifies an already existing solution, it is proven to be effective, durable and reliable. This, accompanied by its seamless integration into various spaces, made it the ideal choice.

9.0 Measures of Success

The success of our proposed design will be measured through a series of calculations, and tests done to ensure the design satisfies the main objectives: unmonitored function and prevention of microbial growth over a period of 7 days. To validate the success of our design, a timeline was created to ensure that all aspects are considered before the final deadline in Table 11.

Table 11. Timeline of prototype production

Timeline	Details of actions during the period of time
March 26-28	Creating a virtual prototype using 3D modelling on SolidWorks
March 28th-April 5	Completion of prototype development of the waterline-fed humidifying module
April 6-7	Run controlled test on prototype.
April 8	Making final revisions and refining before the final solution

Test 1: Evaluating Continuous Function

This test will evaluate whether the design will ensure the humidifier can function effectively for at least 1 week without user input and malfunctions as denoted by our Convenience & Monitoring objective.

Objective **:** Test for user convenience

Environment Description: The testing simulations shall take place in an enclosed isolated room with similar dimensions to the clients' guitar storage room

Method: Switch on the humidifying system once our room humidity reading reaches 30 percent. Use a digital hygrometer to measure the humidity and water consumption of the reservoir located between the filler and the ultrasonic transducer. Our hygrometer of choice is the Govee Bluetooth Hygrometer which has a refresh rate of 2s with an error reading of 2-3 percent listed on Amazon. During normal operation, we can observe readings obtained on the hygrometer, and measure the reservoir water level during 1-hour intervals. Alongside noting readings, we must visually inspect the humidifier daily for leaks and abnormal noises or vibrations. The following conditions of the room environment are outlined below :

- Temperature Maintained within the room standard temperature range of (23-25°C) as specified by the client

- Humidity: Initially set at a low level (e.g., 30%) to trigger humidifier operation. This testing humidifier level can be achieved by opening the windows which may reduce the moisture in the air.

Analysis and data collection :

Obtain and plot humidity and water level readings obtained over 1 week against time intervals of 1 hour for each day. We can create a scatter diagram and plot a line of best fit. Using our readings we can determine :

- How quickly the humidifier reaches the target humidity
- Fluctuations over the 7 days
- Calculate the median, average, and standard deviation

To conclude our test we must verify that our humidity readings are consistent throughout the duration of this test.

10. Conclusion

Three distinct solutions have been proposed to address Grace Shan's concern about designing a cost-efficient method to humidify her guitars. The proposed humidifying system, a water-line-fed humidifier design, carefully addresses the client's primary concern: maintaining optimal humidity levels within 53%-55% RH for extended periods to preserve and provide optimal playing conditions for their guitar collection. This design solution also satisfies the top objectives of operating independently, allowing guitars to be easily accessible, and preventing mold growth for at least 7 days. Thorough testing and evaluation procedures will ensure optimal user experience, protecting the structural integrity of the guitars.

11.0 Reference List

[1] “Symptoms of a Dry Guitar,” Taylor Guitars. Accessed: Feb 15, 2024. [Online]. Available: https://www.taylorguitars.com/support/maintenance/symptoms-dry-guitar

[2] “Guitars & Humidity (Part 1): Eight signs of humidity damage.” MONO Blog. Accessed: Feb 15, 2024. [Online]. Available: https://blog.monocreators.com/guitars-and-humidity-nine-signs-of-guitar-humidity-damage/

[3] Grace Shan, “Designing a cost-efficient method for humidifying solid wood guitars,” Jan. 2024. Accessed: Jan. 29, 2024. [Online]. Available: https://docs.google.com/document/d/1CIizgRdLew0EbRUFBCLwBrk9qZ8taP5YC_Sk8J_0dNc/edit?usp=sharing

[4] Toronto Weather Stats. “Monthly Relative Humidity in Toronto, Ontario.” Accessed: Feb. 10, 2024. [Online]. Available: https://toronto.weatherstats.ca/charts/relative_humidity-monthly.html

[5] Environment and Natural Resources, “Toronto weather.” Government of Canada. Accessed: Feb. 10, 2024. [Online]. Available: https://weather.gc.ca/airquality/pages/onaq-018_e.html.

[6] “Taylor Guitars - GS Mini-e Koa Acoustic-Electric Guitar w/Bag,” Long and McQuade. [Online]. Available: https://www.long-mcquade.com/92895/Guitars/Acoustic-Guitars/Taylor-Guitars/GS-Mini-e-Koa-Acoustic-Electric-Guitar-w-Bag.htm. [Accessed: 01-Feb-2023].

[7] “Yamaha - F325D Dreadnought Acoustic,” Long and McQuade. [Online]. Available: https://www.long-mcquade.com/66611/Guitars/Acoustic-Guitars/Yamaha/F325D-Dreadnought-Acoustic.htm?ref=suggestive-search [Accessed: 01-Feb-2023].

[8] “Denver - Classical Guitar - 3/4 Size - Natural,” Long and McQuade. [Online]. Available: https://www.long-mcquade.com/25281/Guitars/Classical-Guitars/Denver/Classical-Guitar---3-4-Size---Natural.htm [Accessed: 01-Feb-2023].

[9] “Epiphone - SG Special Satin E1 - Vintage Cherry,” Long and McQuade. [Online]. Available: https://www.long-mcquade.com/91791/Guitars/Electric-Guitars/Epiphone/SG-Special-VE---Vintage-Cherry.htm [Accessed: 01-Feb-2023].

[10] “Epiphone - Les Paul Studio - Alpine White,” Long and McQuade. [Online]. Available: https://www.long-mcquade.com/164916/Guitars/Electric-Guitars/Epiphone/Les-Paul-Studio---Alpine-White.htm [Accessed: 01-Feb-2023].

