BME Design-Spring 2022 - SAMUEL BARDWELL
Complete Notebook

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MAYA TANNA

on

May 04, 2022 @11:56 AM CDT

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Team contact Information

SAMUEL BARDWELL - Jan 28, 2022, 1:06 PM CST

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Project description

Bella Raykowski - May 03, 2022, 10:05 PM CDT

Course Number: BME 301

Project Name: Microscopic Cell Incubator

Short Name: Cell Incubator

Project description/problem statement:

Develop a low cost cell culture incubation chamber that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO_2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Constraints:

The prototype must maintain an internal environment of 37 C, 5% CO_2, and ~95% humidity over the course of 1 week. It must not interfere with the microscope optics or functionality. The overall cost of fabrication must be below $100 in order for this to be an affordable option.

About the client:

John Puccinelli is the head of the Biomedical Engineering Deparment at the University of Wisconsin-Madison, along with being an undergraduate advisor. He is a course instructor with interests in developing hands-on approaches to teaching especially related to biomaterials, tissue/cellular engineering, biomemes/microfluidics, and design. He corrdinators, instructors and advises the design curriculum at UW-Madison.

02/02/2022 Client Meeting #1 Notes

MAYA TANNA - Feb 06, 2022, 9:45 AM CST

Title: Client Meeting #1 Notes

Date: 02/02/2022

Content by: Katie

Present: Katie, Sam, Bella, Drew

Goals: To document what was discussed at our initial meeting with Dr. Puccinelli and next steps from there

Content:

Initial Client Meeting 2/2/2022

https://uwmadison.zoom.us/j/9406883128

Questions for Puccinelli

1. **What did you like about last year?**
    a. Overall the construction of the box(shout out Sam)
    b. Approach to heating
        i. Need to make sure that we are able to calculate how long it is going to take to heat to 37℃
    c. Very sterile
2. **Do you have any materials that you think would improve the box? Or Any ideas for which material should be used in the future to prevent leaking?**
    a. Box is a *great size ;)*
    b. Acrylic on the laser cutter (black acrylic for insulation and fluorescent imaging)
        i. Also sterile and doesn't leak
        ii. Special super glue to prevent leaking (acrylic glue)
3. **Do you have any suggestions for having better seals around the box?**
    a. Special super glue for the acrylic for seamed and sturdy box
    b. Recommends we do it first in cardboard
    c. Polyethylene? Polyurethane spray *
    d. Sandwich of acrylic insulation
        i. Don't want to take up too much space
        ii. Or on the bottom (not where the plate is)
4. ~~**Does the BME department have spare breadboards we could borrow, as last semester we were using my electronics kit from 201, but I need that for 310 this year.**~~
    I have my 310 kit if we want to use it (i already took the class)
    Bella u lifesaver! Yes plz!!
    I'll grab it when i go home this weekend
    Perfect just text me and i'll show you our locker in ECB next week
    - Email Dr. P for arduinos and breadboards
5. **What is the budget for this semester?**
    a. $100
6. **What was the issue with expenses, and how can that be improved upon? Is reimbursement possible?**
    a. BUY DIRECTLY FROM THE MAKERSPACE
        i. BME Design_ScopeIncubator
        ii. Can 3D print and buy acrylic

   b. Check with Puccinelli before we buy anything

7. **Will we have access to a CO_2 tank this semester?**
   a. Give Puccinelli a weeks notice and then we have a pay per month rental
   b. Tank in the incubator room is 100% CO_2 and the incubator controls how much goes in and out
      i. $6/month
   c. We can also order one that is only 5% CO_2 so that the system can stay at 5% (more expensive)
      i. $6/month to rent
      ii. $50 to buy

Dr. P's Questions for Us

1. Water circulator → fairly expensive and is not counted in our budget, but outside the department it might be neat to have our own water circulator (bruh wat… hot plates???)
2. More challenges (noooooooooooooooo) (can we not pls)
3. Open source thing
   a. Have people assemble it themselves
   b. Make it free (boo i want money)

Conclusions/action items: We got our list of questions that we made before the meeting answered and also noted some questions Dr. Puccinelli had for us going forward. Going forward, we will be sure to be in constant communication with him if we need any assistance with purchasing and suggestions about the technical components of the project. This was a good first meeting, because the new members of the team got introduced to our client and learned more about his expectations and hopes for the project.

02/04/2022 Advisor Meeting #1 Notes

MAYA TANNA - Feb 06, 2022, 9:39 AM CST

Title: Advisor Meeting #1 Notes

Date: 02/04/2022

Content by: Katie

Present: Whole Team

Goals: To document what was discussed at our meeting with Dr. Kinney at our weekly meeting on Friday and next steps from there

Content:

2/4/2022 Advisor Meeting #1 Notes

- Had our first client meeting
- Goals for the semester
    - Black acrylic for the box and laser cut it
    - CO2 monitoring
    - More insulation → homogeneity for the inside
        - Math for copper tubing
    - Get humidity formula correct
- Puccinelli's challenge for the semester: *create a heated water pump*
- How will we combat losing heat throughout the wall of the box?
    - Unsure if we lost heat throughout the box since the reservoir of water was not heated
    - Polyurethene foam to coat the creases to help waterproof and insulate
    - Maybe a tar as well?
    - AFTER CONDUCTION, focus on cheap, waterproof, insulator
- Maybe jacketing our box with an insulator?
- CO2 feedback system
    - Valve that opens and connects to the sensor
- Next steps:
    - Start updating the testing protocols to be more accurate
    - Improve on the statistical analysis
    - Get a physical box prototype going
        - Two types of lids (one for testing and one for final project)
        - Slide or tackle?
    - Streamline all the electronics
    - Work on CO2
    - Break up into groups
    - PDS due next Friday

Conclusions/action items:

After going over our goals for the semester and introducing Bella/Drew to the project, we discussed next steps moving forward since the PDS and intro work is mostly completed already. Our next steps consist of updating the testing protocols, improving on the statistical analysis, getting a physical box prototype going, working to combine electronic components, starting CO2 work, and dividing up the team to conquer all of these goals.

02/11/2022 Advisor Meeting #2 Notes

Katie Day - Feb 11, 2022, 1:00 PM CST

Title: Advisor Meeting #2 Notes

Date: 02/11/2022

Content by: Katie

Present: Whole Team

Goals: To document what was discussed at our meeting with Dr. Kinney at our weekly meeting on Friday and next steps from there.

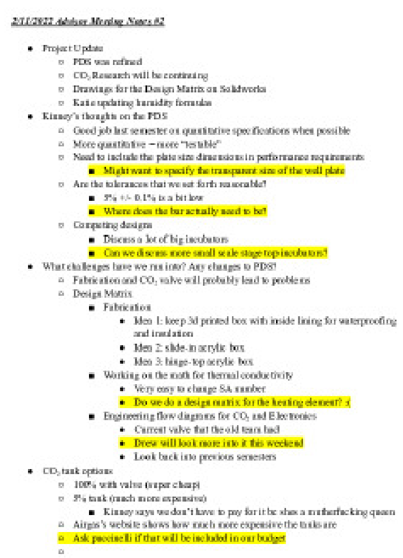
Content:

See Attached File.

Conclusions/action items:

See highlighted portions of attached file.

Katie Day - Feb 11, 2022, 1:00 PM CST



2/11/2022 Advisor Meeting Notes #2

- Project Update
  - PDS was refined
  - CO_2 Research will be continuing
  - Drawings for the Design Matrix on Solidworks
  - Katie updating humidity formulas
- Kinney's thoughts on the PDS
  - Good job last semester on quantitative specifications when possible
  - More quantitative → more "testable"
  - Need to include the plate size dimensions in performance requirements
    - Might want to specify the transparent size of the well plate
  - Are the tolerances that we set forth reasonable?
    - 5% +/- 0.1% is a bit low
    - Where does the bar actually need to be?
  - Competing designs
    - Discuss a lot of big incubators
    - Can we discuss more small scale stage top incubators?
- What challenges have we run into? Any changes to PDS?
  - Fabrication and CO_2 valve will probably lead to problems
  - Design Matrix
    - Fabrication
      - Idea 1: keep 3d printed box with inside lining for waterproofing and insulation
      - Idea 2: slide-in acrylic box
      - Idea 3: hinge-top acrylic box
    - Working on the math for thermal conductivity
      - Very easy to change SA number
      - Do we do a design matrix for the heating element? :(
    - Engineering flow diagrams for CO_2 and Electronics
      - Current valve that the old team had
      - Drew will look more into it this weekend
      - Look back into previous semesters
- CO_2 tank options
  - 100% with valve (super cheap)
  - 5% tank (much more expensive)
    - Kinney says we don't have to pay for it bc shes a motherfucking queen
  - Airgas's website shows how much more expensive the tanks are
  - Ask puccinelli if that will be included in our budget

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2_11_2022_Advisor_Meeting_Notes_2.pdf (61.6 kB)

04/08/2022 Advisor Meeting #3 Notes

Katie Day - Apr 10, 2022, 7:09 PM CDT

Title: Advisor Meeting #3 Notes

Date: 04/08/2022

Content by: Katie

Present: Whole Team

Goals: To discuss our progress in the project and asses what our next steps are for fabrication and testing.

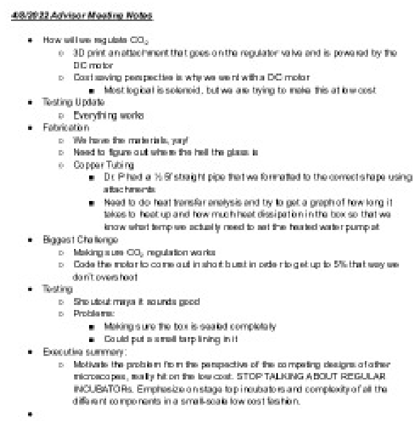
Content:

See Attached File.

Conclusions/action items:

See highlighted portions of attached file.

Katie Day - Apr 10, 2022, 7:09 PM CDT



4/8/2022 Advisor Meeting Notes

- How will we regulate CO_2
  - 3D print an attachment that goes on the regulator valve and is powered by the DC motor
  - Cost saving perspective is why we went with a DC motor
    - Most logical is solenoid, but we are trying to make this at low cost
- Testing Update
  - Everything works
- Fabrication
  - We have the materials, yay!
  - Need to figure out where the hell the glass is
  - Copper Tubing
    - Dr. P had a ½ 8' straight pipe that we formatted to the correct shape using attachments
    - Need to do heat transfer analysis and try to get a graph of how long it takes to heat up and how much heat dissipation in the box so that we know what temp we actually need to set the heated water pump at
- Biggest Challenge
  - Making sure CO_2 regulation works
  - Code the motor to come out in short burst in order to get up to 5% that way we don't overshoot
- Testing
  - Shoutout maya it sounds good
  - Problems:
    - Making sure the box is sealed completely
    - Could put a small tarp lining in it
- Executive summary:
  - Motivate the problem from the perspective of the competing designs of other microscopes, really hit on the low cost. STOP TALKING ABOUT REGULAR INCUBATORs. Emphasize on stage top incubators and complexity of all the different components in a small-scale low cost fashion.
-

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4_8_2022_Advisor_Meeting.pdf (45.7 kB)

04/15/2022 Advisor Meeting #4

Katie Day - Apr 17, 2022, 4:17 PM CDT

Title: Advisor Meeting #4 Notes

Date: 04/15/2022

Content by: Katie

Present: Whole Team

Goals: To discuss our progress in the project and asses what our next steps are for testing and the Final Deliverables

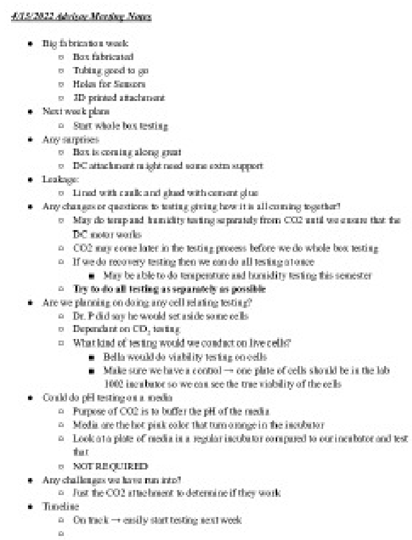
Content:

See Attached File.

Conclusions/action items:

See highlighted portions of attached file.

Katie Day - Apr 17, 2022, 4:17 PM CDT



4/15/2022 Advisor Meeting Notes

- Big fabrication week
  - Box fabricated
  - Tubing good to go
  - Holes for Sensors
  - 3D printed attachment
- Next week plans
  - Start whole box testing
- Any surprises
  - Box is coming along great
  - DC attachment might need some extra support
- Leakage:
  - Lined with caulk and glued with cement glue
- Any changes or questions to testing giving how it is all coming together?
  - May do temp and humidity testing separately from CO2 until we ensure that the DC motor works
  - CO2 may come later in the testing process before we do whole box testing
  - If we do recovery testing then we can do all testing at once
    - May be able to do temperature and humidity testing this semester
  - **Try to do all testing as separately as possible**
- Are we planning on doing any cell relating testing?
  - Dr. P did say he would set aside some cells
  - Dependant on CO_2 testing
  - What kind of testing would we conduct on live cells?
    - Bella would do viability testing on cells
    - Make sure we have a control → one plate of cells should be in the lab 1002 incubator so we can see the true viability of the cells
- Could do pH testing on a media
  - Purpose of CO2 is to buffer the pH of the media
  - Media are the hot pink color that turn orange in the incubator
  - Look at a plate of media in a regular incubator compared to our incubator and test that
  - NOT REQUIRED
- Any challenges we have run into?
  - Just the CO2 attachment to determine if they work
- Timeline
  - On track → easily start testing next week

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4_15_2022_Advisor_Meeting_Notes.pdf (82.2 kB)

09/17/2021 Client Meeting #1 Introductions to Client/Project Details

MAYA TANNA - Sep 18, 2021, 1:00 PM CDT

Title: Client Meeting #1 Introductions to Client/Project Details

Date: 09/17/2021

Content by: Maya Tanna

Present: Sam Bardwell, Katie Mcgovern, Maya Tanna, Caroline Craig, Olivia Jaekle, Ethan Hannon

Goals: To document the discussion with our client, Dr. Puccinelli, as well as the answers to our list of questions prepared for the meeting

Content:

Questions for Dr. Puccinelli

Overview of the Project:

Experimental Teaching Lab → Tissue engineering lab needs culture cells for the long term (*what is long term?*) that doesn't have a lot of money. Looking for a smaller, less expensive, and less bulky incubator that doesn't encompass the whole microscope or can be removed. Stage-top cell culture incubator. Grow cells and watch them over the course of time. Have to be able to stay alive with cell culture conditions for at least a week.

1. What is the budget for this project? **$100**
   a. Will this project be paid for using UW Funds? **Departmental teaching funds**
2. What is the device being used for, industry, research, etc?
   a. Used for teaching purposes, but if we get it right we can market this to other researchers
3. What is our margin of error in regards to temperature, CO2 levels, and humidity?
   a. 37*C → look at industry standard for temp ranges
   b. 5% CO2 → helps with buffering from sodium bicarbonate
4. Is there a size constraint for the incubation chamber?
   a. Has to sit on microscope stage and hold a well plate that also doesn't interfere with the optics (ideal if both sides are transparent, but bottom must be transparent)
   b. Needs to work with inverted microscope
5. What are your preferred dimensions for the incubation chamber?
   a. Sits on microscope stage and holds well plate
6. When you imagine the finished product, what color would you want it to be?
   a. No preference in color
   b. Well plates are clear, black (*stops contamination*), and white (*increases light*).
   c. Something that blocks out external light would be ideal, but is not required
7. Could we test our design with live cells?
   a. Yes, Dr. P will give us some when/if we are ready
   b. Use cells that are hard to kill → that's good for us
   c. TELL HIM IF WE WANT THEM AFTER THANKSGIVING
8. What are the most important design requirements/specifications (apart from the temperature, CO_2, and humidity level measurements provided)?
   a. Optical transparence, microscope stage (google that)
9. How many devices should be created?
   a. Just one :)
10. Are there any materials that you prefer we use?
    a. Nope :)
11. How long will this device be used in the lab?
    a. Could be used up to two weeks, but shoot towards one week at a time.
12. How often do you plan on using this device daily?
    a. Device would be used for one week at a time during tissue lab
13. What is the shelf life of this product?

   a. **Long time → 10 years**

14. What has been working well for previous projects? What hasn't?
    a. **Seal insulated box completely?**
    b. **Sterilization is very important → autoclaving ideal but UV works too**
15. Anything particular you would like us to continue with from past projects?
    a. **Temperature gradients are a large problem for cell cultures (reason for bulky products) look towards first project insulated box**
16. What types of cell culture plates do you use?
    a. What are their dimensions?
       i. ***6 Well plate, 24 well plate, 90 well plate → omnitrays?***
       ii. **Standard petri dish**
       iii. **Flasks → T25/T75 not really used but her**
    b. What type of medium do you use?
       i. **MEM**
       ii. **10% SPS and antibiotics**
17. Will any other microscopes be used with this incubation chamber? Or, should it only be compatible with the inverted microscope?
    Mainly inverted microscope
18. Should this device be ergonomic(able to move it on your own)?
    a. **Be able to carry it around and store it**
    b. **Wires should not be hanging out freely**
    c. **Easy to pick up and put away**

Notes:

- CO2 humidifiers and such are done using wires and a breadboard
- No team has successfully created an incubator.
- Something that can be easily taken apart would be ideal
- Temp gradients with small amounts of liquid can be evaporated very quickly so humidity is a big issue

Research To Do for Week 9/17-9/24

- Materials
  - What can hold heat?
  - What is transparent?
- Industry Standards
  - What are the industry standards for margin of errors for temp, CO2, and humidity
  - What is the size of well plates and inverted microscope stages?
- Cells
  - Look up the biology and physiology of MEM
    - When does it evaporate?
    - What temps do we need to stay under?
    - What humidity is best for it?
- Temperature
  - How can we create a better temperature gradient?
  - How can we insulate in a small space?
  - Look towards less industry and more experimental research as to how we can heat things in a small space
- Sterilization
  - Autoclave
  - UV Sterilization
- Past Projects
  - Check out the older projects to see what other teams did

Conclusions/action items: Tailor research to these specifications and use this information to create the product design specifications document. Look into previous projects and determine what worked well and what led to less successful results.

09/28/2021 Client Meeting #2 Collecting Dimensions and Clarifying Project Details

SAMUEL BARDWELL - Sep 29, 2021, 11:27 AM CDT

Title: Client Meeting #2

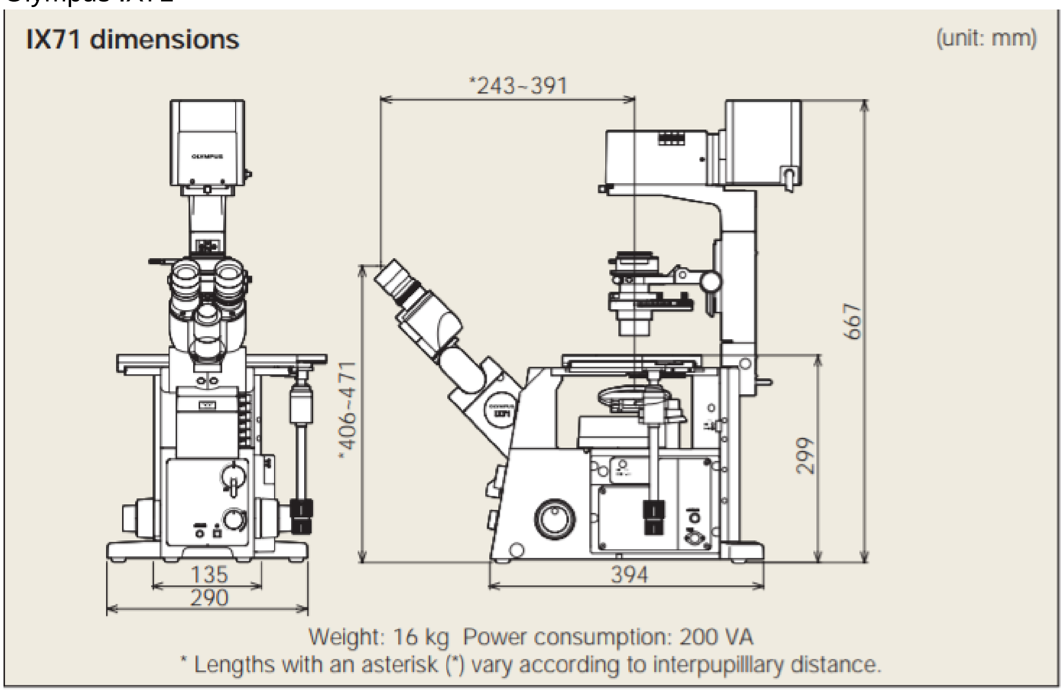
Date: 9/28/21

Present: Sam, Caroline, Ethan, Katie

Goals: To get a more in depth understanding of the project, tighten up loose ends, and get dimensions of the inverted microscope.

Content:

1. What is the exact model of inverted microscope for use? (for accurate dimensions)
    1. Olympus IX71



    2. Nikon *Eclipse* T*i*- S
        1. Don’t want to change the distance sample is from the lens (32.40mm) **thickness**
        2. 310 x 300 mm
2. Could we use a laboratory CO_2 gas line? Or, will an external CO_2 gas supply be necessary to include in materials?
    1. Tank with a regulator, hose into incubator
    2. Don’t need to purchase, readily available with hoses
        1. What is the diameter of the hose? 7.16mm wide
3. How many cell plates do you need in the incubator?
    1. One - *Prefers just one well plate per incubator*
4. Would it be possible for us to test transparent materials with the microscope?
    1. Optically clear enough?
    2. Refraction of light?
    3. Bottom of glass on multiwell plates.. Look into

    4. YES ALL POSSIBLE

5. What is the use of the incubator during the week of class time?
    1. AN ENTIRE WEEK
6. Do you have any specifications in the margins from industry standard? Or, is the tolerance cells can handle acceptable?
    1. pH levels → CO_2 levels, what is tolerance for a buffer?
7. What are the dimensions of the well plates? (Can look up online)
    1. length = 127.44 mm
    2. Width = 84.91mm
    3. Height = 21.60mm
8. What would be the ideal recovery time for internal conditions after opening the cell culture incubator “door”? (Flow rates)
    1. Five minutes after 30 second opening
9. Would you prefer manual CO_2 addition, or an automatic regulation with sensors?
    1. Incubator itself has a valve and a sensor → *automatic prefered*
10. Is the budget for the final design, or does it include materials for preliminary designs?
    1. Yes but if the prototype works well then it can be flexible

Notes:

- Current incubator is water jacketed with co2 tank at ~10psi
- Microscope is able to lift head up so that we can fit the incubator in
-

Conclusions/action items:

We learned more about the intentions for the project and have a clear understanding of the route we will have to take. The design matrix will be updated with the new information after this meeting. More detailed Solidworks drawings can be made with the new dimensions of the project. A lot of the sensors and parts of the project that we were planning to buy are accessible from past projects and in the BME teaching lab.

11/02/2021 Client Meeting #3 Fabrication Updates

ETHAN HANNON (ehannon@wisc.edu) - Nov 03, 2021, 9:42 PM CDT

Title: Client Meeting #3

Date: 11/2/21

Content by: Sam & Ethan

Present: Sam & Ethan

Goals: To update the client on our position with the project and to receive more feedback on our incubator design.

Content:

- Thermistor to record temperature if the DH22 sensor does not work. Doesn't record humidity. Need a calibration curve

- The lens height is adjustable. He will get back to us with a height at the best refractive value. This will help solidify the dimensions of the incubator box so it can be 3D printed.

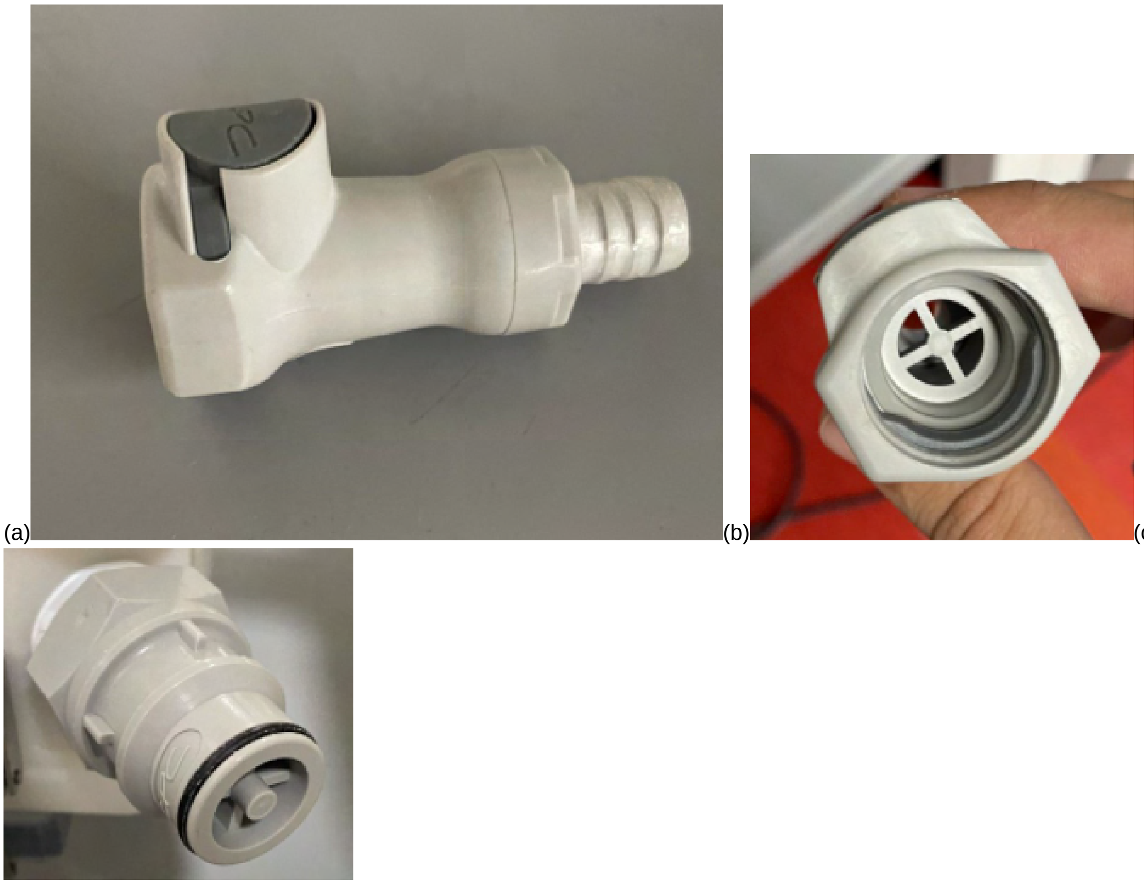
- We have the glass plates but they are very small. Will have to update box drawings to account of this change. Intended plan is to have a covering and the set the glass plate on top of the covering to allow transparency.

- Can use any tubing found in the old ECB lab room. Preferably 1/4 to 3/8 inch tubing. 1/4 inch tubing would work best with push adaptors (need to find a way to connect it to heated water incubator). 3/8 may work better for connection to heated water pump.

- He will set aside some cells for us to use to test with in the future.

- He already ordered a new DH22 temperature and humidity sensor to see if the old one was truly faulty.

- Lots of different adaptors to look at. Hose adaptors, push connectors and the gray connector for the heated water bath.



(a) (b) (c)

Figure 1: Different views of gray heated water pump adaptors.

Ethan found links online to order if need be:

For the coupling body: https://products.cpcworldwide.com/en_US/ProductsCat/NS4/NS4D17006

For the valve coupling insert: https://products.cpcworldwide.com/en_US/ProductsCat/HFC12/HFCD22612

Figure 2: Push adaptor for 1/4 inch tubing. Very easy to use.

- Avoid buying from ACE hardware because we can't get reimbursed. If anything needs to be ordered go to Puccinelli and he can have it within a couple of days.

Conclusions/action items:

SOLIDWORKS drawings will be updated to account for the glass dimensions. Testing on the glass can be conducted since some materials have arrived. Sensors will continue to be tested. May have to go a different temperature sensing route. Adaptors will be the main focus for the fabrication team and to figure out the best tubing to use to heat the inside of the cell culture incubator.

09/17/2021 Advisor Meeting #1

MAYA TANNA - Sep 25, 2021, 9:30 AM CDT

Title: Advisor Meeting #1

Date: 09/17/2021

Content by: Maya Tanna

Present: Sam Bardwell, Katie Mcgovern, Maya Tanna, Caroline Craig, Olivia Jaekle, Ethan Hannon

Goals: To document what was discussed at our first advisor meeting with Dr. Melissa Kinney

Content:

Advisor Meeting Notes 9/17/2021

- Prof. Kinney has a lot of experience using cell incubators
- Logistics
    - Find out where we will go for the 2 hours for presentations, show and tell, and final
    - Friday Meetings: 30 minute meetings to productively ask questions, connect to resources, brainstorm ideas. Send questions to everyone in advance for Friday meetings so that we can come to the meeting prepared for the questions we need to tackle. Weekly Recap, Goals, Discussion, and Problems we are running into.
    - Weekly Reports: send to both Prof. Kinney and Dr. P
        - Address the email to Dr. P
- Advice
    - Communication: keep communications open at all times
    - Delegation
    - Fast Paced Class = TIME MANAGEMENT
    - Set concrete goals and intermediate deadlines
    - Make sure that your goals have an actionable concrete outcome and a deadline for that outcome
        - *Targeted Research and SMART Goals*
    - Be as specific as possible with your PDS
        - Quantitative more than qualitative
- Grading
    - Using Canvas More
    - Final Deliverables **-** weighted most heavily
    - Preliminary Report is graded as if it was a final report (5% of grade)
    - Entire team gets roughly the same grade
    - Individual grades
        - Peer evaluations
        - Lab notebooks
    - Course deliverables
        - **Notebooks** (preliminary 5% and final 25%)
        - **Oral presentation**(preliminary 5% and final 20%)
        - **Written documentation** (preliminary 5% and final 25%)
    - Project output and team function
        - **Prototype** construction and evaluation (client satisfaction 5%)
        - **Participation** (contributions to weekly advisor meetings, group meetings, and team objectives, peer/self assessment 10%)
        - Technical leadership and outreach (for 402)

Conclusions/action items: Make sure to keep consistent communication with Dr. Kinney. It would also be helpful to send out weekly meeting agendas for meetings with her so that everyone on the team is on the same page and questions/clarifications can be dealt with effectively.

09/24/2021 Advisor Meeting #2

MAYA TANNA - Sep 25, 2021, 9:31 AM CDT

Title: Advisor Meeting #2

Date: 09/24/2021

Content by: Katie McGovern

Present: Sam Bardwell, Caroline Craig, Dr. Kinney, Maya Tanna, and Ethan Hannon

Goals: To recap our team accomplishments this week and discuss PDS and design matrix.

Content:

9/24/2021 Advisor Meeting Notes

- Refractive index in glass optical properties
- Look into the glass that they use on the bottom of multi-use well plate
- Maybe 3D print the sides and have optically transparent tops
- Ask about Routine Use
    - Are we using it for multiple labs for 3 hours only?
    - Are we using it for multiple days in the same lab?
- Loosen our variation parameters
    - What level of tolerance will we allow to meet Dr. P's specifications rather than industry standards?
- Size Requirements
    - Meet on Tuesday with Dr. P to get size requirements
    - More specific size of microscope and well plates as they are all the same size it just depends on the amount of wells
- Opening and closing the microscope
    - How to keep the gas in when the microscope slides are switched?
    - Sealed?
    - How long will it take to get back to necessary parameters?
        - Flow rate and time to get to stabilization → may need to do during testing
- CO_2
    - Comes in a tank with a regulatory on it, there is a hose on the side that you plug into the incubator; usually with a feedback loop on them
    - Tanks already have regulators on them :)
- How will we tackle all different pieces
    - Main goal: how to keep temp even
        - Water Jacketed or Direct Heat
- Stage-top Incubators

    - 2 competing designs that have stage-top incubators
        - wet sponge in incubator and whole incubator is placed into conditions for temperature so temp regulated within environment
        - Use outside humidifier to control the inside
- What is the range of pH that we need to keep and will this affect if we heat the incubator manually vs mechanically?
- Design Matrix
    - Figure out where the key parts are and put the weights in
    - Better figure out brainstorming to multi-aspect designs

Conclusions/action items:

- Questions for Puccinelli
    - Ask about Routine Use
        - Are we using it for multiple labs for 3 hours only?
        - Are we using it for multiple days in the same lab?
    - How will flow rates come into play with a very small box? Is there a required flow rate? Should we include a specification for this?
    - Meet on Tuesday with Dr. P to get size requirements
    - Look into materials and equipment already in tissue culture lab

10/01/2021 Advisor Meeting #3

MAYA TANNA - Oct 10, 2021, 8:35 AM CDT

Title: Advisor Meeting #3

Date: 10/01/2021

Content by: Maya Tanna

Present: Maya Tanna, Sam Bardwell, Katie Mcgovern, Caroline Craig, Olivia Jaekle, Ethan Hannon

Goals: To document notes and conversation from our third advisor meeting with Dr. Kinney

Content:

10/1/2021 Advisor Meeting #3

- Recap of weekly events
- Get preliminary report written well!!
  - Prelim report is very similar to final with the exception of testing and results
- Design Matrix
  - Previous Project Extension
  - Heater Pumped Incubator
    - Dr. Kinney likes that idea
    - Water level will be very small to minimize risk of leakage
    - Assuming that with materials we can seal the box
    - Load the plate in from the top
      - Either slot, snap, or hinge
    - **Can we do the math to determine how much volume of water needs to be heated to get to 37*C. Depends as well on the tubing.**
    - **How long does it take to get to that equilibrium?**
      - ***Maybe leave a port or a sensor so that we can measure temp***
      - ***Easy to design ports with 3D printed material***
  - Shelving Design
    - Do we brainstorm more based on priority now that we have met with the client?
- Autoclaving will affect material choice
  - **How hot does an autoclave get**?
  - **What is the pressure of an autoclave?**
  - **Autoclaving doesn't always keep material properties?**
    - **We can test this in the lab**
- How will we seal it?
  - Glass on the bottom will be very secure → glue like
  - Glass on the top → **need to discuss how the top will fit together (sliding verus hinge)**
    - **Maybe using a rubber casket, like a water bottle cap.**
    - **Lip in top of box with a cap?**
- We can access sensors from old bme labs
  - Still double check that we could build it with cheapo sensors
  - Most incubators do not tell humidity levels → people just put water in and assume that it will be enough
  - Will we get condensation on the inside of the box?
    - NO! → only time they get condensation is when the pan goes dry so as long as there is an equilibrium we should not be getting active condensation

Conclusions/action items: Use this feedback when writing the preliminary presentation and report. Start determining materials and think about how all the design components will come together.

10/08/2021 Advisor Meeting #4

MAYA TANNA - Oct 22, 2021, 12:22 PM CDT

Title: Advisor Meeting #4

Date: 10/08/2021

Content by: Maya Tanna

Present: Maya Tanna, Sam Bardwell, Katie Mcgovern, Caroline Craig, Olivia Jaekle, Ethan Hannon

Goals: To document notes and conversation from our fourth advisor meeting with Dr. Kinney

Content:

10/8/2021 Advisor Meeting Notes

- Comments on general update
  - 3D printing - incubator box will be printed
  - Order quickly because shipping is taking a long time
- Design Matrix
  - Next step is figuring out how to put sensors inside th incubator
- Observed Geometry of the box
  - Make sure we include in our presentation of how we will put this together
- Sensors
  - Temp definitely maybe even a CO_2, but less important
    - Temp gage is an output sensor → sensor inside incubator that figures out CO_2, percentage and opens the solenoid when CO_2 levels drop or increase too rapidly
  - Automatic not manual
- Multiple aspects of the project
  - Building the box
  - Figuring out the sensor/
  - nternal environment maintenance
- Q&A
  - Any recommendations to get started on?
    - TESTING PLAN
  - Try to break up the project so that we are never waiting on someone else
  - Send us the preliminary presentation on TUESDAY

Conclusions/action items: Use this feedback when writing the preliminary presentation and report. Start determining materials and think about how all the design components will come together. Also, divide up into subcommittees: 1 for fabrication, 1 for sensor coding, and 1 for ordering materials/writing test protocols.

10/22/2021 Advisor Meeting #5

MAYA TANNA - Oct 22, 2021, 12:22 PM CDT

Title: Advisor Meeting #5

Date: 10/22/2021

Content by: Katie Mcgovern

Present: Maya Tanna, Sam Bardwell, Katie Mcgovern, Caroline Craig, Olivia Jaekle, Ethan Hannon

Goals: To document notes and conversation from our fifth advisor meeting with Dr. Kinney

Content:

10/22/2021 Advisor Meeting #5

- Impressions on the Prelim Presentations
  - Talk more about Client maybe → needs of client
  - Bit on on how we picked design criteria
  - Stood out in quantitative data
- Poster Presentation at the end of the semester
  - Still debating whether this will be in person poster or a presentation type thing
- Where we are at in the design process
  - Finalized prelim deliverables
  - Finished the materials purchase request
  - This weekend: Sam and Maya are checking out adaptors for tubing and such
    - Dr. Kinney recommends Ace Hardware in Hildale
  - Split teams up
    - Arduino
    - Materials and Testing protocols
    - Fabrication
- Materials Purchasing List
  - Asked Dr. P if he has any prior materials
  - Follow up email
  - Try to move forward with confidence otherwise
  - There is a way to reimburse if we do choose something
- Next week we will discuss the report
- **Show and Tell is in 2 weeks**

Conclusions: Reach out to Dr. Puccinelli again to move forward with material purchasing. Take pictures of parts from Ace Hardware, Menards, and Home Depot for more info on adaptors and tubing.

11/12/2021 Advisor Meeting #6

MAYA TANNA - Nov 12, 2021, 1:11 PM CST

Title: Advisor Meeting #6

Date: 11/12/2021

Content by: Katie Mcgovern

Present: Maya Tanna, Sam Bardwell, Katie Mcgovern, Caroline Craig, Olivia Jaekle, Ethan Hannon

Goals: To document notes and conversation from our sixth advisor meeting with Dr. Kinney

Content:

See attachment below.

Conclusions: Edit and execute test protocols. Create instructions for use document. Work on full system printing/assembly as well as ensuring that the code outputs correct values for CO2. Investigate CO2 sensors and go in depth with this component of the project.

MAYA TANNA - Nov 12, 2021, 1:11 PM CST

Advisor Meeting 11/12/2021

- Recap on progress
- For materials check out McMaster-Carr
    - Talk to Dr. P about how to get reimbursed for Ace Hardware
    - Dr. P can get it tax free on Amazon using p card
- Polyethylene Tubing
    - One inner tube and one outer tube
    - Need to do calculations or test the temperature stability and recovery
- Testing protocols
    - How to insert the thermometer without poking more holes?
        - Use a digital thermometer on the glass (need to be waterproof)
        - Look in BME teaching lab for options
    - Create a testing protocol for CO_2
    - Calibrate the percentage if the CO_2 is not accurate → very difficult to do please avoid
    - Automatic control from the tank to the incubator
        - Look at the regulator
            - Pressure in take
            - Output pressure
            - Look at a solenoid but that will require outside control needs valve potentially to control it
            - Valve → find out how much CO_2 could fall per graph
                - Read the CO_2 and code to open and close the valve
        - CO_2 side of things is the hardest part
            - Look at tank to see what we need to do
    - Glass testing
        - Quantitative test for optical information
        - Take pictures of cells with and without glass and imageJ to see how many cells you can look at, edge with and imge similarity (sorry y keyboard isn't working well)
    - Recovery testing portol
        - Report the graph of internal conditions vs time
        - Time to go abov 0.5% for testing
- Fabrication
    - How to put the sensor into teh incubator to get redings t different areas
    - Side where the tubing is
    - Eighdrilled holes for the thermistor → due to them removable to keep the sensors dry
        - To slides so then you are biliig a lot of hardware in

Download

Advisor_Meeting_11_12_2021.docx (564 kB)

11/19/2021 Advisor Meeting #7

MAYA TANNA - Nov 25, 2021, 2:41 PM CST

Title: Advisor Meeting #8

Date: 11/19/2021

Content by: Katie

Goals: To document advice given by Dr. Kinney at our weekly meeting

Content:

See attachment below.

Conclusions/action items: Execute testing and heavily investigate the CO2 tank situation.

MAYA TANNA - Nov 25, 2021, 2:41 PM CST

11/19/21 Advisor Meeting Notes #8

- Check to see if the microscope has a camera in order to test the glass
- Do everything blinded
- Sensors
  - Throw a sensor into an incubator and see if it at least responds to changes
- CO_2 feedback link
  - Not too much progress

Download

11_19_21_Advisor_Meeting_Notes.docx (6.67 kB)

12/03/2021 Advisor Meeting #8

Katie Day - Dec 08, 2021, 9:16 PM CST

Title: Advisor Meeting #9

Date: 12/0/2021

Content by: Katie

Goals: To document advice given by Dr. Kinney at our weekly meeting

Content:

See attachment below.

Conclusions/action items: Execute testing and heavily investigate the CO2 tank situation.

Katie Day - Dec 08, 2021, 9:16 PM CST

12/03/21 Advisor Meeting Notes #9

- Testing
  - CO_2 and Temp Sensing are complete
  - Optical Testing will be completed by Monday 12/6
    - Computer password: 2005
    - Dr. P sent a lab doc with how to use it
- The Box
  - Everything is in we just need the tubing
  - Glass will be superglued
- CO_2
  - Just pump it in bc its late in the semester and I'm tired
  - Need a meeting on our own with puoc to get our own CO_2 tank
- Print our poster early
- Day of
  - Be there early to put up poster
  - Bring physical version of incubator
  - Presentation is very similar to prelim presentation
    - Anyone can watch
    - There will be a peer evaluation
- Individual Notebook
  - Do we need to add to other research stuff?
    - Nah
  - Testing results
  - User manuals
- Statistical Test should be used with Optical Testing
  - Show that the p value shows that they are not different
- There will be a survey at the end of the semester and we can propose to continue the project

Download

12_03_21_Advisor_Meeting_Notes_9.docx (7.24 kB)

09/20/2021 Team Meeting #1 Working/Finalizing PDS

MAYA TANNA - Sep 20, 2021, 5:20 PM CDT

Title: Team Meeting #1 Working/Finalizing PDS

Date: 09/20/2021

Content by: Maya Tanna

Present: Sam Bardwell, Katie Mcgovern, Maya Tanna, Caroline Craig, Olivia Jaekle, Ethan Hannon

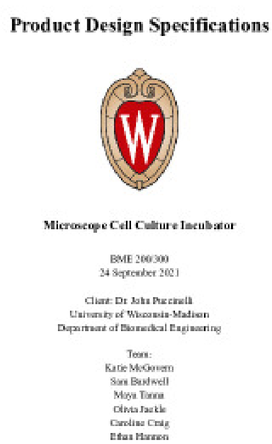
Goals: To document the progress we made on the product design specifications document as a team

Content:

1. Met to discuss upcoming project deadlines and initial research done by each member of the team
2. Everyone read over the PDS and made last edits as well as references
    1. Final and submitted draft is below

Conclusions/action items: We will meet next week to start coming up with ideas for the design matrix and go over the team's relevant research. We will also continue to update the PDS if design or client requirements change throughout the semester.

MAYA TANNA - Sep 20, 2021, 5:23 PM CDT



Product Design Specifications

Microscope Cell Culture Incubator

BME 200/300
24 September 2021

Client: Dr. John Puccinelli
University of Wisconsin-Madison
Department of Biomedical Engineering

Team:
Katie McGovern
Sam Bardwell
Maya Tanna
Olivia Jaekle
Caroline Craig
Ethan Hannon

Download

Product_Design_Specifications.pdf (219 kB)

09/27/2021 Team Meeting #2 Design Idea Brainstorm

Katie Day - Sep 28, 2021, 3:38 PM CDT

Title: Team Meeting #2

Date: 9/27/2021

Content by: Katie McGovern

Present: Katie McGovern, Sam Bardwell, Maya Tanna, Caroline Craig, Ethan Hannon, Olivia Jaekle

Goals: To brainstorm ideas for our preliminary design and create a design matrix.

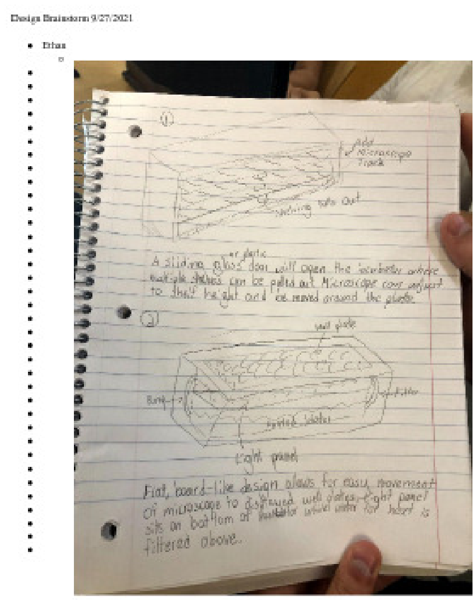
Content:

See attached File.

Conclusions/action items:

Begin working on preliminary presentation and further research different materials.

Katie Day - Sep 28, 2021, 3:38 PM CDT



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Design_Brainstorm_9_27_2021.pdf (1.39 MB)

10/04/2021 Team Meeting #3 Finalizing Design Matrix

MAYA TANNA - Oct 10, 2021, 8:58 AM CDT

Title: Team Meeting #3

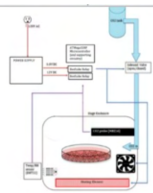
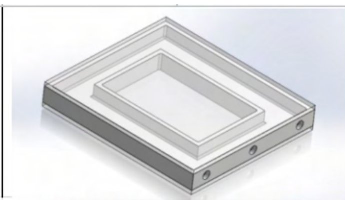
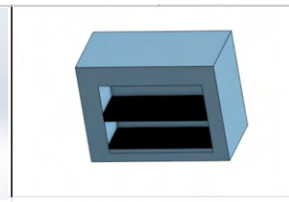
Date: 10/04/2021

Content by: Maya Tanna

Present: Katie McGovern, Sam Bardwell, Maya Tanna, Caroline Craig, Ethan Hannon, Olivia Jaekle

Goals: To finalize our design matrix and start evaluating potential design solutions.

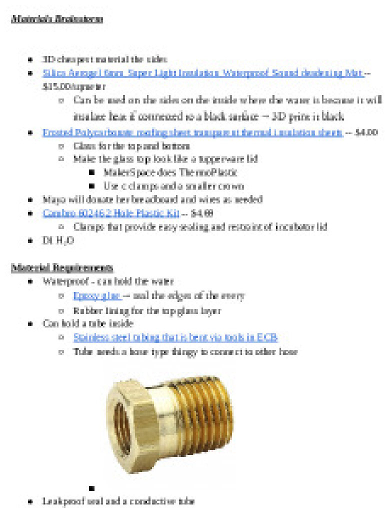
Content:

								
			Past Project Refurbished		**Heated Water Pump Incubator**		**Shelving Incubator**	
Rank	Criteria	Weight	Score (10 max)	Weighted Score	Score (10 max)	Weighted Score	Score (10 max)	Weighted Score
1	Internal Environment	25	9	23	7	18	5	13
2	Microscope Compatibility	20	10	20	10	20	10	20
3	Accuracy and Reliability	20	7	14	8	16	4	8
4	Ergonomics	15	5	8	8	12	4	6
5	Cost	10	2	2	4	4	3	3
6	Life in Service	5	10	5	10	5	10	5
7	Safety	5	10	5	10	5	10	5
	Sum	**100**	**Sum**	**76**	**Sum**	**80**	**Sum**	**60**

Conclusions/action items:

Begin working on preliminary presentation and report and further research different materials.

MAYA TANNA - Oct 10, 2021, 9:02 AM CDT



Materials Brainstorm

- 3D cheapest material the sides
- Silica Aerogel 6mm Super Light Insulation Waterproof Sound deadening Mat -- $15.00/sqmeter
    - Can be used on the sides on the inside where the water is because it will insulate heat if connected to a black surface → 3D print it black
- Frosted Polycarbonate roofing sheet transparent thermal insulation sheets -- $4.00
    - Glass for the top and bottom
    - Make the glass top look like a tupperware lid
        - MakerSpace does ThermoPlastic
        - Use c clamps and a smaller crown
- Maya will donate her breadboard and wires as needed
- Cambro 60246 2 Hole Plastic Kit -- $4.69
    - Clamps that provide easy sealing and restraint of incubator lid
- DI H_2O

Material Requirements

- Waterproof - can hold the water
    - Epoxy glue → seal the edges of the every
    - Rubber lining for the top glass layer
- Can hold a tube inside
    - Stainless steel tubing that is bent via tools in ECB
    - Tube needs a hose type thingy to connect to other hose
        -
- Leakproof seal and a conductive tube

Download

Materials_and_Heating_Brainstorm.docx (612 kB)

10/11/2021 Team Meeting #4 Finalizing Presentation/Organizing Subcommittees

MAYA TANNA - Oct 18, 2021, 5:28 PM CDT

Title: Team Meeting #4 Finalizing Presentation/Organizing Subcommittees

Date: 10/11/2021

Content by: Maya Tanna

Present: Katie McGovern, Sam Bardwell, Maya Tanna, Caroline Craig, Ethan Hannon, Olivia Jaekle

Goals: To finalize our presentation and make revisions according to Dr. Kinney's feedback

Content:

Hi Katie,

Great job – my comments are below:

- Include your advisor/client and the date on your title slide
- You don't need a presentation overview slide
- Great job with a quantitative PDS!
- Competition: are there other small/low cost incubators that have been developed outside of UW BME design?
- Make sure that the labels on your figures are large enough to read easily (Fig. 5 labels are really small)
- Include a slide describing your design criteria and how they were chosen
- Label the dimensions and points of interest on all of your figures (i.e. Fig 6)
- It might be helpful to include a separate slide describing the workflow for how it will be used

Conclusions/action items:

To finalize the preliminary report and begin compiling materials for purchasing.