[11] Andy Fraser, “How Much Do Guitars Weigh?” Guitar Inside Out, Nov. 13, 2022. [Online]. Available: https://www.guitarinsideout.com/how-much-do-guitars-weigh/

[12] Daddario, “Humidity and Temperature Sensor.” Accessed: Feb. 07, 2024. [Online]. Available: https://www.daddario.com/products/accessories/humidification/sensors/humidity-temperature-sensor/

[13] Toronto Hydro, “Direct supply from Toronto Hydro’s transformer,” *How to Power Up With Toronto Hydro,* 2021, pp. 12. [Online]. Available: https://www.torontohydro.com/documents/20143/185118906/how-to-power-up-with-toronto-hydro-developer-manual.pdf/7dbb1284-5c01-7569-f60b-bb99d921cf69?t=1673036179696

[14] HomeLane, “What’s The Ideal Dimension of a Standard Wardrobe?” Accessed: Feb. 07, 2024. [Online]. Available: https://www.homelane.com/blog/everything-you-need-to-know-about-wardrobe-measurements/#:~:text=What%20Is%20the%20Standard%20Size,a%20depth%20of%20two%20 feet

[15] Government of Québec. “Noise Measurement,” *The effects of environmental noise on health,* June 16, 2022. [Online]. Available: https://www.quebec.ca/en/health/advice-and-prevention/health-and-environment/the-effects-of-environmental-noise-on-health/noise-measurement

[16] Williams, R. Sam, “Finishing of wood,” in *Wood handbook : wood as an engineering material*. Madison, WI : USDA Forest Service, Forest Products Laboratory, 1999, ch. 16, pp. 11. [Online]. Available: https://cdn.homeownershub.com/media/30517/5f8d87fb8de147.25798922.pdf

[17] Government of Canada, Canadian Conservation Institute, 2020, “How to prevent mould growth in the collection,” *Mould Prevention and Collection Recovery: Guidelines for Heritage Collections – Technical Bulletin 26*, Feb. 19, 2020, s. 1.2 [Online]. Available: https://www.canada.ca/en/conservation-institute/services/conservation-preservation-publications/technical-bulletins/mould-prevention-collection-recovery.html#a3b

[18] W. Stroebe, B. A. Nijstad, E. F. Rietzschel, “Beyond productivity loss in brainstorming groups: The Evolution of a Question”, vol. 43, 2010, pp.157-203. Accessed Nov. 26 2023. [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S006526011043004X

[19] Tom Moor, “What's the Lifespan of a Humidifier?”, HVAC.com blog. Accessed: March 24, 2024. [Online]. Available: https://www.hvac.com/expert-advice/how-long-do-humidifiers-last/

[20] G. Grass, C. Rensing, and M. Solioz, “Metallic copper as an antimicrobial surface,” Applied and environmental microbiology, Accessed: March 20, 2024. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3067274/

[21] “LEVOIT Humidifiers For Bedroom Large Room Home, 6L Top Fill Warm and Cool Mist for Whole House, Smart Wifi Alexa Control, Customized Humidity, Essential Oil, Sleep Mode, Timer, White,1.58 gallons : Amazon.ca: Home,” www.amazon.ca. https://www.amazon.ca/dp/B095KGXPW5?btn_ref=srctok-a3c7a7c1dd5666e1&ascsubtag=11077z51993&linkCode=gs2&tag=thewire0f-20&th=1 (accessed Mar. 25, 2024).

[22]“MILSBO glass-door cabinet, anthracite, 73x175 cm (283/4x687/8"),” IKEA. https://www.ikea.com/ca/en/p/milsbo-glass-door-cabinet-anthracite-30396448/ (accessed Mar. 25, 2024).

[23] Kevin and Bluerig, “Custom building products RedGard 13.25 l ready-to-use waterproofing and crack prevention M...,” The Home Depot Canada, https://www.homedepot.ca/product/custom-building-products-redgard-13-25-l-ready-to-use-waterproofing-and-crack-prevention-membrane-with-quick-dry-formula-for-tile-and-stone-installations/1000737357 (accessed Mar. 25, 2024).

12.0 Appendix

Appendix A: Client Meeting Notes (consolidated, then from engineering notebooks)

1. Placement Preference: The humidification system will be placed in a room of the client's parents' house, which has a single heating valve for forced heating.

2. Portability: While it would be preferable for the system to be portable for potential relocations of your guitars, it's not a critical requirement in the short term.

3. Functions: The primary function of the system is to humidify the guitars. However, it would be preferable if the design allows for easy access to the guitars and enables immediate playing.

4. Accessibility: While there's no preference for guitars to be on the wall or on stands, it's important that they're easily accessible and not stored in cases.

5. Ease of Access: Having to use a tool or unlock something to access the guitars is preferable to storing them in cases, but the ease of access is still important.

6. Aesthetics: The system should not obstruct the view of the guitars and should have a minimalistic design that blends with the room decor, preferably in subdued tones.

7. Modifications: There are no restrictions on modifications to walls, but the HVAC system cannot be altered.

8. Humidity Monitoring: While constant visual display of humidity is not crucial, the system should maintain humidity levels without the need for frequent monitoring.

9. Size Constraint: While there's no strict size constraint, the system should not dominate the room space.

10. Temperature Fluctuations: The temperature in the room is relatively stable, and humidity is the primary concern.

11. Water Type: There's no specific water preference, but filtered water might be preferable for optimal humidification.

12. History of Leaks: There's no history of water leaks or spills in the apartment.

13. Other Concerns: The main concern is avoiding mold growth due to excessive humidity.

14. Impact on Others: The system should not disturb others in the house, and chemicals used should be safe for human health and should not affect the guitars' finish.

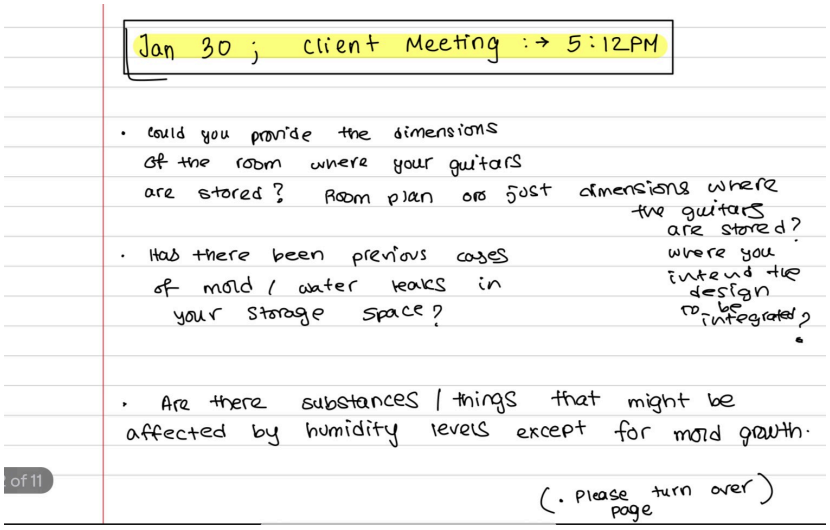
15. Additional Information: The client will provide the floor plan, hygrometers, and pictures of the room to assist with system development.

16. Multi-modularity : The system components operate together seamlessly in conjunction and offer a intuitive interface to the client

17. Reservoir : refers to the small water storage tank connected to a permanent water line between the filler and the ultrasonic transducer

18. User intervention : Involves the client refilling , triggering , relocating , maintaining the system which should be as minimal as possible.

Notes: Munshatia

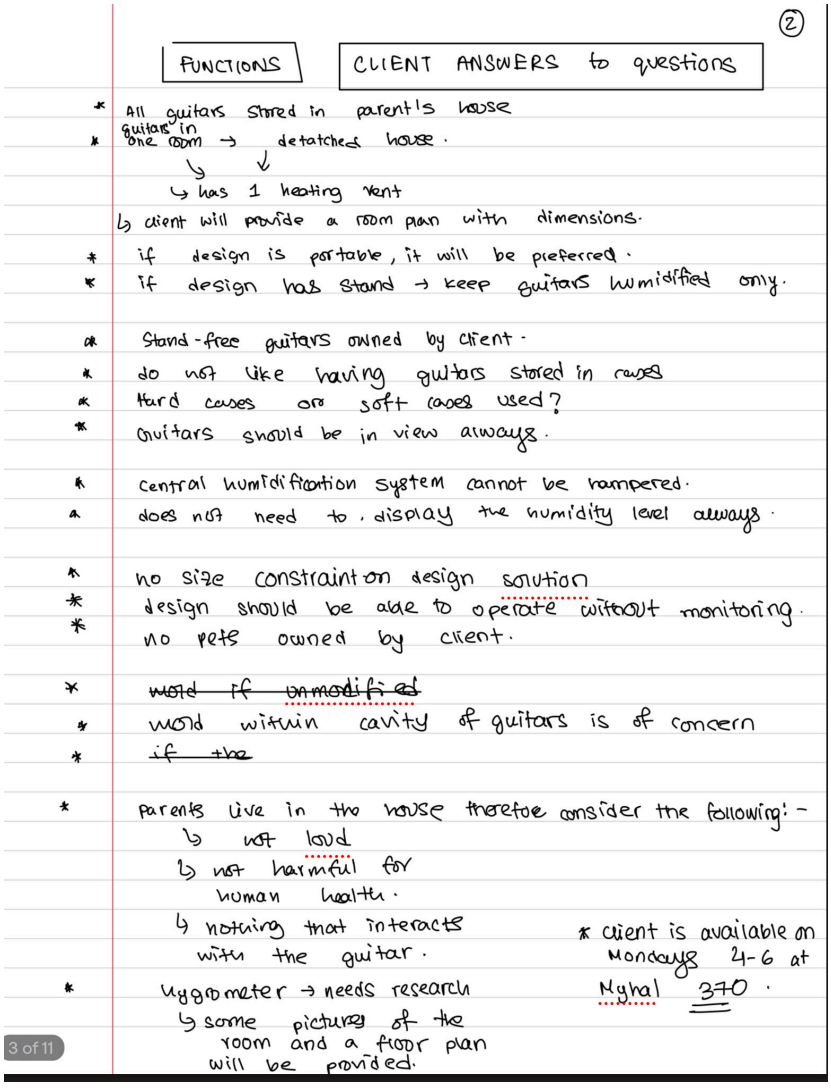


Jan 30 ; Client Meeting :→ 5:12PM

- could you provide the dimensions of the room where your guitars are stored? Room plan or just dimensions where the guitars are stored? where you intend the design to be integrated?
- Has there been previous cases of mold / water leaks in your storage space?
- Are there substances / things that might be affected by humidity levels except for mold growth.

1 of 11

(. Please turn over page)