10/18/2021 Team Meeting #5 Materials Purchasing Organization/Final Edits on Preliminary Report

MAYA TANNA - Oct 18, 2021, 5:31 PM CDT

Title: Team Meeting #5 Materials Purchasing Organization/Final Edits on Preliminary Report

Date: 10/18/2021

Content by: Maya Tanna

Present: Katie McGovern, Sam Bardwell, Maya Tanna, Caroline Craig, Ethan Hannon, Olivia Jaekle

Goals: To finalize our report and gather all the materials for purchasing together in a document

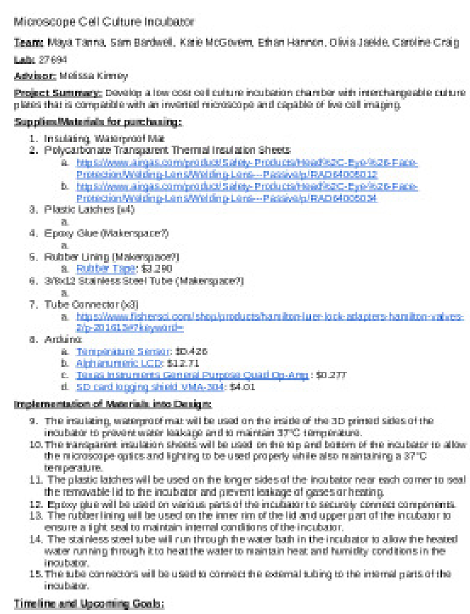
Content:

Progress is below

Conclusions/action items:

To finalize the preliminary report and purchase materials.

MAYA TANNA - Oct 18, 2021, 5:31 PM CDT



Microscope Cell Culture Incubator

Team: Maya Tanna, Sam Bardwell, Katie McGovern, Ethan Hannon, Olivia Jaekle, Caroline Craig

Lab: 27694

Advisor: Melissa Kinney

Project Summary: Develop a low cost cell culture incubation chamber with interchangeable culture plates that is compatible with an inverted microscope and capable of live cell imaging.

Supplies/Materials for purchasing:

1. Insulating, Waterproof Mat
2. Polycarbonate Transparent Thermal Insulation Sheets
   a. https://www.airgas.com/product/Safety-Products/Head%2C-Eye-%26-Face-Protection/Welding-Lens/Welding-Lens---Passive/p/RAD64005012
   b. https://www.airgas.com/product/Safety-Products/Head%2C-Eye-%26-Face-Protection/Welding-Lens/Welding-Lens---Passive/p/RAD64005034
3. Plastic Latches (x4)
   a.
4. Epoxy Glue (Makerspace?)
   a.
5. Rubber Lining (Makerspace?)
   a. Rubber Tape: $3.290
6. 3/8x12 Stainless Steel Tube (Makerspace?)
   a.
7. Tube Connector (x3)
   a. https://www.fishersci.com/shop/products/hamilton-luer-lock-adapters-hamilton-valves-2/p-201613#?keyword=
8. Arduino:
   a. Temperature Sensor: $0.426
   b. Alphanumeric LCD: $12.71
   c. Texas Instruments General Purpose Quad Op-Amp : $0.277
   d. SD card logging shield VMA-304: $4.01

Implementation of Materials into Design:

9. The insulating, waterproof mat will be used on the inside of the 3D printed sides of the incubator to prevent water leakage and to maintain 37°C temperature.
10. The transparent insulation sheets will be used on the top and bottom of the incubator to allow the microscope optics and lighting to be used properly while also maintaining a 37°C temperature.
11. The plastic latches will be used on the longer sides of the incubator near each corner to seal the removable lid to the incubator and prevent leakage of gases or heating.
12. Epoxy glue will be used on various parts of the incubator to securely connect components.
13. The rubber lining will be used on the inner rim of the lid and upper part of the incubator to ensure a tight seal to maintain internal conditions of the incubator.
14. The stainless steel tube will run through the water bath in the incubator to allow the heated water running through it to heat the water to maintain heat and humidity conditions in the incubator.
15. The tube connectors will be used to connect the external tubing to the internal parts of the incubator.

Timeline and Upcoming Goals:

Download

Materials_Purchasing_Request_-_Microscope_Cell_Culture_Incubator.docx (48.3 kB)

10/18/21 TeamLab Meeting Summary

SAMUEL BARDWELL - Oct 19, 2021, 1:48 PM CDT

Title: TeamLab Meeting Summary

Date: 10/18/21

Content by: Sam

Present: Sam & Ethan

Goals: To confirm the intended design for the incubator on Solidworks is feasible and what type of adaptors to use between the tubing.

Content:

Notes:

Pipe threading

Rubber Strips

Epoxy is available

Conclusions/action items:

The TeamLab professional saw no problems with our intended design for the project. The biggest questions were surrounding the adaptors between the tubing of the metal and heated water pump. There were a couple ways to go about connecting these and one would be to thread the pipe and the screw on an adaptor to one side and then epoxy the other. The next idea was to just epoxy the metal side of the adaptor and connect the other. The adaptor would have to have a ribbed cone shape for the rubber tubing from the heated water pump to being pushed on. This could then be surrounded with a zip tie to make sure it stays on when the water is being pumped. The professional also said there are different types of epoxy's that would work better for different materials and some research should be done to find which epoxy to use.

10/23/2021 Ace Hardware Visit

MAYA TANNA - Oct 27, 2021, 11:08 AM CDT

Title: Ace Hardware Visit

Date: 10/23/2021

Content by: Maya

Present: Maya & Sam

Goals: To document findings on part specifications from Ace Hardware as well as future action items based on that information

Content:

Rubber water hose heats up to 150 degrees Fahrenheit (we are looking for 98 degrees Fahrenheit) - research if it is effective.

Conclusions/action items: Do more research on vinyl tubing and rubber water hoses (fuel line hose). Look into copper rust specifications to determine feasibility of using copper.

MAYA TANNA - Oct 27, 2021, 11:29 AM CDT

Download

Ace_Hardware_Visit_Pictures.docx (3.97 MB)

11/05/2021 Show and Tell Feedback

MAYA TANNA - Nov 05, 2021, 2:40 PM CDT

Title: Show and Tell Feedback

Date: 11/05/2021

Content by: Maya

Present: Whole Team

Goals: To document feedback received from other teams regarding sensor and tubing placement

Content:

- Zig zag needs pegs to hold in place
- Sensors on the top
- Carbonate water
- Hydrophilic materials
- Just use waterproofed sensors? RESEARCH
- CO2 sensor waterproofing test protocol
- Zig zag best idea, but secure
- Tubing: twice wrap around, tubing coming out of incubator above water
- Waterproof fabric (rain coat material)
- Randomized zig zag
- Thermistor, coating that works with temperature but waterproof
- Get curve and calibration stuff from class
- Snail system with tubing
- Look into ideas for water proofing the sensors (rubber, styrofoam)
- Test coiled vs. uncoiled tubing (tubing test protocols)

Conclusions/action items: Use a thermistor for measuring temperatures. Write test protocols for tubing and CO2 sensor waterproofing. Use snail system with tubing.

09/28/2021 Design Matrix

Olivia Jaekle - Oct 11, 2021, 5:03 PM CDT

Title: Design Matrix

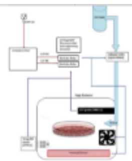
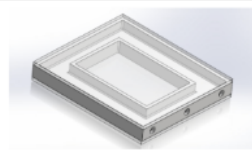
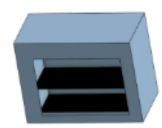
Date: 9/28/2021

Content by: Caroline Craig, Ethan Hannon, Olivia Jaekle, Maya Tanna, Katie McGovern, Sam Bardwell

Present: Team

Goals: To document design matrix and provide reasoning for rankings.

Content:

			 Past Project Refurbished		 Heated Water Pump Incubator		 Shelving Incubator	
Rank	Criteria	Weight	Score (10 max)	Weighted Score	Score (10 max)	Weighted Score	Score (10 max)	Weighted Score
1	Internal Environment	25	9	23	7	18	5	13
2	Microscope Compatibility	20	10	20	10	20	10	20
3	Accuracy and Reliability	20	7	14	8	16	4	8
4	Ergonomics	15	5	8	8	12	4	6
5	Cost	10	2	2	4	4	3	3
6	Life in Service	5	10	5	10	5	10	5
7	Safety	5	10	5	10	5	10	5
	Sum	100	Sum	76	Sum	80	Sum	60

- Internal Environment
  - For this criteria, the Past Project Refurbished scored the highest since the previous BME groups have already done testing on the device's ability to regulate temperature, CO2, and humidity. Our team believed that further work on this system could have improved the device's ability to maintain these conditions by improving the materials. For these reasons, we gave Past Project Refurbished a 9.
  - The Heated Water Pump Incubator scored the next highest because our team believes improving upon previous BME groups' designs by using a heated water tube would benefit the ability to create a better cell culture environment. It scored lower than the Past Project Refurbished design because we would not have the previous testing to use. For these reasons, we gave Heated Water Pump Incubator a 7.
  - Finally, the Shelving Incubator scored lowest with a 5 because the ability of our team to maintain the conditions once the drawers were pulled out had not been completely understood.
- Microscope Compatibility
  - All designs scored a 10 in microscope compatibility because each design was created and could successfully be used with an inverted microscope.
- Accuracy and Reliability
  - For this criteria, our team scored the Heated Water Pump Incubator highest. We believe that the finalized design would have a more reliably designed system for the intended use of the incubator with the materials and external devices we plan to use. For this reason, gave this design an 8.
  - The Past Project Refurbished design scored the next highest with a 7. Like the Heated Water Pump Incubator, the Past Project Refurbished design would have improved upon materials in comparison with previous BME projects, but the mechanics of the system would not be as reliable as the other incubator.
  - The Shelving Incubator received the lowest score of 4 because altering the shape of the environment by opening a drawer would be difficult to maintain accurate internal conditions, and the size of the machine may hinder its reliability in reading accurate conditions. Also, moving components are more susceptible to wear and tear making it less likely to live through its self-life
- Ergonomics
  - Our team scored the Heated Water Pump Incubator highest for this criteria, again because its materials and components would allow it to function the best in comparison with our other designs. For this reason, it scored an 8.
  - The Past Project Refurbished design scored a 5 because the design components implemented by previous BME teams that we planned on keeping the same would not function in maintaining internal environment conditions as the Heated Water Pump Incubator could.

  - Finally, the Shelving Incubator scored lowest with a 4 because it would be the most difficult to use with having to pull out drawers each time one wanted to view a sample.
- Cost
  - All the designs scored low for cost because our team's smaller budget will be difficult to stay in range with. The Heated Water Pump Incubator scored the best with a 4 because lots of the components we plan on using will be provided to us. Our biggest difficulty in staying within the budget will be limiting the need to repurchase materials wasted in prototyping.
  - The Past Project Refurbished design scored a 3 because components of the previous design would be reused, but the components we plan on replacing would end up being more expensive than just creating the Heated Water Pump Incubator design.
  - The Shelving Incubator scored lowest with a 2 because its size would increase the cost and create a greater likelihood to go over budget if lots of prototypes are made.
- Life in Service
  - All the designs scored a 10 for Life in Service because they were designed with the intent of functioning for a week period of time every year for 10 years.
- Safety
  - All the designs scored a 10 for safety because the components involved in their designs would not be harmful to the user in any way.

Conclusions/action items:

Based on this design matrix, our team will be moving forward with creating the Heated Water Pump Incubator for our client. This design was ranked the reliable, ergonomic, and cost-effective in comparison with the other designs. The design will include a slot for the well plate, a tube containing heated water to maintain a 37*C temperature and assist in evaporation, and a water well for evaporation water to maintain high humidity. The dimensions of the incubator will match the size of the microscope stand, or it will go over the edges slightly, and the height will not exceed the lowest point of the top light microscope component. Finally, sensors compatible with Arduino will be used to regulate the internal conditions.

10/19/21 Preliminary SolidWorks Incubator Design

SAMUEL BARDWELL - Oct 19, 2021, 1:22 PM CDT

Title: Preliminary SOLIDWORKS Incubator Design

Date: 10/19/21

Content by: Sam

Goals: To create a detailed Solidworks assembly and drawing of the proposed incubator design.

Content:

Item NO.	Item Description	Dimensions (mm)	QTY.
1	Top glass plate	250 x 200 x 5	1
2	Sealed glass plate holder	260 x 210 x 6	1
3	Metal tube for water	d = 7.16	1
4	Outer box of incubator	250 x 200 x 28	1
5	Inner box of incubator to hold cell plate	140 x 96 x 18	1
6	Lower glass plate	250 x 200 x 5	1

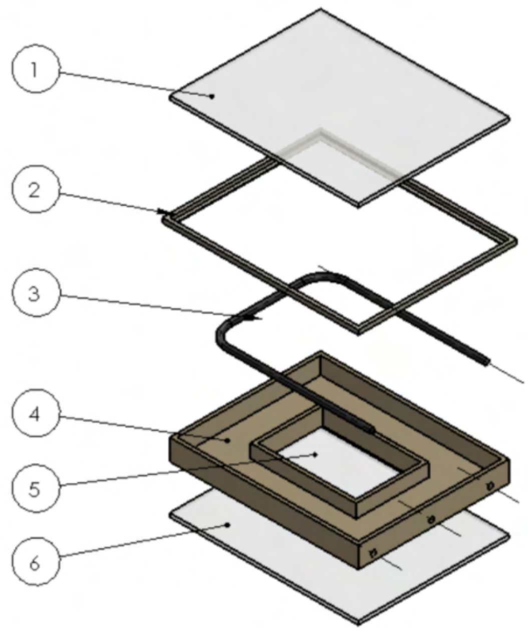


Figure 1: Exploded view of the Solidworks drawing showing the part names and descriptions.

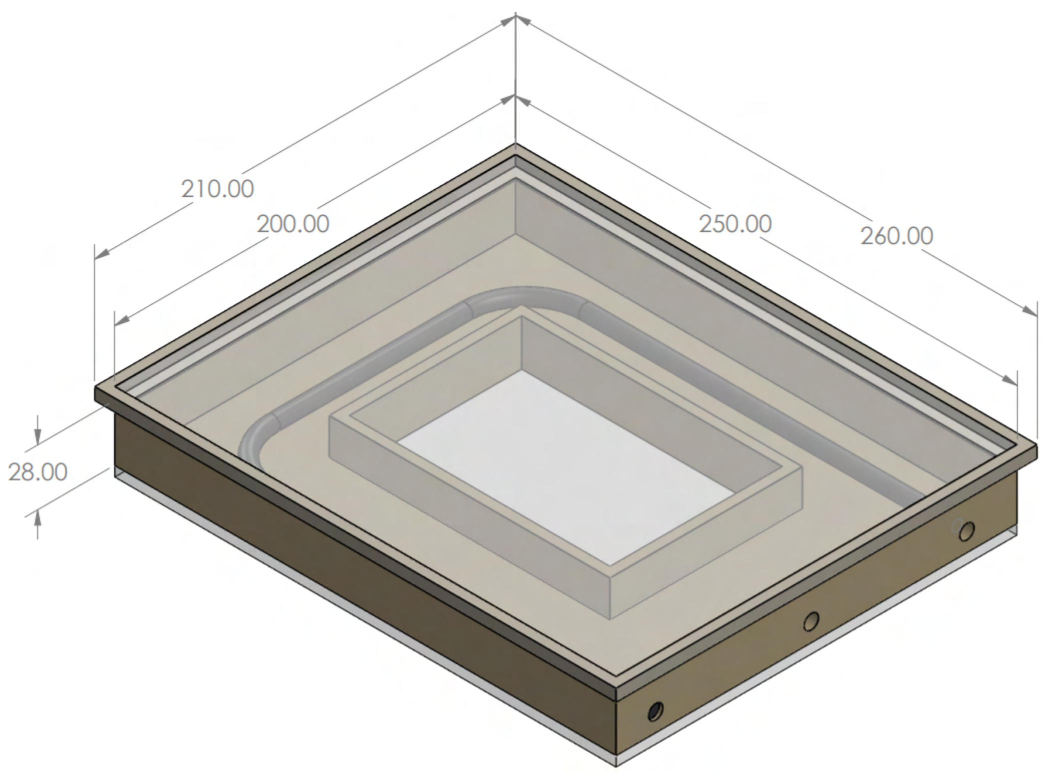


Figure 2: Collapsed view of incubator with dimensions of the box.

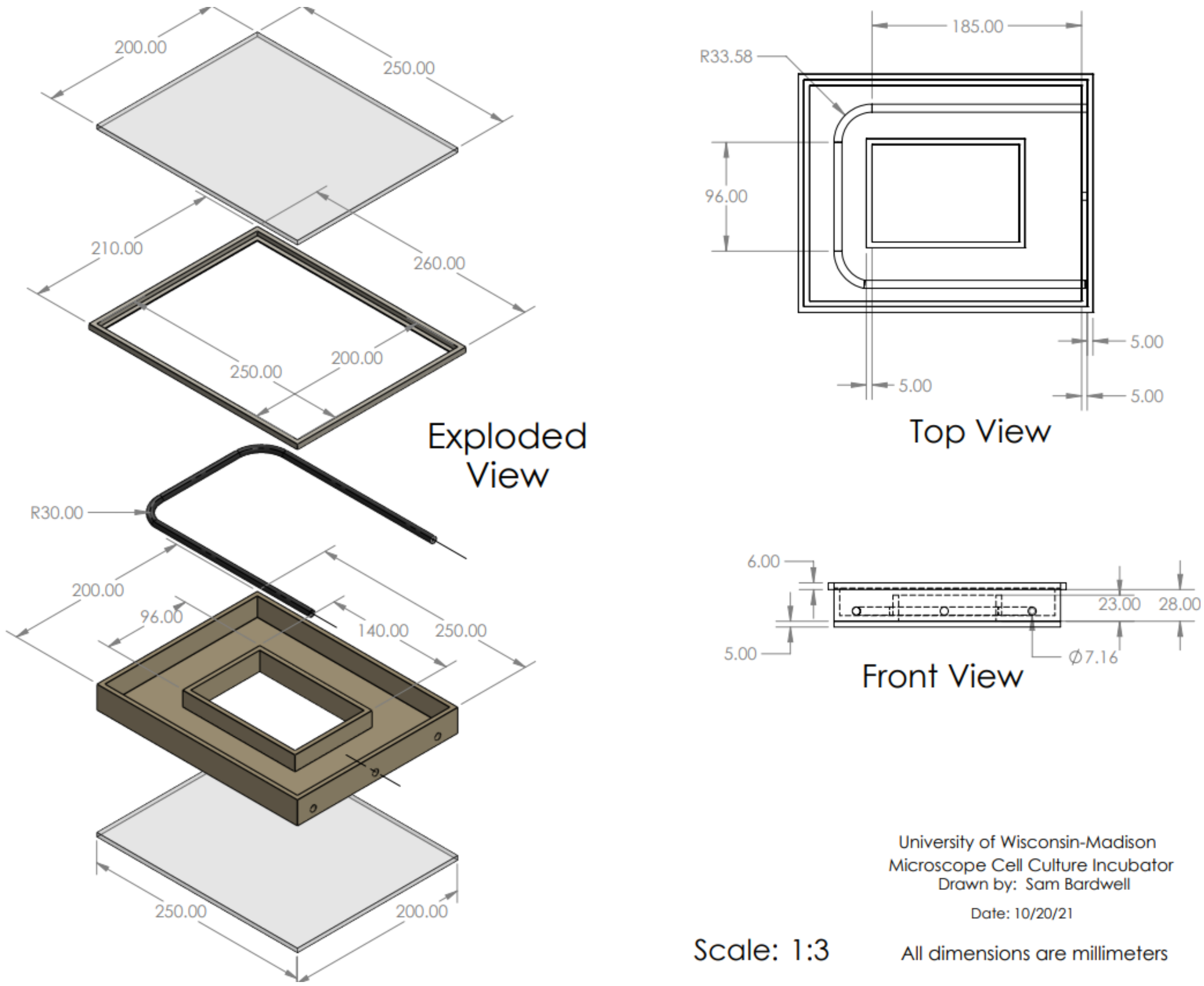
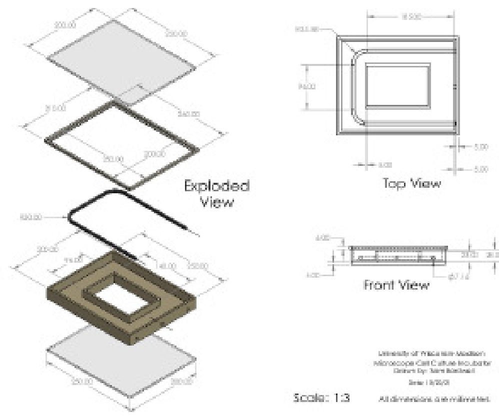


Figure 3: Solidworks drawing showing more detailed dimensions of all the parts in the incubator.

Conclusions/action items:

This is the preliminary design we are going to continue going forward with. The next step are to obtain the materials needed to fabricate the incubator. Once materials arrive, final touches and dimensions will be updated to the Solidworks design and then the box will be 3D printed at the UW - Madison Makerspace.

SAMUEL BARDWELL - Oct 19, 2021, 1:24 PM CDT



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BME300_Incubator__Drawing_10.19.21.pdf (196 kB)

11/05/2021 Show and Tell Preparations

MAYA TANNA - Nov 05, 2021, 2:54 PM CDT

Title: Show and Tell Preparations

Date: 11/05/2021

Content by: Maya/Caroline/Katie

Present: Whole Team

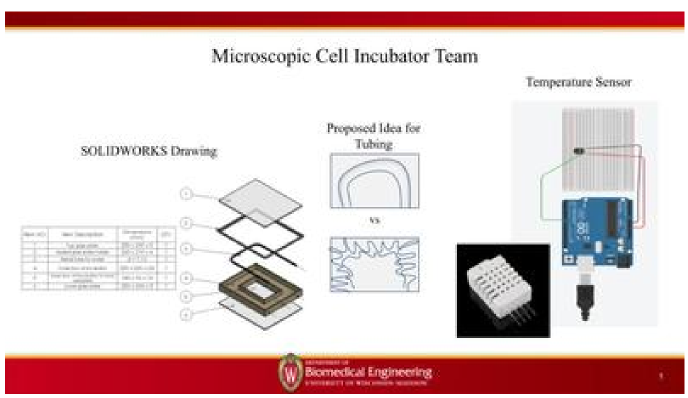
Goals: To document work done to prepare for show and tell

Content:

Hi everyone! Our team has been tasked with developing a low-cost cell culture incubation chamber that is compatible with an inverted microscope and capable of live-cell imaging culture plates. The incubator must be able to maintain an internal environment of 37℃, 5% CO_2, and 95-100% humidity without compromising the integrity of the microscope's optics or functionality. Our final design consists of a heated water pump where a conducting plastic tube will be wrapped around the inside of the incubator and connected to a heated water pump that will be set to 37°C. The inside of the incubator will be filled with water, submerging the plastic tubing, allowing the internal environment to be heated by conduction as well as increasing the humidity to 95% or higher. The incubator box will also include a tube connector to allow CO_2 gas to be pumped in. Lastly, a separate box will be placed inside the incubator to allow for wiring and sensors to be inside the internal environment. The sensors will be connected to an Arduino microcontroller where temperature, humidity, and CO_2 levels will be collected and analyzed. Our call to action is to ask for your help on how we can arrange the plastic tubing or sensors in order to achieve a homogeneous temperature environment.

Conclusions/action items: Use feedback from show and tell to drive the remainder of the semester and continue testing/fabrication of device.

MAYA TANNA - Nov 05, 2021, 2:54 PM CDT



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Show_and_Tell_Presentation.jpg (55.5 kB)

10/18/2021 - Future Expenses Table

Caroline Craig - Oct 18, 2021, 7:26 PM CDT

Title: Future Expenses Table

Date: 10/18/2021

Content by: Team

Present: Team

Goals: To document and update the expenses table with purchases throughout the fabrication process.

Content:

Item	Description	Manufacturer	Part Number	Date	QTY	Cost Each	Total	Link
Category 1 : Incubator								
3D Printed Casing	for sides of incubator	Makerspace			1	$20.00	$20.00	
Transparent Cover Plates	top and bottom of incubator	Radnor	64005034		2	$1.04	$2.08	https://www.airgas.com/
Plastic Latches	secure lid to incubator	Cambro	Cambro 60264		4	$4.69	$18.76	Cambro 60246 2 Hole Pla
Rubber Lining Tape	create tight seal between lid and incubator	Makerspace			1	$0.00	$0.00	
Insulating, Waterproof Mat	lining the 3D printed sides of the incubator	Makerspace			1	$0.00	$0.00	
Category 2 : Components								
3/8x12 Stainless Steel Tube	heated water will flow through	K & S Precision Metals	87119		1	$6.00	$6.00	LINK
3/8 in. Compression Brass Coupler	to connect the stainless steel tube to water pump	Everbuilt	207176323		2	$3.65	$7.30	LINK
1.5mm Tube Connector	connection between CO2 tank and incubator	Fisher Scientific	35031		1	$14.96	$14.96	LINK
Arduino 2x16 character Display		MIDAS	77T3012		1	$12.71	$12.71	Alphanumeric LCD
Arduino Operational Amplifier		ONSEMI	LM324ADR2G		1	$0.28	$0.28	Texas Instruments Genera
Arduino SD card logging shield		VELLEMAN	WPI304		1	$4.01	$4.01	SD card logging shield VM
						TOTAL:	**$86.10**	

Conclusions/action items:

The items documented in the table are potential future purchases for our team. A list including these materials has been sent to the client for purchasing, however, the stainless steel tube and 1.5mm tube connector are still being reviewed for potential cheaper or free options through the client. Other components are being reused from previous team's projects, and improved rubber lining tape and insulating mat will be purchased in the future if needed. With purchases in progress, the team is projected to come in under budget for the final design.

12/06/2021 - Expenses Table

Caroline Craig - Dec 11, 2021, 9:44 PM CST

Title: Expenses Table

Date: 10/18/2021

Content by: Team

Present: Team

Goals: To document and update the expenses table with purchases throughout the fabrication process.

Content:

Item	Description	Manufacturer	Part Number	Date	QTY	Cost Each	Total	Link
Category 1 : Incubator								
3D Printed Casing	for sides of incubator	Makerspace		11/9/2021	1	$32.32	$32.32	N/A
Transparent Cover Plates	top and bottom of incubator	Radnor	64005034	10/29/2021	2	$1.04	$2.08	https://www.airgas.com/product
Category 2 : Components								
3/8 and 1/4 in. Polyethylene Tubing	heated water will flow through	USA Sealing	55YU99	11/23/2021	1	$1.96	$1.96	LINK
Epoxy glue	to attach loose components	Makerspace				$1.50	$0.00	N/A
1.5mm Tube Connector	connection between CO2 tank and incubator	Fisher Scientific	35031	10/29/2021	1	$14.96	$14.96	LINK
Vinyl Tubing 3/8" x 1/2"	heated water will flow through	Ace Hardware	4027504	12/6/2021	1	$8.33	$8.33	N/A
Barbed Vacuum Connector	connection between tubing	Grainger	5ZMHI	11/23/2021	2 (of 10)	$0.95	$1.90	LINK
						TOTAL:	**$61.55**	

Conclusions/action items:

The items documented in the expenses table are the items that were purchased for our microscope cell culture incubator. All costs were covered by the client. Other components are being reused from the previous team's projects, so the cost of those materials is not included in the expenses table. If the project were to be reproduced from scratch the total cost would be roughly $150. Altogether the team came in under budget for the final design.

11/29/2021 Box Fabrication: 3D Print

SAMUEL BARDWELL - Dec 05, 2021, 5:16 PM CST

Title: Box Fabrication: 3D Print

Date: 11/29/21

Content by: Sam

Goals: To 3D print the incubator box and assemble it.

Content:

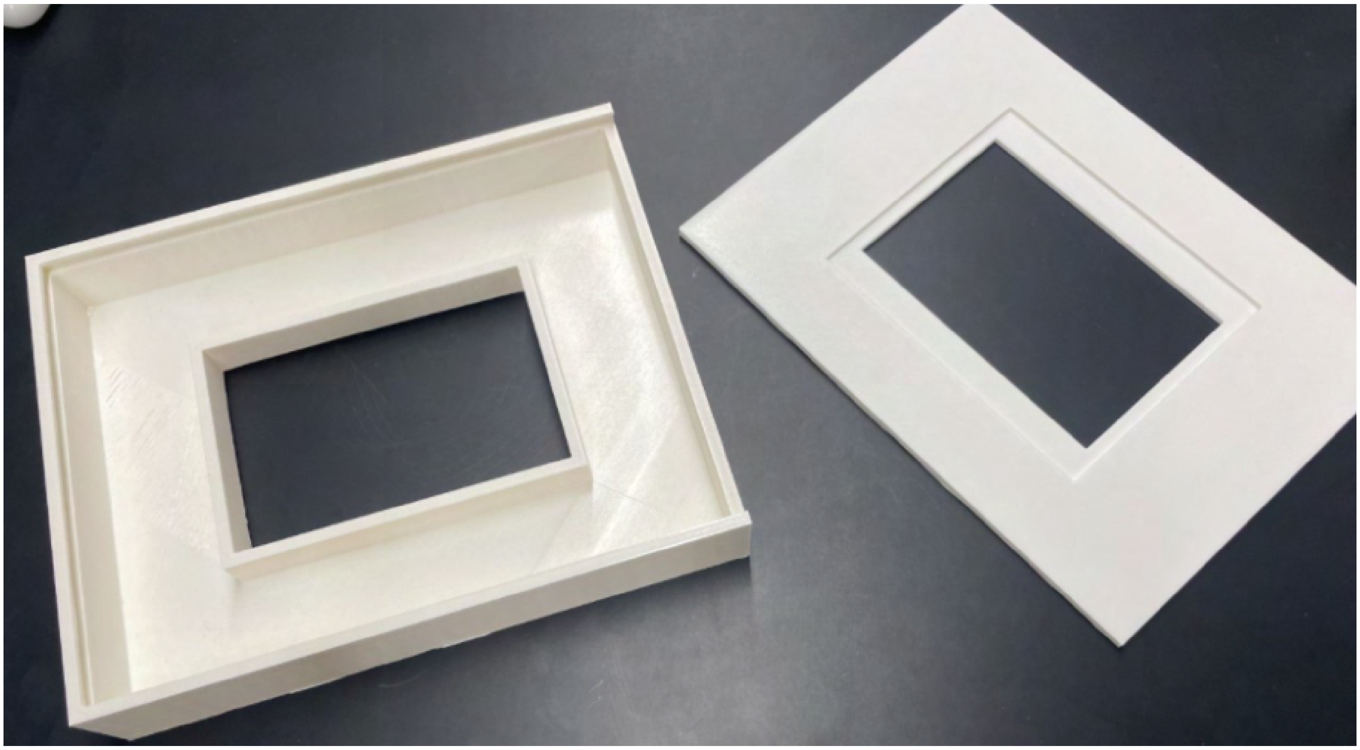


Figure 1: Top view of incubator box and crown 3D prints

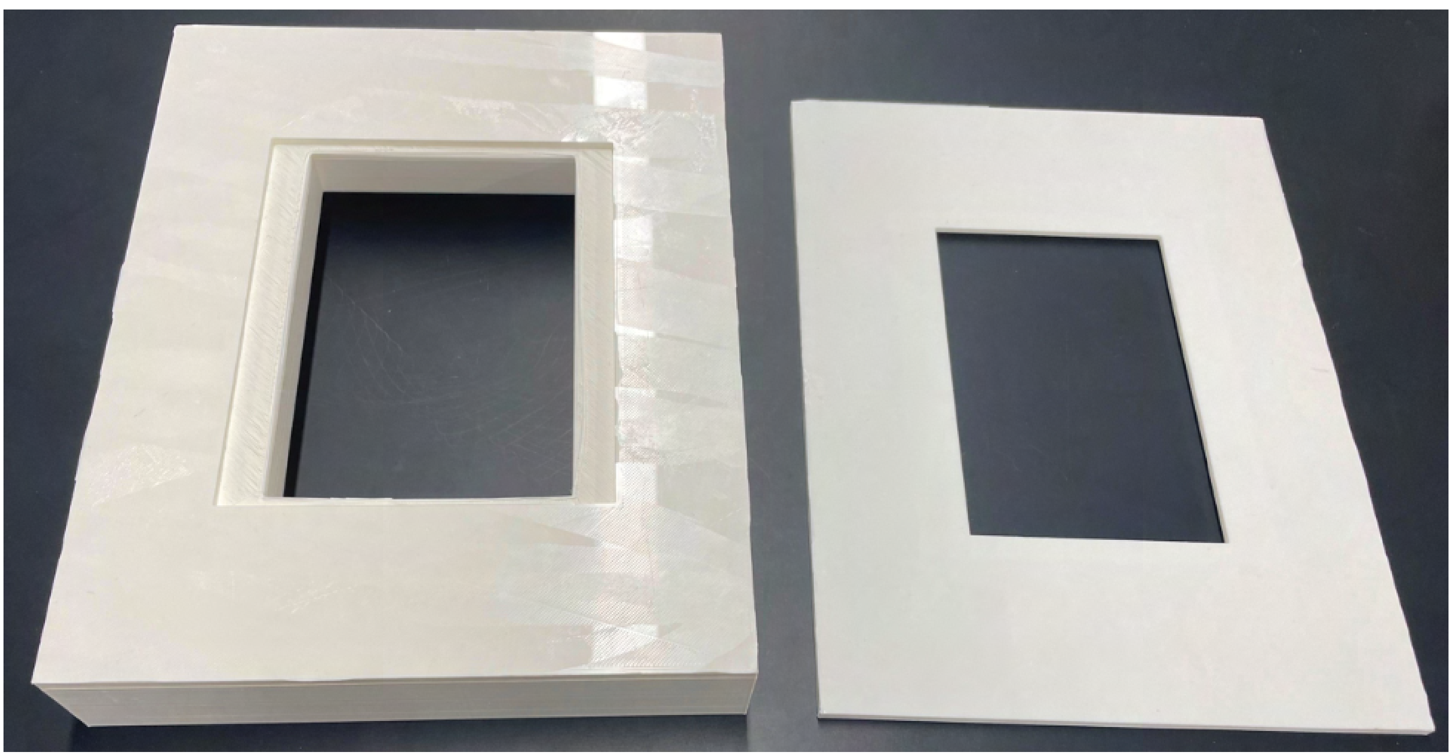


Figure 2: Bottom view of incubator box and crown 3D prints

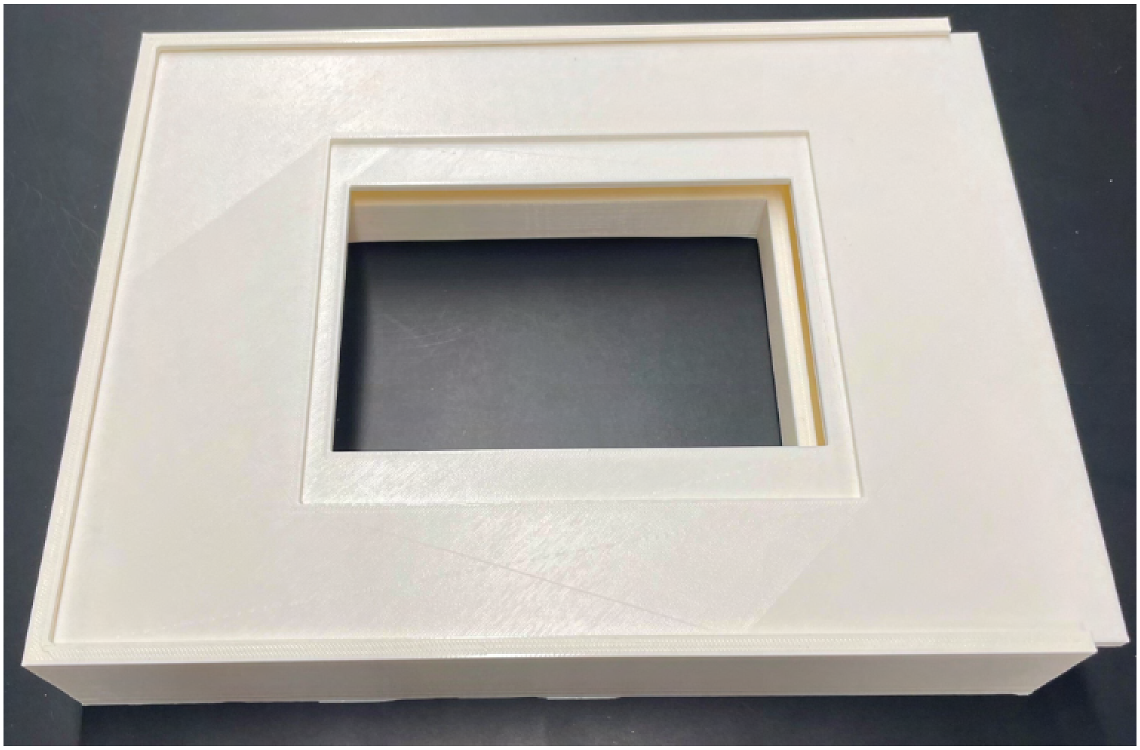


Figure 3: Assembled 3D printed incubator box.

Conclusions/action items:

The printed box turned out nicely. There are a couple straggling PLA plastic strings from the 3D printer. Sliding in the crown of the box to the slit printed into the box is a little difficult and not smooth, but it does go all the way in. Next steps are to epoxy the glass to the plastic squares as well as drill holes into the plastic and epoxy adaptors and tubing to the box as well.

11/29/2021 Hardware Setups

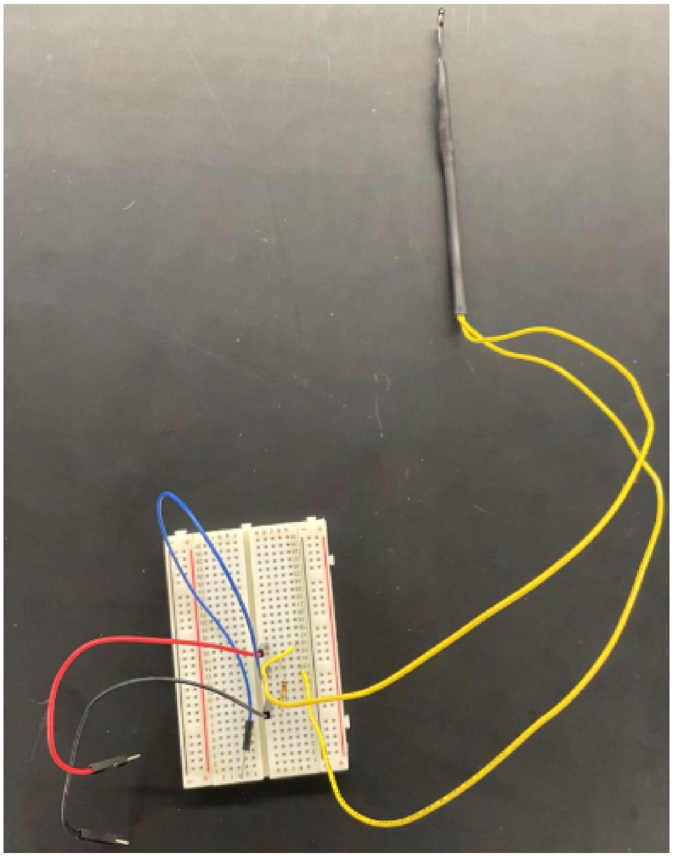
SAMUEL BARDWELL - Dec 09, 2021, 1:26 PM CST

Title: Hardware Setups

Date: 11/29/21

Goals: To show photos of the electrical set up for the sensors in the incubator.

Content:



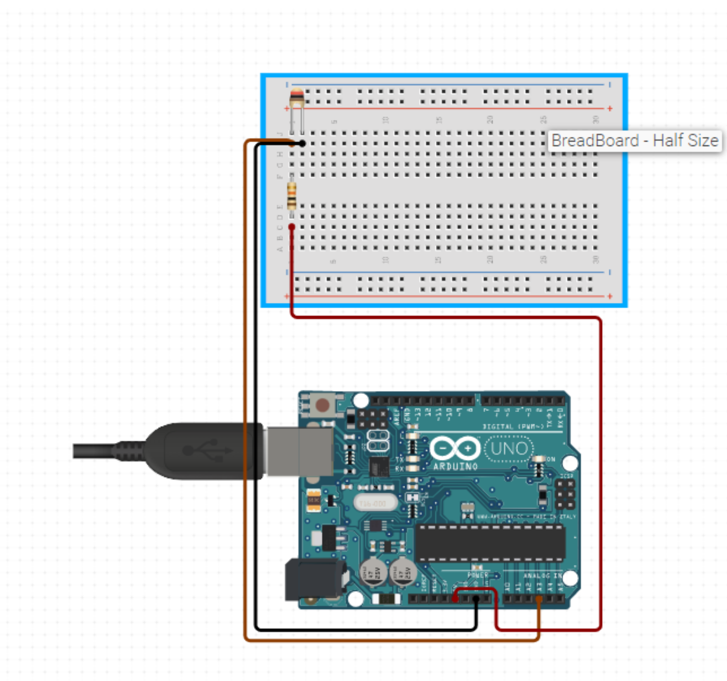


Figure 1: Thermistor hardware set up.

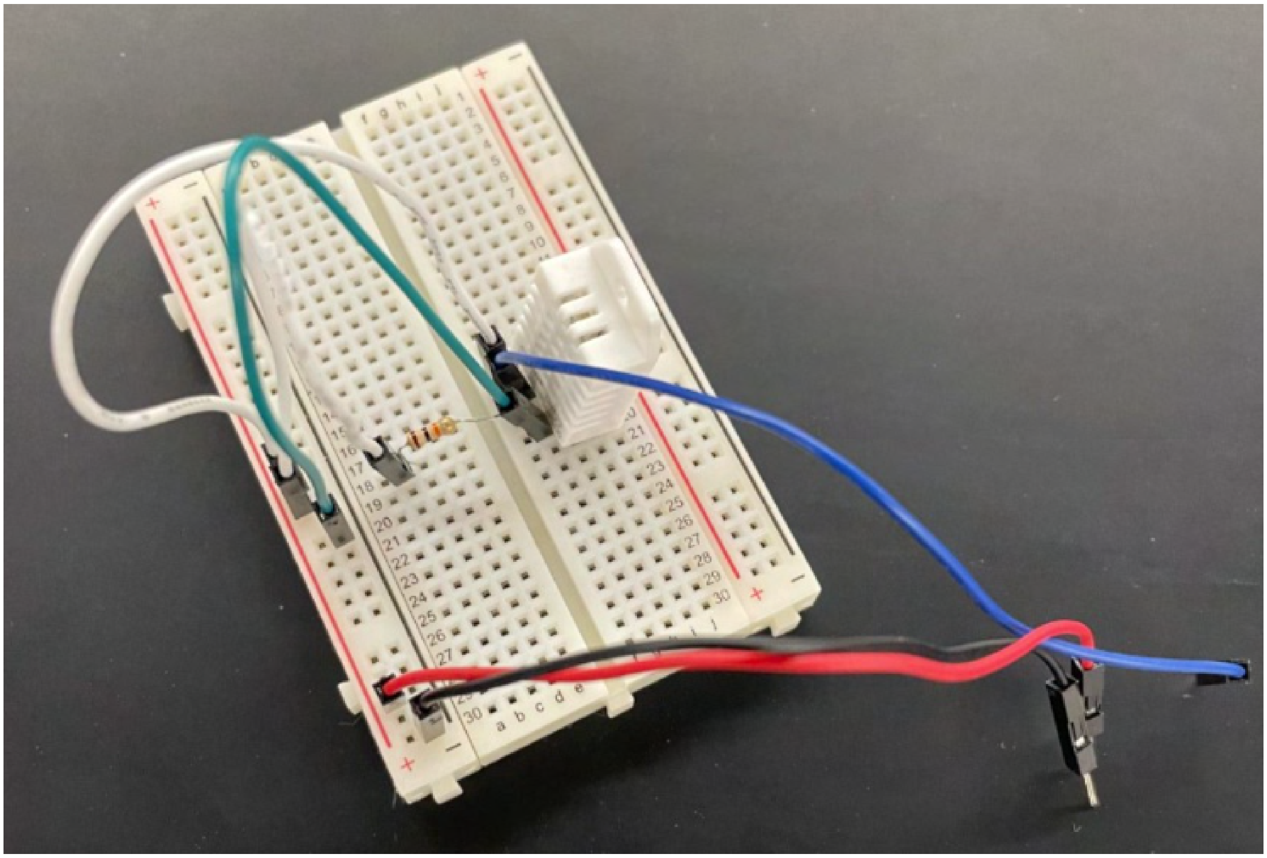


Figure 2: DHT22 sensor hardware set up

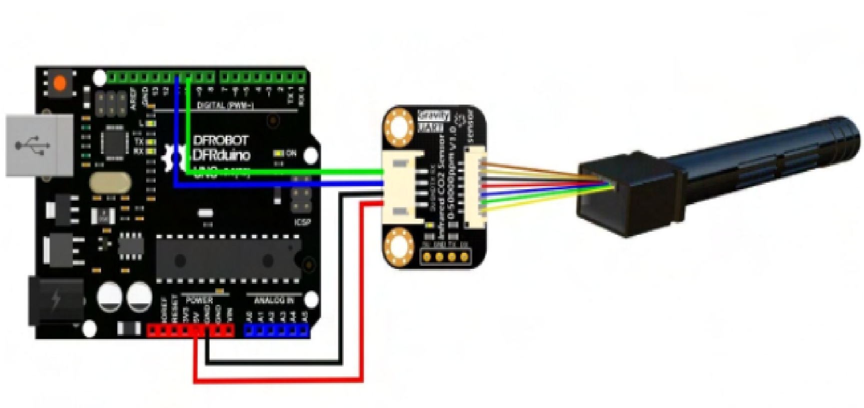


Figure 3: CO2 sensor hardware set up

Conclusions/action items:

All of the sensors are up and running. The coding and the schematics will be added to the notebook. Next is to test the sensors and eventually implement them into the incubator box design.

12/07/2021 Incubator Fabrication

Katie Day - Dec 07, 2021, 8:04 PM CST

Title: Incubator Fabcrication

Date: 12/07/2021

Content by: Katie McGovern

Present: Katie McGovern and Sam Bardwell

Goals: To fabricate the incubator.

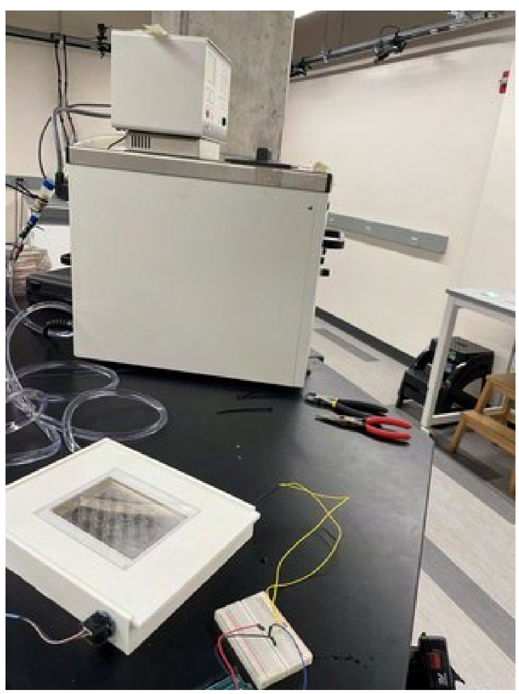
Content:

The box was fabricated by first drilling 3/8 inch diameter holes in the front of the box and then using a circular file to expand them so that the barbed connectors could fit in the incubator. They were then hot glued. The glass was hot glued onto the small divot made for them in the design. A 1/4 inch hole was drilled on the bottom right corner for the thermistor and filed with a circular file. A 1/2 inch hole was drilled and expanded via circular file for the CO2 sensor to fit in. The CO2 sensor and the thermistor were hot glued into place. The 3/8x1/4 inch tubing was wrapped in a circular fashion along the interior of the box and connected to the barbed vacuum connectors. They were then secured by zip ties. They were connected to a 1/2x3/8 inch tubing that was secured via zip ties to both the connector and the hot water pump. Then roughly 16 oz of water was poured into the incubator.

Conclusions/action items:

The PLA material needs to be changed as it was difficult to drill into, very brittle, and appeared to be leaking in random places.