②

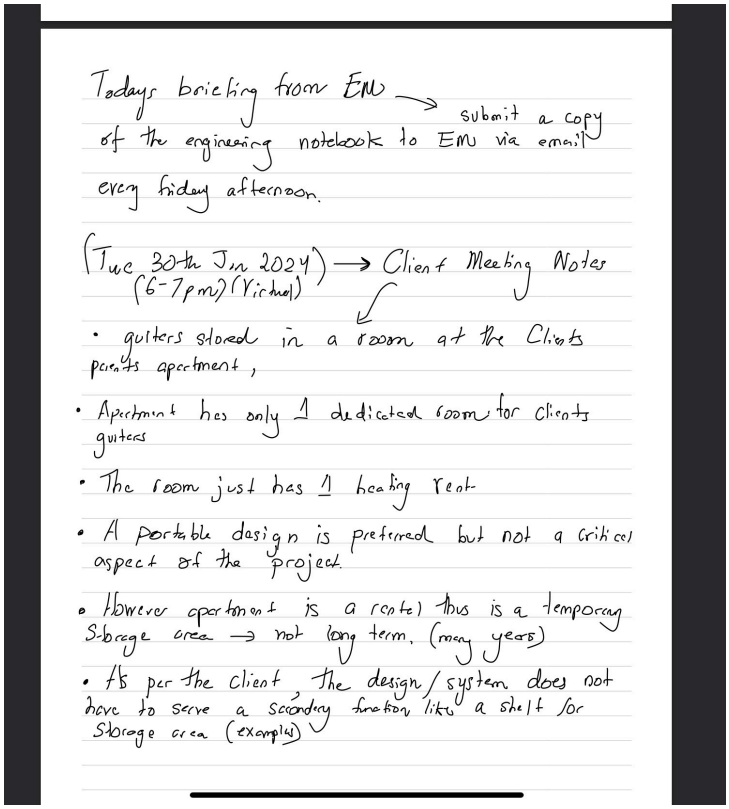
FUNCTIONS | CLIENT ANSWERS to questions

- All guitars stored in parent's house
- guitars in one room → detatched house.
  - ↳ has 1 heating vent
  - ↳ client will provide a room plan with dimensions.
- if design is portable, it will be preferred.
- if design has stand → keep guitars humidified only.
- Stand-free guitars owned by client.
- do not like having guitars stored in cases
- hard cases or soft cases used?
- Guitars should be in view always.
- central humidification system cannot be hampered.
- does not need to display the humidity level always.
- no size constraint on design solution
- design should be able to operate without monitoring.
- no pets owned by client.
- ~~wood if unmodified~~
- wood within cavity of guitars is of concern
- ~~if the~~
- parents live in the house therefore consider the following:-
  - ↳ not loud
  - ↳ not harmful for human health.
  - ↳ nothing that interacts with the guitar.
- Hygrometer → needs research
  - ↳ some picture of the room and a floor plan will be provided.

* client is available on Mondays 4-6 at Nyhal 370.

3 of 11

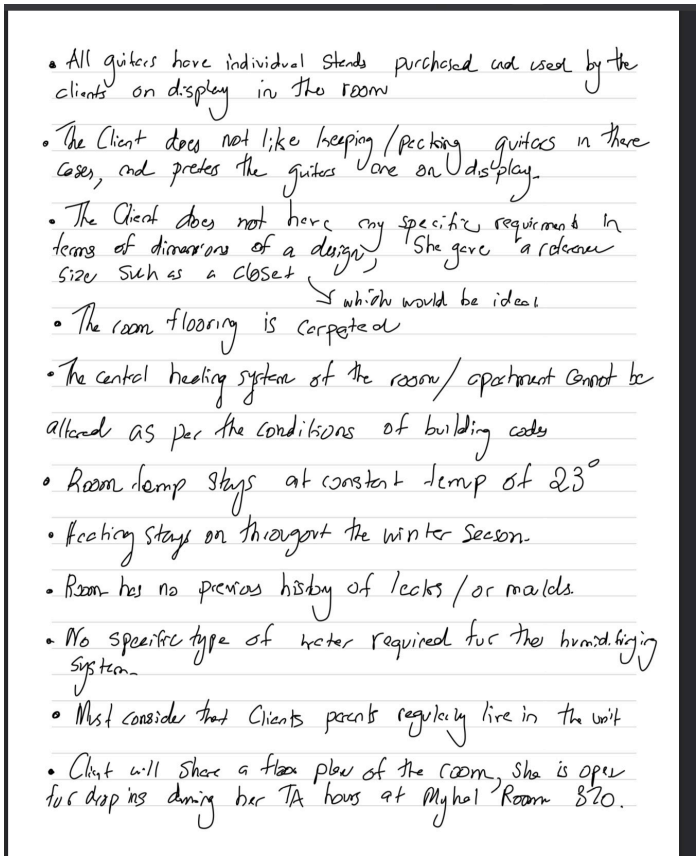
Saad:



Todays briefing from EMU → submit a copy of the engineering notebook to EMU via email every friday afternoon.

(Tue 30th Jan 2024) (6-7pm) (Virtual) → Client Meeting Notes

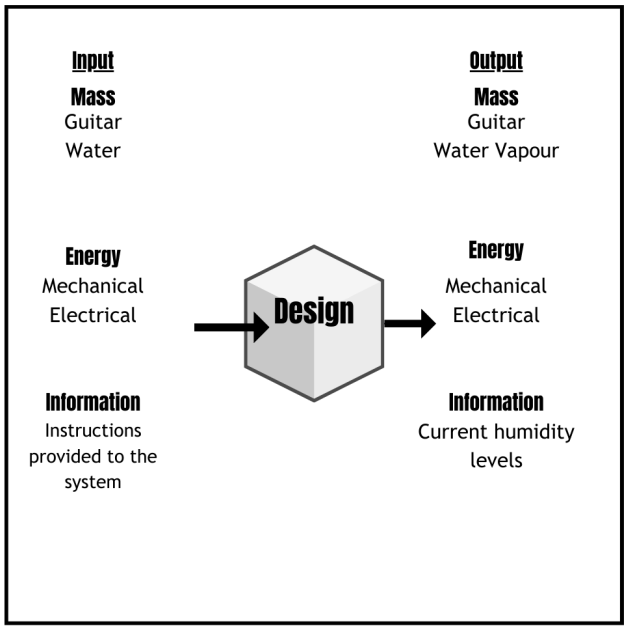
- guiters stored in a room at the Clients parents apartment,
- Apartment has only 1 dedicated room for clients guiters
- The room just has 1 heating vent
- A portable design is preferred but not a critical aspect of the project
- However apartment is a rental thus is a temporary Storage area → not long term. (many years)
- As per the client, the design/system does not have to serve a secondary function like a shelf for Storage area (example)



- All guitars have individual stands purchased and used by the clients on display in the room
- The Client does not like keeping/packing guitars in there cases, and prefers the guitars are on display.
- The Client does not have any specific requirements in terms of dimensions of a design. She gave a reference size such as a closet, which would be ideal
- The room flooring is carpeted
- The central heating system of the room/apartment cannot be altered as per the conditions of building codes
- Room temp stays at constant temp of 23°
- Heating stays on throughout the winter season.
- Room has no previous history of leaks/or molds.
- No specific type of water required for the humidifying system.
- Must consider that Clients parents regularly live in the unit
- Client will share a floor plan of the room, she is open for drop ins during her TA hours at Myhal Room 820.

Appendix B Black Box Method:

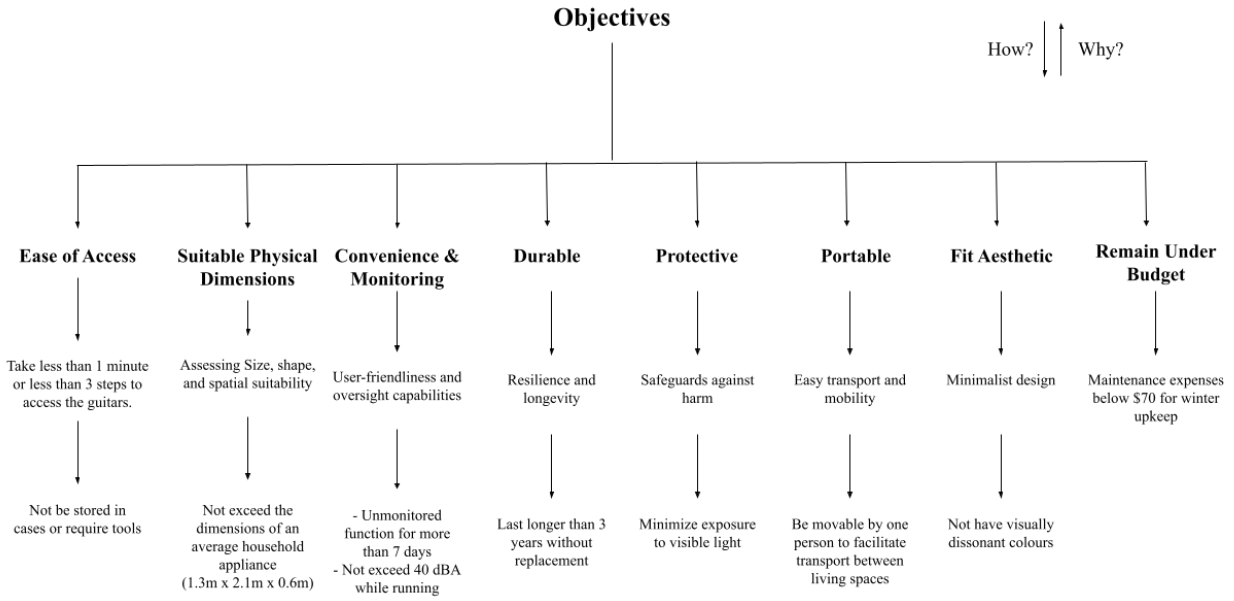
This appendix outlines the team's approach to function development, as cited in section 6.1. The black box method examines different inputs and outputs related to mass, energy, and information, aiding in defining the design requirements to ensure an optimal solution for the humidification system.



Appendix C: Objectives Pairwise Comparison Chart

Objectives	Physical Dimensions	Accessibility	Mold Growth	Convenience & Monitoring	Portability	Protection	Durability	Cost	Humidity Level	**Total**
Physical Dimensions	-	0	0	0	1	1	1	1	0	4
Accessibility	1	-	0	0	1	1	1	1	0	5
Mold Growth	1	1	-	0	1	1	1	1	0	6
Convenience & Monitoring	1	1	1	-	1	1	1	1	0	7
Portability	0	0	0	0	-	0	0	1	0	1
Protection	0	0	0	0	1	-	0	1	0	2
Durability	0	0	0	0	1	1	-	1	0	3
Cost	0	0	0	0	0	0	0	-	0	0
Humidity Level	1	1	1	1	1	1	1	1	-	8