Katie Day - Dec 07, 2021, 8:04 PM CST



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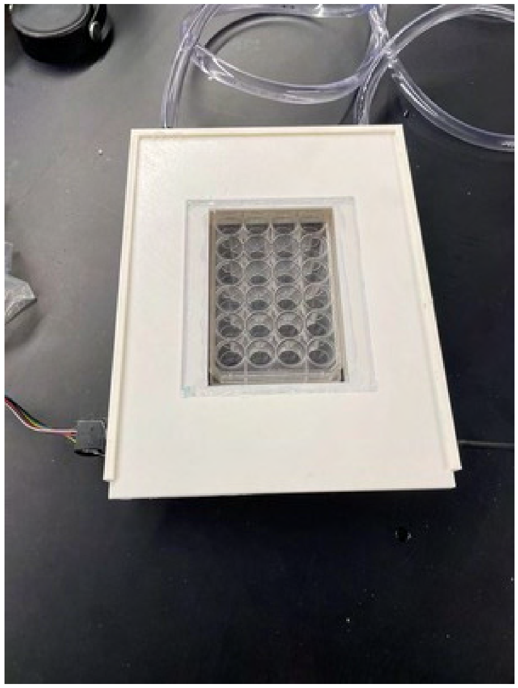
Katie Day - Dec 07, 2021, 8:04 PM CST



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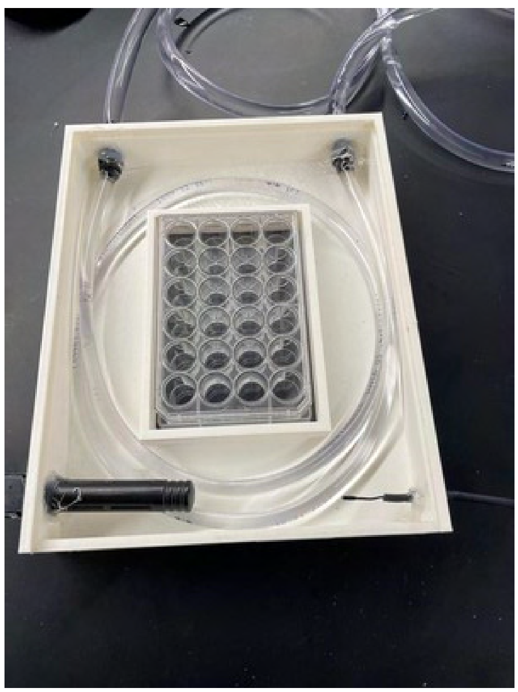

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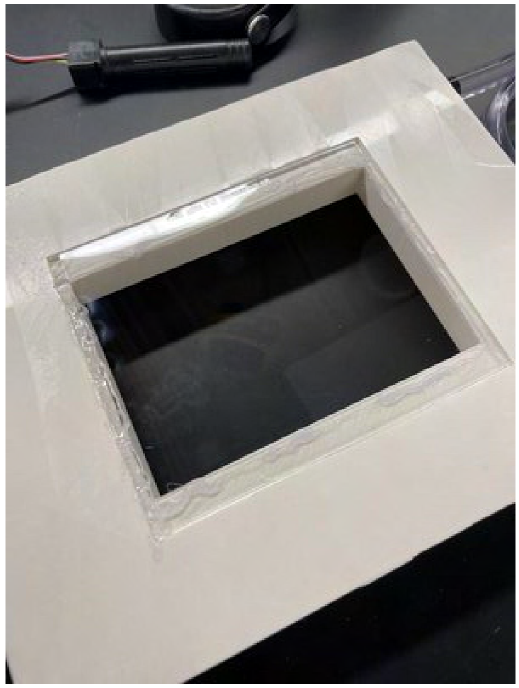

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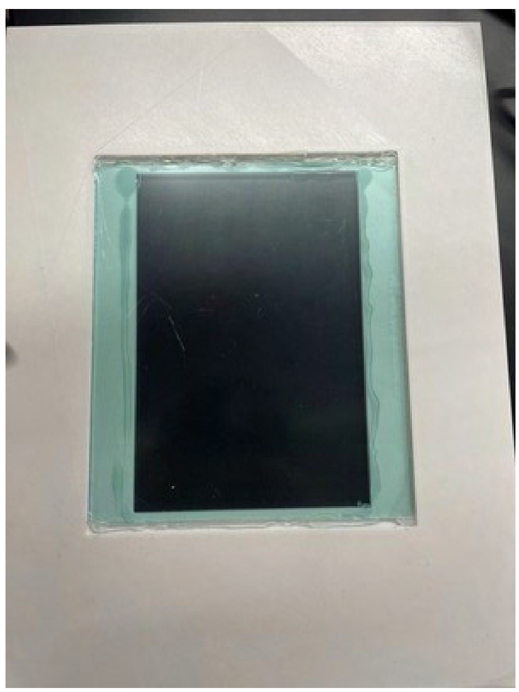
Katie Day - Dec 07, 2021, 8:04 PM CST



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Katie Day - Dec 07, 2021, 8:04 PM CST

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Katie Day - Dec 07, 2021, 8:04 PM CST

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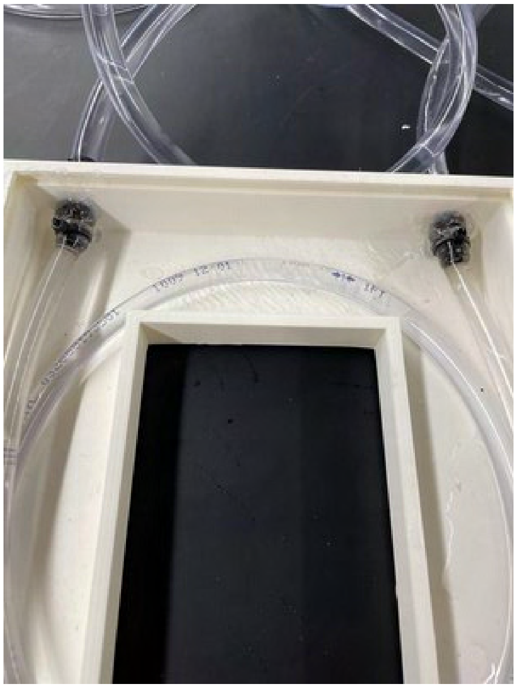
Katie Day - Dec 07, 2021, 8:04 PM CST



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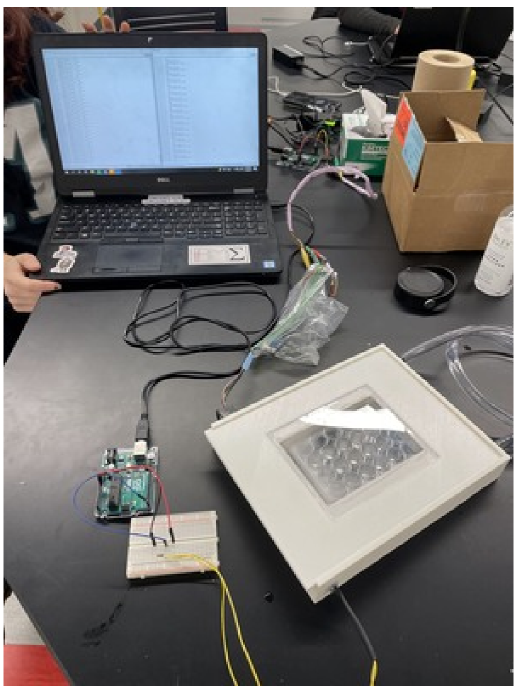
Katie Day - Dec 07, 2021, 8:04 PM CST



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11/01/2021 Testing Protocols Initial Draft

MAYA TANNA - Nov 05, 2021, 2:51 PM CDT

Title: Testing Protocols Initial Draft

Date: 11/01/2021

Content by: Caroline and Maya

Present: Team

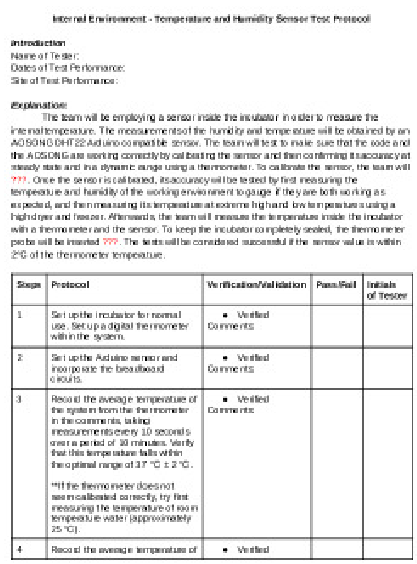
Goals: To document the initial draft of test protocols that were sent to Dr. Kinney for review/approval

Content:

See attachment below.

Conclusions/action items: Use feedback from Dr. Kinney to improve test protocols as well as feedback from Show and Tell to add components to test to ensure the most successful final design.

MAYA TANNA - Nov 05, 2021, 2:51 PM CDT



Internal Environment - Temperature and Humidity Sensor Test Protocol

Introduction
Name of Tester:
Dates of Test Performance:
Site of Test Performance:

Explanation:
The team will be employing a sensor inside the incubator in order to measure the internal temperature. The measurements of the humidity and temperature will be obtained by an AOSONG DHT22 Arduino compatible sensor. The team will test to make sure that the code and the AOSONG are working correctly by calibrating the sensor and then confirming its accuracy at steady state and in a dynamic range using a thermometer. To calibrate the sensor, the team will ???. Once the sensor is calibrated, its accuracy will be tested by first measuring the temperature and humidity of the working environment to gauge if they are both working as expected, and then measuring its temperature at extreme high and low temperatures using a high dryer and freezer. Afterwards, the team will measure the temperature inside the incubator with a thermometer and the sensor. To keep the incubator completely sealed, the thermometer probe will be inserted ???. The tests will be considered successful if the sensor value is within 2°C of the thermometer temperature.

Steps	Protocol	Verification/Validation	Pass/Fail	Initials of Tester
1	Set up the incubator for normal use. Set up a digital thermometer within the system.	• Verified Comments		
2	Set up the Arduino sensor and incorporate the breadboard circuits.	• Verified Comments		
3	Record the average temperature of the system from the thermometer in the comments, taking measurements every 10 seconds over a period of 30 minutes. Verify that this temperature falls within the optimal range of 37 °C ± 2 °C. **If the thermometer does not seem calibrated correctly, try first measuring the temperature of room temperature water (approximately 25 °C).	• Verified Comments		
4	Record the average temperature of	• Verified		

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Testing_Protocols_1_.docx (597 kB)

11/15/2021 Incubator User Manual

Katie Day - Dec 07, 2021, 8:08 PM CST

Title: Incubator User Manual

Date: 11/15/2021

Content by: Sam Bardwell and Ethan Hannon

Present:

Goals: To establish a user manual to determine how to use the incubator once printed.

Content:

See attached user manual.

Conclusions/action items:

Katie Day - Dec 07, 2021, 8:09 PM CST

Boot up Process

1) Remove sliding crown from incubator
2) Connect heated water pump tubing to the ribbed cone adaptor on incubator
3) Connect CO_2 tank hosing to incubator
4) Place incubator onto microscope shelf
5) Turn on heated water pump and set water temperature to 37° C
6) Fill incubator with enough DI water to submerge inner tubing
7) Turn on CO_2 tank and gauge to fill the internal environment to 5% CO_2 levels
8) Replace sliding crown back on the incubator
9) Allow time for internal environment to be set to 5% CO_2, 37° C, and 95-100% humidity
10)

Inserting Well Plate

1) Slide open crown seal to expose well plate cavity
2) Insert a 138mm x 95mm or smaller well plate into designated cavity
   a) DO NOT use a well plate larger than dimensions given
3) Slide crown seal back into place on incubator
   a) make sure seal is firmly in place
   b) DO NOT open until data acquisition is complete and sample isn't required anymore (will compromise internal environment otherwise)

Data Acquisition

1) Connect Arduino Microcontroller to a power source
2) Set up sensors to collect internal environment data
3) Upload designated code on Arduino IDE to print live internal environmental data
4) Record any desired values given by data

Cleaning and Disassembly

1) Make sure all power sources are disconnected
2) Empty DI water from inside
3) Remove external and inner tubing from incubator
4) Use

Download

Incubator_User_Directions.pdf (47.4 kB)

11/19/2021 Testing Protocols Final Version

MAYA TANNA - Nov 25, 2021, 2:44 PM CST

Title: Testing Protocols Final Version

Date: 11/19/2021

Content by: Maya/Caroline

Goals: To document the final draft of the testing protocols, which were edited based on the team and advisor's feedback

Content:

See attachment below.

Conclusions/action items: Execute testing wherever possible and investigate CO_2 component of the project.

MAYA TANNA - Nov 25, 2021, 2:45 PM CST

Internal Environment - Temperature and Humidity Sensor Test Protocol

Introduction
Name of Tester:
Dates of Test Performance:
Site of Test Performance:

Explanation:
The team will be employing a sensor inside the incubator in order to measure the internal temperature. The measurements of the humidity and temperature will be obtained by an AOSONG DHT22 Arduino compatible sensor. The team will test to make sure that the code and the AOSONG are working correctly by calibrating the sensor and then confirming its accuracy at steady state and precision in a dynamic range using a thermometer. To calibrate the sensor, the team will use resistance values on the Arduino Website. Once the sensor is calibrated, its accuracy will be tested by first measuring the temperature and humidity of the working environment to gauge if they are both working as expected, and then measuring its temperature at extreme high and low temperatures using a high dryer and freezer. Afterwards, the team will measure the temperature inside the incubator with a thermometer and the sensor. To keep the incubator completely sealed, the thermometer probe and reading display will be inserted into the incubator and read through the glass. The tests will be considered successful if the sensor value is within 2°C of the thermometer temperature.

Steps	Protocol	Verification/Validation	Pass/Fail	Initials of Tester
1	Calibrate the sensor using resistance values on Arduino Website.	• Verified Comments		
2	Test the precision of the Arduino microcontroller at extreme high and low temperatures. Heat a cup of water in a microwave for two minutes. Place the sensor in the cup of hot water and ensure the temperature outputs increase the longer it is under heat. Then, place the sensor in the freezer and ensure the temperature outputs decrease the longer it is under there. If the sensor follows these trends it is verified.	• Verified Comments		
3	Set up the incubator for normal use. Set up a digital thermometer within the system.	• Verified Comments		

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Testing_Protocols_Template_1_.docx (599 kB)

12/03/2021 CO2

Katie Day - Dec 07, 2021, 8:05 PM CST

Title: CO2 Testing

Date: 12/3/2021

Content by: Katie, Olivia, Maya, and Caroline

Present: Katie and Olivia

Goals: To test the CO2 sensor to make sure that it is working properly.

Content:

Attached our the results of our testing, testing protocols written by Maya and Caroline, performed by Olivia and me.

Conclusions/action items:

The CO2 sensor is ready for incorporation into the incubator.

Katie Day - Dec 07, 2021, 8:05 PM CST

Download

concentration.csv (2.43 kB)

Katie Day - Dec 07, 2021, 8:05 PM CST

Download

concentration_graphs.csv (2.34 kB)

12/03/2021 Thermistor

Katie Day - Dec 07, 2021, 8:05 PM CST

Title: Thermistor Testing

Date: 12/3/2021

Content by: Katie, Olivia, Maya, and Caroline

Present: Katie and Olivia

Goals: To test the accuracy of our thermistor against an incubator.

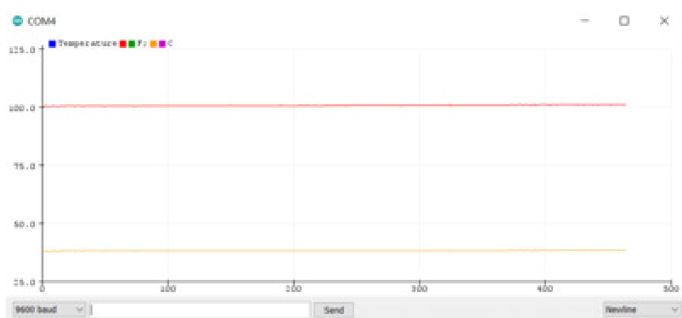
Content:

Testing protocol written by Maya and Caroline and performed by Olivia and me. Results are below.

Conclusions/action items:

Thermistor is working properly and ready for implementation.

Katie Day - Dec 07, 2021, 8:05 PM CST



Download

Misty_In_Incubator_10-min.PNG (15.4 kB)

12/03/2021 Humidity

SAMUEL BARDWELL - Dec 11, 2021, 1:53 PM CST

Title: Humidity Testing

Date: 12/3/2021

Content by: Katie and Olivia

Present: Katie and Olivia

Goals: To test the accuracy of our humidity formula against the DHT22 sensor

Content:

Humidity data gathered over time in order to perform ttest to determine statistically significance compared to the DHT22 sensor.

	Variable 1	*Variable 2*
Mean	12.61830986	12.16718182
Variance	0.090374245	0.424219419
Observations	71	220
Hypothesized Mean Difference	0	
df	255	
t Stat	7.973463829	
P(T<=t) one-tail	2.59912E-14	
t Critical one-tail	1.650851092	
P(T<=t) two-tail	5.19824E-14	
t Critical two-tail	1.96931057	

Figure 1: T-test results comparing the thermistor humidity readings to the DHT22 readings.

Conclusions/action items:

Send data to caroline, olivia, and maya for analysis. The t-test was determined to be significant (significance value of .05). This is not what we expected because the average values are within .5% between the DHT22 and thermistor. We will most likely have to improve the calibration of the thermistor if we want to continue with this project.

Katie Day - Dec 07, 2021, 8:05 PM CST

Download

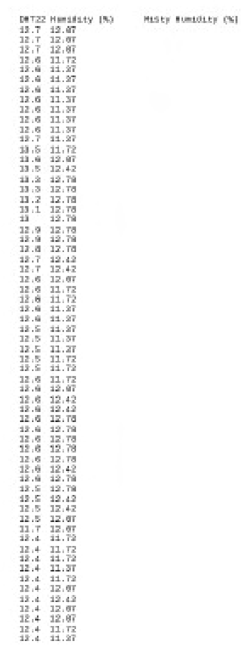
Misty_Humidity_Data.csv (1.55 kB)

Katie Day - Dec 07, 2021, 8:05 PM CST

Download

Combined_Humidity_Data.csv (4.23 kB)

Katie Day - Dec 07, 2021, 8:05 PM CST



DHT22 Humidity (%)	Misty Humidity (%)
12.7	12.07
12.7	12.07
12.7	12.07
12.6	11.72
12.6	11.27
12.6	11.27
12.6	11.27
12.6	11.37
12.6	11.37
12.6	11.37
12.6	11.37
12.7	11.27
13.5	11.72
13.4	12.07
13.5	12.42
13.3	12.78
13.3	12.78
13.2	12.78
13.1	12.78
13	12.78
12.9	12.78
12.9	12.78
12.8	12.78
12.7	12.42
12.7	12.42
12.6	12.07
12.6	11.72
12.6	11.72
12.6	11.27
12.6	11.27
12.5	11.27
12.5	11.37
12.5	11.27
12.5	11.72
12.5	11.72
12.6	11.72
12.6	12.07
12.6	12.42
12.6	12.42
12.6	12.78
12.6	12.78
12.6	12.78
12.6	12.78
12.6	12.78
12.6	12.42
12.6	12.78
12.5	12.78
12.5	12.42
12.5	12.42
12.5	12.07
11.7	12.07
12.4	11.72
12.4	11.72
12.4	11.72
12.4	11.37
12.4	11.72
12.4	12.07
12.4	12.42
12.4	12.07
12.4	12.07
12.4	11.72
12.4	11.27

Download

Combined_Humidity_Data.txt (2.08 kB)

Katie Day - Dec 07, 2021, 8:05 PM CST

Download

DHT22_Humidity_Data.csv (441 B)

12/05/2021 Optical Testing

Caroline Craig - Dec 11, 2021, 9:47 PM CST

Title: Optical Testing

Date: 12/05/2021

Content by: Caroline Craig and Maya Tanna

Present: Caroline Craig and Maya Tanna

Goals: To determine whether or not the glass being used interfered with the optics of the microscope.

Content:

ImageJ Results of the Optical Testing

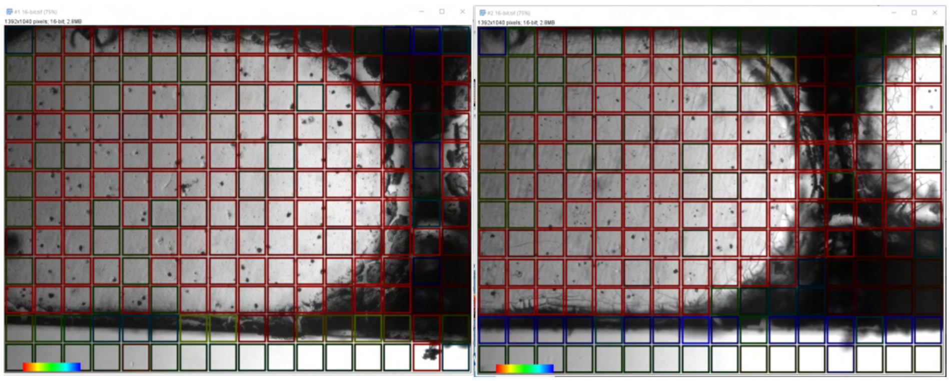


Figure 13: Optical analysis from ImageJ of microscopic cells with glass (left) and without glass (right)

Conclusions/action items:

The Optics were not interferred with.

MAYA TANNA - Dec 11, 2021, 8:25 PM CST

	Microscope Image with Glass	Microscope Image without Glass
Red Squares	130	120
Green Squares	54	51
Blue Squares	8	21
Total	192	192

MAYA TANNA - Dec 11, 2021, 8:26 PM CST

Results from this test show that the image with the glass had a slightly higher, yet very similar focus quality compared to the image without glass present.

12/07/2021 Attempted Incubator Testing

Katie Day - Dec 07, 2021, 8:04 PM CST

Title: Attempted Incubator Testing

Date: 12/07/2021

Content by: Katie McGovern and Sam Bardwell

Present: Katie McGovern and Sam Bardwell

Goals: To initially determine whether or not our incubator was working as expected.

Content: Data collected during testing.

Conclusions/action items:

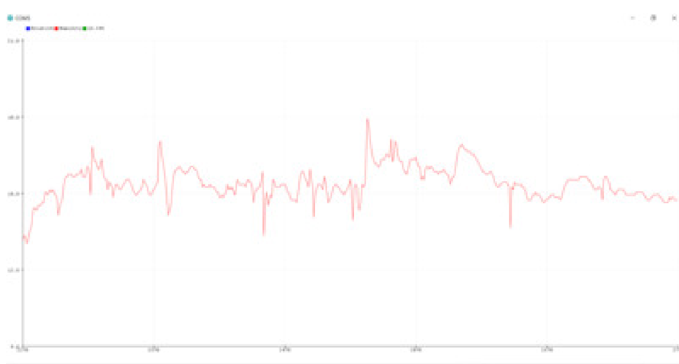
1. Polyethelene tubing acted more as an insulator than a conductor and would not heat up the water bath to the desired temperature. Need to use a metal tube.
2. PLA box was leaking slightly. It is unclear where or how it is leaking as it has been sealed via hot glue and zipties.
3. Glass did fog up after about 30 minutes so we will need to figure out how to demist the glass.

Katie Day - Dec 07, 2021, 8:04 PM CST

Download

Incubator_Temp_Over_Time.csv (5.1 kB)

Katie Day - Dec 07, 2021, 8:04 PM CST



Download

Incubator_Temp_Over_Time.PNG (68.7 kB)

Katie Day - Dec 07, 2021, 8:04 PM CST

Download

Incubator_Temp_Hum_Over_Time.csv (5.1 kB)

Katie Day - Dec 07, 2021, 8:04 PM CST

Download

Actual_Inc_HUm_Data.csv (2.19 kB)

09/24/2021 Product Design Specifications

SAMUEL BARDWELL - Sep 21, 2021, 7:12 AM CDT

Title: Product Design Specifications

Date: 9/24/21

Content by: Everyone

Present: Everyone

Goals: To create a PDS in order to show our intended project in great detail.

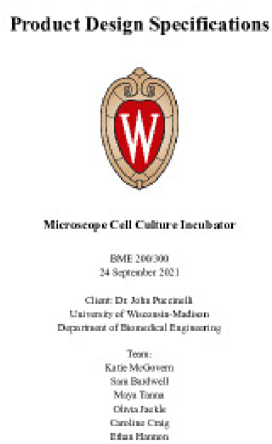
Content:

PDF of PDS is attached

Conclusions/action items:

We will follow this PDS throughout the entire project to make sure we create a device that meets the clients needs.

SAMUEL BARDWELL - Sep 21, 2021, 7:13 AM CDT



Product Design Specifications

Microscope Cell Culture Incubator

BME 200/300
24 September 2021

Client: Dr John Puccinelli
University of Wisconsin-Madison
Department of Biomedical Engineering

Team:
Katie McGovern
Sam Bardwell
Maya Tanna
Olivia Jackle
Caroline Craig
Ethan Hanson

[Download](#)

Product_Design_Specifications.pdf (219 kB)

09/27/2021 Design Matrix

MAYA TANNA - Oct 10, 2021, 9:11 AM CDT

Title: Design Matrix

Date: 09/27/21

Content by: Everyone

Present: Everyone

Goals: To create a design matrix to evaluate our potential solutions to the project.

Content:

See attachment below.

Conclusions/action items:

We will follow these design specifications to ensure we deliver the desired product to the client.

MAYA TANNA - Oct 10, 2021, 9:11 AM CDT

Rank	Criteria	Weight	Score (10 max)	Weighted Score	Score (10 max)	Weighted Score	Score (10 max)	Weighted Score
1	Internal Environment	25	9	23	7	18	5	13
2	Microscope Compatibility	20	10	20	10	20	10	20
3	Accuracy and Reliability	20	7	14	8	16	4	8
4	Ergonomics	15	5	8	8	12	4	6
5	Cost	10	2	2	4	4	3	3
6	Life in Service	5	10	5	10	5	10	5
7	Safety	5	10	5	10	5	10	5
	Sum	100	Sum	76	Sum	80	Sum	60

Download

Design_Matrix_.xlsx (681 kB)

10/15/2021 Preliminary Presentation

MAYA TANNA - Oct 19, 2021, 4:32 PM CDT

Title: Preliminary Presentation

Date: 10/15/2021

Content by: Katie McGovern, Sam Bardwell, Maya Tanna, Olivia Jaekle, Caroline Craig, and Ethan Hannon

Present: Whole Team

Goals: To present our preliminary findings, goals, and proposed design to our client and advisor.

Content:

Attached is the preliminary presentation.

Conclusions/action items:

Begin ordering materials and prototyping.

Katie Day - Oct 18, 2021, 3:56 PM CDT

Download

Preliminary_Presentation_Slides_1_.pdf (971 kB)

10/19/2021 Preliminary Report

MAYA TANNA - Oct 19, 2021, 10:04 PM CDT

Title: Preliminary Report

Date: 10/15/2021

Content by: Katie McGovern, Sam Bardwell, Maya Tanna, Olivia Jaekle, Caroline Craig, and Ethan Hannon

Present: Whole Team

Goals: To document our final version of the preliminary report.

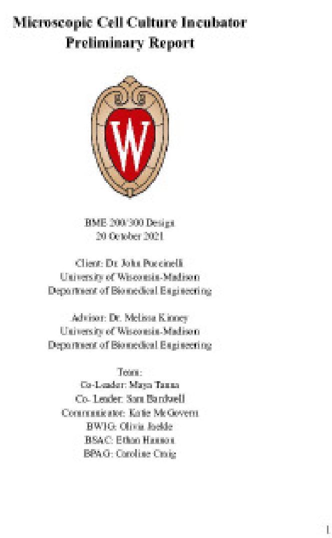
Content:

See attachment below.

Conclusions/action items:

Order materials and get feedback on final design/preliminary deliverables from advisor and client.

MAYA TANNA - Oct 19, 2021, 10:04 PM CDT



Microscopic Cell Culture Incubator
Preliminary Report

BME 200/300 Design
20 October 2021

Client: Dr. John Puccinelli
University of Wisconsin-Madison
Department of Biomedical Engineering

Advisor: Dr. Melissa Kinney
University of Wisconsin-Madison
Department of Biomedical Engineering

Team:
Co-Leader: Maya Tanna
Co- Leader: Sam Bardwell
Communicator: Katie McGovern
BWIG: Olivia Jaekle
BSAC: Ethan Hannon
BPAG: Caroline Craig

1

Download

Preliminary_Report-_Microscopic_Cell_Incubator.pdf (1.51 MB)

12/10/2021 Final Poster Presentation

Katie Day - Dec 11, 2021, 4:32 PM CST

Title: Final Poster Presentation

Date: 12/10/2021

Content by: Katie Day, Sam Bardwell, Maya Tanna, Caroline Craig, Olivia Jaekle, and Ethan Hannon

Present: Katie Day, Sam Bardwell, Maya Tanna, Caroline Craig, Olivia Jaekle, and Ethan Hannon

Goals: To present the work we have done over the course of the semester in a clear and concise fashion.

Content:

See attachment.

Conclusions/action items:

N/A

Katie Day - Dec 11, 2021, 4:33 PM CST

Download

Final_Poster_-_Final_1_.pdf (2.45 MB)

09/15/2021 Progress Report 1

Katie Day - Dec 08, 2021, 9:18 PM CST

Title: Progress Report 1

Date: 9/15/2021

Content by: Katie, Sam, Maya, Caroline, Olivia, and Ethan

Present:

Goals: To document our progress over the course of a week in the semester.

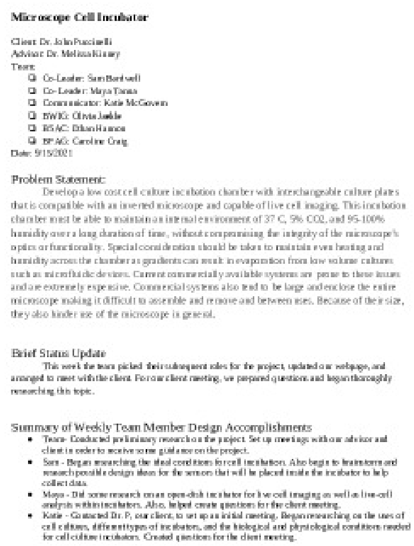
Content:

See attached file.

Conclusions/action items:

See attached file.

Katie Day - Dec 08, 2021, 9:18 PM CST



Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:
- Co-Leader: Sam Bardwell
- Co-Leader: Maya Tanna
- Communicator: Katie McGovern
- BWIG: Olivia Jaekle
- BSAC: Ethan Hannon
- BPAG: Caroline Craig

Date: 9/15/2021

Problem Statement:

Develop a low cost cell culture incubation chamber with interchangeable culture plates that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update

This week the team picked their subsequent roles for the project, updated our webpage, and arranged to meet with the client. For our client meeting, we prepared questions and began thoroughly researching this topic.

Summary of Weekly Team Member Design Accomplishments

- Team- Conducted preliminary research on the project. Set up meetings with our advisor and client in order to receive some guidance on the project.
- Sam - Began researching the ideal conditions for cell incubation. Also begin to brainstorm and research possible design ideas for the sensors that will be placed inside the incubator to help collect data.
- Maya - Did some research on an open-dish incubator for live cell imaging as well as live-cell analysis within incubators. Also, helped create questions for the client meeting.
- Katie - Contacted Dr. P, our client, to set up an initial meeting. Began researching on the uses of cell cultures, different types of incubators, and the biological and physiological conditions needed for cell culture incubators. Created questions for the client meeting.

Download

cell_incubator-progress_report-1.docx (11.5 kB)

09/23/2021 Progress Report 2

Katie Day - Dec 08, 2021, 9:22 PM CST

Title: Progress Report

Date: 9/23/2021

Content by: Katie, Sam, Maya, Caroline, Olivia, and Ethan

Present:

Goals: To document our progress over the course of a week in the semester.

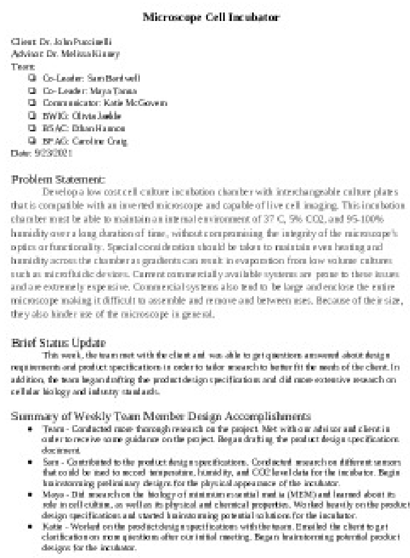
Content:

See attached file.

Conclusions/action items:

See attached file.

Katie Day - Dec 08, 2021, 9:21 PM CST



Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:

- Co-Leader: Sam Bardwell
- Co-Leader: Maya Tanna
- Communicator: Katie McGovern
- BWIG: Olivia Jaekle
- BSAC: Ethan Hannon
- BPAG: Caroline Craig

Date: 9/23/2021

Problem Statement:

Develop a low cost cell culture incubation chamber with interchangeable culture plates that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update

This week, the team met with the client and was able to get questions answered about design requirements and product specifications in order to tailor research to better fit the needs of the client. In addition, the team began drafting the product design specifications and did more extensive research on cellular biology and industry standards.

Summary of Weekly Team Member Design Accomplishments

- Team - Conducted more thorough research on the project. Met with our advisor and client in order to receive some guidance on the project. Began drafting the product design specifications document.
- Sam - Contributed to the product design specifications. Conducted research on different sensors that could be used to record temperature, humidity, and CO2 level data for the incubator. Begin brainstorming preliminary designs for the physical appearance of the incubator.
- Maya - Did research on the biology of minimum essential media (MEM) and learned about its role in cell culture, as well as its physical and chemical properties. Worked heavily on the product design specifications and started brainstorming potential solutions for the incubator.
- Katie - Worked on the product design specifications with the team. Emailed the client to get clarification on more questions after our initial meeting. Began brainstorming potential product designs for the incubator.

Download

cell_incubator-progress_report-2.docx (11.7 kB)

09/30/2021 Progress Report 3

Katie Day - Dec 08, 2021, 9:22 PM CST

Title: Progress Report

Date: 9/30/2021

Content by: Katie, Sam, Maya, Caroline, Olivia, and Ethan

Present:

Goals: To document our progress over the course of a week in the semester.

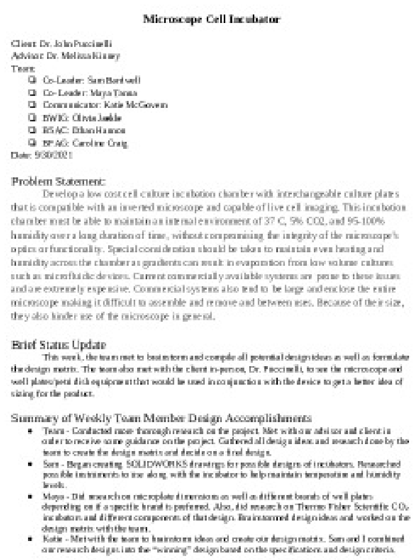
Content:

See attached file.

Conclusions/action items:

See attached file.

Katie Day - Dec 08, 2021, 9:21 PM CST



Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:
- Co-Leader: Sam Bardwell
- Co-Leader: Maya Tanna
- Communicator: Katie McGovern
- BWIG: Olivia Jaekle
- BSAC: Ethan Hannon
- BPAG: Caroline Craig

Date: 9/30/2021

Problem Statement:

Develop a low cost cell culture incubation chamber with interchangeable culture plates that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update

This week, the team met to brainstorm and compile all potential design ideas as well as formulate the design matrix. The team also met with the client in-person, Dr. Puccinelli, to see the microscope and well plates/petri dish equipment that would be used in conjunction with the device to get a better idea of sizing for the product.

Summary of Weekly Team Member Design Accomplishments

- Team - Conducted more thorough research on the project. Met with our advisor and client in order to receive some guidance on the project. Gathered all design ideas and research done by the team to create the design matrix and decide on a final design.
- Sam - Began creating SOLIDWORKS drawings for possible designs of incubators. Researched possible instruments to use along with the incubator to help maintain temperature and humidity levels.
- Maya - Did research on microplate dimensions as well as different brands of well plates depending on if a specific brand is preferred. Also, did research on Thermo Fisher Scientific CO_2 incubators and different components of that design. Brainstormed design ideas and worked on the design matrix with the team.
- Katie - Met with the team to brainstorm ideas and create our design matrix. Sam and I combined our research designs into the "winning" design based on the specifications and design criteria.

Download

cell_incubator-progress_report-3.docx (11.9 kB)

10/07/2021 Progress Report 4

Katie Day - Dec 08, 2021, 9:22 PM CST

Title: Progress Report

Date: 10/07/2021

Content by: Katie, Sam, Maya, Caroline, Olivia, and Ethan

Present:

Goals: To document our progress over the course of a week in the semester.

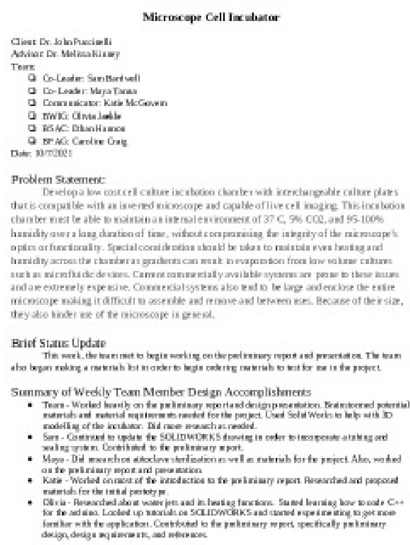
Content:

See attached file.

Conclusions/action items:

See attached file.

Katie Day - Dec 08, 2021, 9:22 PM CST



Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:
- Co-Leader: Sam Bardwell
- Co-Leader: Maya Tanna
- Communicator: Katie McGovern
- BWIG: Olivia Jaekle
- BSAC: Ethan Hannon
- BPAG: Caroline Craig

Date: 10/7/2021

Problem Statement:

Develop a low cost cell culture incubation chamber with interchangeable culture plates that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update

This week, the team met to begin working on the preliminary report and presentation. The team also began making a materials list in order to begin ordering materials to test for use in the project.

Summary of Weekly Team Member Design Accomplishments

- Team - Worked heavily on the preliminary report and design presentation. Brainstormed potential materials and material requirements needed for the project. Used SolidWorks to help with 3D modelling of the incubator. Did more research as needed.
- Sam - Continued to update the SOLIDWORKS drawing in order to incorporate a tubing and sealing system. Contributed to the preliminary report.
- Maya - Did research on autoclave sterilization as well as materials for the project. Also, worked on the preliminary report and presentation.
- Katie - Worked on most of the introduction to the preliminary report. Researched and proposed materials for the initial prototype.
- Olivia - Researched about water jets and its heating functions. Started learning how to code C++ for the arduino. Looked up tutorials on SOLIDWORKS and started experimenting to get more familiar with the application. Contributed to the preliminary report, specifically preliminary design, design requirements, and references.

Download

cell_incubator-progress_report-4.docx (11.3 kB)

10/14/2021 Progress Report 5

Katie Day - Dec 08, 2021, 9:22 PM CST

Title: Progress Report

Date: 10/14/2021

Content by: Katie, Sam, Maya, Caroline, Olivia, and Ethan

Present:

Goals: To document our progress over the course of a week in the semester.

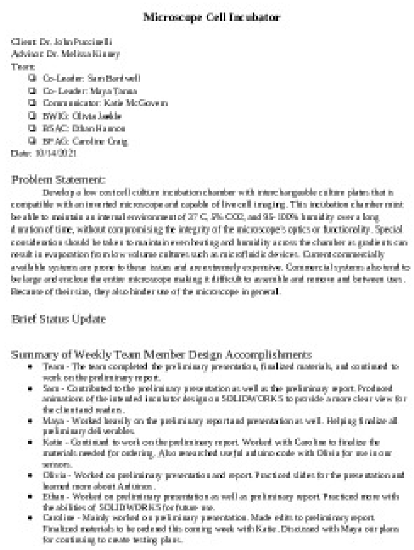
Content:

See attached file.

Conclusions/action items:

See attached file.

Katie Day - Dec 08, 2021, 9:22 PM CST



Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:
- Co-Leader: Sam Bardwell
- Co-Leader: Maya Tanna
- Communicator: Katie McGovern
- BWIG: Olivia Jaekle
- BSAC: Ethan Hannon
- BPAG: Caroline Craig

Date: 10/14/2021

Problem Statement:

Develop a low cost cell culture incubation chamber with interchangeable culture plates that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

- Team - The team completed the preliminary presentation, finalized materials, and continued to work on the preliminary report.
- Sam - Contributed to the preliminary presentation as well as the preliminary report. Produced animations of the intended incubator design on SOLIDWORKS to provide a more clear view for the client and readers.
- Maya - Worked heavily on the preliminary report and presentation as well. Helping finalize all preliminary deliverables.
- Katie - Continued to work on the preliminary report. Worked with Caroline to finalize the materials needed for ordering. Also researched useful arduino code with Olivia for use in our sensors.
- Olivia - Worked on preliminary presentation and report. Practiced slides for the presentation and learned more about Arduinos.
- Ethan - Worked on preliminary presentation as well as preliminary report. Practiced more with the abilities of SOLIDWORKS for future use.
- Caroline - Mainly worked on preliminary presentation. Made edits to preliminary report. Finalized materials to be ordered this coming week with Katie. Discussed with Maya our plans for continuing to create testing plans.

Download

cell_incubator-progress_report-5.docx (11.2 kB)

10/21/2021 Progress Report 6

Katie Day - Dec 08, 2021, 9:22 PM CST

Title: Progress Report

Date: 10/21/2021

Content by: Katie, Sam, Maya, Caroline, Olivia, and Ethan

Present:

Goals: To document our progress over the course of a week in the semester.

Content:

See attached file.

Conclusions/action items:

See attached file.

Katie Day - Dec 08, 2021, 9:23 PM CST

Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:
- Co-Leader: Sam Bardwell
- Co-Leader: Maya Tanna
- Communicator: Katie McGovern
- BWIG: Olivia Junkle
- BSAC: Ethan Hannon
- BPAG: Caroline Craig

Date: 10/21/2021

Problem Statement:

Develop a low cost cell culture incubation chamber with interchangeable culture plates that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update

Summary of Weekly Team Member Design Accomplishments
- Team - The team finalized and submitted all preliminary deliverables, including the report, peer evaluations, and the LabArchives notebook. Also, the team sent the full materials list to Dr. Puccinelli for approval.
- Sam - Finalized the preliminary report as well as created all the solidworks drawings to include dimensions of our proposed final design. Met with a TeamLab professional to receive advice on the best route to fabricate the incubator.
- Maya - Caroline, Katie, and I prepared the materials purchase request to send to Dr. Puccinelli for approval. Helped update the team notebook and finalized the preliminary report with Caroline. Completed peer/team evaluations.
- Katie - Olivia and I both looked at the previous design teams electronic equipment to determine what we could repurpose. I also emailed the client to see if he had any of our desired materials in the teaching lab. Finalized the preliminary report.
- Olivia - Katie and I went through prototypes left by previous design teams and analyzed what type of sensors they used / which sensors would we be able to reuse. I revised the report, submitted the report and the notebook.
- Ethan - Sam and I went to the old makerspace to find more parts for the project as well as meeting with a professional in the TeamLab to figure out better fabrication methods for the

[Download](#)

cell_incubator-progress_report-6.docx (11.6 kB)

10/28/2021 Progress Report 7

Katie Day - Dec 09, 2021, 10:52 AM CST

Title: Progress Report

Date: 10/28/2021

Content by: Katie, Sam, Maya, Caroline, Olivia, and Ethan

Present:

Goals: To document our progress over the course of a week in the semester.

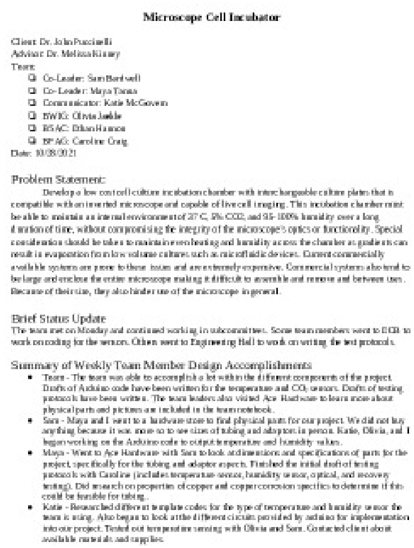
Content:

See attached file.

Conclusions/action items:

See attached file.

Katie Day - Dec 09, 2021, 10:56 AM CST



Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:

- Co-Leader: Sam Bardwell
- Co-Leader: Maya Tanna
- Communicator: Katie McGovern
- BWIG: Olivia Jaekle
- BSAC: Ethan Hanson
- BPAG: Caroline Craig

Date: 10/28/2021

Problem Statement:

Develop a low cost cell culture incubation chamber with interchangeable culture plates that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update

The team met on Monday and continued working in subcommittees. Some team members went to ECB to work on coding for the sensors. Others went to Engineering Hall to work on writing the test protocols.

Summary of Weekly Team Member Design Accomplishments

- Team - The team was able to accomplish a lot within the different components of the project. Drafts of Arduino code have been written for the temperature and CO_2 sensors. Drafts of testing protocols have been written. The team leaders also visited Ace Hardware to learn more about physical parts and pictures are included in the team notebook.
- Sam - Maya and I went to a hardware store to find physical parts for our project. We did not buy anything because it was more so to see sizes of tubing and adaptors in person. Katie, Olivia, and I began working on the Arduino code to output temperature and humidity values.
- Maya - Went to Ace Hardware with Sam to look at dimensions and specifications of parts for the project, specifically for the tubing and adaptor aspects. Finished the initial draft of testing protocols with Caroline (includes temperature sensor, humidity sensor, optical, and recovery testing). Did research on properties of copper and copper corrosion specifics to determine if this could be feasible for tubing.
- Katie - Researched different template codes for the type of temperature and humidity sensor the team is using. Also began to look at the different circuits provided by arduino for implementation into our project. Tested out temperature sensing with Olivia and Sam. Contacted client about available materials and supplies.

Download

cell_incubator-progress_report-7.docx (11.9 kB)

11/04/2021 Progress Report 8

Katie Day - Dec 09, 2021, 10:52 AM CST

Title: Progress Report

Date: 11/04/2021

Content by: Katie, Sam, Maya, Caroline, Olivia, and Ethan

Present:

Goals: To document our progress over the course of a week in the semester.

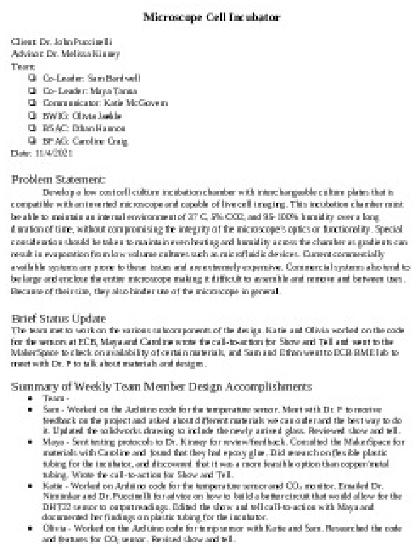
Content:

See attached file.

Conclusions/action items:

See attached file.

Katie Day - Dec 09, 2021, 10:56 AM CST



Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:
- Co-Leader: Sam Bardwell
- Co-Leader: Maya Tanna
- Communicator: Katie McGovern
- BWIG: Olivia Jaekle
- BSAC: Ethan Hannon
- BPAG: Caroline Craig

Date: 11/4/2021

Problem Statement:

Develop a low cost cell culture incubation chamber with interchangeable culture plates that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update

The team met to work on the various subcomponents of the design. Katie and Olivia worked on the code for the sensors at ECB, Maya and Caroline wrote the call-to-action for Show and Tell and went to the MakerSpace to check on availability of certain materials, and Sam and Ethan went to ECB BME lab to meet with Dr. P to talk about materials and designs.

Summary of Weekly Team Member Design Accomplishments

- Team -
- Sam - Worked on the Arduino code for the temperature sensor. Meet with Dr. P to receive feedback on the project and asked about different materials we can order and the best way to do it. Updated the solidworks drawing to include the newly arrived glass. Reviewed show and tell.
- Maya - Sent testing protocols to Dr. Kinney for review/feedback. Consulted the MakerSpace for materials with Caroline and found that they had epoxy glue. Did research on flexible plastic tubing for the incubator, and discovered that it was a more feasible option than copper/metal tubing. Wrote the call-to-action for Show and Tell.
- Katie - Worked on Arduino code for the temperature sensor and CO_2 monitor. Emailed Dr. Nimunkar and Dr. Puccinelli for advice on how to build a better circuit that would allow for the DHT22 sensor to output readings. Edited the show and tell call-to-action with Maya and documented her findings on plastic tubing for the incubator.
- Olivia - Worked on the Arduino code for temp sensor with Katie and Sam. Researched the code and features for CO_2 sensor. Revised show and tell.

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cell_incubator-progress_report-8.docx (12.1 kB)

11/11/2021 Progress Report 9

Katie Day - Dec 09, 2021, 10:53 AM CST

Title: Progress Report

Date: 11/11/2021

Content by: Katie, Sam, Maya, Caroline, Olivia, and Ethan

Present:

Goals: To document our progress over the course of a week in the semester.