Appendix D: How-Why tree

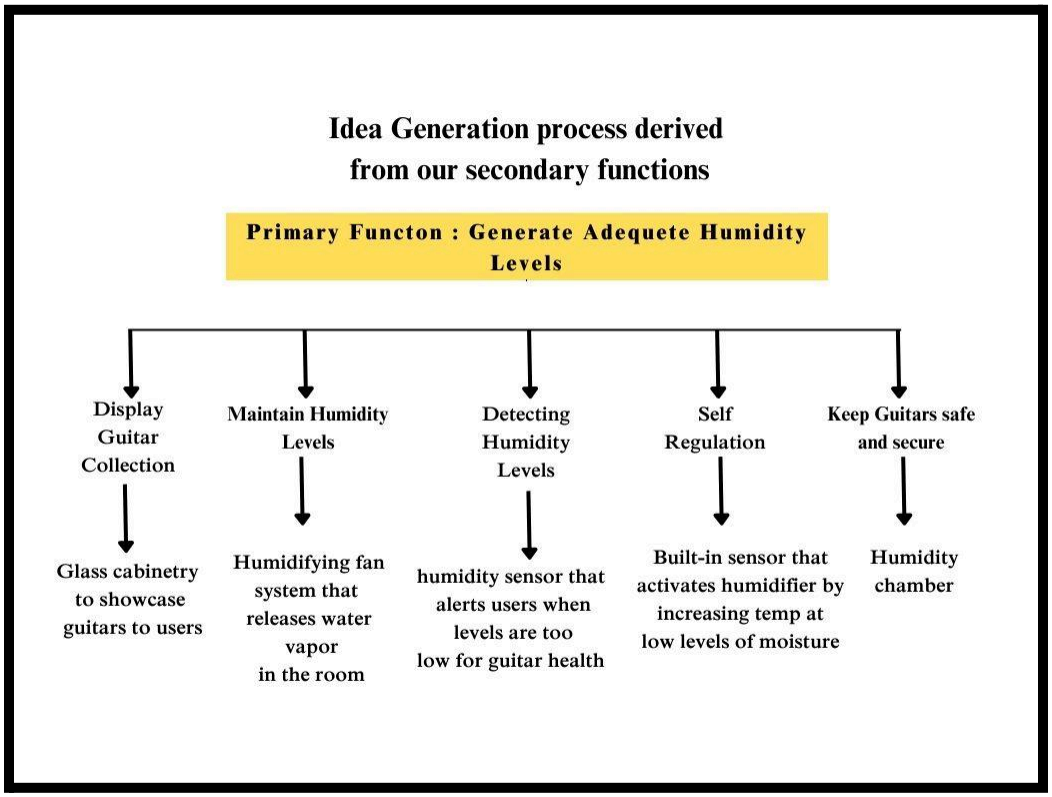


Appendix E: Initial list of ideas

1. AI humidifier system
2. Solar panel pHygroscopic material embedded in the guitar case
3. Humidity-regulating paint
4. Smart humidifier network with guitar case integration
5. Humidifier case inserts
6. Humidifier case lining
7. Water beads(orbeez)
8. Custom display humidifying system
9. Climate-Controlled Room
10. Integrated Instrument Humidification System (installed permanently eg. inside guitar)
11. Self-Regulating Guitar Stand
12. Mist system
13. Remote access design
14. Humidifying robot
15. Self-regulating humidity pack
16. Humidifying guitar strings
17. Stuffed animal humidifier
18. Spray bottle contraption
19. Humidity chamber
20. Water cooled computer where the humidity is transferred to the guitars
21. Smart humidity fabric
22. Sponge in a Container
23. Fish tank (humidity from tank used)
24. Fogging machine
25. Create a humidification system with a built-in filtration system to ensure clean moisture for guitars.
26. Develop a humidification system with a humidity sensor that alerts users when levels are too low for guitar health
27. built-in humidistat for automatic regulation of humidity levels
28. using moisture-absorbing materials like silica gel packets.
29. USB-powered humidifier attachment for guitar cases
30. timer function to control moisture release at specific intervals.
31. a voice commands for hands-free operation
32. Enclosed \ sealed cabinet with built-in humidification capabilities
33. utilises natural evaporation processes
34. system that doubles as a dehumidifier in case humidity levels become to high
35. water reservoir and automatic refill mechanism
36. Install a humidifying system inside the sound hole of the guitar maintaining the internal structure.

37. smartphone app that allows users to monitor and control the humidity levels inside their guitar cases remotely.
38. Humidifying fan system that releases water vapour in the room
39. Develop a lubricant for guitar slides that adjusts viscosity based on humidity
40. system that uses vibrations to evenly distribute moisture within guitar cases
41. Create custom liners for guitar cases made of breathable fabric that helps retain moisture and protect guitars from dryness
42. Zeolite materials to absorb water vapour and release it in higher temperature
43. Built-in sensor that activates humidifier by increasing temp at low levels of moisture for zeolite to release water vapour
44. Unglazed clay pots filled with water releases vapour when temp increase
45. Transparent glass cases integrated with steamers that release water vapour when temp rises above 25 inside the case.
46. Chemicals that lower boiling point of water to 25
47. Impedance sensors integrated with humidifier to check mold growth
48. Cases made of Low-E glass coated with a thin layer of metallic oxides that can reflect UV and infrared (IR) radiation
49. Hydrophobic coatings and water-repellent treatments to inner-surface of glass which release vapour
50. Integrated heating pad with glass to vaporise water that is sprayed on the inner surface
51. Mimic transpiration in plants to release water vapour
52. Chemic procedures such as combustion release water vapour that are stored and released through pores when humidity levels
53. Convection currents set up at desired temperature to release vapour when hygrometer reading decreases
54. A piezoelectric device that can convert mechanical energy from humid air to electrical energy to stay off when air reaches desired humidity level
55. Integrated humidity sensors with IoT to allow remote control of humidity
56. Responsive architectural elements inside music room
57. Use a humidity tray in the room to keep the room humidified
58. Encase the guitars in a cabinet (glass) with a vaporiser and a hygrometer to maintain the humidity level
59. Install ultrasonic humidifiers in room
60. Build humidity chamber
61. Create reusable humidipak
62. Conserve humidity instead of creating more through use of humidity buffering materials (silica)
63. Use materials with high thermal mass can help stabilise temperature and humidity fluctuations
64. Central Humidification System with Ducted Distribution.
65. Guitar humidification system using a small, low-power ultrasonic mist generator.
66. Guitar humidifier that uses a small, piezoelectric atomizer to create a fine mist.
67. A guitar humidification system that employs a small, capillary action humidifier built into the guitar's endpin.

68. A humidity-regulating guitar fretboard oil that helps maintain optimal moisture levels and prevents cracking.
69. Solar powered humidifier cabinet
70. Cabinet with hydrogel beads that release or absorb moisture to maintain a specific level
71. Cabinet with passive wicking humidifier enclosed
72. Wall display or cabinet incorporating a fountain or a waterfall display
73. Cabinet with periodic fogging/misting
74. Window/cold surface heating + room humidifier
75. Fountain
76. Large hanging wet antimicrobial cloth canopy
77. Hydroponic garden to increase room humidity + monitoring and mould control systems
78. Humidifying guitar case with glass front panel and built-in water reservoir
79. Humidifying guitar case, clear front, that attaches a hose to an external reservoir
80. Acrylic cylinder that goes around the guitar, atomizing water periodically to maintain humidity
81. Slug the guitar in oil
82. Cool down the guitars to increase the relative humidity
83. Lay a wet cloth on the guitar
84. Hygroscopic materials
85. Guitar humidification system using a small, thermoelectric humidifier for energy efficiency.



Idea generation derived from our secondary functions

Appendix F: Morph Chart to expand design solution and combine ideas

Secondary Functions	Means	Means	Means	Means
Display Guitar Collection	Encase the guitars in a cabinet (glass)	Install a humidifying system inside the sound hole	Humidifying fan system that releases water vapor in the room	Use a humidity tray in the room to keep the room humidified protecting structural integrity of guitars
Secure Guitar	Build humidity chamber	Humidification system integrated into a guitar stand or wall hanger	Self-Regulating Guitar Stands	USB-powered humidifier attachment for guitar cases to ensure guitars are secured
Maintain Humidity Level	Humidifying guitar strings	Fogging Machine	Moisture absorbing materials like silica gel packets	Create custom liners for guitar cases made of breathable fabric that helps retain moisture
Regulation	Humidity Regulating paint	Built-in humidistat	Built-in sensor that activates humidifier by increasing temp at low levels of moisture	Timer function to control moisture release at specific intervals
Detecting Humidity Level	Smartphone app that alerts user	Humidity sensor that alerts users when levels are too low for guitar health	AI humidifier	Responsive architectural elements inside music room