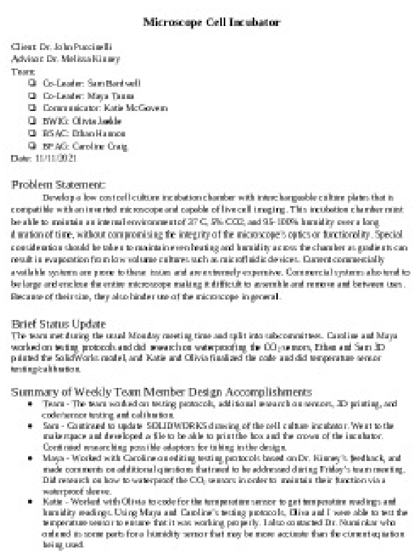
Content:

See attached file.

Conclusions/action items:

See attached file.

Katie Day - Dec 09, 2021, 10:56 AM CST



Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:
- Co-Leader: Sam Bardwell
- Co-Leader: Maya Tanna
- Communicator: Katie McGovern
- BWIG: Olivia Jaskle
- BSAC: Ethan Hansen
- BPAG: Caroline Craig

Date: 11/11/2021

Problem Statement:

Develop a low cost cell culture incubation chamber with interchangeable culture plates that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update

The team met during the usual Monday meeting time and split into subcommittees. Caroline and Maya worked on testing protocols and did research on waterproofing the CO_2 sensors, Ethan and Sam 3D printed the SolidWorks model, and Katie and Olivia finalized the code and did temperature sensor testing/calibration.

Summary of Weekly Team Member Design Accomplishments

- Team - The team worked on testing protocols, additional research on sensors, 3D printing, and code/sensor testing and calibration.
- Sam - Continued to update SOLIDWORKS drawing of the cell culture incubator. Went to the makerspace and developed a file to be able to print the box and the crown of the incubator. Continued researching possible adaptors for tubing in the design.
- Maya - Worked with Caroline on editing testing protocols based on Dr. Kinney's feedback, and made comments on additional questions that need to be addressed during Friday's team meeting. Did research on how to waterproof the CO_2 sensors in order to maintain their function via a waterproof sleeve.
- Katie - Worked with Olivia to code for the temperature sensor to get temperature readings and humidity readings. Using Maya and Caroline's testing protocols, Olivia and I were able to test the temperature sensor to ensure that it was working properly. I also contacted Dr. Nimunkar who ordered us some parts for a humidity sensor that may be more accurate than the current equation being used.

[Download](#)

cell_incubator-progress_report-9.docx (12.5 kB)

11/18/2021 Progress Report 10

Katie Day - Dec 09, 2021, 10:54 AM CST

Title: Progress Report

Date: 11/18/2021

Content by: Katie, Sam, Maya, Caroline, Olivia, and Ethan

Present:

Goals: To document our progress over the course of a week in the semester.

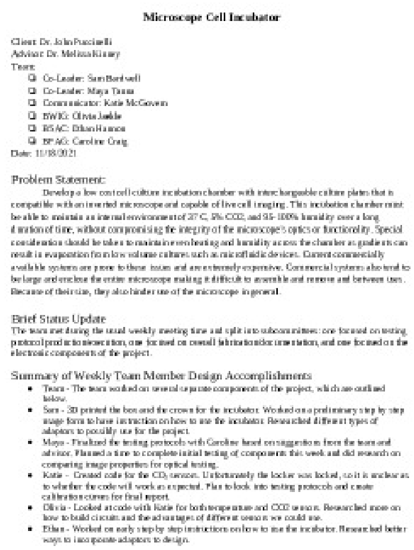
Content:

See attached file.

Conclusions/action items:

See attached file.

Katie Day - Dec 09, 2021, 10:56 AM CST



Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:
- Co-Leader: Sam Bardwell
- Co-Leader: Maya Tanna
- Communicator: Katie McGovern
- BWIG: Olivia Jaekle
- BSAC: Ethan Hannon
- BPAG: Caroline Craig

Date: 11/18/2021

Problem Statement:
Develop a low cost cell culture incubation chamber with interchangeable culture plates that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update
The team met during the usual weekly meeting time and split into subcommittees: one focused on testing protocol prediction/execution, one focused on overall fabrication/documentation, and one focused on the electronic components of the project.

Summary of Weekly Team Member Design Accomplishments
- Team - The team worked on several separate components of the project, which are outlined below.
- Sam - 3D printed the box and the crown for the incubator. Worked on a preliminary step by step image form to have instruction on how to use the incubator. Researched different types of adaptors to possibly use for the project.
- Maya - Finalized the testing protocols with Caroline based on suggestions from the team and advisor. Planned a time to complete initial testing of components this week and did research on comparing image properties for optical testing.
- Katie - Created code for the CO_2 sensor. Unfortunately the locker was locked, so it is unclear as to whether the code will work as expected. Plan to look into testing protocols and create calibration curves for final report.
- Olivia - Looked at code with Katie for both temperature and CO2 sensors. Researched more on how to build circuits and the advantages of different sensors we could use.
- Ethan - Worked on early step by step instructions on how to use the incubator. Researched better ways to incorporate adaptors to design.

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cell_incubator-progress_report-10.docx (12 kB)

12/02/2021 Progress Report 11

Katie Day - Dec 09, 2021, 10:55 AM CST

Title: Progress Report

Date: 12/02/2021

Content by: Katie, Sam, Maya, Caroline, Olivia, and Ethan

Present:

Goals: To document our progress over the course of a week in the semester.

Content:

See attached file.

Conclusions/action items:

See attached file.

Katie Day - Dec 09, 2021, 10:56 AM CST

Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:
- Co-Leader: Sam Bardwell
- Co-Leader: Maya Tanna
- Communicator: Katie McGovern
- BWIG: Olivia Jaekle
- BSAC: Ethan Hanson
- BPAG: Caroline Craig

Date: 12/02/2021

Problem Statement:

Develop a low cost cell culture incubation chamber with interchangeable culture plates that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update

The team met during the usual weekly meeting time and split into subcommittees: one focused on testing protocol prediction/execution, one focused on overall fabrication/documentation, and one focused on the electronic components of the project.

Summary of Weekly Team Member Design Accomplishments

- Team - The team worked on several separate components of the project, which are outlined below.
- Sam - Began working on the final poster. Continued fabrication steps for the project. Began implementing the heated water pump into the project.
- Maya - Worked on optical testing with Caroline. Finally figured out the computer password to the lab in ECB. Also worked on final deliverables with the team.
- Katie - Finalized the code for the CO_2 sensor. Worked with Olivia to create a graph of the thermistors temperature measurements over a 10 minute period in the incubator. Communicated with Dr. Puccinelli on the status of the tubing and tube adaptors. Created new schematics of the circuitry being used and also the past project refurbished design for the final deliverables.
- Olivia - Worked with Katie to finalize the CO2 sensor. We created a graph that showed the thermistors temperature over a 10 minute period within the incubator. Discussed testing protocols with Caroline.
- Ethan - Worked on the final poster. Made some updates to the final report. Continued with some steps in the fabrication process.

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cell_incubator-progress_report-11.docx (12.4 kB)

12/09/2021 Progress Report 12

Katie Day - Dec 09, 2021, 10:55 AM CST

Title: Progress Report

Date: 12/02/2021

Content by: Katie, Sam, Maya, Caroline, Olivia, and Ethan

Present:

Goals: To document our progress over the course of a week in the semester.

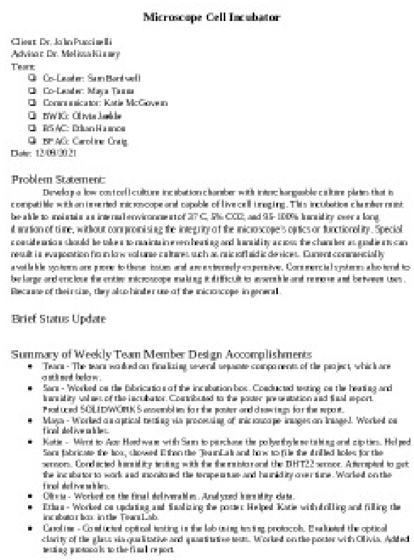
Content:

See attached file.

Conclusions/action items:

See attached file.

Katie Day - Dec 09, 2021, 10:57 AM CST



Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:

- Co-Leader: Sam Bardwell
- Co-Leader: Maya Tanna
- Communicator: Katie McGovern
- BWIG: Olivia Jaekle
- BSAC: Ethan Hanson
- BPAG: Caroline Craig

Date: 12/09/2021

Problem Statement:

Develop a low cost cell culture incubation chamber with interchangeable culture plates that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

- Team - The team worked on finalizing several separate components of the project, which are outlined below.
- Sam - Worked on the fabrication of the incubation box. Conducted testing on the heating and humidity values of the incubator. Contributed to the poster presentation and final report. Produced SOLIDWORKS assemblies for the poster and drawings for the report.
- Maya - Worked on optical testing via processing of microscope images on ImageJ. Worked on final deliverables.
- Katie - Went to Ace Hardware with Sam to purchase the polyethylene tubing and zip ties. Helped Sam fabricate the box, showed Ethan the TeamLab and how to file the drilled holes for the sensors. Conducted humidity testing with the thermistor and the DHT22 sensor. Attempted to get the incubator to work and monitored the temperature and humidity over time. Worked on the final deliverables.
- Olivia - Worked on the final deliverables. Analyzed humidity data.
- Ethan - Worked on updating and finalizing the poster. Helped Katie with drilling and filing the incubator box in the TeamLab.
- Caroline - Conducted optical testing in the lab using testing protocols. Evaluated the optical clarity of the glass via qualitative and quantitative tests. Worked on the poster with Olivia. Added testing protocols to the final report.

Download

cell_incubator-progress_report-12.docx (12.6 kB)

2/10/22 PDS

Katie Day - Feb 10, 2022, 9:42 AM CST

Title: PDS

Date: 2/10/2022

Content by: Katie Day, Sam Bardwell, Maya Tanna, Drew Hardwick, and Bella Raykowski

Present:

Goals: To update our former PDS to better reflect our current project.

Content:

See attached file.

Conclusions/action items:

Begin working on design matrix.

Katie Day - Feb 10, 2022, 9:42 AM CST

Product Design Specifications

Microscope Cell Culture Incubator

BME 301
11 February 2022

Client: Dr. John Puccinelli
University of Wisconsin-Madison
Department of Biomedical Engineering

Team:
Katie Day
Sam Bardwell
Maya Tanna
Drew Hardwick
Bella Raykowski

Download

Product_Design_Specifications_Spring_2022.pdf (233 kB)

2/15/22 Design Matrices

SAMUEL BARDWELL - Feb 28, 2022, 12:05 PM CST

Title: Design Matrices

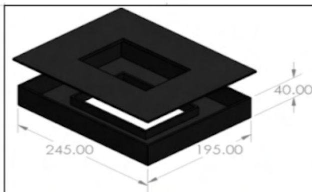
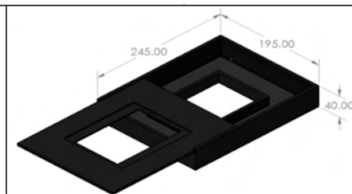
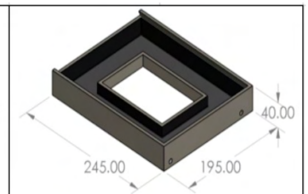
Date: 2/15/22

Content by: Everyone

Goals: To create design matrices for the incubator box and CO2 input in order to pick the best option to continue with for the project.

Content:

Table 1: Design matrix for the incubator box design with highlighted winning portions.

								
			Hinge Top Acryllic Incubator		**Slide Top Acryllic Incubator**		**3D Printed Incubator**	
Rank	Criteria	Weight	Score (5 max)	Weighted Score	Score (5 max)	Weighted Score	Score (5 max)	Weighted Score
1	Internal Environment	25	5	25	4	20	4	20
2	Microscope Compatibility	20	5	20	5	20	5	20
3	Accuracy and Reliability	20	4	16	4	16	3	12
4	Ergonomics	15	5	15	5	15	5	15
5	Cost	10	4	8	4	8	3	6
6	Life in Service	5	5	5	5	5	4	4
7	Safety	5	5	5	5	5	5	5
	Sum	**100**	**Sum**	**94**	**Sum**	**89**	**Sum**	**82**

* All box dimesions are in millimeters

Table 2: Design matrix for the CO2 input with highlighted winning portions.

						
			100% CO2 Tank Controlled Input		**5% CO2 Tank Input**	
Rank	Criteria	Weight	Score (5 max)	Weighted Score	Score (5 max)	Weighted Score
1	Performance	25	4	20	5	25
2	Cost	25	5	25	1	5
3	Accuracy and Reliability	20	3	12	5	20
4	Independance	15	2	6	4	12
6	Life in Service	10	5	10	5	10
7	Safety	5	5	5	5	5
	Sum	**100**	**Sum**	**78**	**Sum**	**77**

Conclusions/action items:

The team will use these design matrices to decide what the best route to take for the incubator box and CO2 input. The winning incubator box design is the hinge top incubator. Prototype fabrication will begin as soon as possible. The winning CO2 input design is the 100% CO2 input. The input sensor and coding will be a little more complicated than the 5% CO2 but the cost is much cheaper.

4/24/22 Final Design SOLIDWORKS Files

SAMUEL BARDWELL - Apr 24, 2022, 12:54 PM CDT

Title: Final Design SOLIDWORKS Files

Date: 4/24/22

Content by: Sam

Goals: To provide SOLIDWORKS files for the incubator box if someone needs to replicate the dimensions.

Content:

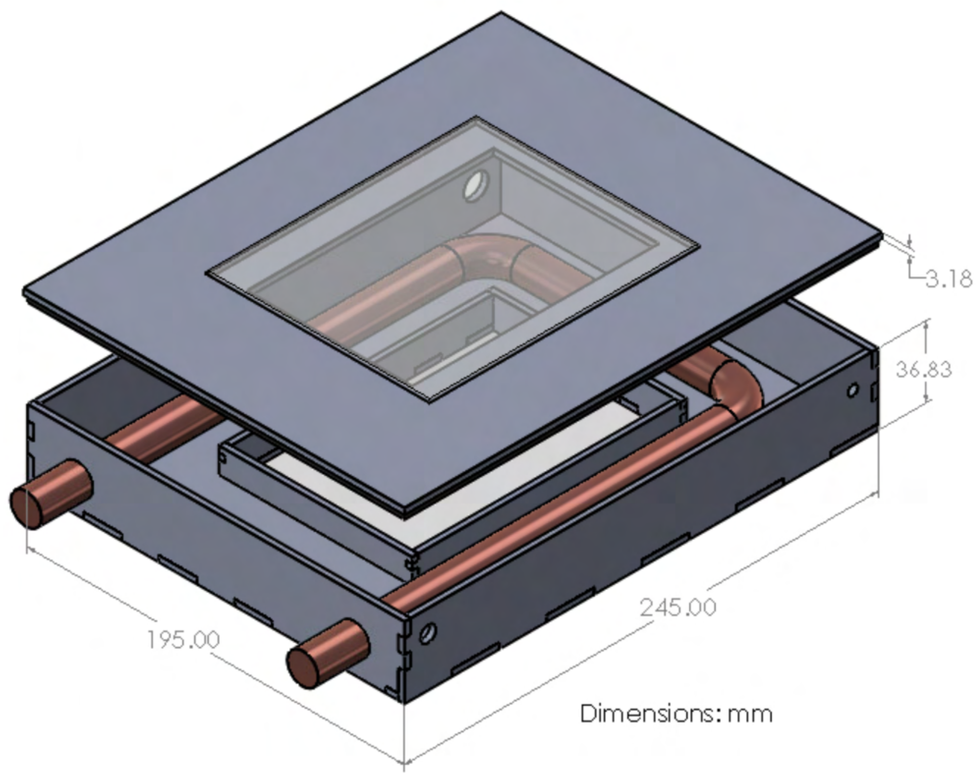
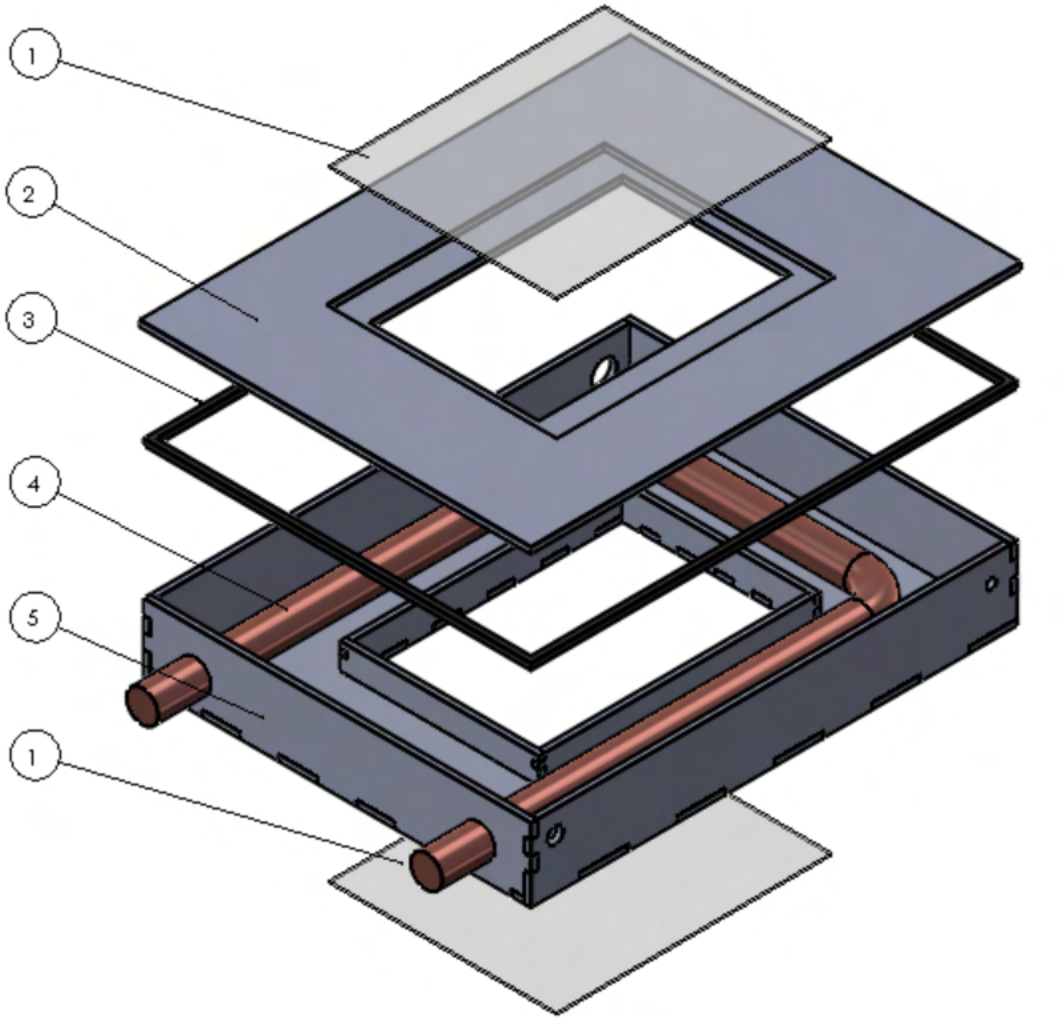


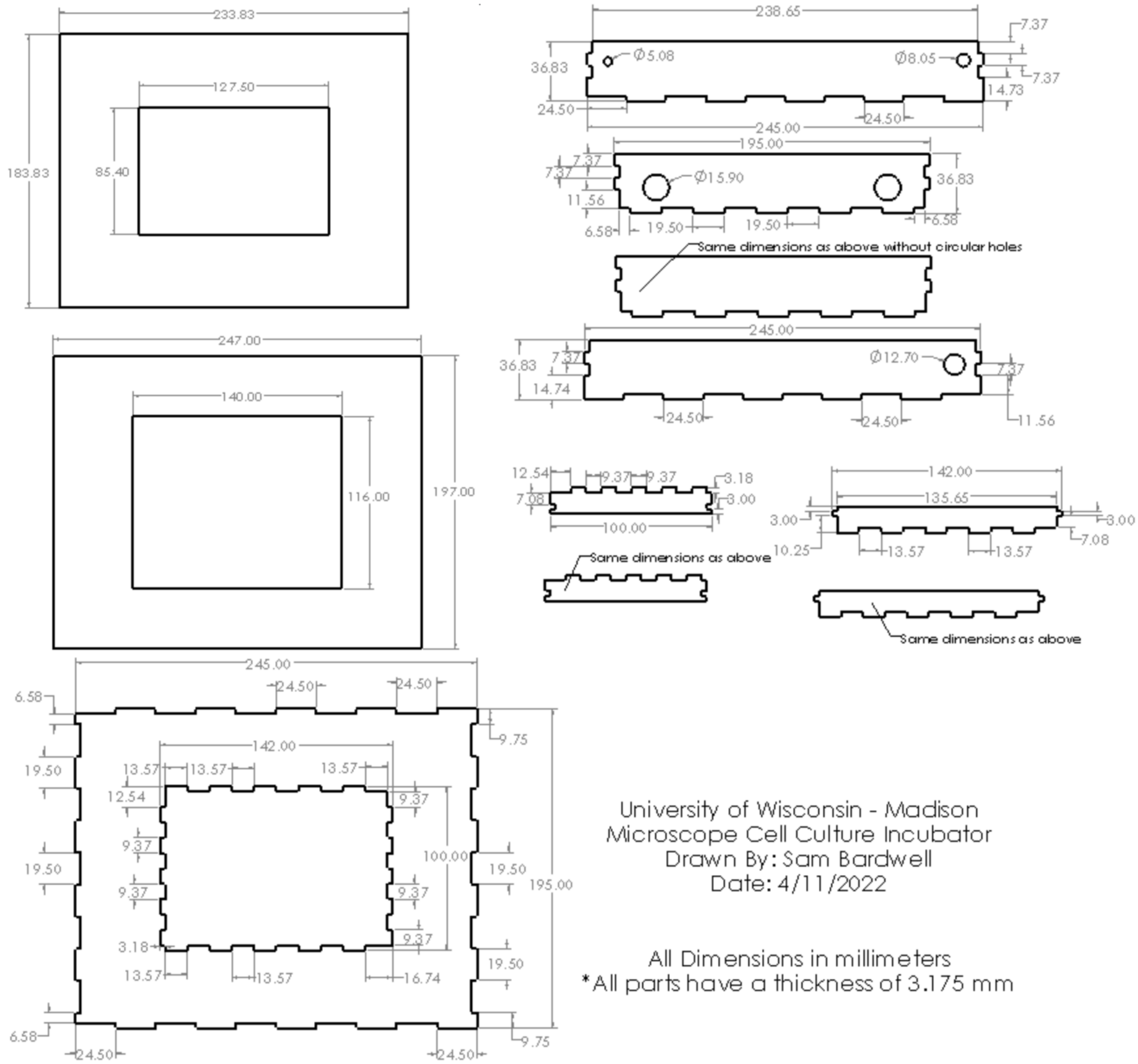
Figure 1: Final SOLIDWORKS drawing of the final design in mm



Item No.	Item Description	Dimensions [mm]	QTY.
1	Glass plates to allow transparent viewing	114.5 x 138.5 x 1.3	2
2	Lid of box to enclose the incubator	247 x 197 x 6.35	1
3	Rubber linning to allow tight seal	245 x 195 x 3.175	1
4	Copper tubing to provide heat transfer	Outside Diameter: 15.875 Inside Diamter: 12.7 Length: 610	1
5	Black acrylic box to maintain a controlled internal environment	Outside Cut: 245 x 195 x 36.83 Inner Cut: 142 x 100 x 16.25	1

Figure 2: Exploded SOLIDWORKS assembly of the final design along with a table explaining the dimensions and parts

SOLIDWORKS DRAWING OF BOX USED FOR LASER CUTTER



Conclusions/action items:

These drawings and images will be implemented into the final report and poster. These are helpful because if the box needs to be replicated in the future, all of the dimensions we used are here.

4/29/22 Final CO2 Design SOLIDWORKS and testing setup

Drew Hardwick - May 03, 2022, 7:09 PM CDT

Title: Final CO2 Design SOLIDWORKS and testing setup

Date: 4/29/22

Content by: Drew

Present: N/A

Content:

- Below are the SOLIDWORKS files and dimensions used to create the CO2 regulating apparatus. The valve connector is printed to the exact diameter of the valve on the CO2 tank that releases the gas.
- A DC motor will turn this connector and thus turn the valve, opening and closing the CO2 tank and allowing/preventing flow into the incubator based on the incubator's current atmosphere
- The circuitry setup shown below will read the CO2 levels and turn the DC motor to turn the open/close valve accordingly
- This process and the results are elaborated more on in the Final Report

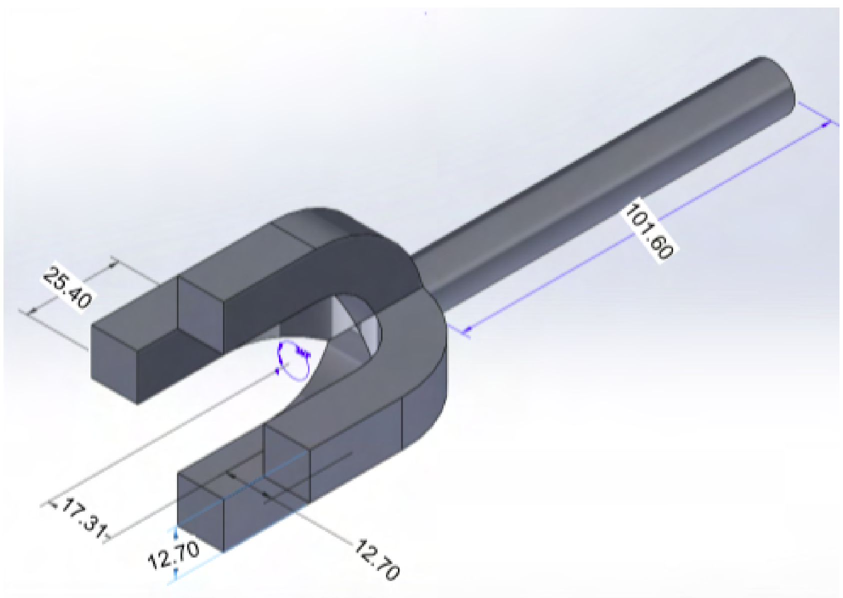


Figure 1: SOLIDWORKS DC Motor Attachment with dimensions shown in mm

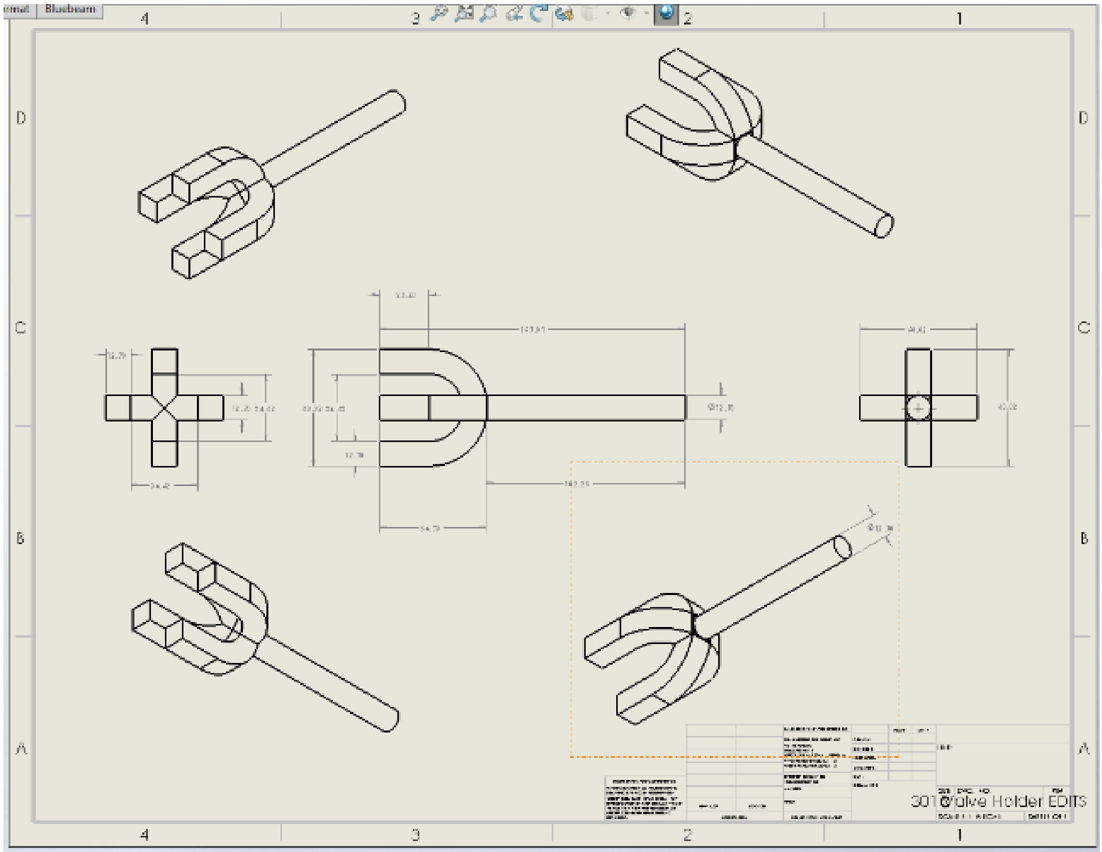


Figure 2: SOLIDWORKS Drawing of DC Motor Attachment with dimensions shown in mm

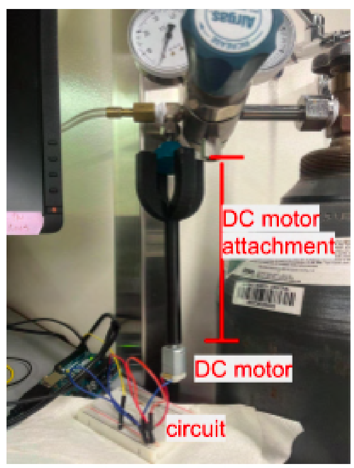


Figure 3: Testing setup with motor, valve holder, and circuits all attached to the CO2 tank

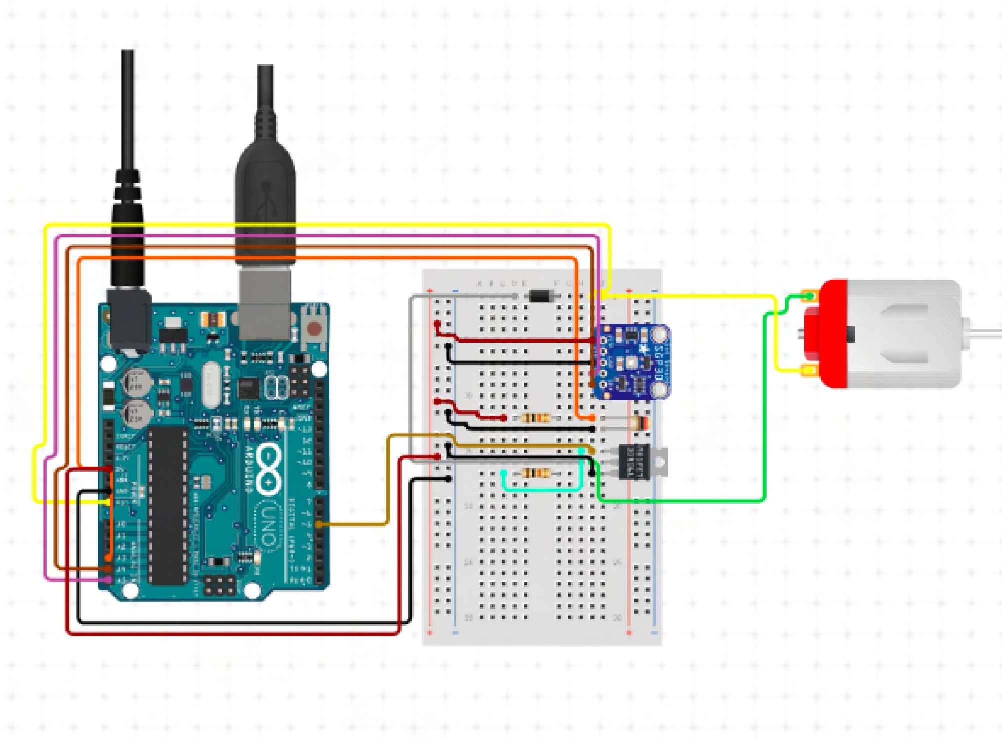


Figure 4: Complete Incubator Circuit Design

3/9/2022 Materials Purchasing Request

Bella Raykowski - Apr 12, 2022, 11:31 AM CDT

Title: Materials Purchasing Request

Date: 3/9/2022

Content by: Katie Day, Sam Bardwell, Maya Tanna, Drew Hardwick, Bella Raykowski

Goals: Create a comprehensive list of what needs to be purchased for this project as well as all purchasing links for our client

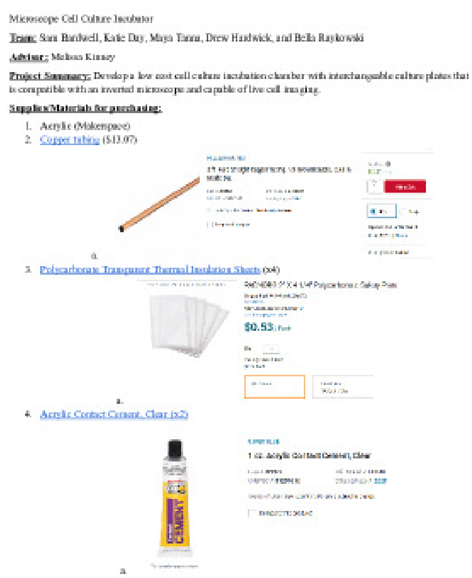
Content:

See attached file.

Conclusions/action items:

See attached file.

Bella Raykowski - Apr 12, 2022, 11:31 AM CDT


Microscope Cell Culture Incubator

Team: Sam Bardwell, Katie Day, Maya Tanna, Drew Hardwick, and Bella Raykowski

Advisor: Melissa Kinney

Project Summary: Develop a low cost cell culture incubation chamber with interchangeable culture plates that is compatible with an inverted microscope and capable of live cell imaging.

Supplies/Materials for purchasing:

1. Acrylic (Makerspace)
2. Copper tubing ($13.07)
3. Polycarbonate Transparent Thermal Insulation Sheets (x4)
4. Acrylic Contact Cement, Clear (x2)

Download

Materials_Purchasing_Request_-_Microscope_Cell_Culture_Incubator_-_Google_Docs.pdf (628 kB)

3/22/2022 UW Makerspace Expenses

Bella Raykowski - Apr 12, 2022, 11:37 AM CDT

Title: Materials Purchasing Request

Date: 3/22/2022

Content by: Katie Day, Sam Bardwell, Maya Tanna, Drew Hardwick, Bella Raykowski

Goals: Create a comprehensive list of what needs to be purchased for this project as well as all purchasing links for our client

Content:

Item	Description	Date	QTY	Cost Each	Total	
Hard Wood	36x24x ⅛ Hard wood that was used to fabricate the prototype	3/21/2022	1	$2.50	1	
Hard Wood	18x24x ⅛ Hard wood that was used to fabricate the prototype	3/21/2022	1	$1.25	1	

Conclusions/action items:

The team has spent $3.75 on the wood prototype and now that we have confirmed that the dimensions are correct will move forward with laser cutting the final acrylic prototype.

5/3/2022 Final Expenses

Drew Hardwick - May 03, 2022, 7:14 PM CDT

Title: Final Expenses

Date: 5/3/2022

Content by: Katie Day, Bella Raykowski, Drew Hardwick, Sam Bardwell, Maya Tanna

Present:

Goals: To present our final expenses for the entire semester.

Content:

Expenses

m	Description	Manufacturer	Part Number	Date	QTY	Cost Each	Total	Link
mponent 1								
lycarbonate Transparent hermal Insulation Sheets	2"x4.25" clear Polycarbonate safety plate for covering cells while viewing	Airgas	RAD64005012	3/9/22	4	$0.53	$2.12	Link
mponent 2								
Acrylic Contact Cement	1 oz Clear Contact Cement to mount clasps and assemble acrylic box	Grainger	3EHR7	3/9/22	2	$2.73	$5.46	Link
mponent 3								
Buna-N Square Rubber Cord	5ft, ⅛" x ⅛", 70A, 0℃ - 210℃ square rubber cord to prevent leakage with clasp lid	Grainger	784U15	3/9/22	1	$4.86	$4.86	Link
mponent 4								
rd Wood	36x24x ⅛ Hard wood that was used to fabricate the prototype	UW Makerspace	1	3/21/2022	1	$2.50	$2.50	Link
mponent 5								
rd Wood	18x24x ⅛ Hard wood that was used to fabricate the prototype	UW Makerspace	1	3/21/2022	1	$1.25	$1.25	Link
mponent 6								
rbed Adapter	Barbed x MNPT Adapter, Polyethylene, ⅜ in barb size, natural used to connect copper tubing to heated water tank	Grainger	1	3/29/2022	10	$1.26	$12.63	Link
mponent 7								

ack Acrylic	Black Acrylic used to fabricate the incubation chamber 18x24 sheet with ½ inch thickness	UW Makerspace	1	4/11/2022	1	$21.50	$21.50	Link
mponent 8								
print DC motor achment	PVA plastic used to fabricate the DC motor attachment for the regulation of CO_2 input into the incubation chamber	UW Makerspace	1	4/11/2022	1	$2.72	$2.72	Link
mponent 9								
DC Motor	Actual Motor used for control of CO2 regulation	UW Makerspace	1	4/11/2022	1	$2.00	$2.00	Link
TAL:	$53.54							

Conclusions/action items:

3/22/22 Laser Cut HDF Prototype

SAMUEL BARDWELL - Mar 22, 2022, 9:23 PM CDT

Title: Laser Cut HDF Prototype

Date: 3/22/22

Content by: Sam and Katie

Goals: To laser cut the HDF board prototype to test the fabrication of the box.

Content:

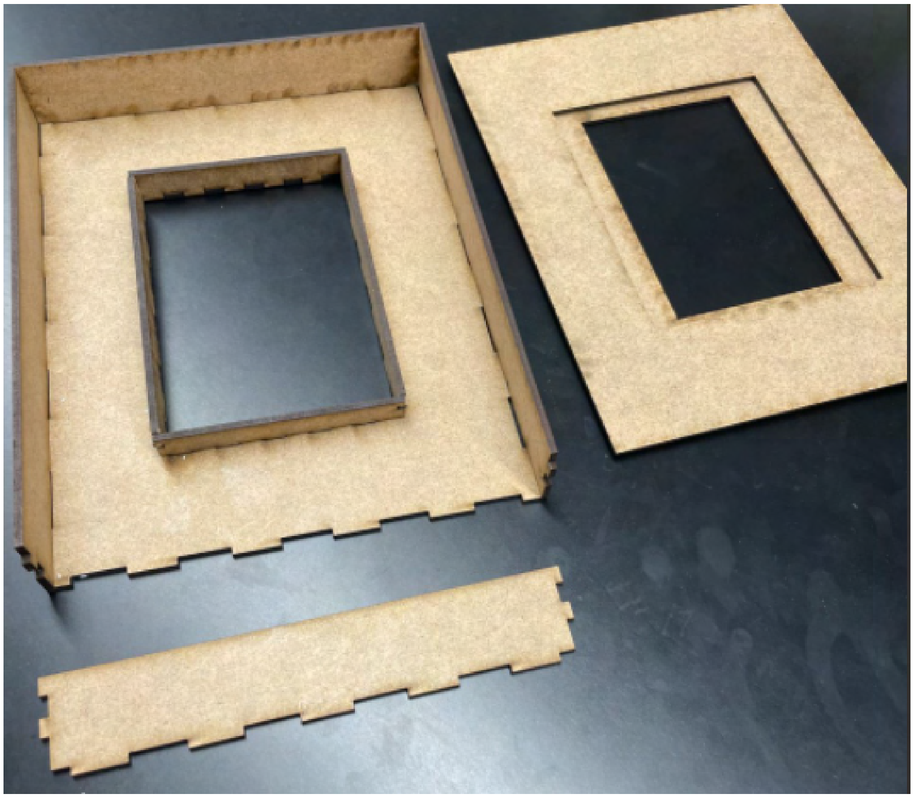


Figure 1: Photo of the laser cut HDF showing the parts being not completely assembled

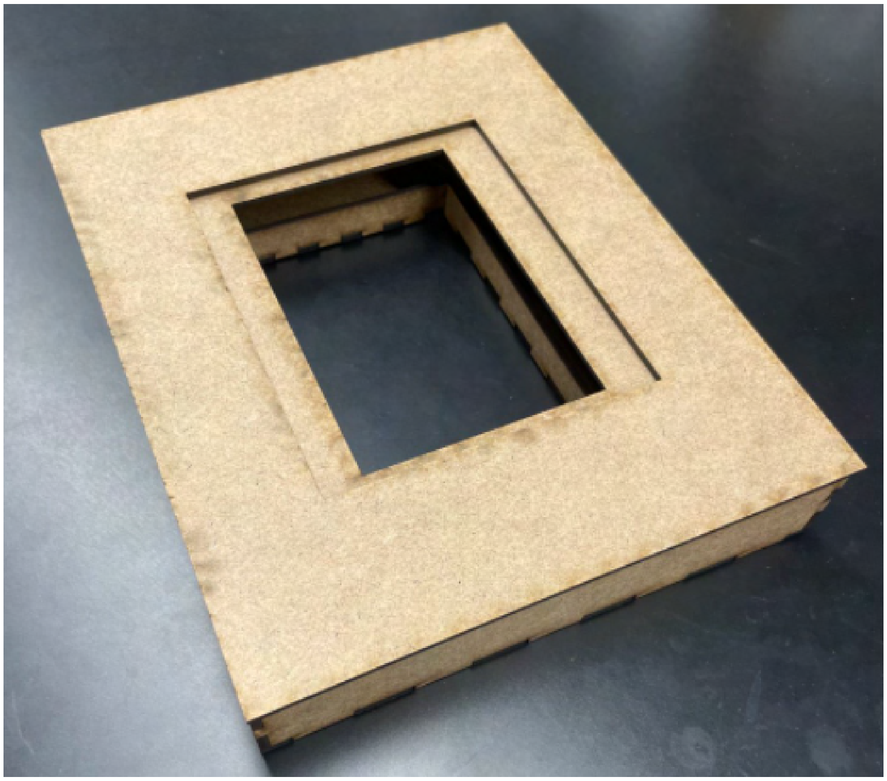


Figure 2: Photo of the laser cut HDF prototype with all the pieces assembled together.

- Box fit very well together

- We were able to figure out the correct setting for the laser cutter and we are ready to laser cut the acrylic sheet when the time comes

- We will have to use hot glue and the acrylic cement in order to seal all the holes of the acrylic when its fabricated. This is because the HDF had a lot of holes and close to perfect but not perfect fits with the fingers.

Conclusions/action items:

Begin preparing files for the acrylic to be laser cut. Begin testing of the incubator with the acrylic box.

3/30/22 Copper Tubing Fabrication

Drew Hardwick - May 03, 2022, 10:45 PM CDT

Title: Copper Tubing Fabrication

Date: 3/30/22

Content by: Sam and Drew

Goals: To fabricate the inner copper tubing ring.

Content:

Figure 1: Inner copper tubing fabrication within the prototyped box.

- Copper was cut to length using the drop saw

- Two copper couplings were used to produce two 90 degree turns to circle the inside of the incubator.

- Copper couplings were fastened to the straight copper piper with soldering glue

- End of the copper tubing will be connected to 1/2 inch threaded to 3/8th inch barbed wire adaptor.

Conclusions/action items:

Connected the adaptor to the copper tubing and then connect the copper to the heated water pump tubing. Test for any leaks and fix any problems.

4/11/2022 Incubation Chamber Fabrication

Katie Day - Apr 11, 2022, 8:24 PM CDT

Title: Incubation Chamber Fabrication

Date: 4/11/2022

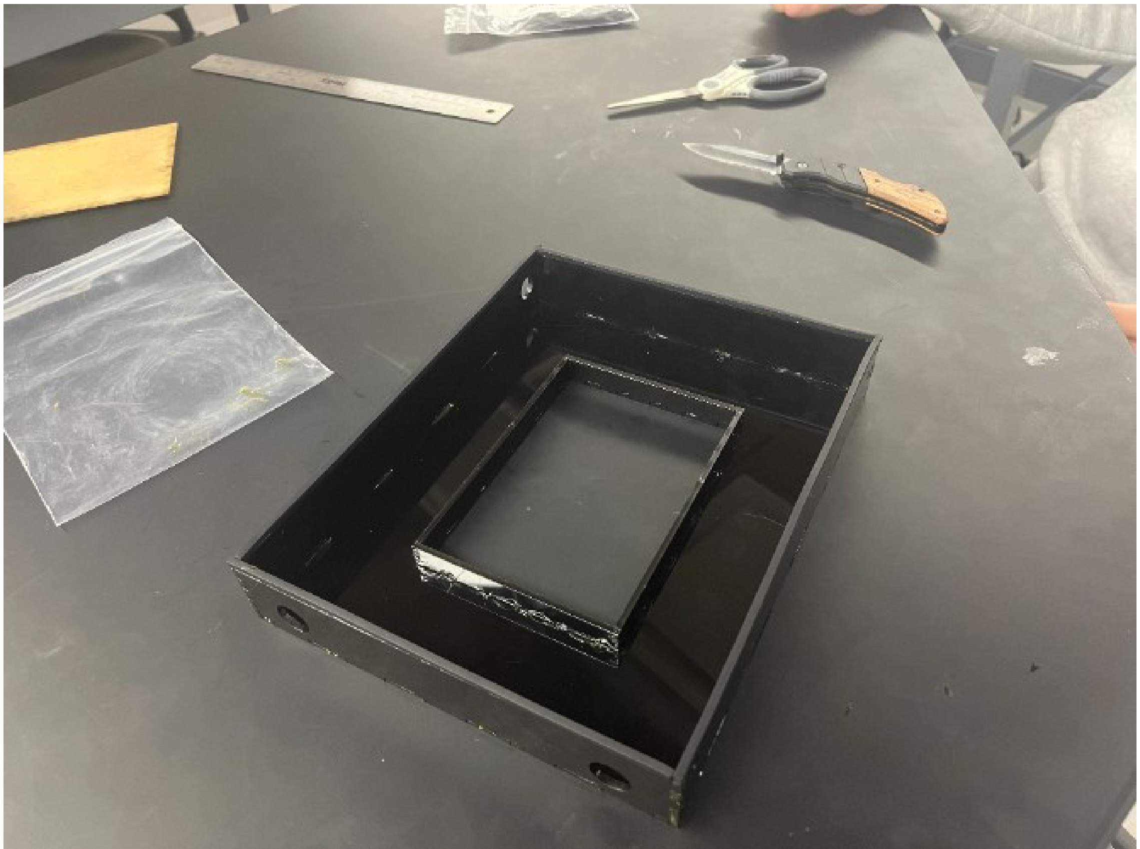
Content by: Katie Day and Sam Bardwell

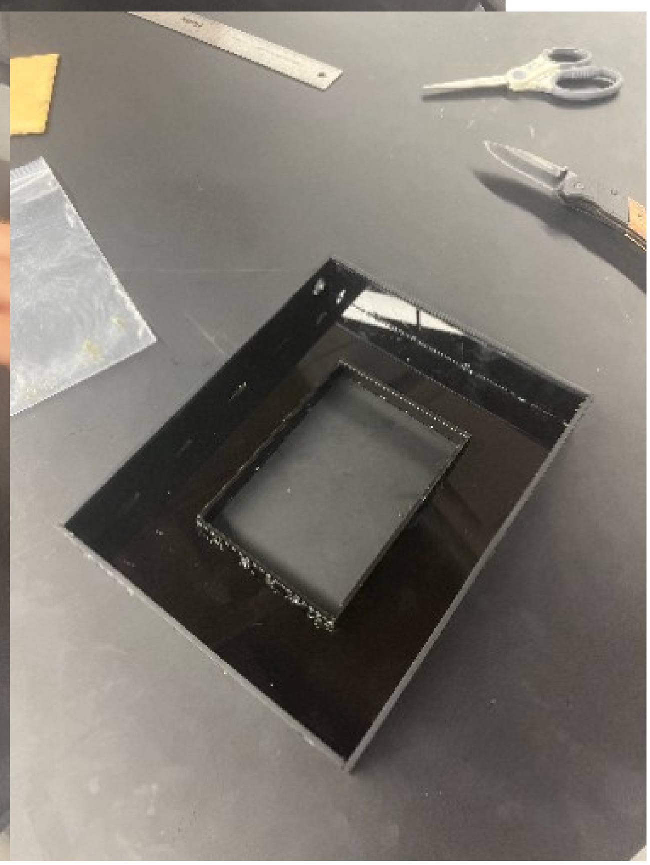
Present:

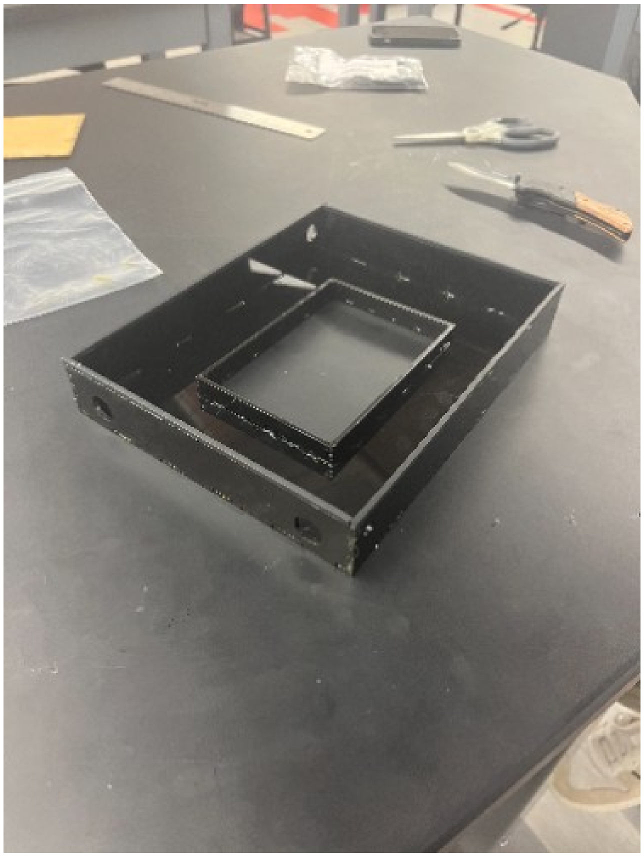
Goals: To fabricate, glue, and attach all elements of the incubation chamber.

Content:

See photos. The rubber lining was also added to the top.







Conclusions/action items:

Seal the box using caulk, file a bigger hole for the NDIR sensor, and consider spraying with an adhesive to ensure water tight.

4/19/22 Final Design Fabrication

Katie Day - May 03, 2022, 6:23 PM CDT

Title: Final Design Fabrication

Date: 4/19/22

Content by: Everyone

Goals: To fabricate the final prototype and make sure there are no water leaks.

Content:

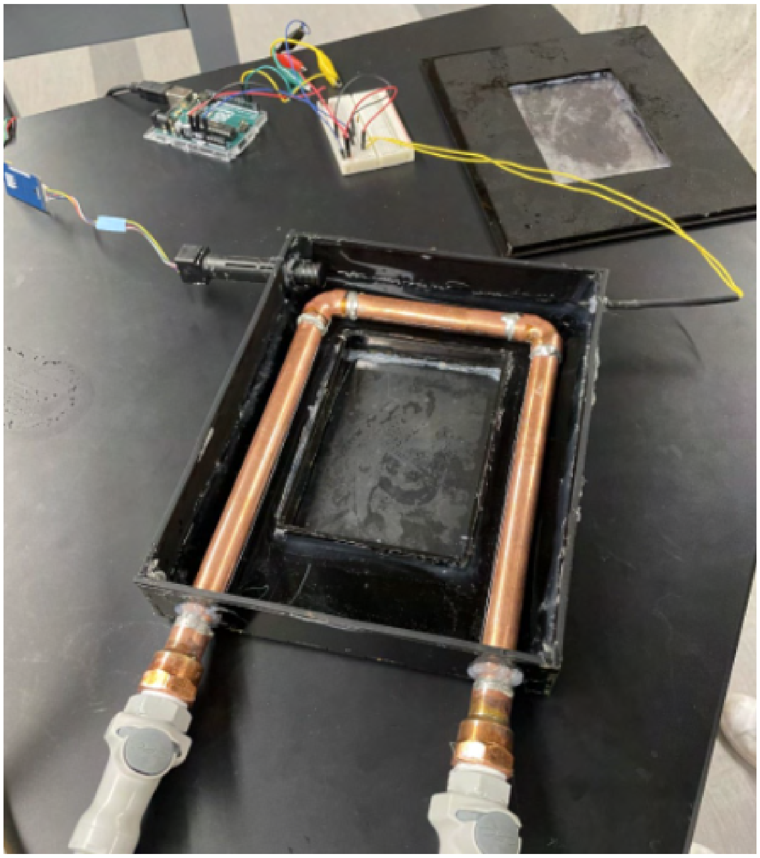


Figure 1: Final design fabrication with an open lid.

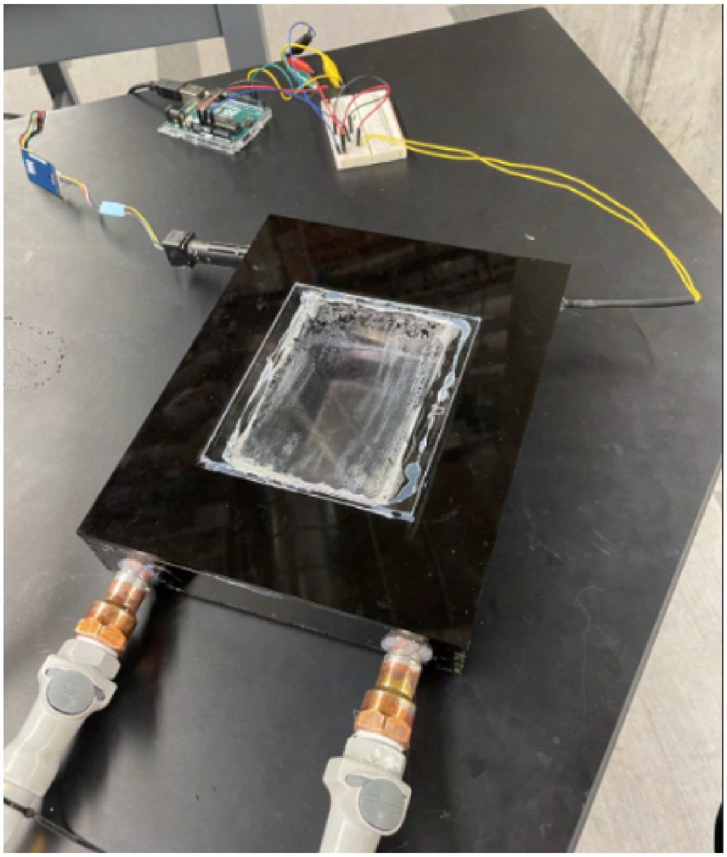


Figure 2: Final design fabrication with an closed lid.

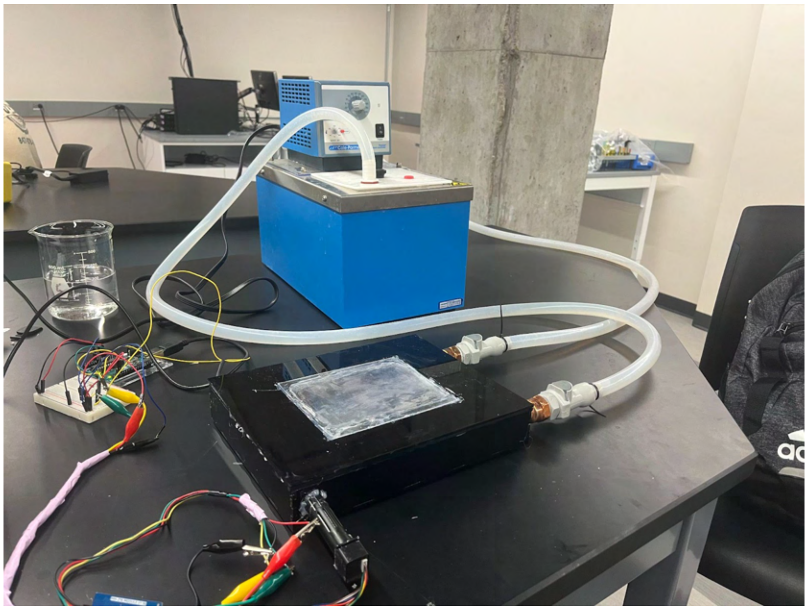


Figure 3: Whole Incubation Set-up

- Copper tubing was soldered to prevent water leakage in the heated water pump contraption.

- Acrylic box was lined with caulk to prevent water leakage within the crevices of the box.

- Adaptors were added to have adjustable tubing options.

- Sensor were hot glued into their appropriate entry holes to prevent internal environment leakage within the design.

- Glass was added from the previous semester design.

- Sensors were connected to the microcontroller and were functioning properly and outputting temperature and humidity values.

- CO_2 is still being worked on.

Conclusions/action items:

There was no water leakage after an hour of water being pumped and placed in the water bed. Temperature values were able to reach and maintain 37 degree Celsius. Humidity started at above 95 percent but slowly declined. Possible errors are loose seals within the box. CO_2 input is still being worked on.

4/10/2022 Testing Protocols

Katie Day - Apr 10, 2022, 7:12 PM CDT

Title: Testing Protocols

Date: 4/10/2022

Content by: Maya Tanna and Bella Raykowski

Present:

Goals: To document all testing protocols that were created for each element of the project this semester.

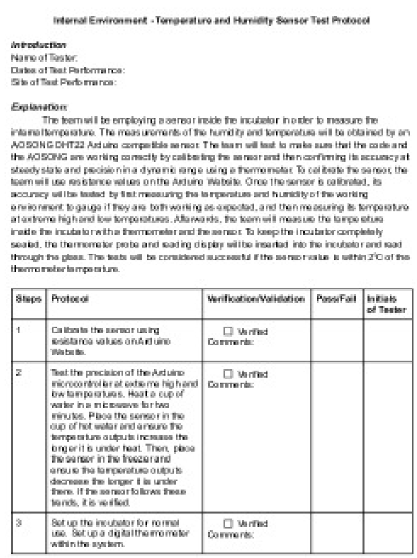
Content:

See attached file.

Conclusions/action items:

Use the following testing protocols to ensure accuracy and reliability in the design.

Katie Day - Apr 10, 2022, 7:13 PM CDT



Internal Environment - Temperature and Humidity Sensor Test Protocol

Introduction
Name of Tester:
Dates of Test Performance:
Site of Test Performance:

Explanation:
The team will be employing a sensor inside the incubator in order to measure the internal temperature. The measurements of the humidity and temperature will be obtained by an AOSONG DHT22 Arduino compatible sensor. The team will test to make sure that the code and the AOSONG are working correctly by calibrating the sensor and then confirming its accuracy at steady state and precision in a dynamic range using a thermometer. To calibrate the sensor, the team will use resistance values on the Arduino Website. Once the sensor is calibrated, its accuracy will be tested by first measuring the temperature and humidity of the working environment to gauge if they are both working as expected, and then measuring its temperature at extreme high and low temperatures. Afterwards, the team will measure the temperature inside the incubator with a thermometer and the sensor. To keep the incubator completely sealed, the thermometer probe and reading display will be inserted into the incubator and read through the glass. The tests will be considered successful if the sensor value is within 2°C of the thermometer temperature.

Steps	Protocol	Verification/Validation	Pass/Fail	Initials of Tester
1	Calibrate the sensor using resistance values on Arduino Website.	☐ Verified Comments:		
2	Test the precision of the Arduino microcontroller at extreme high and low temperatures. Heat a cup of water in a microwave for two minutes. Place the sensor in the cup of hot water and ensure the temperature outputs increase the longer it is under heat. Then, place the sensor in the freezer and ensure the temperature outputs decrease the longer it is under there. If the sensor follows these trends, it is verified.	☐ Verified Comments:		
3	Set up the incubator for normal use. Set up a digital thermometer within the system.	☐ Verified Comments:		

Download

Testing_Protocols_Template_.pdf (478 kB)

5/3/2022 Testing Protocol Template Revisions

MAYA TANNA - May 03, 2022, 7:38 PM CDT

Title: Testing Protocol Template Revisions

Date: 05/03/2022

Content by: Maya/Bella

Present: Maya

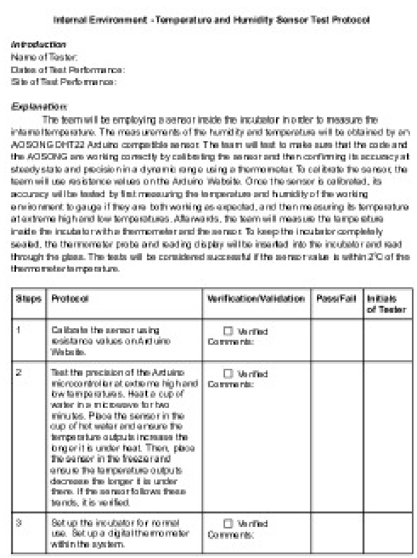
Goals: To document revisions made to the testing protocol template in order to better reflect current information

Content:

See attached file. (Cell Viability Test Protocol was added)

Conclusions/action items: Continue testing wherever possible next semester. Help other areas of the project so they can get to the testing stage and then lead that.

MAYA TANNA - May 03, 2022, 7:39 PM CDT



Internal Environment - Temperature and Humidity Sensor Test Protocol

Introduction
Name of Tester:
Dates of Test Performance:
Site of Test Performance:

Explanation:
The team will be employing a sensor inside the incubator in order to measure the internal temperature. The measurements of the humidity and temperature will be obtained by an AOSONG DHT22 Arduino compatible sensor. The team will test to make sure that the code and the AOSONG are working correctly by calibrating the sensor and then confirming its accuracy at steady state and precision in a dynamic range using a thermometer. To calibrate the sensor, the team will use resistance values on the Arduino Website. Once the sensor is calibrated, its accuracy will be tested by first measuring the temperature and humidity of the working environment to gauge if they are both working as expected, and then measuring its temperature at extreme high and low temperatures. Afterwards, the team will measure the temperature inside the incubator with a thermometer and the sensor. To keep the incubator completely sealed, the thermometer probe and reading display will be inserted into the incubator and read through the glass. The tests will be considered successful if the sensor value is within 2°C of the thermometer temperature.

Steps	Protocol	Verification/Validation	Pass/Fail	Initials of Tester
1	Calibrate the sensor using resistance values on Arduino Website.	☐ Verified Comments:		
2	Test the precision of the Arduino microcontroller at extreme high and low temperatures. Heat a cup of water in a microwave for two minutes. Place the sensor in the cup of hot water and ensure the temperature outputs increase the longer it is under heat. Then, place the sensor in the freezer and ensure the temperature outputs decrease the longer it is under there. If the sensor follows these trends, it is verified.	☐ Verified Comments:		
3	Set up the incubator for normal use. Set up a digital thermometer within the system.	☐ Verified Comments:		

Download

Testing_Protocols_Template_2_.pdf (95.7 kB)

3/24/2022 Optical Testing

Katie Day - Apr 10, 2022, 7:14 PM CDT

Title: Optical Testing

Date: 3/24/2022

Content by: Maya Tanna and Bella Raykowski

Present:

Goals: To conduct optical testing to determine the usability of the glass.

Content:

See attached file.

Conclusions/action items:

The glass is not statistically significant and passes all tests.

Katie Day - Apr 10, 2022, 7:14 PM CDT

Optical Testing - Prior to and After Installation

Introduction
Name of Tester: Maya Tanna/Bella Raykowski
Dates of Test Performance: 03/24/2022
Site of Test Performance: ECB 1002

Explanation:
The team will test High Transparent Lexan Polycarbonate sheets to determine which best matches the optical properties of well plates. Well Plates have a gloss percentage of 75-90, a haze percentage of 11, and a transparency percentage of 85-90 [16]. The team has researched that the transparency percentage of polycarbonate is 88-89 and the haze is 1%[17]. The team will determine through live-cell imaging, either by fluorescent microscopy or bright field microscopy depending on the client's cell cultures, whether 88% transparency is acceptable.

Steps	Protocol	Verification/Validation	Pass/Fail	Initials of Tester
1	Have one team member complete steps 1-2. Prepare the microscope for use. Place resolution test paper between the 2 sheets of High Transparent Lexan Polycarbonate, and place onto the microscope stage.	☑ Verified Comments:	Pass	MT/BR
2	Adjust the optical components of the microscope to best clarity based on personal judgment. Ensure the resolution test paper is centered under the microscope lens. Take an image of what is observed under the microscope.	☑ Verified Comments:	Pass	MT/BR
3	Repeat steps 1-2 without the polycarbonate sheets, but still including the resolution test paper.	☑ Verified Comments:	Pass	MT/BR
4	Have 3 team members, other than the one who completed steps 1-3, complete this step. The team members will rank the two images on a scale of 1-10 based on focus quality. The image with the higher focus quality will then be determined. Record this image in the comments.	☑ Verified Comments: Participants indicated that the image without the polycarbonate sheet was more clear and had a higher focus quality.	Pass	MT/BR

Download

Maya_Bella_Optical_Testing.pdf (63.8 kB)

3/30/22 Flow Rate Experiment

SAMUEL BARDWELL - Mar 30, 2022, 7:14 PM CDT

Title: Flow Rate Experiment

Date: 3/30/22

Content by: Sam and Katie

Goals: To calculate the flow rate of 100% CO_2 coming out of the CO_2 tank at 14.7 psi.

Content:

Time to fill balloon with CO2 = 3s

Initial Water Volume = 2650mL

Trial	Displacement L	Flow Rate L/sec
1	1.9	0.6333333333
2	1.925	0.6416666667
3	2.4	0.8
4	2.1	0.7
5	2.35	0.7833333333
Average	2.135	0.7116666667

Flow rate = 0.7116666667 L/sec

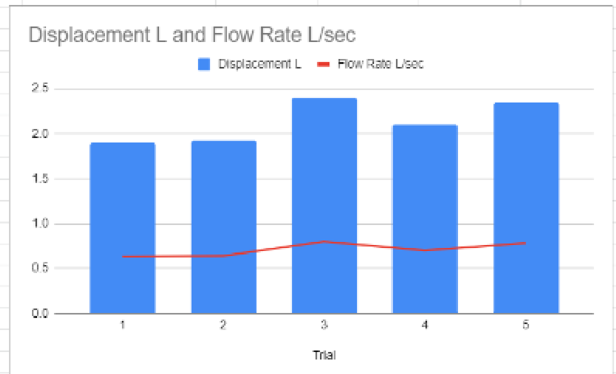


Figure 1: Photo of the flow rate data and graph showing the average flow rate at 14.7 psi.

- Katie and I filled up a balloon for three seconds with 14.7 psi CO2 from the CO2 tank

- When then placed the balloon in a known amount of water and measured the displacement to find the volume of CO2 that was outputted

- Using the output in Liters and the known time in seconds, we were able to estimate the flow rate to be 0.7116 L/s

Conclusions/action items:

This estimated flow rate will be used for the CO_2 input mechanism and within the Arduino coding to determine how long the DC motor should be opened and the closed for in order to keep the internal environment at 5% CO_2.

4/5/2022 Humidity Testing

Katie Day - Apr 10, 2022, 7:10 PM CDT

Title: Humidity Testing

Date: 4/5/2022

Content by: Katie Day

Present:

Goals: To test the accuracy of the humidity formula against the DHT22 humidity sensor.

Content:

The DHT22 and Thermistor both measured the humidity in ECB 1002 at ambient temperatures for 5 minutes. The resulting values and means were then compared via a t-Test.

See attached files.

Conclusions/action items:

There is no statistical significance between the DHT22 and Thermistor.

Katie Day - Apr 10, 2022, 7:10 PM CDT

Download

Misty_final_data.csv (1.75 kB)

Katie Day - Apr 10, 2022, 7:10 PM CDT

Download

Humidity_Test.csv (380 B)

4/5/2022 Temperature Testing (along with incubator Humidity Testing)

Katie Day - Apr 10, 2022, 7:10 PM CDT

Title: Temperature Testing

Date: 4/5/2022

Content by: Katie Day

Present:

Goals: To complete the testing protocols in order to determine the accuracy of the thermistor against the incubator in the teaching lab.

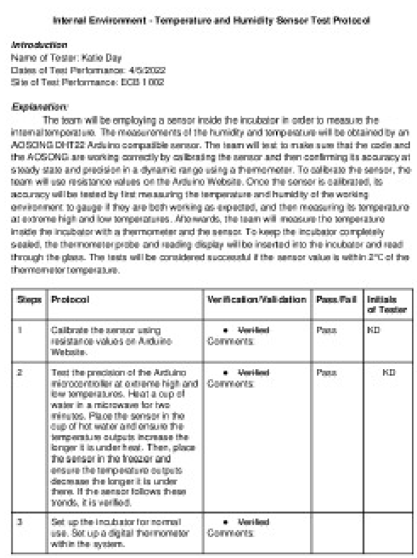
Content:

See attached files.

Conclusions/action items:

There is no statistical significance between the thermistor and the incubator readings.

Katie Day - Apr 10, 2022, 7:10 PM CDT



Internal Environment - Temperature and Humidity Sensor Test Protocol

Introduction
Name of Tester: Katie Day
Dates of Test Performance: 4/5/2022
Site of Test Performance: ECB 1002

Explanation:

The team will be employing a sensor inside the incubator in order to measure the internal temperature. The measurements of the humidity and temperature will be obtained by an AOSONG DHT22 Arduino compatible sensor. The team will test to make sure that the code and the AOSONG are working correctly by calibrating the sensor and then confirming its accuracy at steady state and precision in a dynamic range using a thermometer. To calibrate the sensor, the team will use resistance values on the Arduino Website. Once the sensor is calibrated, its accuracy will be tested by first measuring the temperature and humidity of the working environment to gauge if they are both working as expected, and then measuring its temperature at extreme high and low temperatures. Afterwards, the team will measure the temperature inside the incubator with a thermometer and the sensor. To keep the incubator completely sealed, the thermometer probe and reading display will be inserted into the incubator and read through the glass. The tests will be considered successful if the sensor value is within 2°C of the thermometer temperature.

Steps	Protocol	Verification/Validation	Pass/Fail	Initials of Tester
1	Calibrate the sensor using resistance values on Arduino Website.	• **Verified** Comments:	Pass	KD
2	Test the precision of the Arduino microcontroller at extreme high and low temperatures. Heat a cup of water in a microwave for two minutes. Place the sensor in the cup of hot water and ensure the temperature outputs increase the longer it is under heat. Then, place the sensor in the freezer and ensure the temperature outputs decrease the longer it is under there. If the sensor follows these trends, it is verified.	• **Verified** Comments:	Pass	KD
3	Set up the incubator for normal use. Set up a digital thermometer within the system.	• **Verified** Comments:		

Download

Katie_Temperature_Humdity_Testing.pdf (93.2 kB)

Katie Day - Apr 10, 2022, 7:10 PM CDT

Download

Temp_final_data.csv (673 B)

Katie Day - Apr 10, 2022, 7:10 PM CDT

Download

Temp_final_data.csv (673 B)

4/21/2022 Whole Incubator Temperature and Humidity Testing

Katie Day - Apr 21, 2022, 12:38 PM CDT

Title: Incubator Temperature and Humidity Testing

Date: 4/21/2022

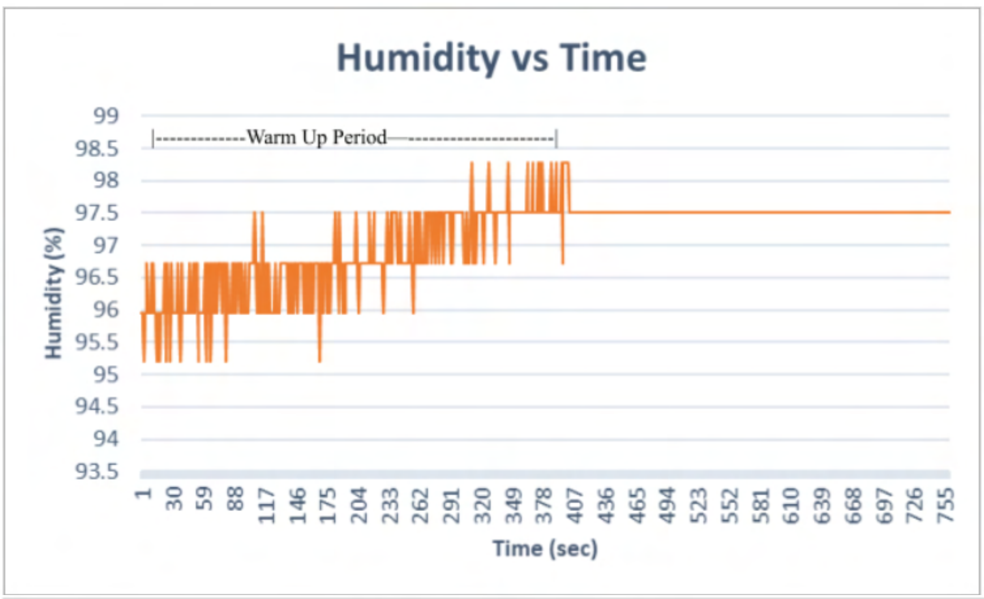
Content by: Katie Day, Maya Tanna, Bella Raykowski, Drew Hardwick, and Sam Bardwell

Present:

Goals: To test the internal environment of the incubator in regards to temperature and humidity.

Content:

- Temperature had an average temperature of 37.6℃, the dip in the graph represents turning the heated water pump down from it's warm up temperature of 40℃ to slightly below 34℃.
- Humidity testing was successful on the second try, after the formula was re-calibrated in the Arduino code. The results showed an average of 97.1% over the tested time interval.



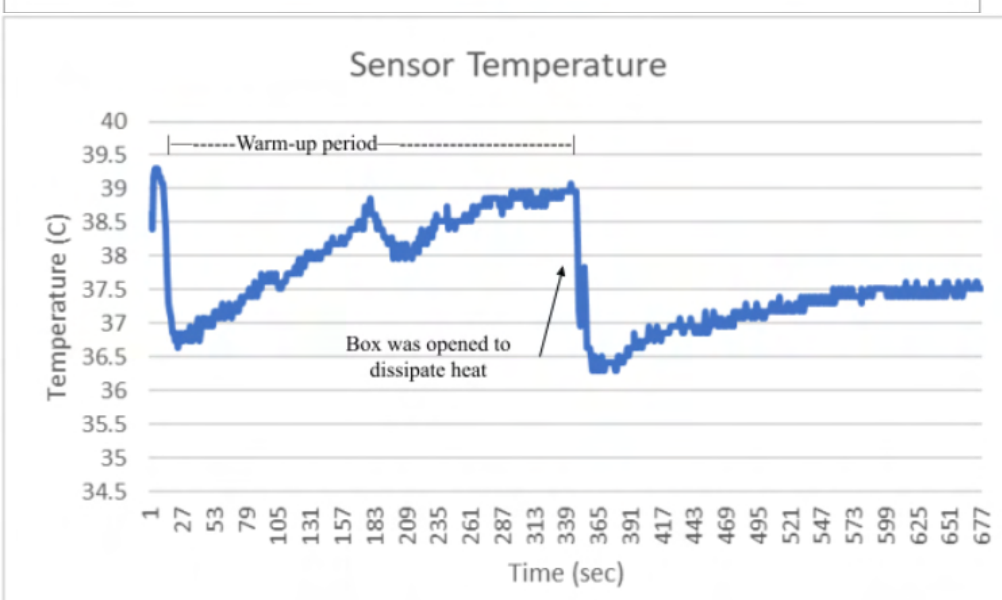


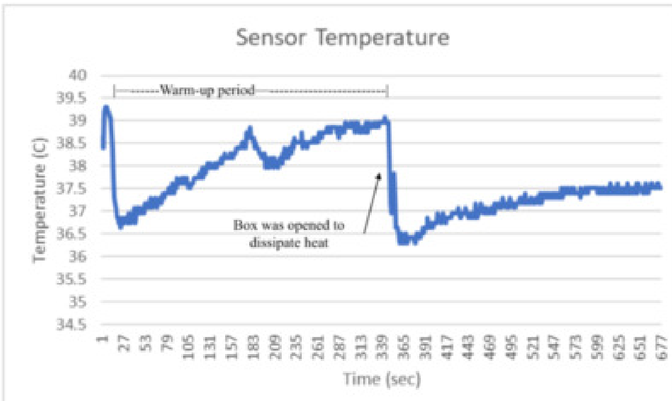
Figure 1: Sensor Humidity Results *Figure 2: Sensor Temperature Results*

See attached for raw data

Conclusions/action items:

Complete recovery testing.

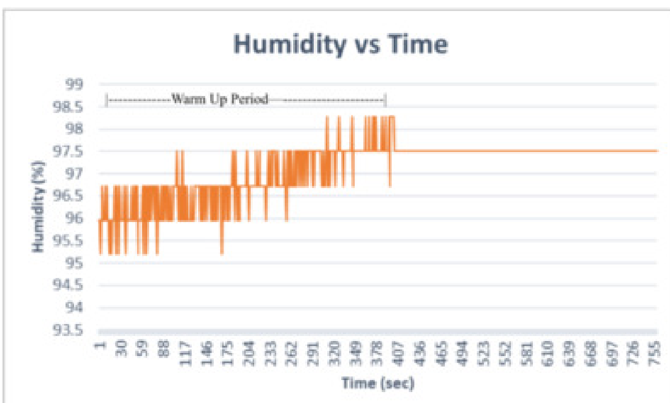
Katie Day - Apr 21, 2022, 12:37 PM CDT



Download

Sensor_temp_graph.png (74.9 kB)

Katie Day - Apr 21, 2022, 12:37 PM CDT



Download

Sensor_hum_graph.png (84.9 kB)

Katie Day - Apr 21, 2022, 12:37 PM CDT

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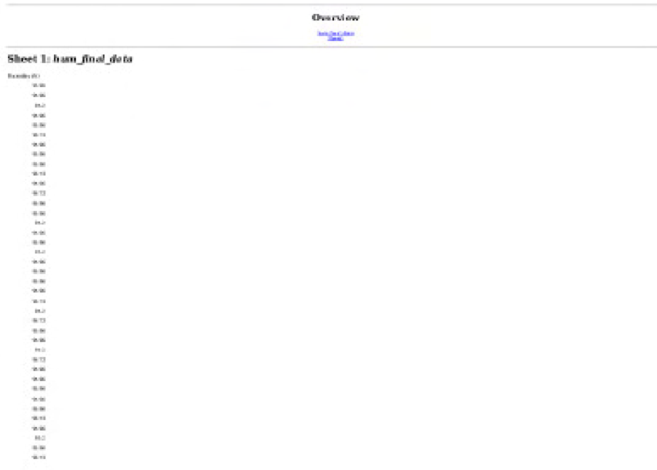
Incubator_temp_testing.csv (20.1 kB)

Katie Day - Apr 21, 2022, 12:37 PM CDT



Overview

Sheet 1: hum_final_data

Download

hum_final_data.xls (60.4 kB)

Katie Day - Apr 21, 2022, 12:37 PM CDT

Download

hum_final_data.csv (4.86 kB)

4/21/2022 Completed Arduino Code

Katie Day - Apr 21, 2022, 12:42 PM CDT

Title: Completed Arduino Code

Date: 4/21/2022

Content by: Katie Day

Present:

Goals: To put all of the separate electronic elements onto one circuit and use one code to display all necessary values and perform all necessary functions.

Content:

See attached file.

```
//Combined Arduino Code for Temp, Hum, and CO2

//Concentration
#include <SoftwareSerial.h>
#include <NDIR_SoftwareSerial.h>

//Select 2 digital pins as SoftwareSerial's Rx and Tx. For example, Rx=2 Tx=3
NDIR_SoftwareSerial mySensor(2, 3);
double percent = mySensor.ppm/10000;

// temperature variables
int ThermistorPin = 0;
int Vo;
float R1 = 10000;
float logR2, R2, T, Tc, Tf;
float c1 = 1.009249522e-03, c2 = 2.378405444e-04, c3 = 2.019202697e-07;
float e_s;
float e_d;
float Td = 36.1;

//DC motor variables
const int pwm = 4;
const int in_1 = 8;
const int in_2 = 9 ;
//For providing logic to L298 IC to choose the direction of the DC motor

void setup()
{
    Serial.begin(9600);

    if (mySensor.begin()) {
       Serial.println("Wait 10 seconds for sensor initialization...");
        delay(10000);
    } else {
       Serial.println("ERROR: Failed to connect to the sensor.");
        while(1);
    }
   pinMode(pwm,OUTPUT) ; //we have to set PWM pin as output
   pinMode(in_1,OUTPUT) ; //Logic pins are also set as output
   pinMode(in_2,OUTPUT) ;

}

void loop() {
//  Temperature
  Vo = analogRead(ThermistorPin);
  R2 = R1 * (1023.0 / (float)Vo - 1.0);
```

```
  logR2 = log(R2);
  T = (1.0 / (c1 + c2*logR2 + c3*logR2*logR2*logR2));
  Tc = T - 271.15;
  Tf = (Tc * 9.0)/ 5.0 + 32.0;
  float hum =0;
  e_s = 6.11 * pow(10, ((7.5 * Tc)/(237.7 + Tc)));
  e_d = 6.11 * pow(10, ((7.5 * Td)/(237.7 + Td)));
  hum =exp((17.625*5.2)/(243.04+5.2))/exp((17.625*Tc)/(243.04+Tc)); //rel humidity


 Serial.print("Temperature: ");
 Serial.print(Tf);
 Serial.print(" F; ");
 Serial.print(Tc);
 Serial.println(" C");
 Serial.print("Relative Humidity: ");
 Serial.print((hum*1000)-30);
 Serial.println("%");
 delay(1000);

//Concentration
   if (mySensor.measure()) {
       Serial.print("CO2 Concentration is ");
       Serial.print(mySensor.ppm);
       Serial.println(" ppm");
       Serial.print("CO2 Percentage is ");
       Serial.print((mySensor.ppm/10000));
       Serial.println("%");

    } else {
        Serial.println("Sensor communication error.");
    }
   delay(1000);
//DC Motor
  if (mySensor.ppm < 60000){
   //For Clock wise motion , in_1 = High , in_2 = Low
   digitalWrite(in_1,HIGH) ;
   digitalWrite(in_2,LOW) ;
   analogWrite(pwm,255) ;
   /* setting pwm of the motor to 255 we can change the speed of rotation
   by changing pwm input but we are only using arduino so we are using highest
   value to driver the motor */
  }
  if (mySensor.ppm > 60000){
   //For Anti Clock-wise motion - IN_1 = LOW , IN_2 = HIGH
   digitalWrite(in_1,LOW) ;
   digitalWrite(in_2,HIGH) ;
  }else{
  //For brake
   digitalWrite(in_1,HIGH) ;
   digitalWrite(in_2,HIGH) ;
  }
}
```

Conclusions/action items:

Katie Day - Apr 21, 2022, 12:42 PM CDT

Download

Coding_Spring_22.ino (2.81 kB)

4/26/2022 Recovery Testing

Katie Day - Apr 26, 2022, 9:01 PM CDT

Title: Recovery Testing

Date: 4/26/2022

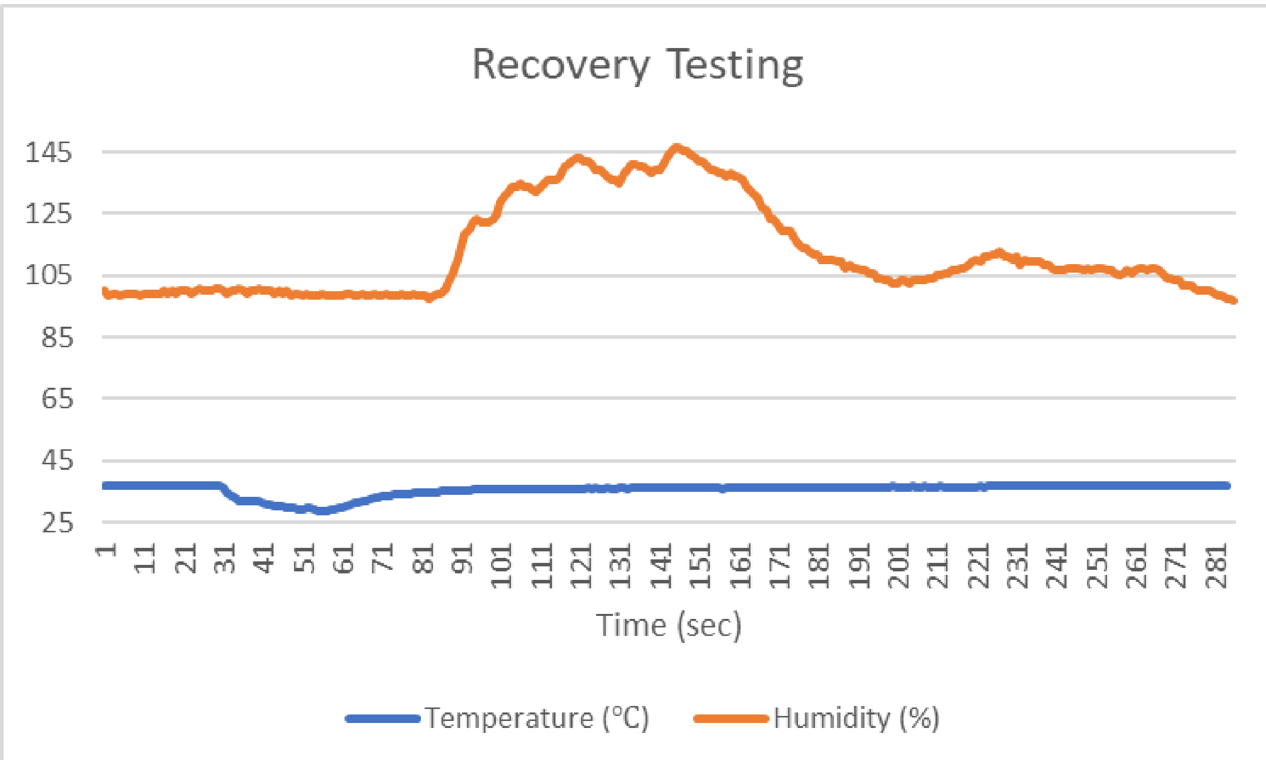
Content by: Katie Day, Maya Tanna, and Bella Raykowski

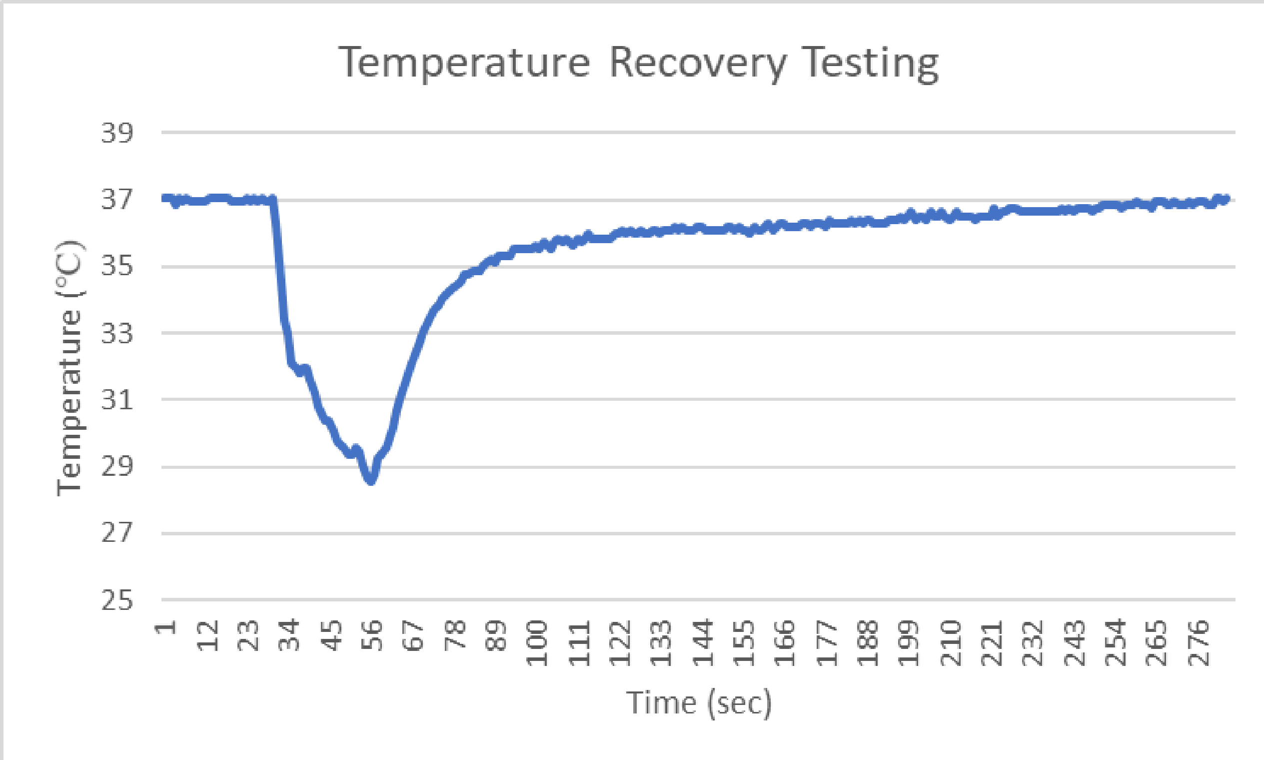
Present: Whole Group

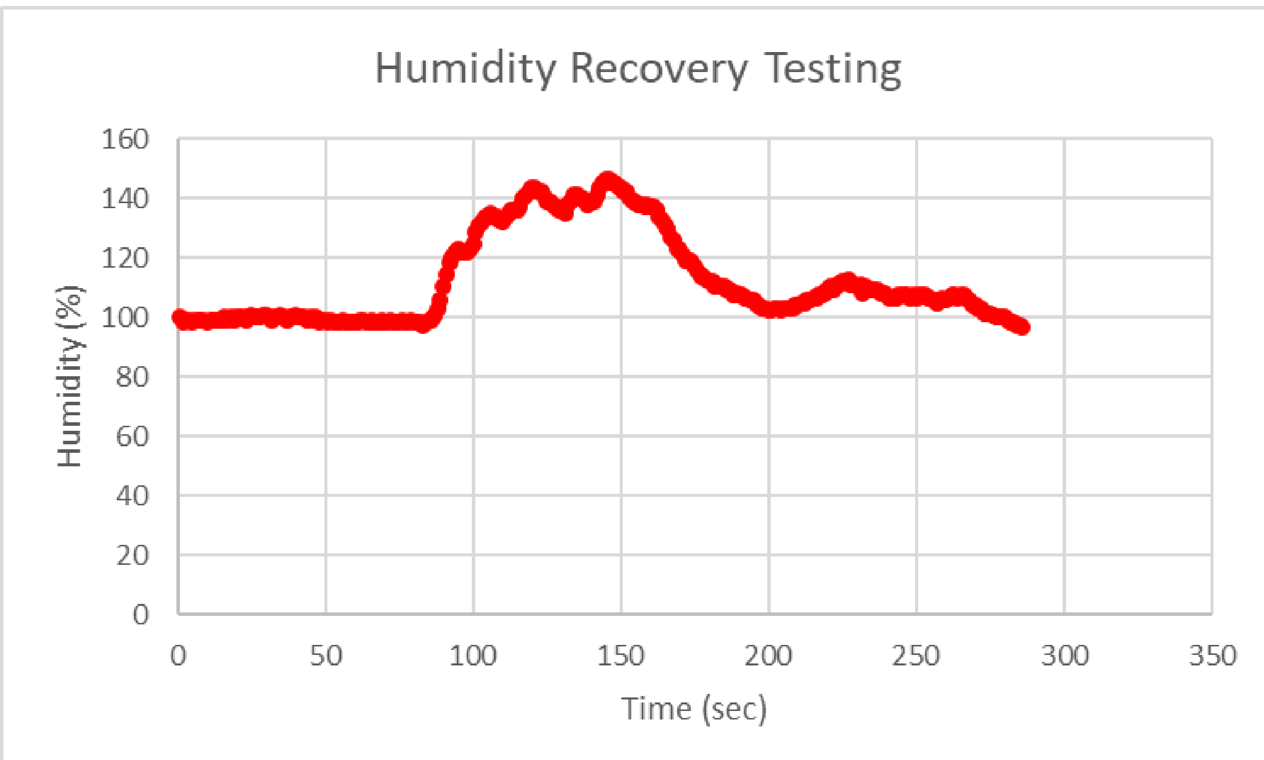
Goals: To determine the amount of time it takes the incubator to return to standard temperature and humidity after opening the box for a short amount of time.

Content:

See attached files.







Conclusions/action items:

The box meets the requirements outlined in the PDS, with an average recovery time of 3:30 per 30 seconds of disruption.

Katie Day - Apr 26, 2022, 9:00 PM CDT

Recovery Test Protocol Test 1

Introduction
Name of Tester: Maya & Katie
Dates of Test Performance: 04/26/2022
Site of Test Performance: ECB 1002

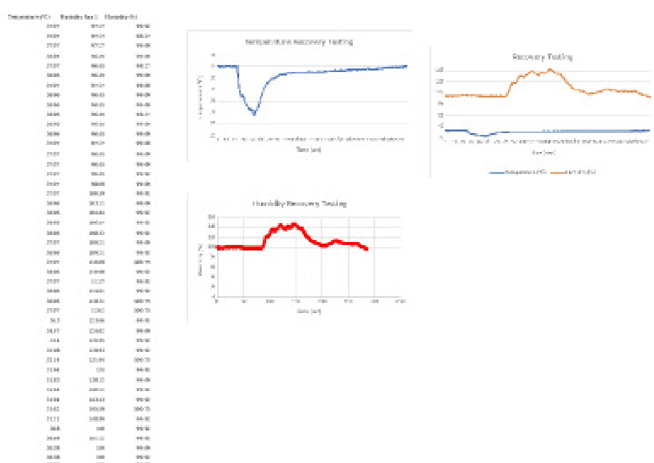
Explanation:
The team will test the recovery time of the incubator after it has been opened by timing how long it takes for the incubator to return to performance conditions (37°C, 5% CO_2, and >95% humidity). The maximum recovery time should not exceed five minutes after a 30 second exposure to the external environment.

Steps	Protocol	Verification/Validation	Pass/Fail	Tester Initials
1	Set up the incubator for normal use. Record internal conditions in the comments and verify that they fall within the correct ranges (37°C, 5% CO_2, and >95% humidity).	☑ Verified Comments: 37.07 C, 97.27%	Pass	KD/MT
2	Open the incubator for 30 seconds. Start stopwatch. Verify that the stopwatch is working.	☑ Verified Comments:	Pass	KD/MT
3	Record internal conditions in the comments at a time of 15 seconds after opening the incubator. Verify that the internal conditions deviate from the normal conditions recorded above.	☑ Verified Comments: 32.77 C, 100%	Pass	KD/MT
4	Close the incubator. Verify that the recovery time did not exceed 5 minutes after a 30 second exposure to the external environment. Record the time it took to revert back to optimal conditions in the comments.	☑ Verified Comments: It took a little over 3 min to recover from the temperature and humidity.	Pass	KD/MT

Download

Maya_Katie_Bella_Recovery_Testing.pdf (66.7 kB)

Katie Day - Apr 26, 2022, 9:01 PM CDT



Download

Recovery_Data.xlsx (34.8 kB)

2/25/22 PDS

Bella Raykowski - May 03, 2022, 10:01 PM CDT

Title: Product Design Specifications

Date: 2/25/22

Content by: Everyone

Present: Everyone

Goals: To present to our client and advisor the product design specifications of the microscopic cell culture incubator project.

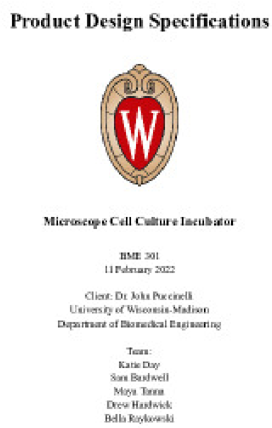
Content:

Slides are attached

Conclusions/action items:

Now that we have the constraints and direction of our project laid out we can begin fabricating

Bella Raykowski - May 03, 2022, 10:01 PM CDT



Product Design Specifications

Microscope Cell Culture Incubator

BME 301
11 February 2022

Client: Dr. John Puccinelli
University of Wisconsin-Madison
Department of Biomedical Engineering

Team:
Katie Day
Sara Bardwell
Maya Tanna
Drew Hardwick
Bella Raykowski

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Product_Design_Specifications_Spring_2022_-_Google_Docs.pdf (237 kB)

2/25/22 Preliminary Presentation Slides

SAMUEL BARDWELL - Feb 28, 2022, 12:02 PM CST

Title: Preliminary Presentation Slides

Date: 2/25/22

Content by: Everyone

Present: Everyone

Goals: To present to our client, advisor, and BME peers our preliminary understandings of the microscopic cell culture incubator project.

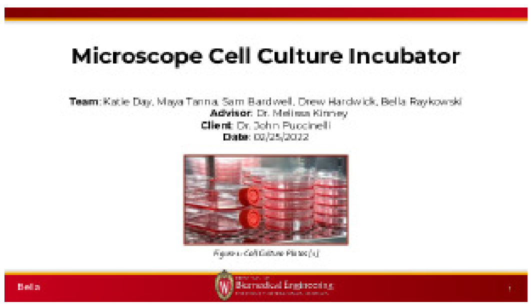
Content:

Slides are attached

Conclusions/action items:

We will use our preliminary presentation to lead us in a good direction this semester. This is only preliminary information and everything can be fluid.

SAMUEL BARDWELL - Feb 28, 2022, 12:03 PM CST



Download

Prelim_Presentation_Slides_Spring_2022.pdf (1.87 MB)

3/1/22 Preliminary Report

MAYA TANNA - Mar 01, 2022, 6:29 PM CST

Title: Preliminary Report

Date: 3/1/22

Content by: Everyone

Present: Everyone

Goals: To document our preliminary report with our preliminary understandings of the microscopic cell culture incubator project.

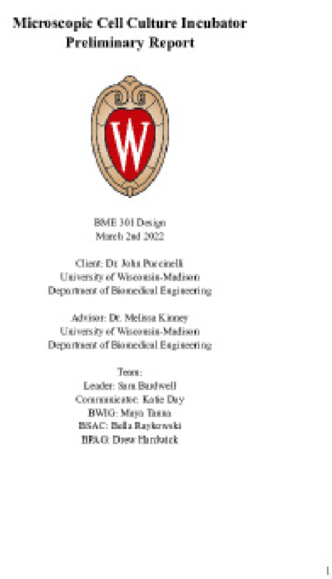
Content:

See attached file.