Iterating Morph Chart to consolidate ideas

Appendix G: SCAMPER Chart

Table[]: SCAMPER method to expand design space

	Designs			
S- **S**ubstitute	Sponge in a Container	Mist system	Zeolite materials to absorb water vapor	Silica Gel packs
C- **C**ombine	Impedance sensors integrated with humidifier to check mould growth	Water-repellent treatments to inner-surface of glass which release vapor	Cases made of Low-E glass coated that can reflect UV and infrared (IR) radiation	Integrated heating pad with glass to vaporize water
A- **A**dapt	-			
M- **M**odify	Climate-Controlled Room	Use a humidity tray in the room to keep the room humidified	Central Humidification System	Individual humidifiers integrated to guitars
P- **P**ut to other uses	Unglazed clay pots filled with water releases vapor when temp increase	Humidity-regulating paint	Fish tank (humidity from tank used)	Mimic transpiration in plants to release water vapor
E- **E**liminate	-			
R- **R**earrange	Utilizes natural evaporation processes	Convection currents set up at desired temperature to release vapor	Vapor isolation for humidity retention	Conserve humidity instead of creating more through use of humidity buffering materials (silica)

Appendix H: Multivoting process

Idea Name	isaac	aurelle	alex	munshatia	saad	sam	Total Votes
timer function to control moisture release at specific intervals.		1	1	1	1	1	5
Humidity-regulating paint		1		1	1	1	4
Create custom liners for guitar cases made of breathable fabric			1	1	1	1	4
Encase the guitars in a cabinet (glass) with a vaporiser		1	1		1	1	4
Self-regulating humidity pack		1		1		1	3
smartphone app that allows users to monitor and control the humidity levels				1	1	1	3
Hydrophobic coatings and water-repellent treatments			1	1		1	3
Open front cabinet with internal humidifier, air curtain to prevent escape of moisture	1	1				1	3
Climate-Controlled Room			1		1		2
using moisture-absorbing materials like silica gel packets.		1	1				2
water reservoir and automatic refill mechanism			1		1		2
Solar-powered humidity monitoring	1			1			2
Trays of wet gravel or pebbles under each guitar	1					1	2
Humidifier case inserts			1				1
Mist system			1				1
Create a humidification system with a built-in filtration system to ensure clean moisture					1		1
built-in humidistat for automatic regulation of humidity levels		1					1
system that doubles as a dehumidifier in case humidity levels become too high			1				1
Zeolite materials to absorb water vapour and release it in higher temperature		1					1
Unglazed clay pots filled with water releases vapour when temp increase				1			1
Transparent glass cases integrated with steamers that release water vapour					1		1
Cases made of Low-E glass that can reflect UV and infrared (IR) radiation				1			1
Convection currents set up at desired temperature to release vapour when hygrometer reading decreases		1					1
Create reusable humidipak		1					1
Guitar humidification system integrated into a guitar stand or wall hanger.						1	1
Glass front humidifying cabinet with heated glass to prevent condensation	1						1
Humidified wall display	1						1
Hydraulic ram pump powered misting system to reduce energy costs					1		1
Room humidifier with heated air curtains for the windows or other cold parts of the apartment	1						1
UVC room disinfection system + room humidifier	1						1
Infrared humidity sensors to avoid sensors all around the room + room humidifier	1						1
Clear case with hydrogel beads that release or absorb moisture to maintain a specific level				1			1
Stand with ultrasonic generated humidity misting jet directly onto the guitar, creating a localized higher humidity area	1						1
Robot that periodically checks the humidity of each guitar and mists them if they are low					1		1
Humidifying platform (humid air rises)	1						1
AI humidifier system							0
Solar panel pHygroscopic material embedded in the guitar case							0
Smart humidifier network with guitar case integration							0
Water beads(orbeez)							0
Custom display humidifying system							0
Integrated Instrument Humidification System (installed permanently eg. inside guitar)							0
Self-Regulating Guitar Stand							0
Humidifying robot							0
Humidifying guitar strings							0
Stuffed animal humidifier							0
Spray bottle contraption							0

48	Water cooled computer where the humidity is transferred to the guitars	0
49	Sponge in a Container	0
50	Fish tank (humidity from tank used)	0
51	Fogging machine	0
52	Develop a humidification system with a humidity sensor that alerts users when levels are too low for guitar health	0
53	USB-powered humidifier attachment for guitar cases	0
54	a voice commands for hands-free operation	0
55	utilises natural evaporation processes	0
56	Install a humidifying system inside the sound hole of the guitar maintaining the internal structure.	0
57	Humidifying fan system that releases water vapour in the room	0
58	Develop a lubricant for guitar slides that adjusts viscosity based on humidity	0
59	system that uses vibrations to evenly distribute moisture within guitar cases	0
60	Built-in sensor that activates humidifier by increasing temp at low levels of moisture for zeolite to release water vapour	0
61	Chemicals that lower boiling point of water to 25	0
62	Impedance sensors integrated with humidifier to check mould growth	0
63	Integrated heating pad with glass to vaporise water that is sprayed on the inner surface	0
64	Mimic transpiration in plants to release water vapour	0
65	Chemic procedures such as combustion release water vapour that are stored and released through pores when humidity levels changes	0
66	A piezoelectric device that can convert mechanical energy from humid air to electrical energy to stay off when air reaches desired humidity level	0
67	Responsive architectural elements inside music room	0
68	Use a humidity tray in the room to keep the room humidified	0
69	Install ultrasonic humidifiers in room	0

Multivoting process

Appendix I: Graphical Decision Chart

Graphical Decision Chart

Obj 1: **Convenience** Humidifying function without human intervention
Obj 2: **Mold growth** Measure of obstruction to playing the instrument

Step 1: Excel was used to vote on the ratings for each idea on a scale from 1 to 20. Each team member rated each idea, and then the average rating was taken as input into the scatterplot.

Voting

	Aurelle		Isaac		Alex	Munshatia		Saad		Sam		Averages		
Idea	Obj 1	Obj 2	Obj 1	Obj 2	Obj 1	Obj 1	Obj 2	Obj 1	Obj 2	Obj 1	Obj 2	Obj 1	Obj 2	label
Timer control function that releases himidity at r	20	15	18	13	20	20	10	20	10	20	10	23.6	13.6	a
Self-regulating humidity pack	15	10	13	10	18	10	10	15	10	5	10	15.2	14	b
smartphone app that allows users to monitor an	10	0	15	0	15	20	0	20	10	5	0	17	4	c
Hydrophobic coatings and water-repellent treatm	10	2	10	0	15	15	10	15	10	7	10	14.4	8.4	d
Open front cabinet with internal humidifier, air cu	5	13	15	18	5	3	10	10	15	15	10	10.6	15.2	e
Zeolite materials to absorb water vapour and rele	5	17	20	20	5	20	20	10	14	13	20	14.6	22.2	f
using moisture-absorbing materials like silica gel	10	10	7	0	10	5	15	20	10	15	15	13.4	13	g
water reservoir and automatic refill mechanism	10	5	5	0	5	10	3	10	20	16	17	11.2	12	h
Solar-powered humidity monitoring	2	2	8	10	4	7	10	5	5	5	10	6.2	11.4	i
Trays of wet gravel or pebbles under each guitar	0	2	10	15	5	3	15	0	0	2	10	4	12	j
Humidifier case inserts	5	0	7	0	15	5	0	5	5	2	10	7.8	5	k
Mist system	2	9	2	8	5	2	2	5	15	20	10	7.2	12.2	l
Create a humidification system with a built-in filtr	2	8	2	6	5	2	2	7	20	8	15	5.2	13.2	m
Vapor isolation for humidity retention	20	16	0	0	20	20	20	15	15	5	14	16	16	n
system that doubles as a dehumidifier in case h	8	12	17	10	15	8	10	13	5	10	10	14.2	11.4	o
whole room humidifying system	15	10	10	10	15	5	15	15	15	17	20	15.4	17	p
Unglazed clay pots filled with water releases vap	4	8	2	2	10	10	5	16	15	0	15	8.4	12	q
Transparent glass cases integrated with steamer	17	1	0	0	13	17	10			10	15	11.4	7.2	r
Cases made of Low-E glass coated with a thin la	0	5	0	0	0	0	10	0	0	15	10	3	6	s
Convection currents to release vapour when hygr	18	18	0	0	20	20	10	15	20	0	5	14.6	14.6	t
Encase the guitars in a cabinet (glass) with a va	10	18	10	3	13	17	17	18	15	2	20	14	18.6	u

The voting process for graphical decision charts.

Appendix J: Use of copper

Copper is a powerful antibacterial metal. It releases ions that damage bacterial cell membranes making copper highly effective at killing a wide range of harmful bacteria including mould. Using copper within our designs kills off any existing mould but also prevents any possible growth and contamination. [20]

Appendix K: Alternative Design Estimates and Calculations

Design	**Cost Breakdown**
Design A: Whole-room humidifier setup	● $150 custom humidifier (based off of $125 retail humidifier) [21] ● $50 for the self-filling system (estimate) ● <$100 everything else - water and electricity usage (estimate) ● $150 plumbing (estimate) ~ 1 hour or DIY = $0
	Total: $300-450 Average $375
Design B: Humidifier Display Cabinet Benchmark humidifier [] lasts 50 hours at an output of 550ml/h. The guitar cabinet is isolated, and should need much less output/time. If it uses 1/10 of the water/hours, it would last for 500 hours, which is slightly less than 3 weeks.	● $50 humidifier (benchmarked with an a small humidifier [21] ● $250 cabinet (benchmarked with a popular glass cabinet [22] ● <$100 everything else - water and electricity usage
	Total: $400
	161 sq foot / 110 square foot per gallon = 1.5 gallons 1.5 gallons * $75 per gallon = $112 of RedGard [23] Humidifier $125 caulking, door sweep, water, electricity <$100
	Total: $350

Attribution Table

Tutorial #:	0110	Team #:	065
Assignment:	Conceptual Design Specification	Date:	25 Mar 2024

The Attribution Table is a major resource used by your TA in determining whether there was equal contribution to the team assignment. If your TA determines that there was significant under contribution, then they may apply an individual penalty to the under contributing team members' grade. As a future professional engineer you should NOT sign any document you have not read and do not agree with.

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As with any engineering statement this attribution table must be backed by credible evidence. In most cases this will be found either in the Google Docs document revision history, or your engineering notebook. Making fraudulent claims in an Attribution Table displays intent to deceive and is a serious academic offence.

Section	**Student Names**					
	Alex	**Aurelle**	**Isaac**	**Munshatia**	**Saad**	**Sam**
Executive Summary	ET	WD	FP	FP		
Introduction (revision)	FP	FP	FP	FP		
Problem Statement (revision)	FP	FP	FP	FP		
Service Environment (revision)	FP	FP	FP	FP		

Stakeholders (revision)	FP	FP	FP	FP		
Detailed Requirements (revision)	FP	ET	FP	FP		
Idea Generation Process	MR ET	ET	MR FP RS1			WD OR1
Alternative Design Selection	FP	ET	MR FP	WD		
Alternative Design Description		ET	WD OR1			
Proposed Conceptual Design		WD	OR1 ET			
Measures of Success	WD ET	ET	FP		WD ET	
Conclusion	WD	FP	FP	FP	WD	
Reference List			FP	WD		
Appendices	WD RS2		WD FP	WD MR	WD	

Fill in abbreviations for roles for each of the required content elements using the abbreviations found on the next page. You do not have to fill in every cell.

RS – Research (give details below) WD – Wrote Draft MR – Major Revision ET – Edited	FP – Final Proofread of COMPLETE DOCUMENT verifying for flow and consistency OR – Other (give details below)

If you put RS (research) please add a number identifier such as RS1, RS2, etc. Give the research question / topic:

RS1: Idea generation techniques research

RS2: Use of copper as an antimicrobial material

RS3:

If you put OR (other) please add a number identifier such as OR1, OR2, etc. Explain the role below:

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Student #1 Name	**Isaac Ali**	Student #5 Name	**Munshatia Islam Merry**
Student #2 Name	**Samaira Jain**	Student #6 Name	**Saad Abdul**
Student #3 Name	**Alex Huy Nguyen**		
Student #4 Name	**Aurelle Vidyagiri**		