Conclusions/action items:

We will use our preliminary presentation to lead us in a good direction this semester, and make revisions as necessary in order to meet the needs of our client.

MAYA TANNA - Mar 01, 2022, 6:29 PM CST


Microscopic Cell Culture Incubator
Preliminary Report

BME 301 Design
March 2nd 2022

Client: Dr. John Puccinelli
University of Wisconsin-Madison
Department of Biomedical Engineering

Advisor: Dr. Melissa Kinney
University of Wisconsin-Madison
Department of Biomedical Engineering

Team:
Leader: Sara Bardwell
Communicator: Katie Day
BWIG: Maya Tanna
BSAC: Bella Raykowski
BPAG: Drew Hardtack

1

Download

Prelim_Report_Spring_2022.pdf (3.01 MB)

04/09/2022 Executive Summary Draft

Katie Day - Apr 10, 2022, 7:17 PM CDT

Title: Executive Summary Rough Draft

Date: 4/9/2022

Content by: Katie Day, Sam Bardwell, Bella Raykowski, Drew Hardwick, and Maya Tanna

Present:

Goals: To draft our executive summary detailing our design process for the BME Excellence Award.

Content:

See attached file.

Conclusions/action items:

Incorporate Dr. Kinney's feedback into the final summary.

Katie Day - Apr 10, 2022, 7:17 PM CDT

Microscopic Cell Culture Incubator

BME Design Excellence Award

Sam Bardwell, Katie Day, Maya Tanna, Drew Hardwick, Bella Raykowski

The goal of the project was to develop a low cost cell culture incubation chamber that is compatible with an inverted microscope and capable of keeping cells alive during imaging. This incubation chamber must be able to maintain an internal environment of 37°C, 5% CO_2, and 95-100% humidity over the course of 1 week, without compromising the integrity of the microscope's optics or functionality. Special consideration must be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive.

There are currently two categories of competing designs. Commercial stand-alone incubators and, less popular, commercially available stage top incubators, both of which range from $500-$40,000[1]. The most popular Thermo Fisher design is the Heracell VIOS 160i CO2 Incubator with Copper Interior Chambers, which has HEPA filtration for ISO Class 5 air quality and an overnight Steri-Run for total sterilization [2]. Commercially available stage-top incubators include those from Okolab and Elliot scientific, which have had great success in maintaining a homogeneous environment in terms of temperature and CO2 percentage [3,4].

The design process has been broken down into three main parts: circuitry, fabrication, and testing. Due to the importance of maintaining a precise internal environment for cell growth, a thermistor, NDIR CO_2 sensor, and a DC motor have been implanted for the purpose of monitoring and inputting temperature, humidity, and CO_2. The thermistor is waterproof, automatically monitors temperature, and additionally has been coded to monitor humidity. The NDIR sensor monitors the CO_2 volume and percentage inside the box. The DC motor, which is paired with a 3D printed attachment, is used to adjust the flow of 100% CO_2 from a tank so the incubator only contains 5% CO_2 at all times. The resulting final design includes a hinge-top acrylic box incubator, fabricated via laser cutting black acrylic. The current prototype is a 245x195x40mm black acrylic box with two polycarbonate glass plates on the top and bottom to allow for optical use of an inverted microscope, a top lid with a rubber lining that is secured via latches, two feet of copper tubing circling the inside, an internal water bath, and holes for the sensors and polyethylene tubing that will deliver 5% CO_2 from the 100% tank, as controlled by the DC motor. The copper tubing will allow for sufficient heat transfer to the water bath, because of high thermal transfer properties, in order to maintain an internal environment of 37°C and 95-100% humidity. The acrylic was chosen as it will provide the best internal environment, reduce the majority of leakage, and is cost efficient.

Testing protocols were written and conducted on sensory accuracy, optical clarity, and the internal environment. All sensors were tested against a commercially available incubator in the teaching lab and were determined to have no statistical significance between the sensor and incubator values. Optical clarity tests showed that there was no optical difference between slides when under the polycarbonate glass, as compared to without glass. The internal environment of the incubator was tested to ensure homogeneity and cell viability, along with recovery testing.

The low cost aspect of the incubator makes it more accessible for research labs, educational institutions, and companies to conduct live cell imaging. More users will be able to image live cells, which could greatly advance the field of pharmaceuticals, virology, and vaccine production, and genetic engineering/gene therapy.

Download

Executive_Summary_1_.pdf (65.9 kB)

4/26/2022 Final Poster

Katie Day - Apr 26, 2022, 9:03 PM CDT

Title: Final Poster

Date: 4/26/2022

Content by: Katie Day, Maya Tanna, Sam Bardwell, Bella Raykowski, and Drew Hardwick

Present:

Goals: To present the entirety of our semesters work into one final poster.

Content:

See attached file.

Conclusions/action items:

Continue the project next semester focusing on CO2 input, live cell imaging, and a professional interior and exterior.

Katie Day - Apr 26, 2022, 9:03 PM CDT

Download

Final_Poster.pdf (3.47 MB)

5/3/22 Final Report

SAMUEL BARDWELL - May 03, 2022, 7:34 PM CDT

Title: Final Report

Date: 5/3/22

Content by: Everyone

Goals: To write a report about the semester's project.

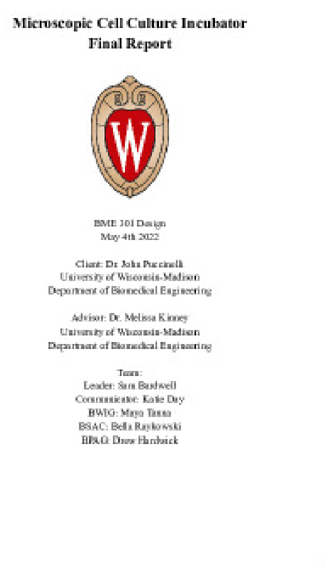
Content:

* See attached file

Conclusions/action items:

Continue the project next semester focusing on CO2 input, live cell imaging, and having a professional interior and exterior design.

SAMUEL BARDWELL - May 03, 2022, 7:36 PM CDT



Microscopic Cell Culture Incubator
Final Report

BME 301 Design
May 4th 2022

Client: Dr. John Puccinelli
University of Wisconsin-Madison
Department of Biomedical Engineering

Advisor: Dr. Melissa Kinney
University of Wisconsin-Madison
Department of Biomedical Engineering

Team:
Leader: Sam Bardwell
Communicator: Katie Day
BWIG: Maya Tanna
BSAC: Bella Raykowski
BPAG: Drew Hardwick

1

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Final_Report_Spring_2022.pdf (11.9 MB)

2/3/2022 Progress Report 1

Katie Day - Feb 10, 2022, 9:44 AM CST

Title: Progress Report 1

Date: 2/3/2022

Content by: Katie Day, Sam Bardwell, Maya Tanna, Drew Hardwick, Bella Raykowski

Present:

Goals: To inform our advisor and our client of our weekly activities and progress on the project.

Content:

See attached file.

Conclusions/action items:

See attached file.

Katie Day - Feb 10, 2022, 9:45 AM CST

Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:

- Leader: Sara Bardwell
- Communicator: Katie McGovern
- BWIG: Maya Tanna
- BSAC: Bella Raykowski
- BPAG: Drew Hardwick

Date: 2/3/2022

Problem Statement:

Develop a low cost cell culture incubation chamber that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update:

This week the team picked their subsequent roles for the project, updated our webpage, and arranged to meet with the client. For our client meeting, we prepared questions and began thoroughly researching different materials for the incubator and better ways to insulate the design.

Summary of Weekly Team Member Design Accomplishments

- Team- Conducted preliminary research. The team also met with the client to discuss his opinion on the project last semester and ask questions on different areas of improvement for this semester. The team also picked a time to meet outside of the allotted time on Friday, as well as set up a time to meet with our advisor.
- Sara- Conducted research on thermal properties for copper and water in order to start making mathematical calculations on heating the incubator water bed. Met with the client in order to discuss any changes or parts to keep working on this semester.
- Katie- Contacted the client to set up an initial meeting, where we met with the client to discuss the successes of last semester, areas of improvement, and our goals for the coming months. I also began researching better ways to measure the humidity of the incubator as well as attempting to fit all of the electronics on one breadboard for simplification.
- Maya- Updated website with team picture and team roles, did research on how copper prevents contamination within incubator systems as well as electrical/thermal properties of copper and

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cell_incubator-progress_report_1.pdf (78.6 kB)

2/10/2022 Progress Report 2

Katie Day - Feb 10, 2022, 9:45 AM CST

Title: Progress Report 2

Date: 2/10/2022

Content by: Katie Day, Sam Bardwell, Maya Tanna, Drew Hardwick, Bella Raykowski

Present:

Goals: To inform our advisor and our client of our weekly activities and progress on the project.

Content:

See attached file.

Conclusions/action items:

See attached file.

Katie Day - Feb 10, 2022, 9:45 AM CST

Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:

- Leader: Sara Bardwell
- Communicator: Katie McGovern
- BWIG: Maya Tanna
- BSAC: Bella Raykowski
- BPAG: Drew Hardwick

Date: 2/10/2022

Problem Statement:

Develop a low cost cell culture incubation chamber that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO_2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update:

The team updated the PDS from last semester, putting in the new requirements for the design and more quantitative information that was gathered. The team also decided on roles for the semester, breaking off into teams to accomplish all of our semester goals.

Summary of Weekly Team Member Design Accomplishments

- Team- The team updated and submitted the PDS for this semester. The team divided ourselves into different groups, testing/optics, electronics, CO_2, and fabrication, in order to make better use of our time during the semester. Drew and Bella were also shown our previous design to get a better understanding of the project overall.
- Sara- Continued to do more research on thermal properties between water and copper. Got certified to use the laser cutter in the Makerspace. Used Makerspace resources to begin developing drawings of a laser cut box. Began to create SOLIDWORKS drawings.
- Katie- I researched a couple of different ways to calculate humidity based on outputted temperature which can be tested later in the design stage. Helped update the PDS with the team. Communicated with the client to gain access to different lab rooms and coordinated getting more electronics materials from Drew, Bella, and Maya.

Download

cell_incubator-progress_report_2.pdf (79 kB)

2/17/2022 Progress Report 3

SAMUEL BARDWELL - Feb 28, 2022, 12:07 PM CST

Title: Progress Report 3

Date: 2/17/2022

Content by: Katie Day, Sam Bardwell, Maya Tanna, Drew Hardwick, Bella Raykowski

Goals: To inform our advisor and our client of our weekly activities and progress on the project.

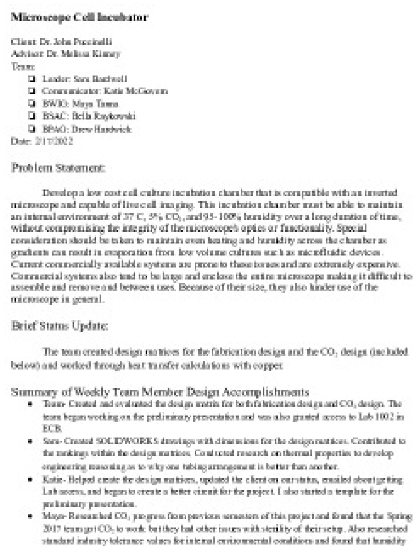
Content:

See attached file.

Conclusions/action items:

See attached file.

SAMUEL BARDWELL - Feb 28, 2022, 12:07 PM CST



Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:
- Leader: Sam Bardwell
- Communicator: Katie McGovern
- BWIG: Maya Tanna
- BSAC: Bella Raykowski
- BPAG: Drew Hardwick

Date: 2/17/2022

Problem Statement:

Develop a low cost cell culture incubation chamber that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO_2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update:

The team created design matrices for the fabrication design and the CO_2 design (included below) and worked through heat transfer calculations with copper.

Summary of Weekly Team Member Design Accomplishments
- Team- Created and evaluated the design matrix for both fabrication design and CO_2 design. The team began working on the preliminary presentation and was also granted access to Lab 1002 in ECB.
- Sam- Created SOLIDWORKS drawings with dimensions for the design matrices. Contributed to the rankings within the design matrices. Conducted research on thermal properties to develop engineering reasoning as to why one tubing arrangement is better than another.
- Katie- Helped create the design matrices, updated the client on our status, emailed about getting Lab access, and began to create a better circuit for the project. I also started a template for the preliminary presentation.
- Maya- Researched CO_2 progress from previous semesters of this project and found that the Spring 2017 team got CO_2 to work but they had other issues with sterility of their setup. Also researched standard industry tolerance values for internal environmental conditions and found that humidity

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cell_incubator-progress_report_3.pdf (1.14 MB)

2/24/2022 Progress Report 4

SAMUEL BARDWELL - Feb 28, 2022, 12:08 PM CST

Title: Progress Report 4

Date: 2/24/2022

Content by: Katie Day, Sam Bardwell, Maya Tanna, Drew Hardwick, Bella Raykowski

Goals: To inform our advisor and our client of our weekly activities and progress on the project.

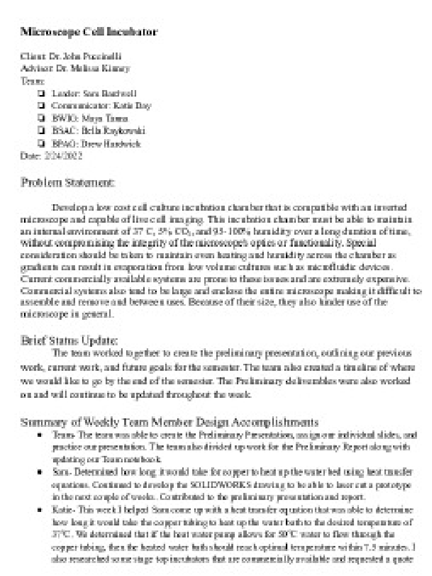
Content:

See attached file.

Conclusions/action items:

See attached file.

SAMUEL BARDWELL - Feb 28, 2022, 12:08 PM CST



Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:

- Leader: Sam Bardwell
- Communicator: Katie Day
- BWIG: Maya Tanna
- BSAC: Bella Raykowski
- BPAG: Drew Hardwick

Date: 2/24/2022

Problem Statement:

Develop a low cost cell culture incubation chamber that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO_2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update:

The team worked together to create the preliminary presentation, outlining our previous work, current work, and future goals for the semester. The team also created a timeline of where we would like to go by the end of the semester. The Preliminary deliverables were also worked on and will continue to be updated throughout the week.

Summary of Weekly Team Member Design Accomplishments

- Team- The team was able to create the Preliminary Presentation, assign our individual slides, and practice our presentation. The team also divided up work for the Preliminary Report along with updating our Team notebook.
- Sam- Determined how long it would take for copper to heat up the water bed using heat transfer equations. Continued to develop the SOLIDWORKS drawing to be able to laser cut a prototype in the next couple of weeks. Contributed to the preliminary presentation and report.
- Katie- This week I helped Sam come up with a heat transfer equation that was able to determine how long it would take the copper tubing to heat up the water bath to the desired temperature of 37°C. We determined that if the heat water pump allows for 50°C water to flow through the copper tubing, then the heated water bath should reach optimal temperature within 7.5 minutes. I also researched some stage top incubators that are commercially available and requested a quote

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cell_incubator-progress_report_4.pdf (78.4 kB)

3/3/2022 Progress Report 5

Bella Raykowski - Apr 12, 2022, 11:24 AM CDT

Title: Progress Report 5

Date: 3/3/2022

Content by: Katie Day, Sam Bardwell, Maya Tanna, Drew Hardwick, Bella Raykowski

Goals: To inform our advisor and our client of our weekly activities and progress on the project.

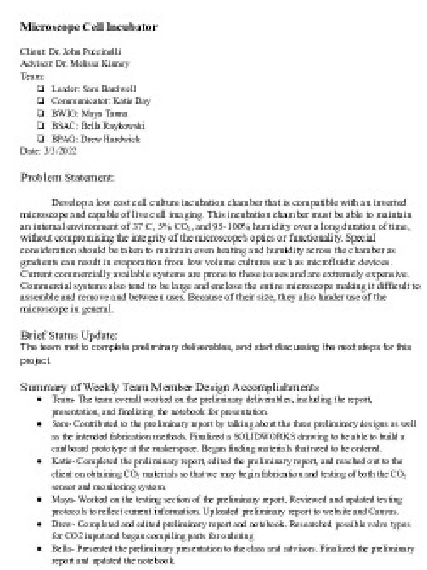
Content:

See attached file.

Conclusions/action items:

See attached file.

Bella Raykowski - Apr 12, 2022, 11:24 AM CDT



Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:
- Leader: Sam Bardwell
- Communicator: Katie Day
- BWIG: Maya Tanna
- BSAC: Bella Raykowski
- BPAG: Drew Hardwick

Date: 3/3/2022

Problem Statement:

Develop a low cost cell culture incubation chamber that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO_2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update:
The team met to complete preliminary deliverables, and start discussing the next steps for this project.

Summary of Weekly Team Member Design Accomplishments:
- Team- The team overall worked on the preliminary deliverables, including the report, presentation, and finalizing the notebook for presentation.
- Sam- Contributed to the preliminary report by talking about the three preliminary designs as well as the intended fabrication methods. Finalized a SOLIDWORKS drawing to be able to build a cardboard prototype at the makerspace. Began finding materials that need to be ordered.
- Katie- Completed the preliminary report, edited the preliminary report, and reached out to the client on obtaining CO_2 materials so that we may begin fabrication and testing of both the CO_2 sensor and monitoring system.
- Maya- Worked on the testing section of the preliminary report. Reviewed and updated testing protocols to reflect current information. Uploaded preliminary report to website and Canvas.
- Drew- Completed and edited preliminary report and notebook. Researched possible valve types for CO2 input and began compiling parts for ordering.
- Bella- Presented the preliminary presentation to the class and advisors. Finalized the preliminary report and updated the notebook.

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cell_incubator-progress_report_5_-_Google_Docs.pdf (94 kB)

3/10/2022 Progress Report 6

Bella Raykowski - Apr 12, 2022, 11:25 AM CDT

Title: Progress Report 6

Date: 3/10/2022

Content by: Katie Day, Sam Bardwell, Maya Tanna, Drew Hardwick, Bella Raykowski

Goals: To inform our advisor and our client of our weekly activities and progress on the project.

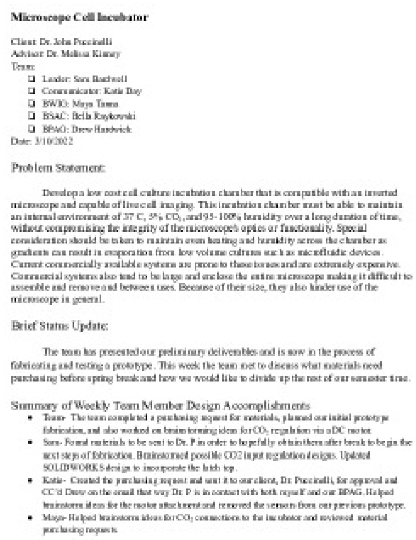
Content:

See attached file.

Conclusions/action items:

See attached file.

Bella Raykowski - Apr 12, 2022, 11:25 AM CDT



Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:

- Leader: Sam Bardwell
- Communicator: Katie Day
- BWIG: Maya Tanna
- BSAC: Bella Raykowski
- BPAG: Drew Hardwick

Date: 3/10/2022

Problem Statement:

Develop a low cost cell culture incubation chamber that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO_2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update:

The team has presented our preliminary deliverables and is now in the process of fabricating and testing a prototype. This week the team met to discuss what materials need purchasing before spring break and how we would like to divide up the rest of our semester time.

Summary of Weekly Team Member Design Accomplishments

- Team- The team completed a purchasing request for materials, planned our initial prototype fabrication, and also worked on brainstorming ideas for CO_2 regulation via a DC motor.
- Sam- Found materials to be sent to Dr. P in order to hopefully obtain them after break to begin the next steps of fabrication. Brainstormed possible CO2 input regulation designs. Updated SOLIDWORKS design to incorporate the latch top.
- Katie- Created the purchasing request and sent it to our client, Dr. Puccinelli, for approval and CC'd Drew on the email that way Dr. P is in contact with both myself and our BPAG. Helped brainstorm ideas for the motor attachment and removed the sensors from our previous prototype.
- Maya- Helped brainstorm ideas for CO_2 connections to the incubator and reviewed material purchasing requests.

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cell_incubator-progress_report_6_-_Google_Docs.pdf (94.2 kB)

3/24/2022 Progress Report 7

Bella Raykowski - Apr 12, 2022, 11:26 AM CDT

Title: Progress Report 7

Date: 3/24/2022

Content by: Katie Day, Sam Bardwell, Maya Tanna, Drew Hardwick, Bella Raykowski

Goals: To inform our advisor and our client of our weekly activities and progress on the project.

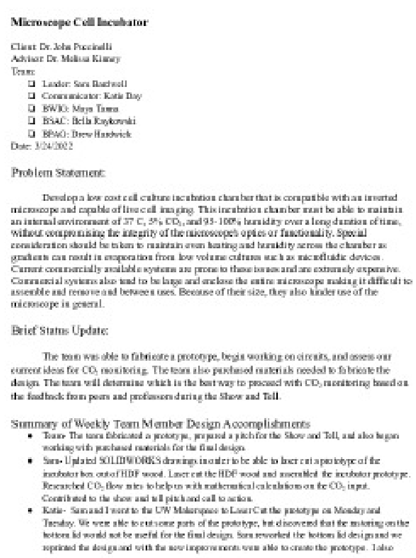
Content:

See attached file.

Conclusions/action items:

See attached file.

Bella Raykowski - Apr 12, 2022, 11:27 AM CDT



Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:

- Leader: Sam Bardwell
- Communicator: Katie Day
- BWIG: Maya Tanna
- BSAC: Bella Raykowski
- BPAG: Drew Hardwick

Date: 3/24/2022

Problem Statement:

Develop a low cost cell culture incubation chamber that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO_2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update:

The team was able to fabricate a prototype, begin working on circuits, and assess our current ideas for CO_2 monitoring. The team also purchased materials needed to fabricate the design. The team will determine which is the best way to proceed with CO_2 monitoring based on the feedback from peers and professors during the Show and Tell.

Summary of Weekly Team Member Design Accomplishments

- Team- The team fabricated a prototype, prepared a pitch for the Show and Tell, and also began working with purchased materials for the final design.
- Sam- Updated SOLIDWORKS drawings in order to be able to laser cut a prototype of the incubator box out of HDF wood. Laser cut the HDF wood and assembled the incubator prototype. Researched CO_2 flow rates to help us with mathematical calculations on the CO_2 input. Contributed to the show and tell pitch and call to action.
- Katie- Sam and I went to the UW Makerspace to Laser Cut the prototype on Monday and Tuesday. We were able to cut some parts of the prototype, but discovered that the texturing on the bottom lid would not be useful for the final design. Sam reworked the bottom lid design and we reprinted the design and with the new improvements were able to create the prototype. I also

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cell_incubator-progress_report_7_-_Google_Docs.pdf (97.9 kB)

3/31/2022 Progress Report 8

Bella Raykowski - Apr 12, 2022, 11:27 AM CDT

Title: Progress Report 8

Date: 3/31/2022

Content by: Katie Day, Sam Bardwell, Maya Tanna, Drew Hardwick, Bella Raykowski

Goals: To inform our advisor and our client of our weekly activities and progress on the project.

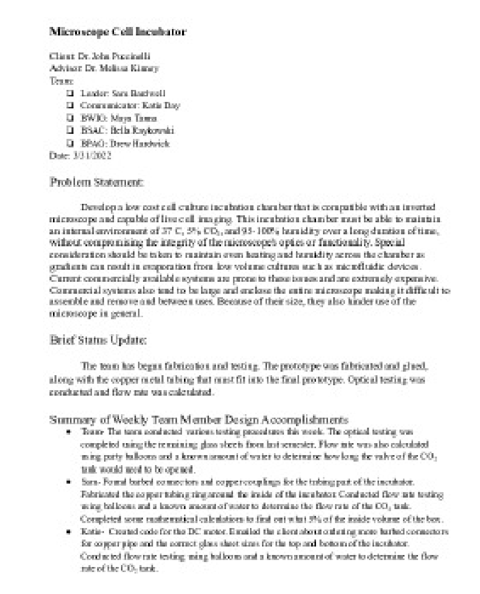
Content:

See attached file.

Conclusions/action items:

See attached file.

Bella Raykowski - Apr 12, 2022, 11:27 AM CDT



Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:
- Leader: Sam Bardwell
- Communicator: Katie Day
- BWIG: Maya Tanna
- BSAC: Bella Raykowski
- BPAG: Drew Hardwick

Date: 3/31/2022

Problem Statement:

Develop a low cost cell culture incubation chamber that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO_2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update:

The team has begun fabrication and testing. The prototype was fabricated and glued, along with the copper metal tubing that must fit into the final prototype. Optical testing was conducted and flow rate was calculated.

Summary of Weekly Team Member Design Accomplishments
- Team- The team conducted various testing procedures this week. The optical testing was completed using the remaining glass sheets from last semester. Flow rate was also calculated using party balloons and a known amount of water to determine how long the valve of the CO_2 tank would need to be opened.
- Sam- Found barbed connectors and copper couplings for the tubing part of the incubator. Fabricated the copper tubing ring around the inside of the incubator. Conducted flow rate testing using balloons and a known amount of water to determine the flow rate of the CO_2 tank. Completed some mathematical calculations to find out what 5% of the inside volume of the box.
- Katie- Created code for the DC motor. Emailed the client about ordering more barbed connectors for copper pipe and the correct glass sheet sizes for the top and bottom of the incubator. Conducted flow rate testing using balloons and a known amount of water to determine the flow rate of the CO_2 tank.

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cell_incubator-progress_report_8_-_Google_Docs.pdf (99.5 kB)

4/7/2022 Progress Report 9

Bella Raykowski - Apr 12, 2022, 11:28 AM CDT

Title: Progress Report 9

Date: 4/7/2022

Content by: Katie Day, Sam Bardwell, Maya Tanna, Drew Hardwick, Bella Raykowski

Goals: To inform our advisor and our client of our weekly activities and progress on the project.

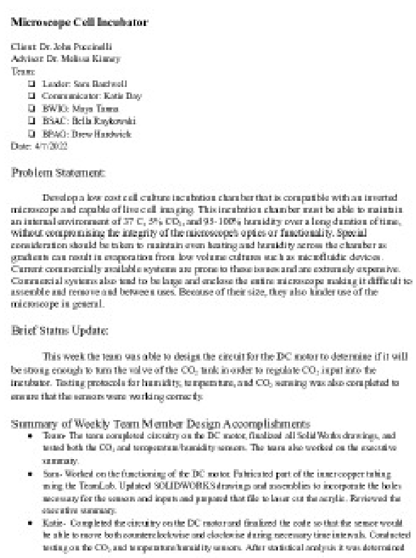
Content:

See attached file.

Conclusions/action items:

See attached file.

Bella Raykowski - Apr 12, 2022, 11:28 AM CDT



Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:
- Leader: Sam Bardwell
- Communicator: Katie Day
- BWIG: Maya Tanna
- BSAC: Bella Raykowski
- BPAG: Drew Hardwick

Date: 4/7/2022

Problem Statement:

Develop a low cost cell culture incubation chamber that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO_2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update:

This week the team was able to design the circuit for the DC motor to determine if it will be strong enough to turn the valve of the CO_2 tank in order to regulate CO_2 input into the incubator. Testing protocols for humidity, temperature, and CO_2 sensing was also completed to ensure that the sensors were working correctly.

Summary of Weekly Team Member Design Accomplishments
- Team- The team completed circuitry on the DC motor, finalized all SolidWorks drawings, and tested both the CO_2 and temperature/humidity sensors. The team also worked on the executive summary.
- Sam- Worked on the functioning of the DC motor. Fabricated part of the inner copper tubing using the TeamLab. Updated SOLIDWORKS drawings and assemblies to incorporate the holes necessary for the sensors and inputs and prepared that file to laser cut the acrylic. Reviewed the executive summary.
- Katie- Completed the circuitry on the DC motor and finalized the code so that the sensor would be able to move both counterclockwise and clockwise during necessary time intervals. Conducted testing on the CO_2 and temperature/humidity sensors. After statistical analysis it was determined

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cell_incubator-progress_report_9_-_Google_Docs.pdf (97.5 kB)

4/14/2022 Progress Report 10

Bella Raykowski - May 03, 2022, 11:08 AM CDT

Title: Progress Report 10

Date: 4/14/2022

Content by: Katie Day, Sam Bardwell, Maya Tanna, Drew Hardwick, Bella Raykowski

Goals: To inform our advisor and our client of our weekly activities and progress on the project.

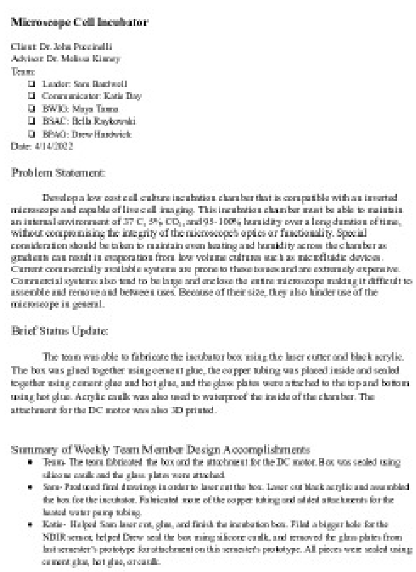
Content:

See attached file.

Conclusions/action items:

See attached file.

Bella Raykowski - May 03, 2022, 11:08 AM CDT



Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:
- Leader: Sam Bardwell
- Communicator: Katie Day
- BWIG: Maya Tanna
- BSAC: Bella Raykowski
- BPAG: Drew Hardwick

Date: 4/14/2022

Problem Statement:

Develop a low cost cell culture incubation chamber that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO_2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update:

The team was able to fabricate the incubator box using the laser cutter and black acrylic. The box was glued together using cement glue, the copper tubing was placed inside and sealed together using cement glue and hot glue, and the glass plates were attached to the top and bottom using hot glue. Acrylic caulk was also used to waterproof the inside of the chamber. The attachment for the DC motor was also 3D printed.

Summary of Weekly Team Member Design Accomplishments

- Team- The team fabricated the box and the attachment for the DC motor. Box was sealed using silicone caulk and the glass plates were attached.
- Sam- Produced final drawings in order to laser cut the box. Laser cut black acrylic and assembled the box for the incubator. Fabricated more of the copper tubing and added attachments for the heated water pump tubing.
- Katie- Helped Sam laser cut, glue, and finish the incubation box. Filed a bigger hole for the NDIR sensor, helped Drew seal the box using silicone caulk, and removed the glass plates from last semester's prototype for attachment on this semester's prototype. All pieces were sealed using cement glue, hot glue, or caulk.

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cell_incubator-progress_report_10_-_Google_Docs.pdf (101 kB)

4/21/2022 Progress Report 11

Bella Raykowski - May 03, 2022, 11:09 AM CDT

Title: Progress Report 11

Date: 4/21/2022

Content by: Katie Day, Sam Bardwell, Maya Tanna, Drew Hardwick, Bella Raykowski

Goals: To inform our advisor and our client of our weekly activities and progress on the project.

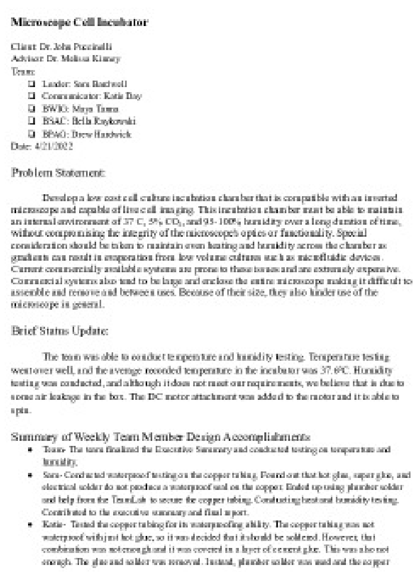
Content:

See attached file.

Conclusions/action items:

See attached file.

Bella Raykowski - May 03, 2022, 11:09 AM CDT



Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:

- Leader: Sam Bardwell
- Communicator: Katie Day
- BWIG: Maya Tanna
- BSAC: Bella Raykowski
- BPAG: Drew Hardwick

Date: 4/21/2022

Problem Statement:

Develop a low cost cell culture incubation chamber that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO_2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update:

The team was able to conduct temperature and humidity testing. Temperature testing went over well, and the average recorded temperature in the incubator was 37.6°C. Humidity testing was conducted, and although it does not meet our requirements, we believe that is due to some air leakage in the box. The DC motor attachment was added to the motor and it is able to spin.

Summary of Weekly Team Member Design Accomplishments

- Team- The team finalized the Executive Summary and conducted testing on temperature and humidity.
- Sam- Conducted waterproof testing on the copper tubing. Found out that hot glue, super glue, and electrical solder do not produce a waterproof seal on the copper. Ended up using plumber solder and help from the TeamLab to secure the copper tubing. Conducting heat and humidity testing. Contributed to the executive summary and final report.
- Katie- Tested the copper tubing for its waterproofing ability. The copper tubing was not waterproof with just hot glue, so it was decided that it should be soldered. However, that combination was not enough and it was covered in a layer of cement glue. This was also not enough. The glue and solder was removed. Instead, plumber solder was used and the copper

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cell_incubator-progress_report_11_-_Google_Docs.pdf (103 kB)

4/28/2022 Progress Report 12

Bella Raykowski - May 03, 2022, 11:09 AM CDT

Title: Progress Report 12

Date: 4/28/2022

Content by: Katie Day, Sam Bardwell, Maya Tanna, Drew Hardwick, Bella Raykowski

Goals: To inform our advisor and our client of our weekly activities and progress on the project.

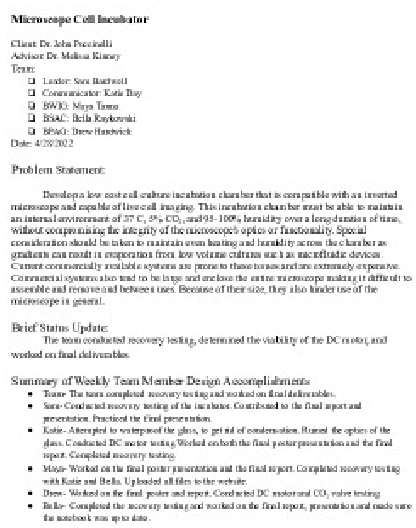
Content:

See attached file.

Conclusions/action items:

See attached file.

Bella Raykowski - May 03, 2022, 11:10 AM CDT



Microscope Cell Incubator

Client: Dr. John Puccinelli
Advisor: Dr. Melissa Kinney
Team:
- Leader: Sara Bardwell
- Communicator: Katie Day
- BWIG: Maya Tanna
- BSAC: Bella Raykowski
- BPAG: Drew Hardwick

Date: 4/28/2022

Problem Statement:

Develop a low cost cell culture incubation chamber that is compatible with an inverted microscope and capable of live cell imaging. This incubation chamber must be able to maintain an internal environment of 37 C, 5% CO_2, and 95-100% humidity over a long duration of time, without compromising the integrity of the microscope's optics or functionality. Special consideration should be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive. Commercial systems also tend to be large and enclose the entire microscope making it difficult to assemble and remove and between uses. Because of their size, they also hinder use of the microscope in general.

Brief Status Update:

The team conducted recovery testing, determined the viability of the DC motor, and worked on final deliverables.

Summary of Weekly Team Member Design Accomplishments:
- Team- The team completed recovery testing and worked on final deliverables.
- Sara- Conducted recovery testing of the incubator. Contributed to the final report and presentation. Practiced the final presentation.
- Katie- Attempted to waterproof the glass, to get rid of condensation. Ruined the optics of the glass. Conducted DC motor testing. Worked on both the final poster presentation and the final report. Completed recovery testing.
- Maya- Worked on the final poster presentation and the final report. Completed recovery testing with Katie and Bella. Uploaded all files to the website.
- Drew- Worked on the final poster and report. Conducted DC motor and CO_2 valve testing.
- Bella- Completed the recovery testing and worked on the final report, presentation and made sure the notebook was up to date.

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cell_incubator-progress_report_12_-_Google_Docs.pdf (98.3 kB)

1/31/22 Copper Thermal Conductivity

SAMUEL BARDWELL - Jan 31, 2022, 8:13 PM CST

Title: Copper Thermal Conductivity

Date: 1/31/22

Content by: Sam

Goals: To research the conductivity of copper to find a more efficient way to heat up the inside of the incubator.

Content:

Link: https://collegedunia.com/exams/thermal-conductivity-of-copper-propertiestesting-methods-application-physics-articleid-941

Cite:

"Thermal Conductivity of Copper: Properties,Testing Methods, Application," *Collegedunia*, Sep. 23, 2021. https://collegedunia.com/exams/thermal-conductivity-of-copper-propertiestesting-methods-application-physics-articleid-941 (accessed Jan. 31, 2022).

Notes:

- The thermal conductivity of copper is 400 W/mK

- The coefficient of thermal conductivity of Copper is 385 W/mK

- Copper has a moderate corrosions rate and a high melting point

- Fourier's Law for heat conduction or the law of thermal conduction

- Thermal Conductivity is expressed by $q = -k.\nabla T$

Where

q → Heat flux or thermal flux ($W.m^{-2}$)

k → Thermal conductivity ($W.m^{-1}.K^{-1}$)

∇T → Temperature gradient ($K.m^{-1}$)

Conclusions/action items:

These values for copper will most likely be used to provide some mathematical analysis of the conduction of the heated water pump and hopefully provide a rough estimate of how long it will take the water bed to be heated up to the desired temperature. Next will be to find the same information for water and then compare the values in order to find out how long the bed of water will take to be heated up with various assumptions.

1/31/22 Thermal Conductivity of Water

SAMUEL BARDWELL - Jan 31, 2022, 8:41 PM CST

Title: Thermal Conductivity of Water

Date: 1/31/22

Content by: Sam

Goals: To research thermal conductivity properties of water.

Content:

Link: https://www.engineeringtoolbox.com/water-liquid-gas-thermal-conductivity-temperature-pressure-d_2012.html

Cite:

"Water - Thermal Conductivity vs. Temperature." https://www.engineeringtoolbox.com/water-liquid-gas-thermal-conductivity-temperature-pressure-d_2012.html (accessed Jan. 31, 2022).

Notes:

- Thermal conductivity is a material property that describes ability to conduct heat

- The thermal conductivity of water at 20, 30, and 40 degrees Celsius is 598.03, 614.50, and 628.56 mW/m*K

*Table 1: Thermal conductivity of water in mW/m*K at different temperatures.*

State of water	Temperature	Thermal conductivity		
	[°C]	[mW/m K]	[kcal(IT)/(h m K)]	[Btu(IT)/(h ft °F)]
Liquid	0.01	555.75	0.4779	0.3211
	10	578.64	0.4975	0.3343
	20	598.03	0.5142	0.3455
	30	614.50	0.5284	0.3551
	40	628.56	0.5405	0.3632
	50	640.60	0.5508	0.3701
	60	650.91	0.5597	0.3761
	70	659.69	0.5672	0.3812
	80	667.02	0.5735	0.3854
	90	672.88	0.5786	0.3888
	99.6	677.03	0.5821	0.3912

Conclusions/action items:

This table of thermal conductivity of water at different temperatures can be used to help approximate how long it will take a certain amount of water to heat up to a desired temperature using a copper heating element. How to connect the thermal values of copper and water should be researched next and then mathematical calculations can be conducted.

2/2/22 Heat Transfer Calculations

SAMUEL BARDWELL - Feb 15, 2022, 7:48 PM CST

Title: Heat Transfer Calculations

Date: 2/2/22

Content by: Sam

Goals: To provide mathematical analysis and calculations to find out how long it will take to theoretically heat up the water bed inside of the incubator.

Content:

- If copper is heated up to 37 degrees C, what is the exact surface area of copper that will be touching the water bed?

SA = 2(pi)(r)(h) + 2(pi)(r^2)

3 ft of copper tubing

SA = 2 (pi) (4.7625) (914.4) = 27362.2 mm^2

- How many Joules will be produced in heat by the copper if it is set at 37 degrees Celsius?

@ 37 degrees Celsius = 70,266.7 J

58.55 minutes to heat from 20 C to 37 C

@ 40 degrees C = 75,964 J

@ 45 degrees C = 85,459.5 J

@ 50 degrees C = 94,955 J

@ 55 degrees C = 104,450.5 J

@ 60 degrees C = 113,946 J

- What is the exact amount of water in the water bed? How many Watts and/or Joules will it take to heat up a liter of water from 20 to 37 degrees Celsius?

1 liter of water

It will take approximately 20 Watts to heat up 1 liter of water from 20 degree Celsius to 37 degrees Celsius.

Link for water heating calculator: https://bloglocation.com/art/water-heating-calculator-for-time-energy-power

- How much heat will the copper absorb/transfer from the 37 degree Celsius water?

0.385 J/g degree C

- How long will it take the copper to heat up the water bed from 20 to 37 degrees Celsius?

Q = h * A * (T(t) = Tenv)

Q = rate of heat transfer

h = heat transfer coefficient

A = SA

T = Time dependent temperature

T env = Environment temperature

Conclusions/action items:

2/22/22 Heat Transfer Calculations Continued

SAMUEL BARDWELL - Feb 22, 2022, 6:06 PM CST

Title: Heat Transfer Calculations Continued

Date: 2/22/22

Content by: Sam

Goals: To use thermal equations and calculations to determine how long it will take the copper tubing to heat up the 1 liter water bed.

Content:

Link: https://en.wikipedia.org/wiki/Copper_in_heat_exchangers#Thermal_conductivity

Cite:

> "Copper in heat exchangers," *Wikipedia*. Jan. 27, 2022. Accessed: Feb. 22, 2022. [Online]. Available: https://en.wikipedia.org/w/index.php?title=Copper_in_heat_exchangers&oldid=1068258477

Notes:

Thermal conductivity of some common metals[6]

Metal	Thermal conductivity	
	(Btu/(hr-ft-F))	(W/(m•K))
Silver	247.87	429
Copper	231	399
Gold	183	316
Aluminium	136	235
Yellow brass	69.33	120
Cast iron	46.33	80.1
Stainless steel	8.1	14.0

Link: http://www.matweb.com/tools/unitconverter.aspx?fromID=10&fromValue=118

Cite: "Unit of Measure Converter." http://www.matweb.com/tools/unitconverter.aspx?fromID=10&fromValue=118 (accessed Feb. 22, 2022).

Notes:

- Useful for unit conversions. Especially for energy conversions

Link: https://www.google.com/search?q=k+of+water&source=lmns&bih=569&biw=1280&rlz=1C1CHBF_enUS985US985&hl=en&sa=X&ved=2ahUKEwies7PF8pP2AhV1hGoFHXiRAkoQ_AUoAHoECAEQAA

Cite: "Specific heat capacity - Wikipedia." https://en.wikipedia.org/wiki/Specific_heat_capacity (accessed Feb. 22, 2022).

Notes:

- The specific heat of water at 20 *C is about 4184 $J \cdot kg^{-1} \cdot K^{-1}$

Link: https://study.com/academy/lesson/heat-transfer-through-conduction-equation-examples.html

Cite: "Heat Transfer Through Conduction: Equation & Examples - Video & Lesson Transcript," *Study.com*. https://study.com/academy/lesson/heat-transfer-through-conduction-equation-examples.html (accessed Feb. 22, 2022).

Notes:

- Helpful equations for heat transfer and conduction

Q/t : The amount of heat transferred per second, measured in Joules per second, or Watts.

k: The thermal conductivity of the material (copper has a thermal conductivity of 390)

T2 - T1: The temperature difference

d: The thickness of the material

A: Surface Area

$$\frac{Q}{t} = \frac{kA(T_2 - T_1)}{d}$$

Conclusions/action items:

If the heated water pump water is heated up to 50 *C, the water bath with take approximately 7.5 minutes to reach 37 *C by heating through the copper tubing. If the water pump is only set to 37*C, the water bath would take approximately 13 minutes to reach 37*C. The plan is to use the higher temperature initially to get the water bath heated up as fast as possible. Once the water bed is set to the correct temperature, the heated water pump will be set to 38*C to keep the correct internal temperature constant and to account for any heat loss do to the initial tubing from the heated water pump and the acrylic box.

2/24/22 EVOS Onstage Incubator

SAMUEL BARDWELL - Feb 28, 2022, 12:35 PM CST

Title: EVOS Onstage Incubator

Date: 2/24/22

Content by: Sam

Goals: To research other on stage incubator designs to get an hopefully get ideas for improvements to our incubator.

Content:

Link: https://www.thermofisher.com/order/catalog/product/AMC1000

Cite: "EVOS^{TM} Onstage Incubator." https://www.thermofisher.com/order/catalog/product/AMC1000 (accessed Feb. 28, 2022).

Notes:

- Cost is extremely high ($18,760.00)

- Enables precise temperature, humidity, and three gases for time-lapse imaging

- Internal environment values are easily selected by user input

- Very small design

- Compatible with imaging software

- Minimizes light exposure

- Hold chamber slides, microscopic slides, multi-well plates, and petri dishes

Conclusions/action items:

This stage top design has all of the features that our microscopic cell culture incubator will have. The biggest differences are the sizes, as the EVOS incubator is extremely small to our design, but we incorporate a larger water heating system to our design. The other big difference is the cost of our product compared to the EVOS incubator. Our product will hopefully be under <$100 production costs while this incubator is over 15,000 dollars. One thing I think we could incorporate to our design based off of the EVOS incubator is to have compatibility with the imaging software used in the BME teaching lab.

1/31/22 Waterproof Insulation Products

SAMUEL BARDWELL - Feb 28, 2022, 12:21 PM CST

Title: Waterproof Insulation Products

Date: 1/31/22

Content by: Sam

Goals: To find possible waterproofing/insulating material to incorporate into the incubator box to prevent leaking and heat loss.

Content:

Link: https://wtrproof.com/types-of-waterproofing-materials/

Cite:

L. W, "7 Common Types Of Waterproofing Materials (Benefits, Uses, & Cost)," *Wtrproof*, Oct. 03, 2019. https://wtrproof.com/types-of-waterproofing-materials/ (accessed Jan. 31, 2022).

Notes:

- There are many types of waterproofing but the material has to be individualized for certain circumstances

- Polyurethane membrane could be an option to use for the inside of the box to seal the edges of the inside of the box. The polyurethane may cause health risks. It is commonly used for water tanks (which can be comparable to our water tank.

- Cementitious coating is an easy waterproofing and insulating option that is made of sand, organic and inorganic chemicals, and silica-based substances. This product is easy application but has little flexibility. There is a spray formula option.

- See rest of the paper for more options (Cementitious and polyurethane were the best options)

Conclusions/action items:

The right waterproofing method will have to be researched more based on the needs of our project. Polyurethane spray foam could be useful to insulate and waterproof the edges of our box but may pose some health risks which could lead to cell death in the incubator from contamination or toxins. Cementitious coating could be a possible final coat on the inside of the box to help seal any tight cracks as well as add waterproofing. More research on specific waterproofing insulation methods should be conducted but the cementitious and polyurethane specifically. Should also research biocompatibility for each.

2/2/22 Black Acrylic Research

Title: Black Acrylic Research

Date: 2/2/22

Content by: Sam

Goals: To get a better understanding of black acrylic and its properties in order to use it for the project.

Content:

Link: https://www.grainger.com/category/raw-materials/plastics/plastic-sheets-bars/acrylic-choose-a-color-sheets-bars?attrs=Color%7CBlack&filters=attrs&gucid=N:N:PS:Paid:MS:CSM-2294:ZQXX1N:20500731&ef_id=0cf5959527bb1e119399f46e1e5abe4c:G:s&s_kwcid=AL!2966!10!78821329009937!2330621053750562&gclid=0cf5959527bb1e119399f46e1e5abe4c&gclsrc

Cite:

"Black Acrylic - Choose-a-Color Sheets & Bars - Grainger Industrial Supply." https://www.grainger.com/category/raw-materials/plastics/plastic-sheets-bars/acrylic-choose-a-color-sheets-bar attrs=Color%7CBlack&filters=attrs&gucid=N:N:PS:Paid:MS:CSM-2294:ZQXX1N:20500731&ef_id=0cf5959527bb1e119399f46e1e5abe4c:G:s&s_kwcid=AL!2966!10!78821329009937!2330621053750562&gclid=0cf5959527bb1e119399f46e1e5abe4c&gc (accessed Feb. 02, 2022).

Notes:

General Purpose Acrylic Sheets

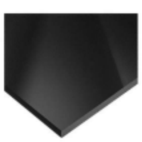
These general purpose acrylic sheets are easy to thermoform and bond with solvent cements. These sheets are scratch- and UV-resistant and commonly used for sight gauges, protective covers, frames and display cases, and indoor and outdoor signs.

Tensile Strength Rating: Excellent
Plastic Hardness Rating: Hard

Plastic Thickness	Color	Plastic Clarity	Tensile Strength	Impact Strength	Temperature Range	Item #	Price
12 in W x 12 in L							
0.125 in	Black	Opaque	11,030 psi	0.28 ft-lb/in	32 Degrees to 170 Degrees F	1UNZ5	$6.64 / each
0.171875 in	Black	Opaque	11,030 psi	0.28 ft-lb/in	32 Degrees to 170 Degrees F	1UNZ6	$8.27 / each
0.234375 in	Black	Opaque	11,030 psi	0.28 ft-lb/in	32 Degrees to 170 Degrees F	1UNZ7	$12.23 / each
24 in W x 24 in L							
0.125 in	Black	Opaque	11,030 psi	0.28 ft-lb/in	32 Degrees to 170 Degrees F	1UNZ8	$27.00 / each
0.171875 in	Black	Opaque	11,030 psi	0.28 ft-lb/in	32 Degrees to 170 Degrees F	1UNZ9	$33.02 / each
0.234375 in	Black	Opaque	11,030 psi	0.28 ft-lb/in	32 Degrees to 170 Degrees F	1UPA1	$48.86 / each
24 in W x 48 in L							
0.125 in	Black	Opaque	11,030 psi	0.28 ft-lb/in	32 Degrees to 170 Degrees F	1UPA2	$48.86 / each
0.171875 in	Black	Opaque	11,030 psi	0.28 ft-lb/in	32 Degrees to 170 Degrees F	1UPA3	$60.95 / each

Top

General Purpose Cast Acrylic Sheets



These cast acrylic sheets are clear and resemble glass in clarity, brilliance, and transparency, but are half the weight. They are easier to machine than extruded acrylic and are scratch- and UV-resistant. They are commonly fabricated into tanks, see-through barrier panels, and light fixture lenses.

Tensile Strength Rating: Good-Excellent
Impact Strength Rating: Poor
Plastic Hardness Rating: Hard
UV Tolerant: Yes

Plastic Thickness	Color	Plastic Clarity	Tensile Strength	Impact Strength	Temperature Range	Item #	Price
12 in W x 12 in L							
0.125 in	Black	Opaque	9,000 psi	0.3 ft-lb/in	40 Degrees to 190 Degrees F	60AZ59	$10.41 / each
0.1875 in	Black	Opaque	9,000 psi	0.3 ft-lb/in	40 Degrees to 190 Degrees F	60AZ60	$12.95 / each
0.25 in	Black	Opaque	9,000 psi	0.3 ft-lb/in	40 Degrees to 190 Degrees F	60AZ61	$15.68 / each
12 in W x 24 in L							
0.125 in	Black	Opaque	9,000 psi	0.3 ft-lb/in	40 Degrees to 190 Degrees F	60AZ62	$15.93 / each
0.1875 in	Black	Opaque	9,000 psi	0.3 ft-lb/in	40 Degrees to 190 Degrees F	60AZ63	$21.00 / each
0.25 in	Black	Opaque	9,000 psi	0.3 ft-lb/in	40 Degrees to 190 Degrees F	60AZ64	$26.55 / each

Top

Figure 1: Information on the Grainger website about black acrylic sheets with different dimension, prices, and transparency.

Makerspace:

Table 1: List of some approved materials to use on the laser cutter at the UW Makerspace

Material Name	Category	Safe for Raster?	Safe for Vector Engraving?	Safe for Vector Cut?	Notes
100% Cotton	Fabrics	Yes	Yes	Yes	
100% Silk	Fabrics	Yes	Yes	Yes	
100% Wool	Fabrics	Yes	Yes	Yes	Wool felt is safe to cut but has a bad odor. Please bag all scraps and cut pieces immediately after cutting.
3form Chroma	No settings currently	Yes	Yes	Yes	
Acrylic	Plastics	Yes	Yes	Yes	For sale in Makerspace
Anodized Aluminium	Other	Yes	Yes	NO	
Balsa Wood	Woods	Yes	Yes	Yes	
Basswood	Woods	Yes	Yes	Yes	Do not cut cut non-plannar (warped) material.
Ceramic	Other	Yes	Yes	NO	

Conclusions/action items:

I can come back to this page when we begin looking to order materials if we decide to continue with the black acrylic. One reason I believe we will continue with it is because the UW Makerspa fairly cheap. Some future work is to research possible adhesives for this acrylic as well as how to laser cut the box in order to merge the walls together.

2/28/22 Draw Latches

Title: Draw Latches Part Search

Date: 2/28/22

Content by: Sam

Goals: To find possible latches to add to the sides of the incubator box in order to have a tight seal when latched.

Content:

Link: https://www.amazon.com/Stainless-Mounting-MERYSAN-Premium-Overall/dp/B07GKHD61X/ref=sxin_14_pa_sp_search_thematic_sspa?crid=7Q7YR24AJYLW&cv_ct_cx=draw+latch&k 5fa1c47b8cd0&pd_rd_w=0tuir&pd_rd_wg=oyxcB&pf_rd_p=277e850d-e5af-4753-a716-a3e99085c62d&pf_rd_r=SNVJZYYAJX7VNZ8G0AHJ&qid=1646073967&sprefix=draw+latch%2Caps%2 spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEyVUhEQ1lVRk1JWlpGJmVuY3J5cHRlZElkPUEwNDY2NTE0MlowNTZKTFkzV05NQyZlbmNyeXB0ZWRBZElkPUEwMjMzMzkyMk4

Cite: “8Pcs Stainless Steel Spring Loaded Toggle with 32Pcs Mounting Screws, AUHOKY Premium Latch Catch Hasps Clamp Clip for Case Box Chest Trunk(72mm Overall Length) - - Amazo crid=7Q7YR24AJYLW&cv_ct_cx=draw+latch&keywords=draw+latch&pd_rd_i=B07GKHD61X&pd_rd_r=5e779ff9-27a5-46dd-a745-5fa1c47b8cd0&pd_rd_w=0tuir&pd_rd_wg=oyxcB&pf_rd_p=2 a73d1c8c-2fd2-4f19-aa41-2df022bcb241-
spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEyVUhEQ1lVRk1JWlpGJmVuY3J5cHRlZElkPUEwNDY2NTE0MlowNTZKTFkzV05NQyZlbmNyeXB0ZWRBZElkPUEwMjMzMzkyMk4
(accessed Feb. 28, 2022).

Notes:

- Stainless Steel Spring Latches

- 8 Pack of latches for $11 on Amazon

- Need to check what the best size would be for our project

Conclusions/action items:

Can come back to this link in order to order this material if it is the one we decide to move forward with. I checked Grainger's website for similar products, but there we similar ones for triple the

3/23/22 Threaded to Barb Tube Adaptors

SAMUEL BARDWELL - Mar 24, 2022, 11:58 AM CDT

Title: Threaded to Barb Tube Adaptors

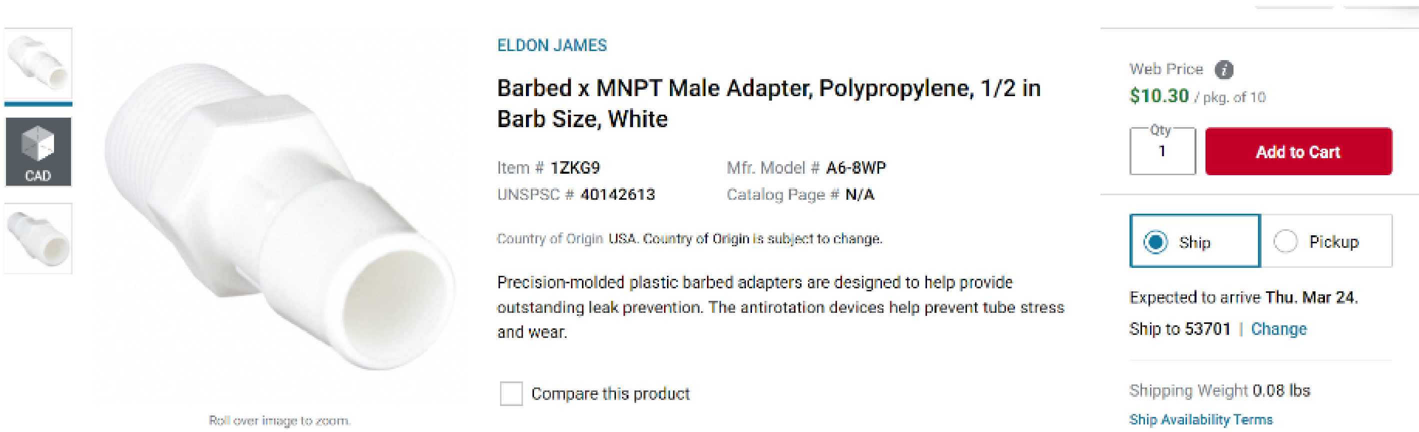
Date: 3/23/22

Content by: Sam

Goals: To research possible adaptors for the incubator tubing.

Content:

Link: https://www.grainger.com/product/ELDON-JAMES-Barbed-x-MNPT-Adapter-1ZJX1



Conclusions/action items:

This adaptor may become useful when we start fabricating the tubing of the incubator box.

3/23/22 Latch Clamp Research

Title: Latch Clamp Research

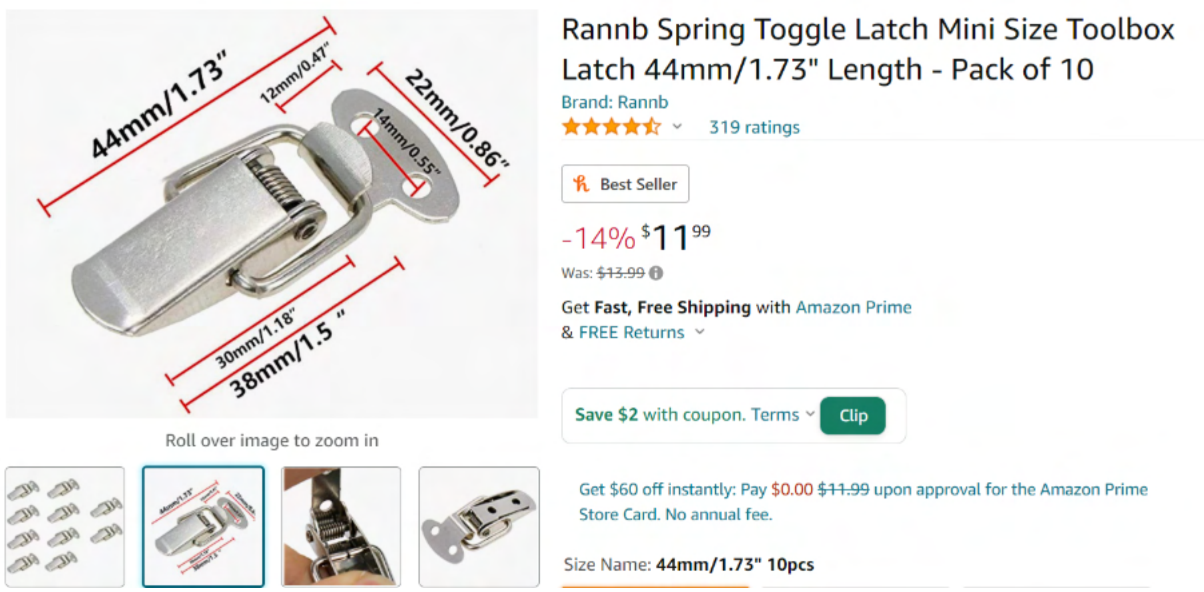
Date: 3/23/22

Content by: Sam

Goals: To find latches that will function with the dimensions of our box.

Content:

Link: https://www.amazon.com/Rannb-Toggle-Stainless-Catches-Toolbox/dp/B07HD246X2/ref=sr_1_29_sspa?crid=XACVOVSEY26R&keywords=small%2Blatch%2Bclamps&qid=1648078071
spons&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUExTUczVk1TTTdOQ1E1JmVuY3J5cHRlZElkPUEwMDIwODAxMU5EOE5SN09RNk1ITiZlbmNyeXB0ZWRBZElkPUEwMDQxODA3VVBNRk9



- Latch body is 30 mm and the side of our box is 36 mm tall. The size of the box with the lid is 42 mm. These latches should be able to fit on our box.

Conclusions/action items:

Order the latches so that we are capable of have the latch box design.

2/6/22 SOLIDWORKS to Laser Cutter Information

SAMUEL BARDWELL - Feb 06, 2022, 3:16 PM CST

Title: SOLIDWORKS to Laser Cutter Information

Date: 2/6/22

Content by: Sam

Goals: To understand how to convert a SOLIDWORKS file to a file that can be exported to the laser cutter.

Content:

Link: https://docs.google.com/document/d/e/2PACX-1vThkIl0GJMtvIAQUHwelMMVX1YcFU06ftMu8NdYquHfHzA7ZaJ27pNdelKNsmFSgfX801T0b9ysJgng/pub

Notes:

- The link shows step by step on how to convert a SOLIDWORKS part to the Laser cutter in the Makerspace

- Provided by UW Madison Makerspace

Conclusions/action items:

I will come back to this link when I have update the SOLIDWORKS parts to the best of their ability and when we want to laser cut the parts if we decide to continue down that route.

SAMUEL BARDWELL - Feb 06, 2022, 3:16 PM CST

Download

Solidworks_to_Universal_Laser.mhtml (1.6 MB)

2/6/22 Automatic Box Generator for the Laser Cutter

SAMUEL BARDWELL - Feb 06, 2022, 3:31 PM CST

Title: Automatic Box Generator for the Laser Cutter

Date: 2/6/22

Content by: Sam

Goals: To have a resource that helps create a box on the laser cutter without having to use fasteners.

Content:

Link: https://www.makercase.com/#/

Notes:

- This link allows you to automatically generate a box that can be laser cut on the laser cutter at the Makerspace

- The dimensions can be set to the desired dimensions that you want in mm or inches

- The link also allows edge joints to be automatically generated and the sizes change so fasteners do not have to be used

- May not be compatible with SOLIDWORKS to add any other features to the box

Conclusions/action items:

I may use this automatic box generator to help visualize how the edge joints can be implemented into our box design. I do not know if this link can help us include the smaller feature of our box which makes the SOLIDWORKS drawings a little more complicated but it is still a good link to be aware of.

2/14/22 SOLIDWORKS Design Matrix Drawings

SAMUEL BARDWELL - Feb 14, 2022, 7:20 PM CST

Title: SOLIDWORKS Design Matrix Drawings

Date: 2/14/22

Content by: Sam

Goals: To draw preliminary designs of the boxes for the design matrix.

Content:

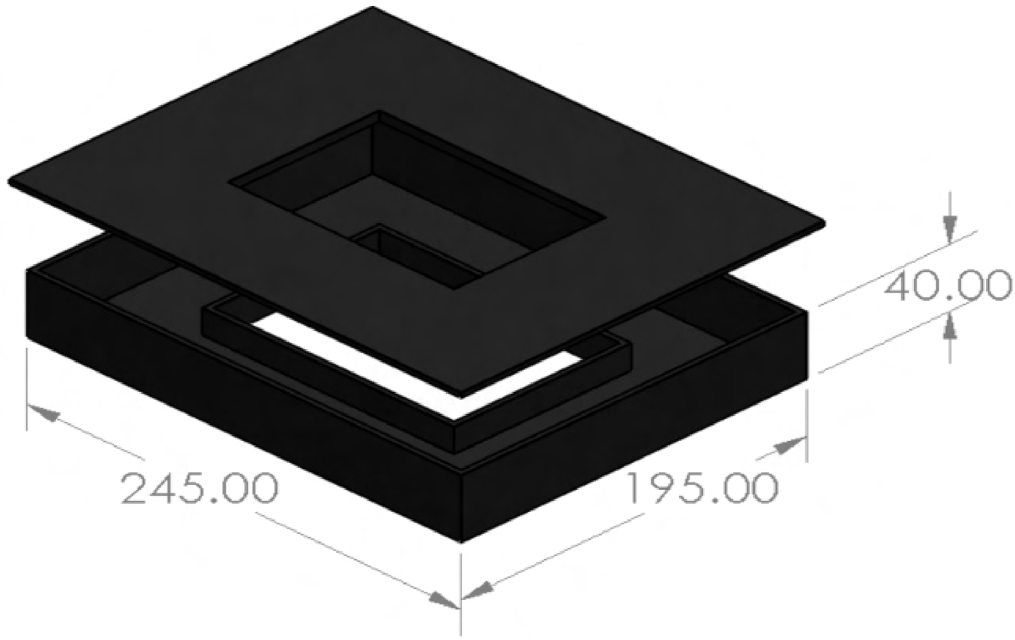


Figure 1: Hinge Top Acrylic Incubator drawing with dimensions in millimeters.

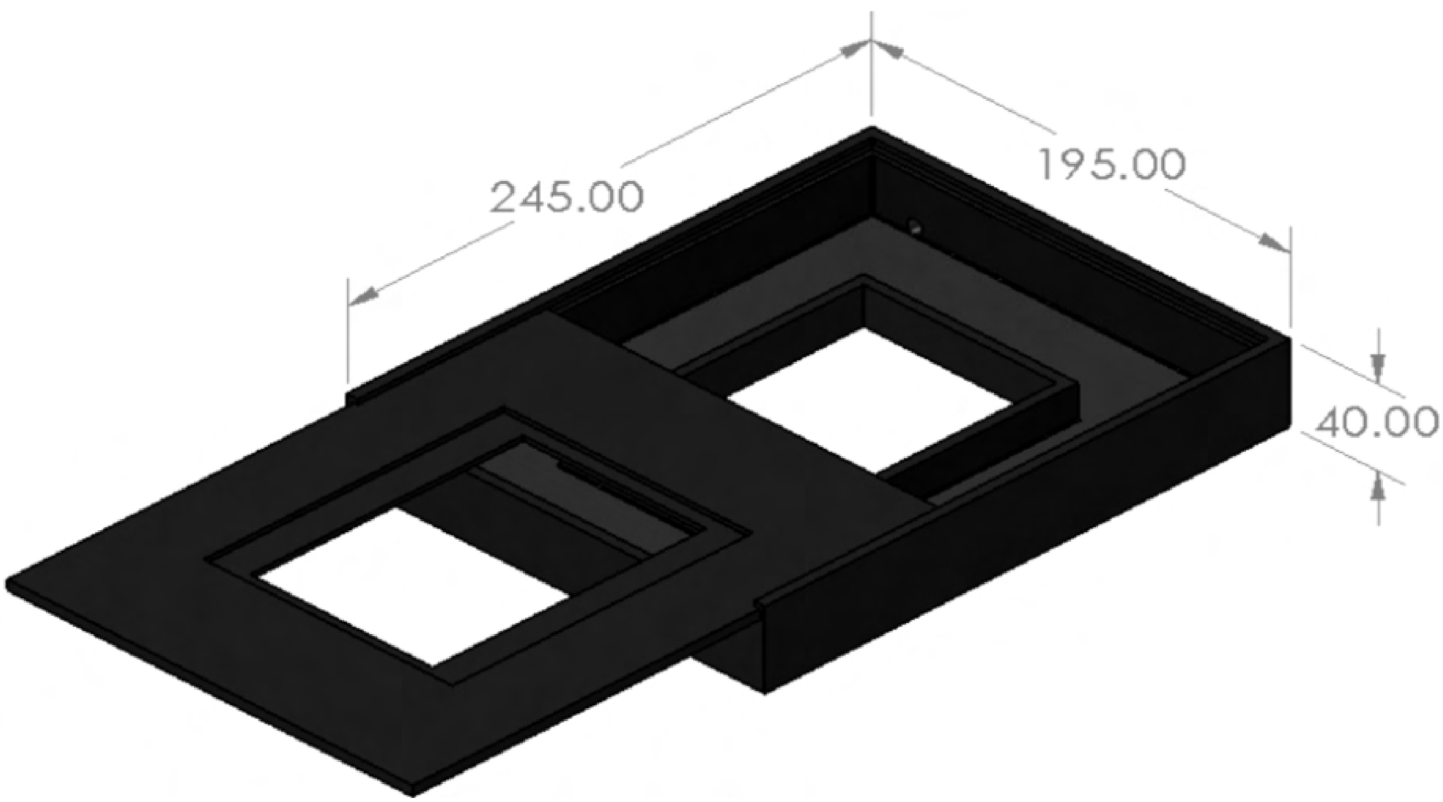


Figure 2: Slide Top Acrylic Incubator drawing with dimensions in millimeters.

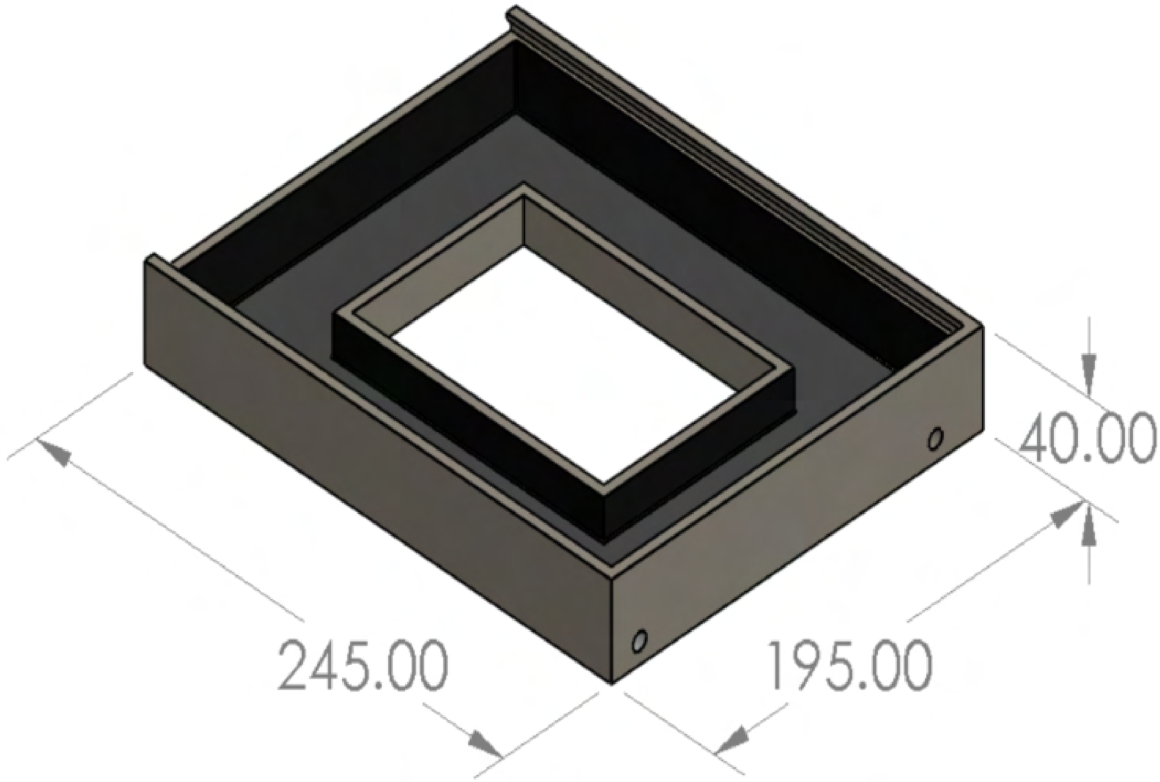


Figure 3: 3D Printed Box with insulation coating drawing with dimensions in millimeters.

Conclusions/action items:

These preliminary drawings will be used for the design matrix for the different box designs. The winning drawing will be updated after scoring is conducted.

2/23/22 SOLIDWORKS Drawing with Fingered Edges

SAMUEL BARDWELL - Feb 27, 2022, 2:19 PM CST

Title: SOLIDWORKS Drawing with Fingered Edges

Date: 2/23/22

Content by: Sam

Goals: To create a SOLIDWORKS drawing that can be cut 2-dimensionaly on the laser cutter with fingered edges.

Content:

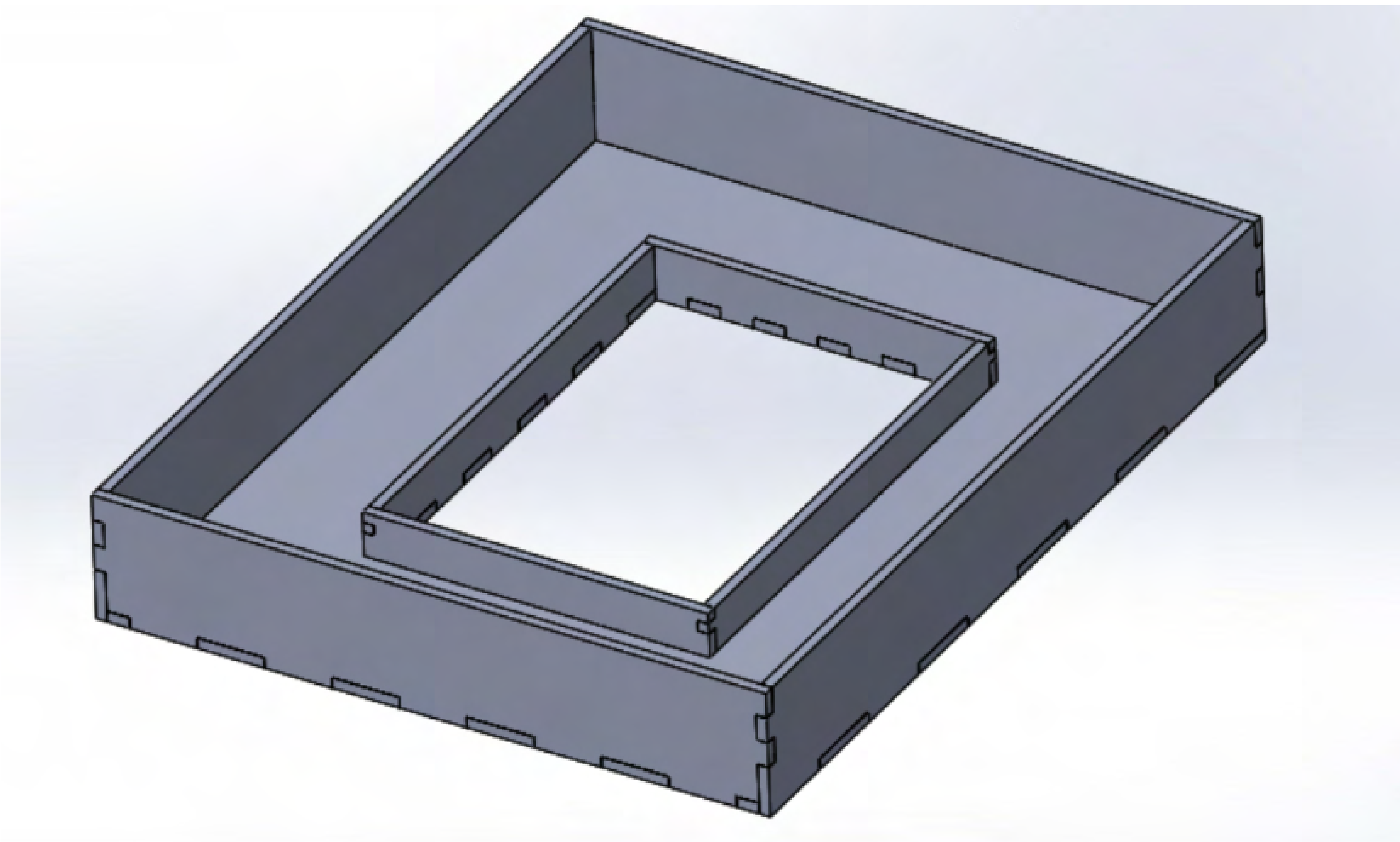


Figure 1: Acrylic hinge top SOLIDWORKS drawing with fingered edges.

Conclusions/action items:

We will use this preliminary assembly to print a cardboard prototype of the incubator box. This is a fluid drawing and assembly and can be updated throughout the semester.

3/8/22 Handwritten Drawing of CO2 Input Controller

SAMUEL BARDWELL - Mar 08, 2022, 8:26 PM CST

Title: Handwritten Drawing of CO2 Input Controller

Date: 3/8/22

Content by: Sam

Goals: To have a preliminary handwritten design of a possible CO2 regulator.

Content:

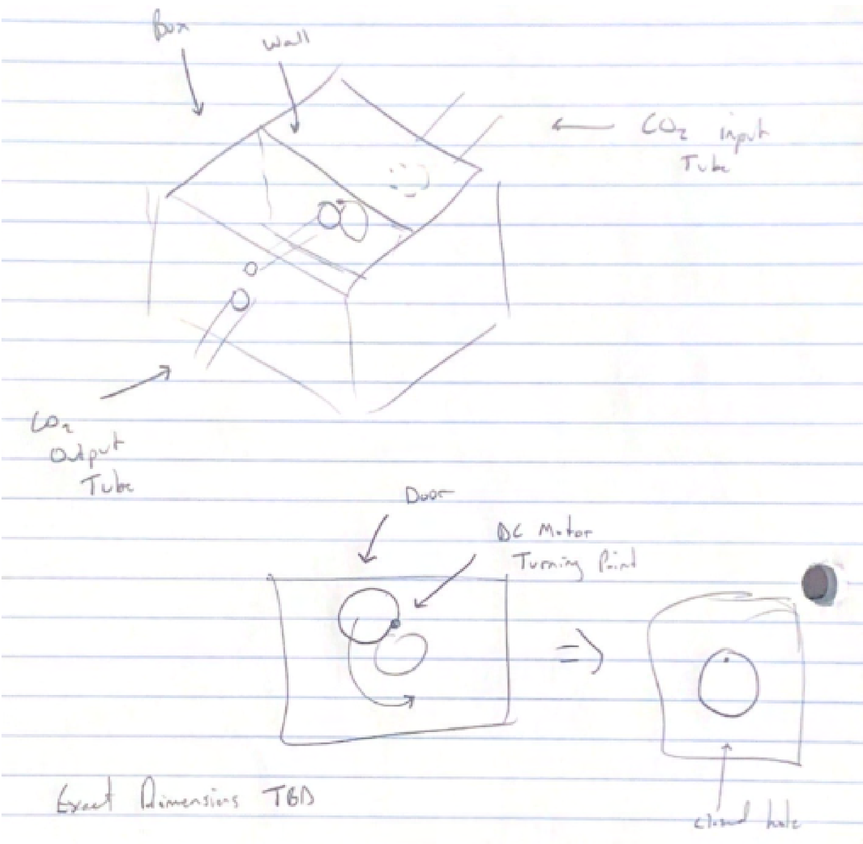


Figure 1: Hand written drawing of possible CO2 monitor for the CO2 input

- Would be 3D printed box of PLA with an inner wall

- There would be a hole in the inner wall that would have a lid attached to a DC motor

- When the CO2 sensor readings got too low, the door would be opened to let CO2 inside the incubator

Conclusions/action items:

Would have to create SOLIDWORKS drawing of the box. Would have to figure out how to connect CO2 tubing. Would have to figure out best way to configure DC motor. Would have to make sure the door can withstand 14 PSI for an extended period of time.

3/22/22 Updated Solidworks Drawing for Laser Cutter

SAMUEL BARDWELL - Mar 22, 2022, 9:30 PM CDT

Title: Updated SOLIDWORKS drawing for Laser Cutter

Date: 3/22/22

Content by: Sam

Goals: To prepare a final SOLIDWORKS drawing for the laser cutter.

Content:

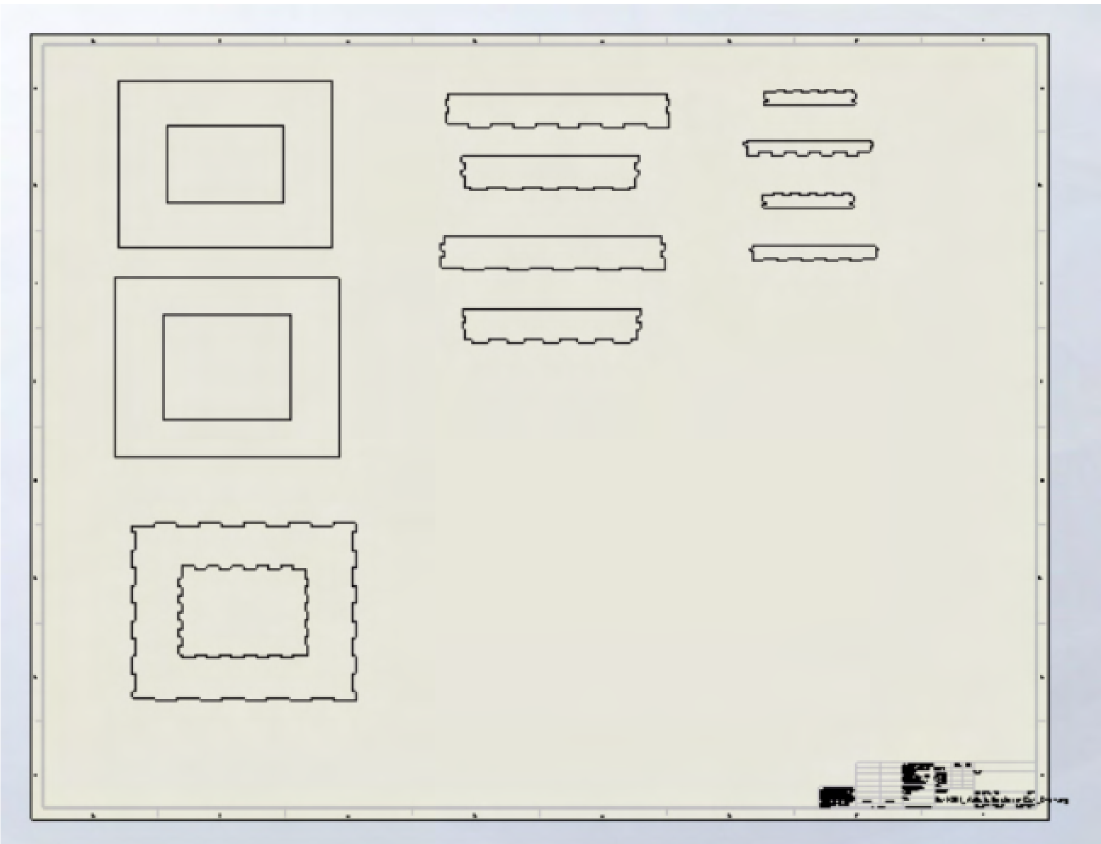


Figure 1: SOLIDWORKS drawing that was converted to ADOBE Illustrator files in order to be printed on the laser cutter

- Files conversions went smoothly

- Little bit of trouble converting ADOBE file to laser cutter language but we figured it out

Conclusions/action items:

Will update this drawing when the final design for the acrylic box is made. Need to include holes for inputs and sensors.

3/22/22 Laser Cut Prototype

SAMUEL BARDWELL - Mar 22, 2022, 9:20 PM CDT

Title: Laser Cut Prototype

Date: 3/22/22

Content by: Sam

Goals: To show progress on the design idea of the acrylic box.

Content:

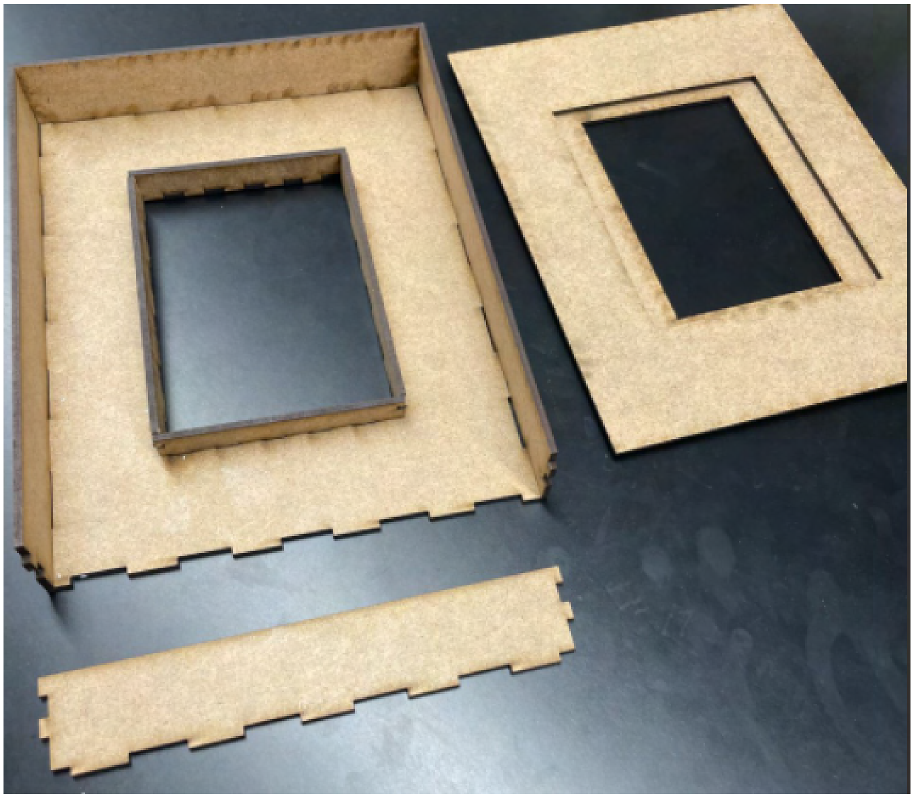


Figure 1: Photo of the laser cut HDF showing the parts being not completely assembled

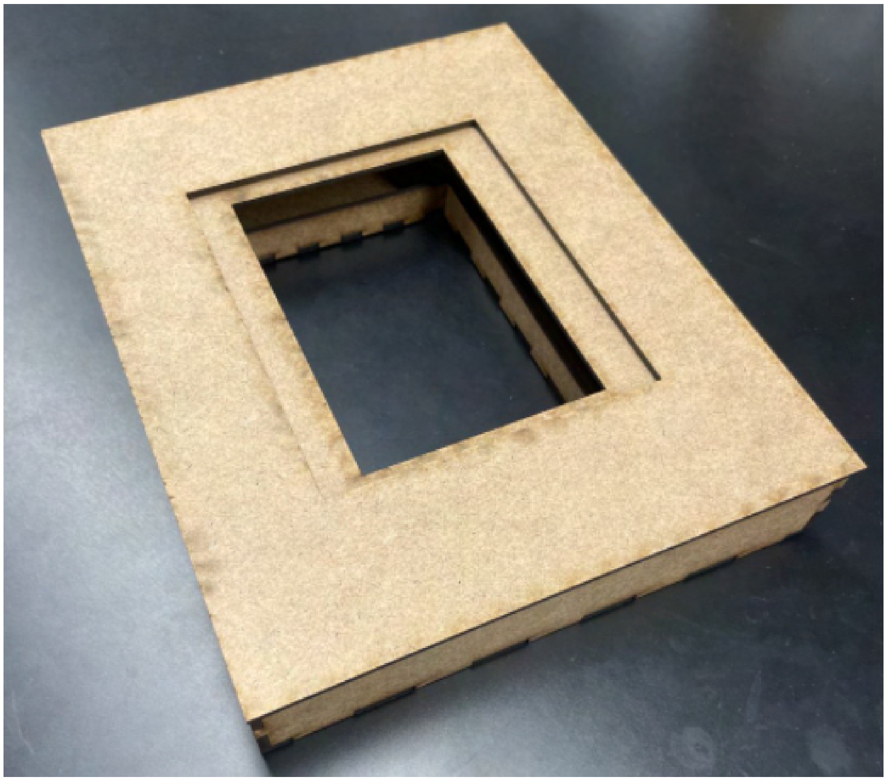


Figure 2: Photo of the laser cut HDF prototype with all the pieces assembled together.

- Box fit very well together

- We were able to figure out the correct setting for the laser cutter and we are ready to laser cut the acrylic sheet when the time comes

- We will have to use either hot glue and the acrylic cement in order to seal all the holes of the acrylic when its fabricated. This is because the HDF had a lot of holes and close to perfect but not perfect fits with the fingers.

Conclusions/action items:

Continue to update the SOLIDWORKS drawing to incorporate holes in the box for sensors and CO2/Water inputs. Laser cut the drawing on acrylic to fabricate the box and begin other testing.

4/6/22 Acrylic Laser Cut SOLIDWORKS and Drawing

SAMUEL BARDWELL - Apr 06, 2022, 6:29 PM CDT

Title: Acrylic Laser Cut SOLIDWORKS and Drawing

Date: 4/6/22

Content by: Sam

Goals: To update the SOLIDWORKS drawing to incorporate entry holes for the inputs and sensors.

Content:

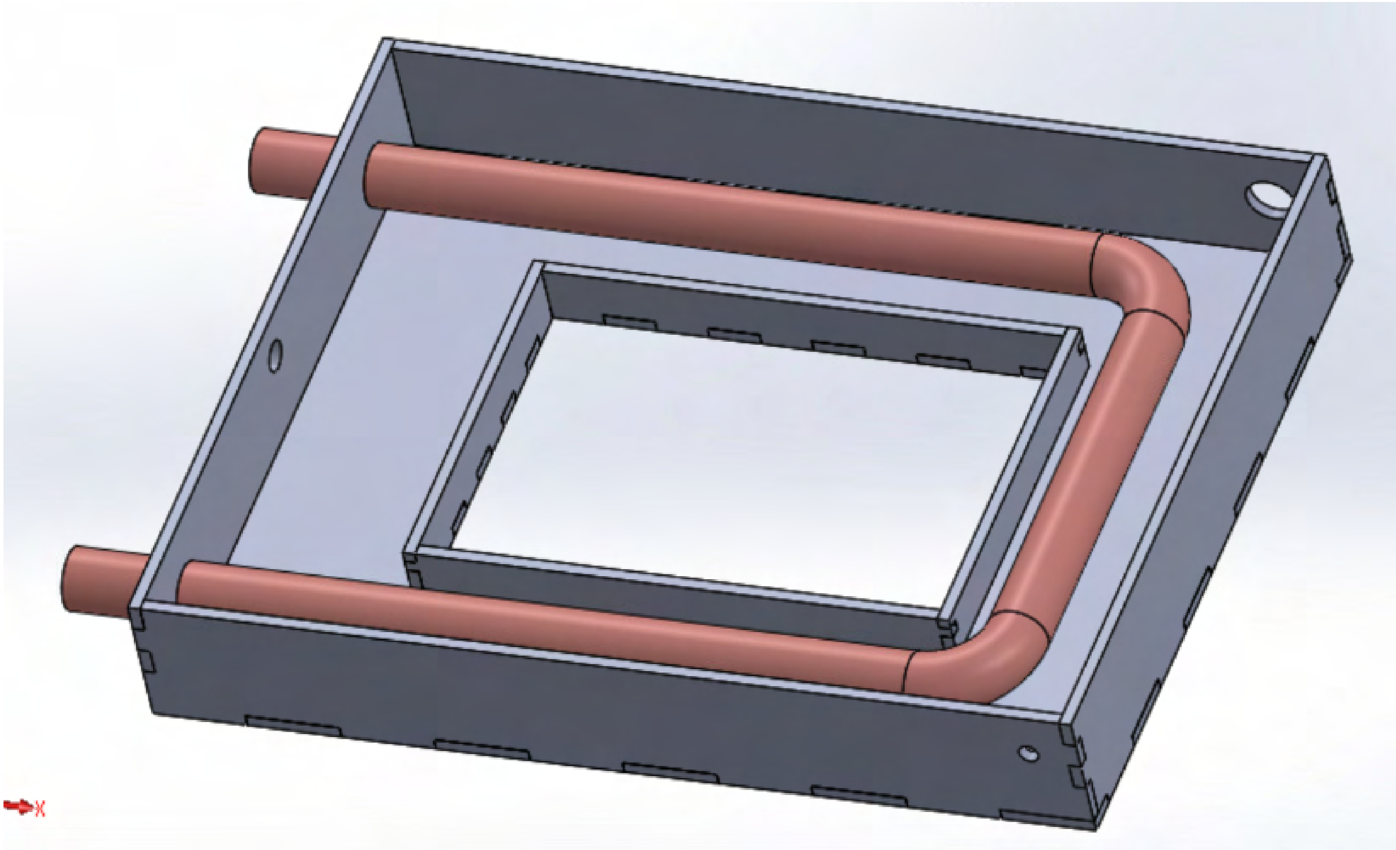


Figure 1: SOLIDWORKS drawing without the lid on the updated assembly.

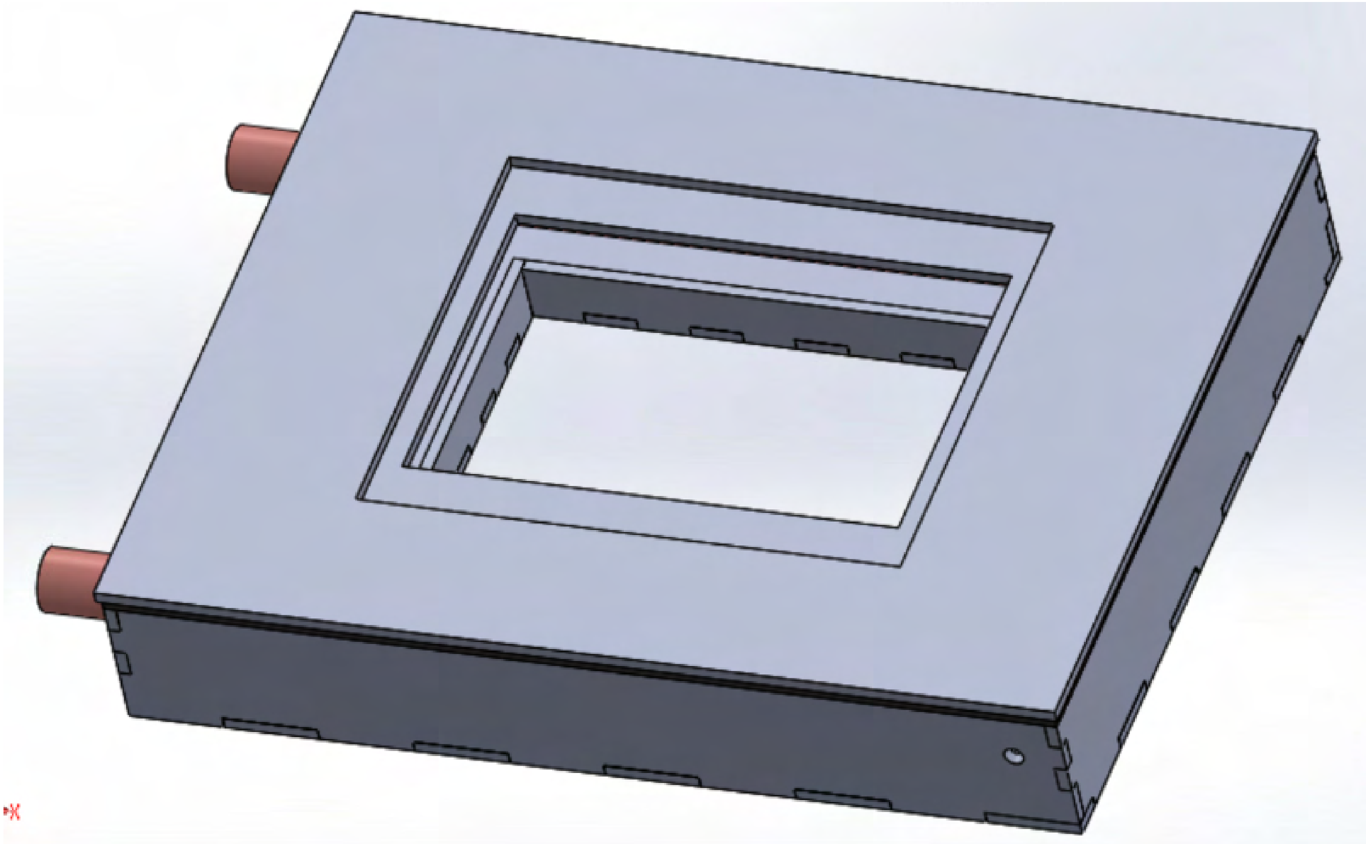


Figure 2: Updated SOLIDWORKS assembly with the lid on top.

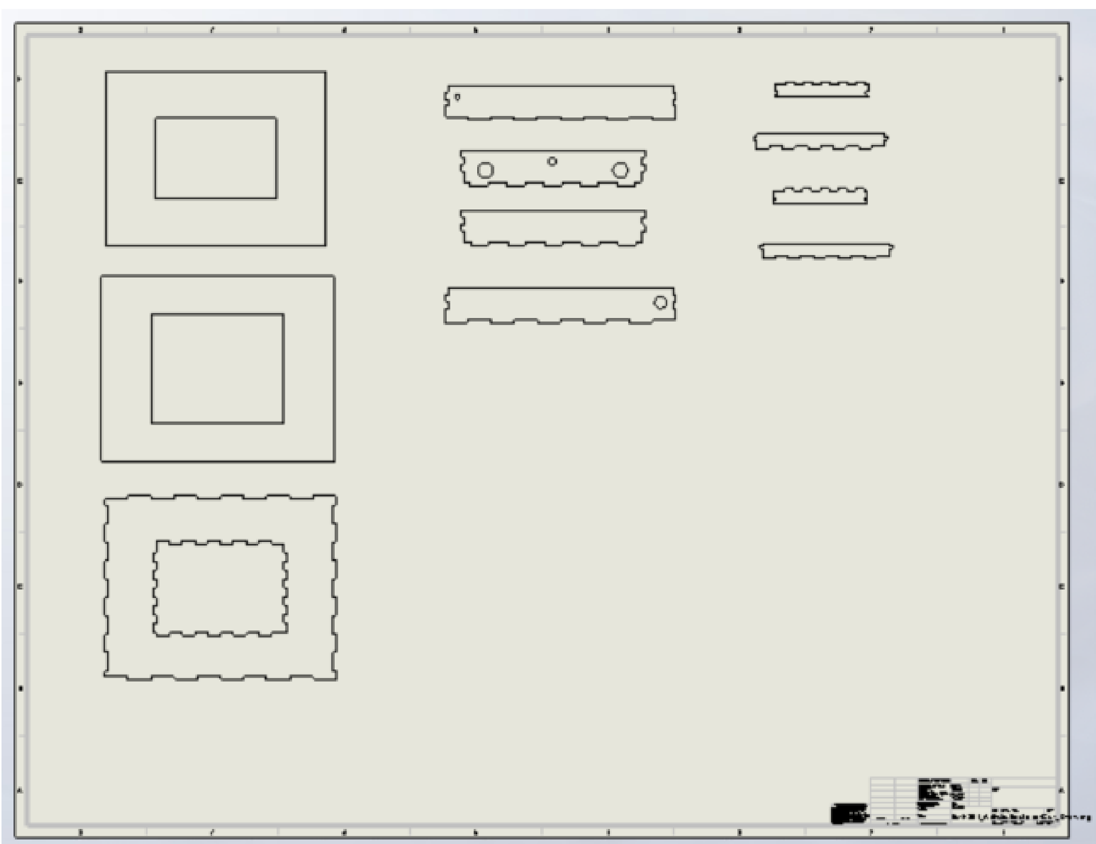


Figure 3: SOLIDWORKS drawing ready to be cut by the laser cutter with acrylic.

Conclusions/action items:

We will use these assemblies and drawing to laser cut the acrylic box so we can continue forward with the incubator and start conducting testing involving the entire box.

2/8/2020 Woodworking 1

SAMUEL BARDWELL - Sep 29, 2020, 11:55 AM CDT

Title: Woodworking Red Permit 1

Date: 9/29/2020

Content by: Sam

Content:

Image preview

Image preview

2/8/21 Biosafety Certification

SAMUEL BARDWELL - Feb 08, 2021, 5:19 PM CST

Title: Biosafety Certification

Date: 2/8/21

Content by: Sam

Goals: To be certified to work with biomaterials.

Content:

University of Wisconsin-Madison

This certifies that SAMUEL BARDWELL has completed training for the following course(s):

Course Name	Curriculum or Quiz Name	Completion Date	Expiration Date
BIOSAFETY REQUIRED TRAINING	BIOSAFETY REQUIRED TRAINING QUIZ	2/4/2021	

Data Effective: Thu Feb 4 13:40:00 2021
Report Generated: Mon Feb 8 17:06:55 2021

Conclusions/action items:

This will be useful for this semester and future semesters in Biomedical Engineering. It allows me to safely work with biomaterials.

3/12/21 Chemical Safety Certification

SAMUEL BARDWELL - Mar 12, 2021, 3:42 PM CST

Title: Chemical Safety Certification

Date: 3/12/21

Content by: Sam

Goals: To be safe while using chemicals.

Content:

University of Wisconsin-Madison

This certifies that SAMUEL BARDWELL has completed training for the following course(s):

Course Name	Curriculum or Quiz Name	Completion Date	Expiration Date
BIOSAFETY REQUIRED TRAINING	BIOSAFETY REQUIRED TRAINING QUIZ	2/4/2021	
CHEMICAL SAFETY: THE OSHA LAB STANDARD	FINAL QUIZ	3/4/2021	

Data Effective: Thu Mar 4 11:25:00 2021
Report Generated: Fri Mar 12 15:37:01 2021

Conclusions/action items:

Can be used for BME 201 project as well as future classes in BME or at UW Madison

10/28/21 Green Permit

SAMUEL BARDWELL - Oct 28, 2021, 8:12 AM CDT

Title: Green Permit

Date: 10/28/21

Content by: Sam

Goals: To obtain a green permit to utilize if necessary.

Content:

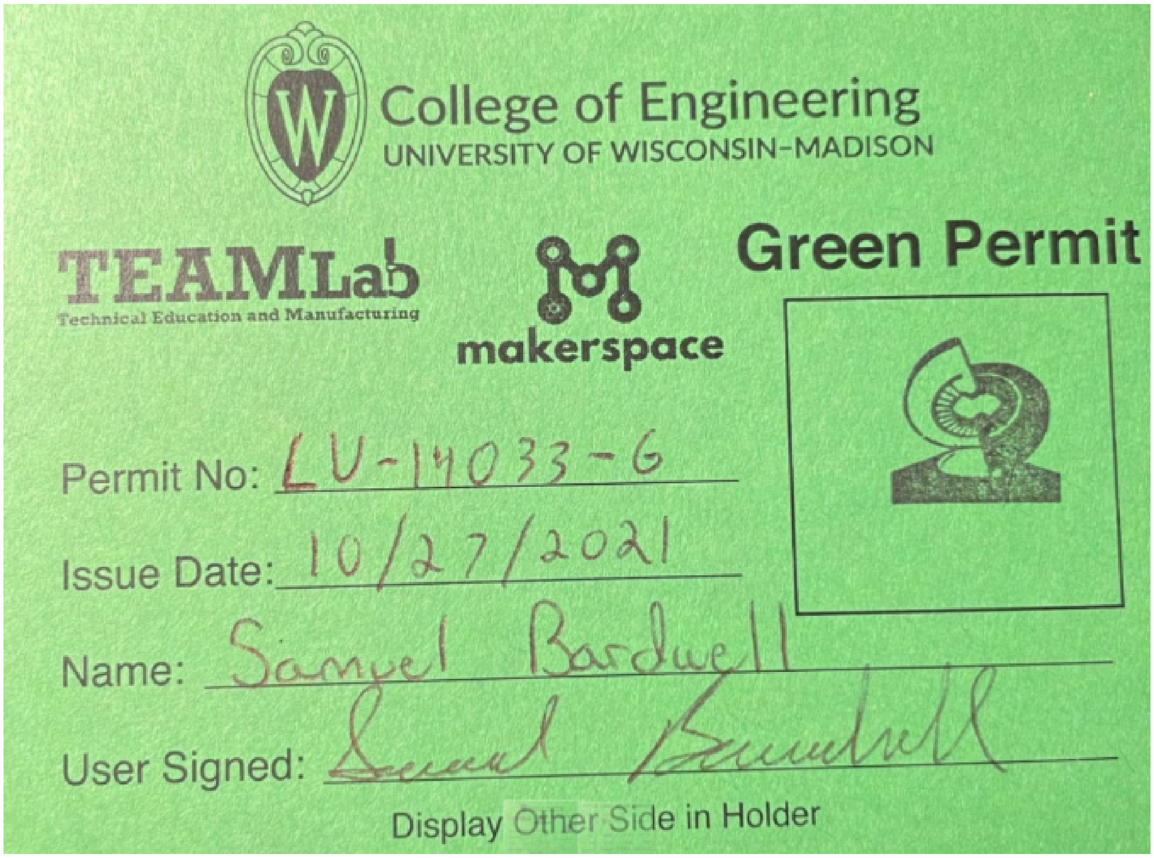


Figure 1: Front side of the green permit

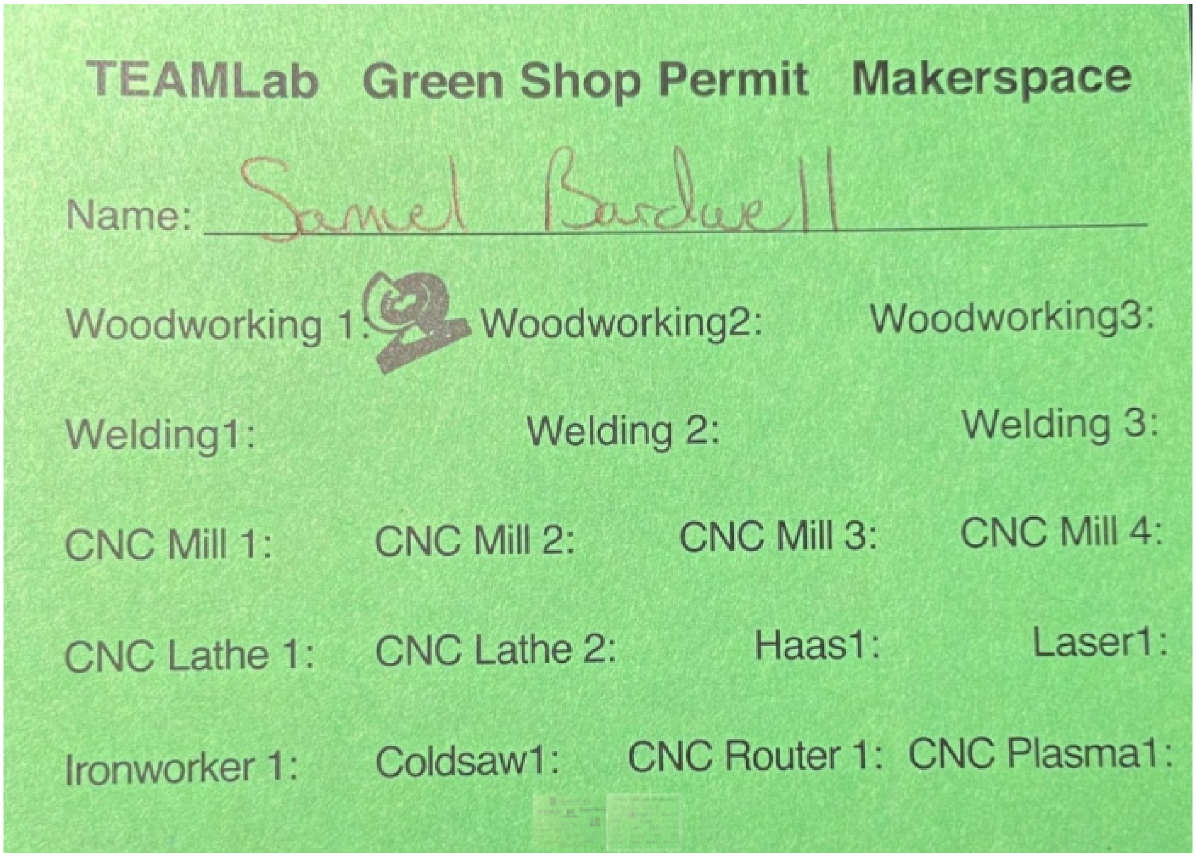


Figure 2: Back side of green permit

Conclusions/action items:

This green permit will be used if necessary for BME design projects.

2/4/22 Laser Cutter Permit

SAMUEL BARDWELL - Feb 04, 2022, 4:07 PM CST

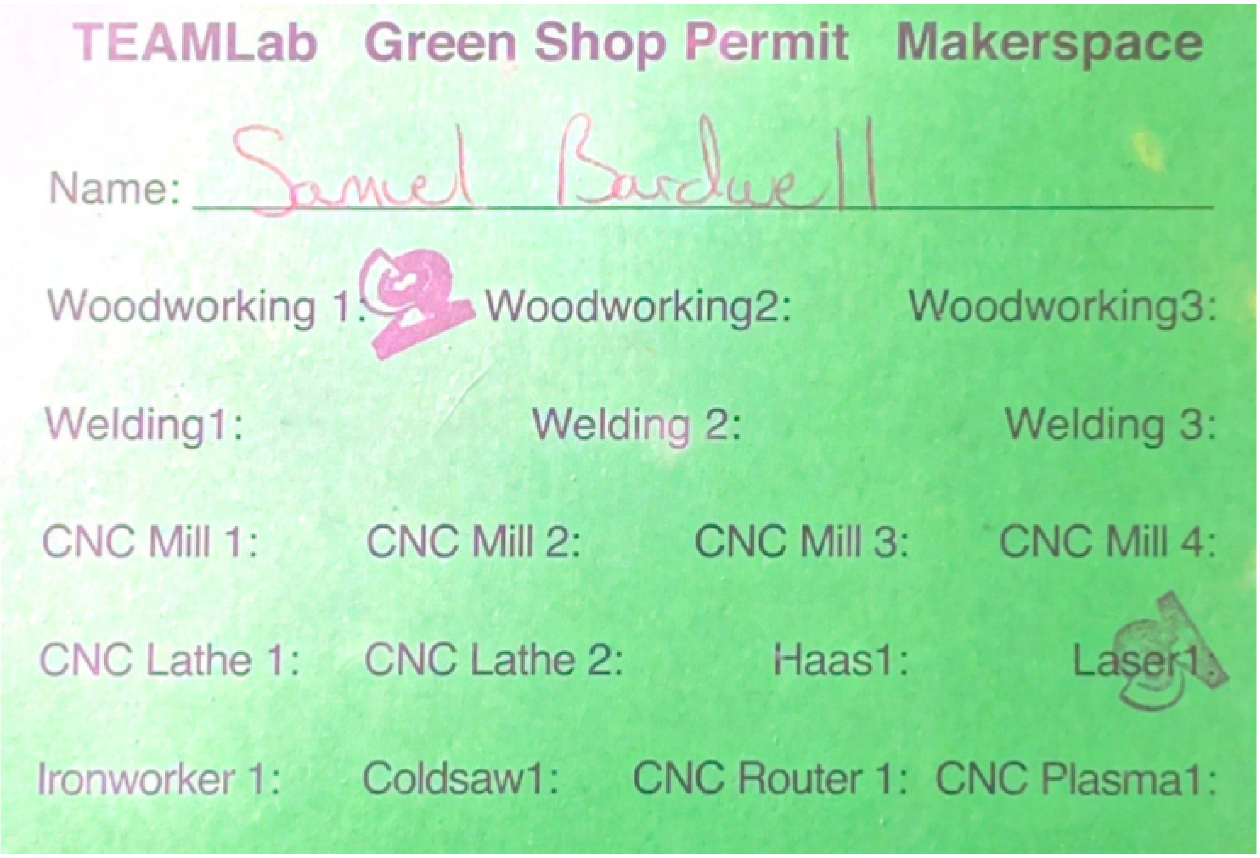
Title: Laser Cutter Permit

Date: 2/4/22

Content by: Sam

Goals: To obtain a laser cutting permit in order to use the laser cutter for BME Design projects.

Content:



Conclusions/action items:

I will use this permit to laser cut prototypes and final designs for BME or individual projects.

3/13/22 WARF Presentation Notes

SAMUEL BARDWELL - Mar 13, 2022, 8:03 PM CDT

Title: WARF Presentation Notes

Date: 3/13/22

Content by: Sam

Goals: To understand how WARF can help me with my career in the future.

Content:

WARF

Beginnings

- Created in 1925 to manage intellectual property

- Organized as a nonprofit, functionally integrated supporting organization

- Proceed support research at UW - Madison

- Governed by Independent board of UW-Madison alumni

Vision

- Enable UW-Madison research to solve the world's problems

Mission

- Support scientific research within UW - Madison by providing financial support

Cycle of Innovation

- 200 Issued US Patents

- Annual grant is $85 million in 2018

- > $200 M in inventor royalties

Protecting Innovation

- Patents/Copyrights/Trademarks

Prior Art

- Definition: "references" created before a specific date

- By the inventor: > 1 year before the filing date of the patent application

- By another: before the filing fate of the patent application

Public Disclosure and Prior Art

Example of typical public disclosures of an invention

- Journal Publication

- Talk or poster at a conference / professional meeting

- Non-confidential department seminar

- Open thesis defense

Requirements for patentability

- Eligibility

- Useful

- Enabled

- Described

- Novel

- Non-obvious

Examination = assessment of the invention

Based on statutory requirements and application of prior art

WARF Management Process

- Disclosure of invention to WARF

- Disclosure committee meets monthly to review new disclosures

- Patent application drafting, filing, and prosecution

- Technology Marketing

- Licensing

Licensing Considerations for New Disclosures

- Chance of licensing

- Timeline for licensing

- Licensing strategy

- Plan for the next year

- Revenue projections

Licensing

- Exclusive or non-exclusive rights to make, use, sell, or import

Licensee Provides

- Develop and commercialize

- Reasonable fees

- Fulfill obligation under Bayh-Dole

Timeline

- Varies form months to years

- Depends on technology

Accelerator Program

- Accelerate commercialization prospects for WARF IP

- Expert consultants with significant business experience

Finding a Licensee

- Internal

Inventor contacts

Meetings

Sponsored research

- External

Technology descriptions of website

Publications

Technology portals

Targeted research

Starting a Company

- Technology

- Market

- Management

- Capital requirements

Start-up Resources

- Discovery to Product, a campus-wide resource for entrepreneurship

- Innovation Roadmap series and UpStart programs

- Law and Business

BME Design Project Startup

- Atrility Medical

Conclusions/action items:

Our design might have intellectual property because we are developing a very low cost microscopic incubator that can be assembled with Lab materials. People are capable of buying microscopically compatible incubators but they are already preassembled and cost a minimum of $400, while ours can be self-assembled and fairly easily made with cost at ~$100.

2/3/22 Progress Report 1

SAMUEL BARDWELL - Feb 02, 2022, 8:04 PM CST

Title: Sam's Progress Report 1

Date: 2/3/22

Content by: Sam

Goals: To show my weekly progress and contributions to the project.

Content:

Progress:

- Conducted research on thermal properties for copper and water in order to start making mathematical calculations on heating the incubator water bed

- Conducted research on possible insulation techniques for the inside of the incubation box

- Met with the client in order to discuss any changes or parts to keep working on this semester.

Conclusions/action items:

I will use this research and client meeting information to continue to improve the project. Some individual goals for this semester are to improve the SOLIDWORKS drawings in order for the box to be laser cut. Create mathematical analysis on the thermal properties for the incubator box. Research more about the possible acrylic walls for the box.

2/10/22 Progress Report 2

SAMUEL BARDWELL - Feb 13, 2022, 4:35 PM CST

Title: Sam's Progress Report 2

Date: 2/10/22

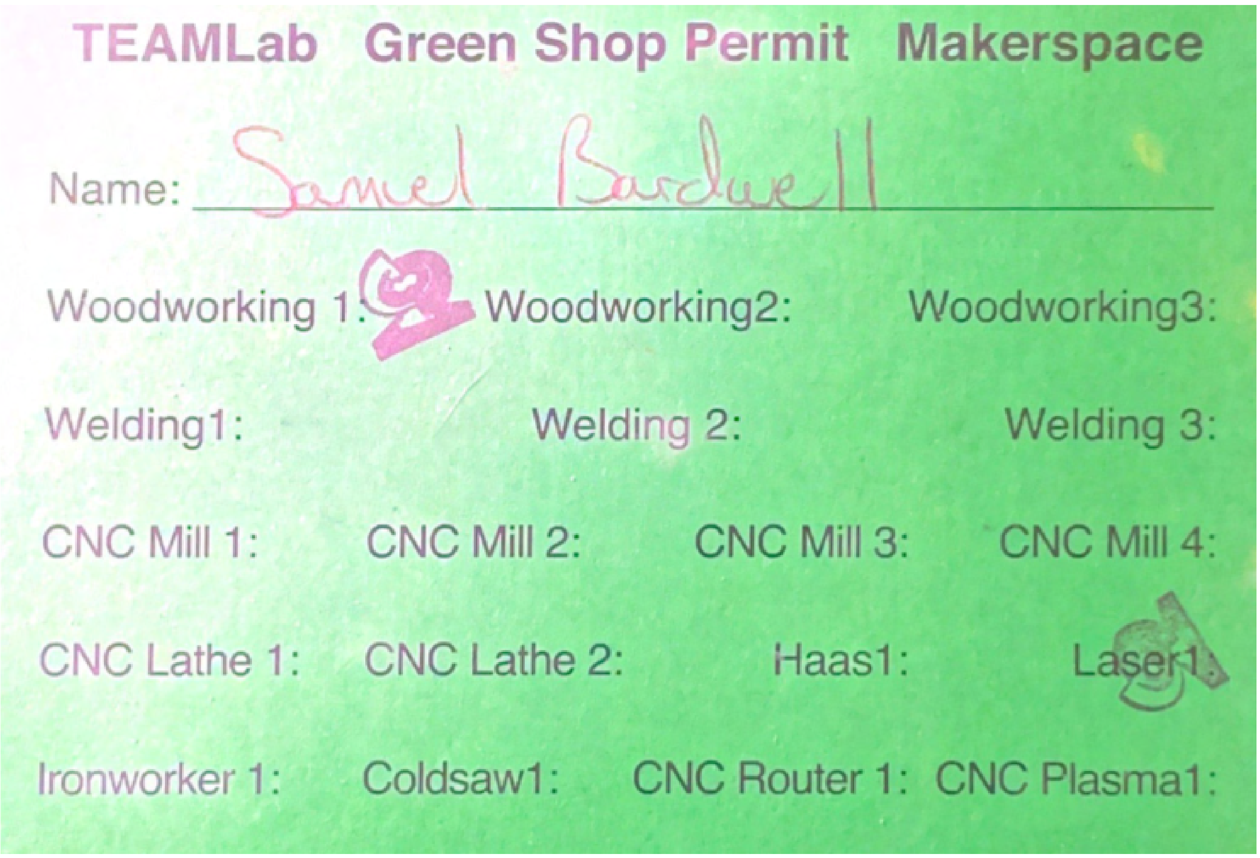
Content by: Sam

Goals: To show my weekly progress and contributions to the project.

Content:

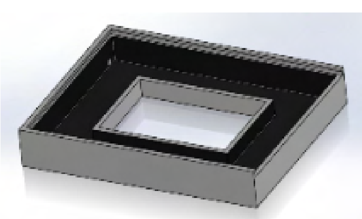
- Continued to do more research on thermal properties between water and copper (See Sam Bardwell > Research Notes > Biology/Physiology/Chemistry > 2/2/22 Heat Transfer Calculations

- Got certified to use the laser cutter in the Makerspace.



- Used Makerspace resources to begin developing drawings of a laser cut box. Sam Bardwell > Design Ideas > 2/6/22 SOLIDWORKS to Laser Cutter and 2/6/22 Automatic Box Generator

- Began to create SOLIDWORKS drawings.



Conclusions/action items:

Finish SOLIDWORKS drawings for the design matrix next week. Finish mathematical calculations for theoretical thermal heating. Begin to find links to materials we want to order.

2/17/22 Progress Report 3

SAMUEL BARDWELL - Feb 21, 2022, 6:26 PM CST

Title: Progress Report 3

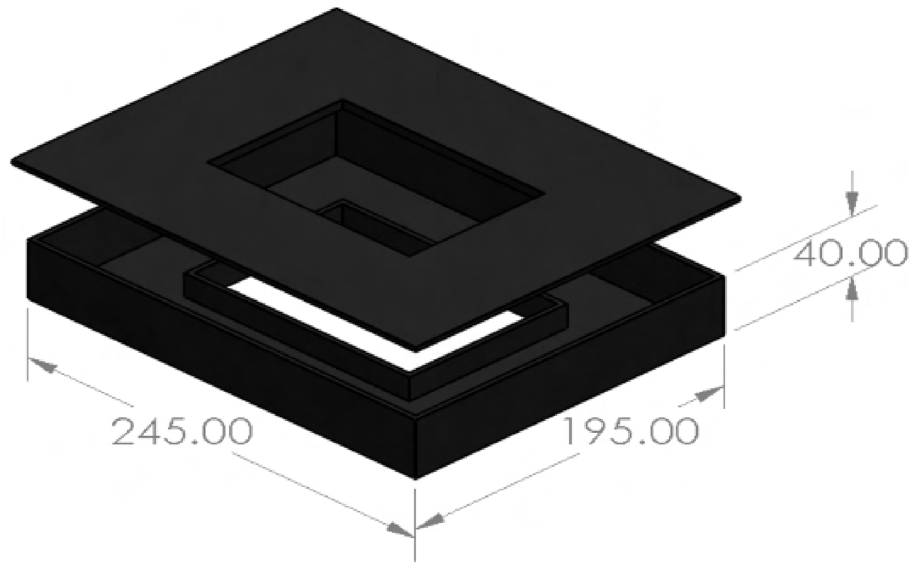
Date: 2/17/22

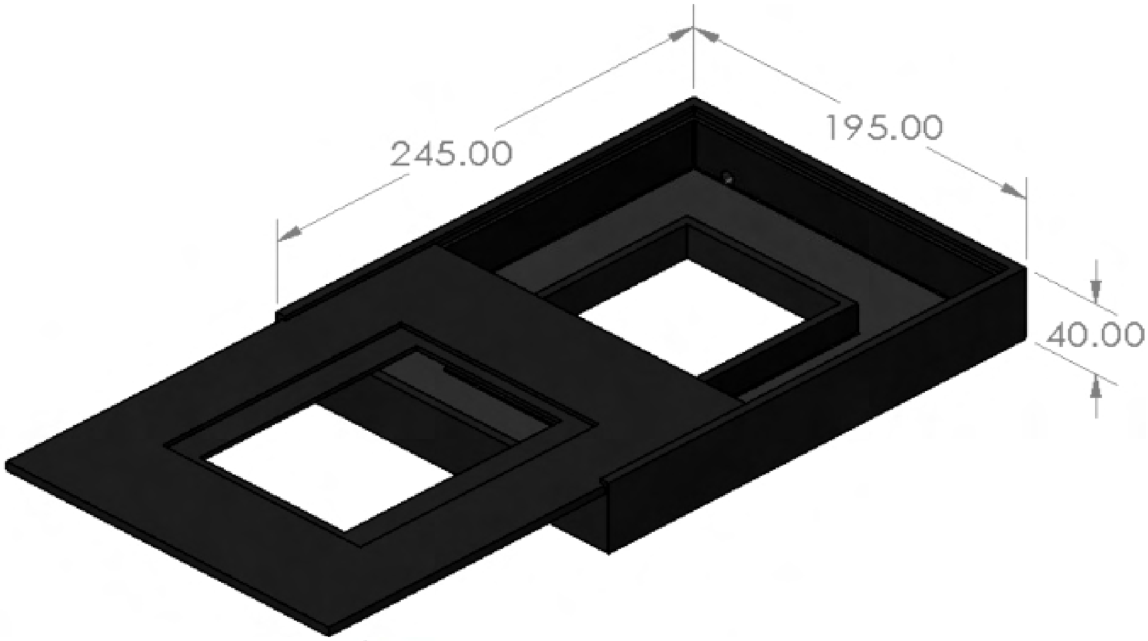
Content by: Sam

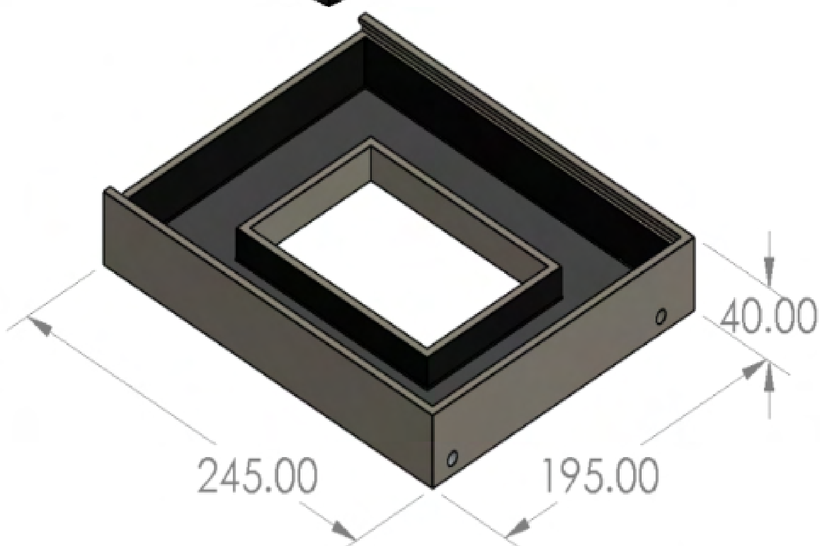
Goals: To show my weekly progress and contributions to the project.

Content:

- Created SOLIDWORKS drawings with dimensions for the design matrices







- Contributed to the rankings within the design matrices

See design matrices in the Design Process folder of Team Activities

- Conducted research on thermal properties to develop engineering reasoning as to why one tubing arrangement is better than another.

See 2/2/22 Heat Transfer Calculations

Conclusions/action items:

Continue to research the physics of thermal properties within the incubator to maximize the heat transfer. Finding the correct equations and values to use, as well as converting different values is proving to be a little more difficult than expected. Continue to update SOLIDWORKS drawings in order to have files ready to be sent to the laser cutter for prototyping. The most challenging aspect of this is having the slots to glue the acrylic slabs together.

2/24/22 Progress Report 4

SAMUEL BARDWELL - Mar 02, 2022, 12:48 PM CST

Title: Progress Report 4

Date: 2/24/22

Content by: Sam

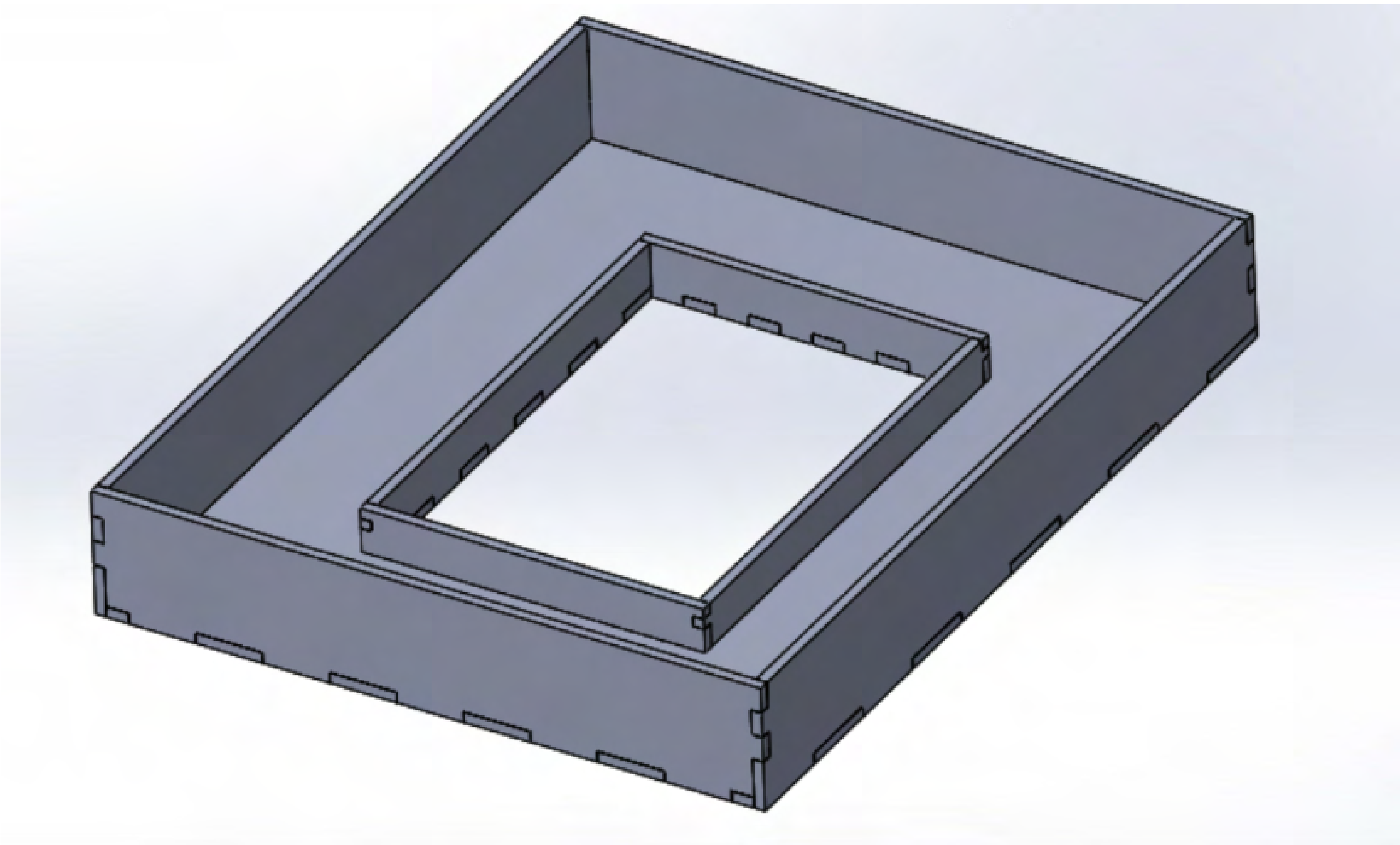
Goals: To show my weekly progress and contributions to the project.

Content:

- Determined how long it would take for copper to heat up the water bed using heat transfer equations.

See 2/22/22 Heat Transfer Calculation page in my Biology/Physiology/Chemistry folder

- Continued to develop the SOLIDWORKS drawing to be able to laser cut a prototype in the next couple of weeks.



- Contributed to the preliminary presentation and report.

Mainly the three preliminary design sections.

Conclusions/action items:

Work on the preliminary report and practice the preliminary presentation for Friday. Finalize the SOLIDWORKS drawing to laser cut a cardboard prototype. Begin to order materials for the fabrication process.

3/3/22 Progress Report 5

SAMUEL BARDWELL - Mar 02, 2022, 12:51 PM CST

Title: Sam's Progress Report 5

Date: 3/3/22

Content by: Sam

Goals: To show my weekly progress and contributions to the project.

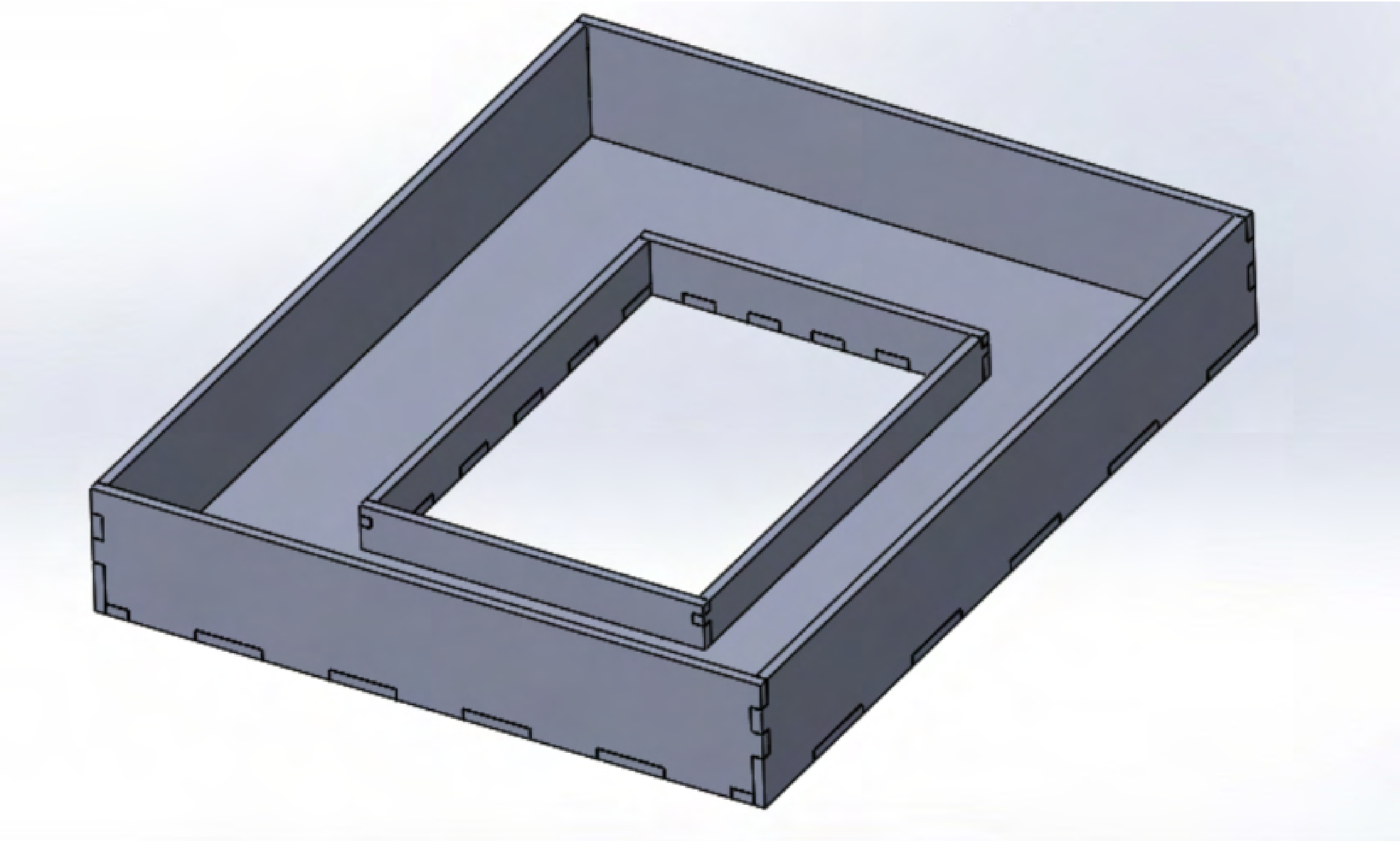
Content:

- Contributed to the preliminary report by talking about the three preliminary designs as well as the intended fabrication methods.

Preliminary presentation went very well and can be found in the Team Activities Project File folder.

Main sections I worked on for the preliminary report were the three preliminary designs, the proposed final design, as well as the methods sections for the fabrication of the box.

- Finalized a SOLIDWORKS drawing to be able to build a cardboard prototype at the makerspace



- Began finding materials that need to be ordered.

See 2/28/22 Draw Latches Entry in Parts Folder of Research

We will have to see if Dr. P will allow us to order materials off of Amazon to reduce costs of items

Need to find cheap, but reliable copper as well as adaptors

Conclusions/action items:

Laser cut a cardboard prototype to determine if the intended box design works. Begin to order materials for the project and once they arrive, update the SOLIDWORKS drawing to include the new materials. Help with the CO2 input mechanisms.

3/10/22 Progress Report 6

SAMUEL BARDWELL - Mar 09, 2022, 4:16 PM CST

Title: Sam's Progress Report 6

Date: 3/10/22

Content by: Sam

Goals: To show my weekly progress and contributions to the project.

Content:

- Found materials to be sent to Dr. P in order to hopefully obtain them after break to begin the next steps of fabrication

Expenses

Item	Description	Manufacturer	Part Number	Date	QTY	Cost Each	Total	Link
Component 1								
Copper Tubing	5 ft rigid Copper Tubing .5 in outer diameter, .43 in inner diameter for inside the incubator well	Grainger	4WTH4	3/9/22	1	$13.70	$13.70	Link
Component 2								
Polycarbonate Transparent Thermal Insulation Sheets	2"x4.25" clear Polycarbonate safety plate for covering cells while viewing	Airgas	RAD64005012	3/9/22	4	$0.53	$2.12	Link
Component 3								
Acrylic Contact Cement	1 oz Clear Contact Cement to mount clasps and assemble acrylic box	Grainger	3EHR7	3/9/22	2	$2.73	$5.46	Link
Component 4								
Buna-N Square Rubber Cord	5ft, ⅛" x ⅛", 70A, 0°C - 210°C square rubber chord to prevent leakage with clasp lid	Grainger	784U15	3/9/22	1	$4.86	$4.86	Link
TOTAL:	$26.14							

Table 1: Table showing the details of each material we are sending to Dr. P to order before spring break.

- Brainstormed possible CO_2 input regulation designs

* See 3/8/22 Handwritten Drawing of CO_2 Input in the design folder in my folder *

- Updated SOLIDWORKS design to incorporate the latch top.

Conclusions/action items:

Laser cut a prototype of the box to check if the dimensions are accurate and see if the non-fastener finger lock design works. Update SOLIDWORKS designs to incorporate new materials. Possibly create a SOLIDWORKS drawing for CO_2 input regulation

3/24/22 Progress Report 7

SAMUEL BARDWELL - Mar 23, 2022, 6:40 PM CDT

Title: Sam's Progress Report 7

Date: 3/24/22

Content by: Sam

Goals: To show my weekly progress and contributions to the project.

Content:

- Updated SOLIDWORKS drawings in order to be able to laser cut a prototype of the incubator box out of HDF wood.

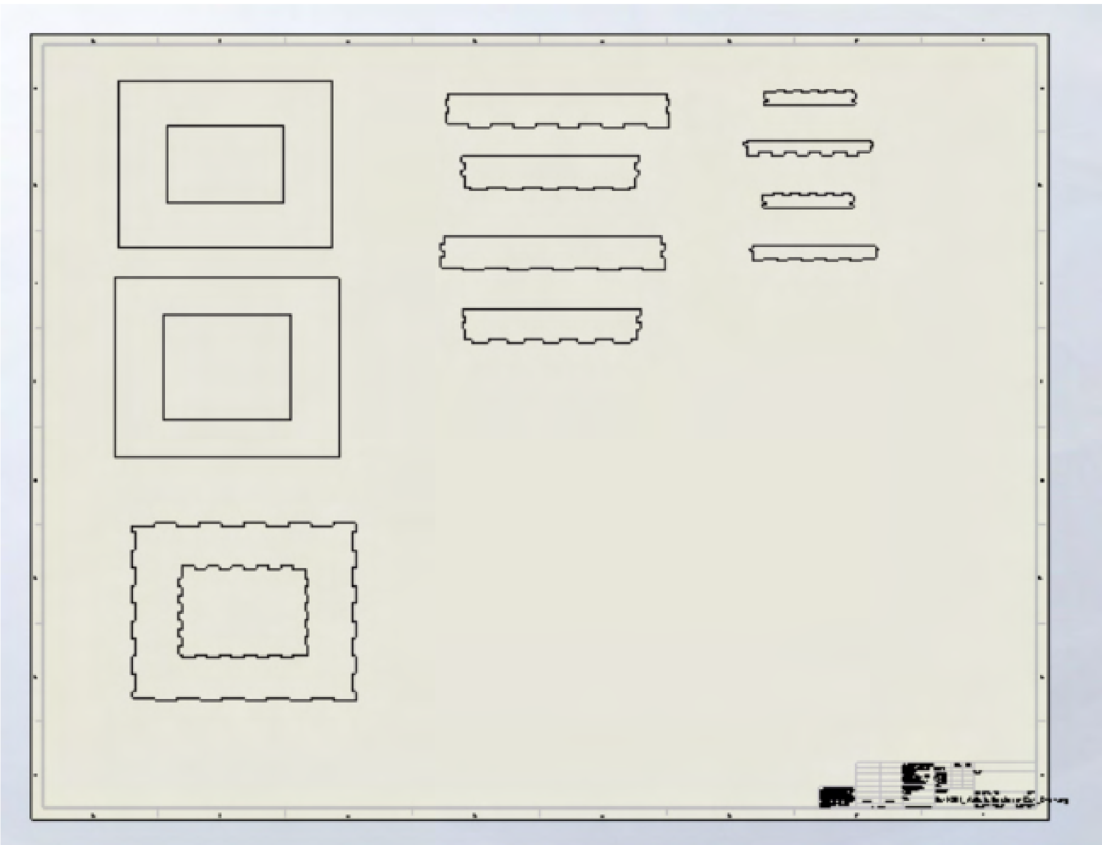


Figure 1: SOLIDWORKS drawing of the box used for the laser cutter.

- Laser cut the HDF wood and assembled the incubator prototype.

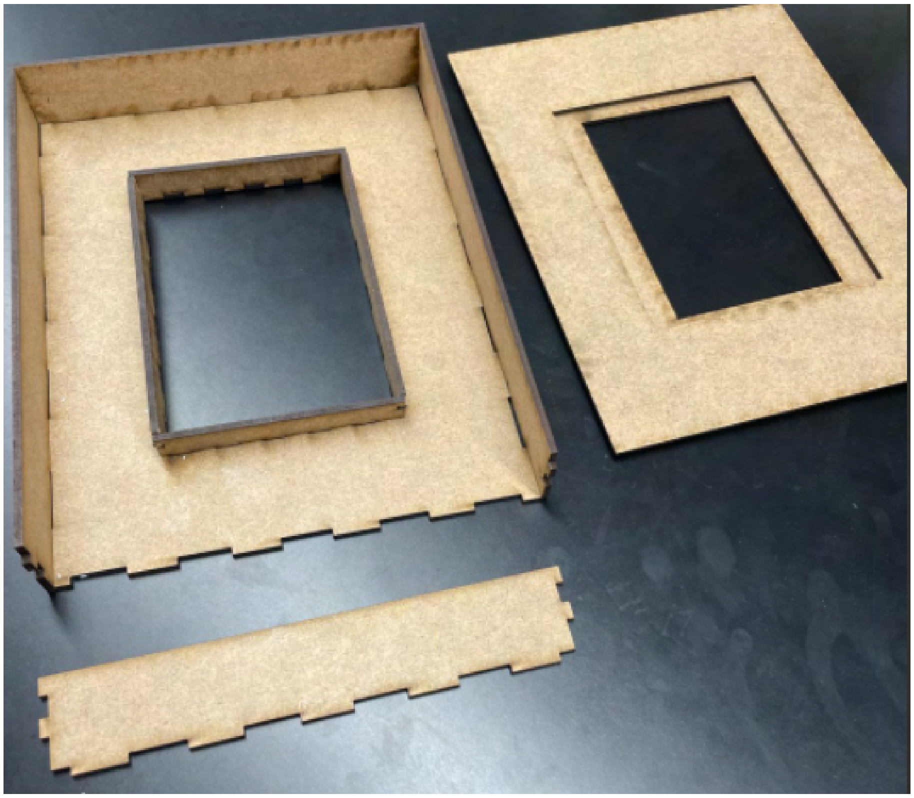


Figure 2: Disassembled laser cut box made from HDF wood in the Makerspace

- Researched CO_2 flow rates to help us with mathematical calculations on the CO_2 input.

Easiest way to determine flow rate at 1 atm (14.7 psi) of the CO2 tank is to use a sensor.

Using a sensor will help us determine how long to leave the valve open and closed for to maintain 5% CO2 in the incubator box.

- Contributed to the show and tell pitch and call to action.

Need help waterproofing the inside of our box or help finding a airflow rate sensor.

Conclusions/action items:

Conduct more research and mathematical calculations on the CO_2 input and flow rates to help Katie write code for the DC motor. Obtain a DC motor and begin the fabrication of the CO_2 regulation. Fabricate more of the acrylic box. Obtain latches to see if they are compatible with the incubator box.

3/31/22 Progress Report 8

SAMUEL BARDWELL - Apr 06, 2022, 6:23 PM CDT

Title: Progress Report 8

Date: 3/31/22

Content by: Sam

Goals: To show my weekly progress and contributions to the project.

Content:

- Found barbed connectors and copper couplings for the tubing part of the incubator

Figure 1: Photo of the threaded piping and barbed tubing adaptor.

- Fabricated the copper tubing ring around the inside of the incubator

Figure 2: Inner copper tubing fabrication within the prototyped box.

- Conducted flow rate testing using balloons and a known amount of water to determine the flow rate of the CO_2 tank

Time to fill balloon with CO2 = 3s

Initial Water Volume = 2650mL

Trial	Displacement L	Flow Rate L/sec
1	1.9	0.6333333333
2	1.925	0.6416666667
3	2.4	0.8
4	2.1	0.7
5	2.35	0.7833333333
Average	2.135	0.7116666667

Flow rate = 0.7116666667 L/sec

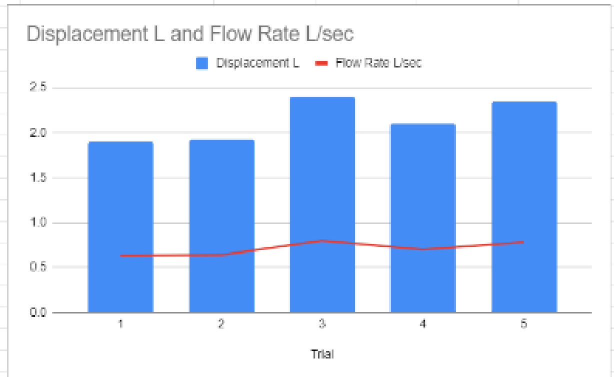


Figure 3: Photo of the flow rate data and graph showing the average flow rate at 14.7 psi.

- Completed some mathematical calculations to find out what 5% of the inside volume of the box

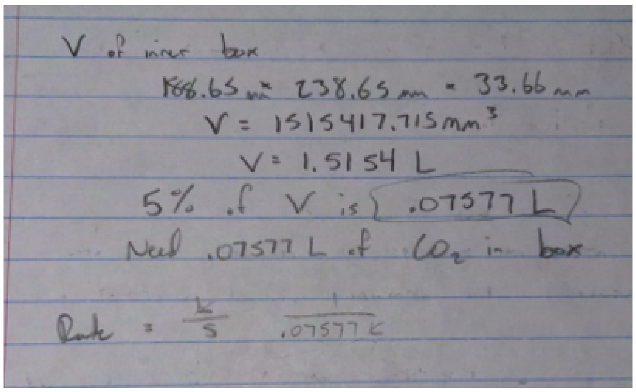


Figure 4: Photo of the mathematical calculations for the inner volume of the incubator box.

Conclusions/action items:

Finish fabricating the tubing on the inside of the incubator. Update the SOLIDWORKS drawings to incorporate the input and sensor holes. Help Katie transfer flow rate and 5% volume of the box to the DC motor code.

4/7/22 Progress Report 9

SAMUEL BARDWELL - Apr 06, 2022, 6:30 PM CDT

Title: Sam's Progress Report 9

Date: 4/7/22

Content by: Sam

Goals: To show my weekly progress and contributions to the project.

Content:

- Worked on the functioning of the DC motor.

- Fabricated part of the inner copper tubing using the TeamLab space.

Figure 1: Inner copper tubing fabrication within the prototyped box.

- Updated SOLIDWORKS drawings and assemblies to incorporate the holes necessary for the sensors and inputs and prepared that file to laser cut the acrylic

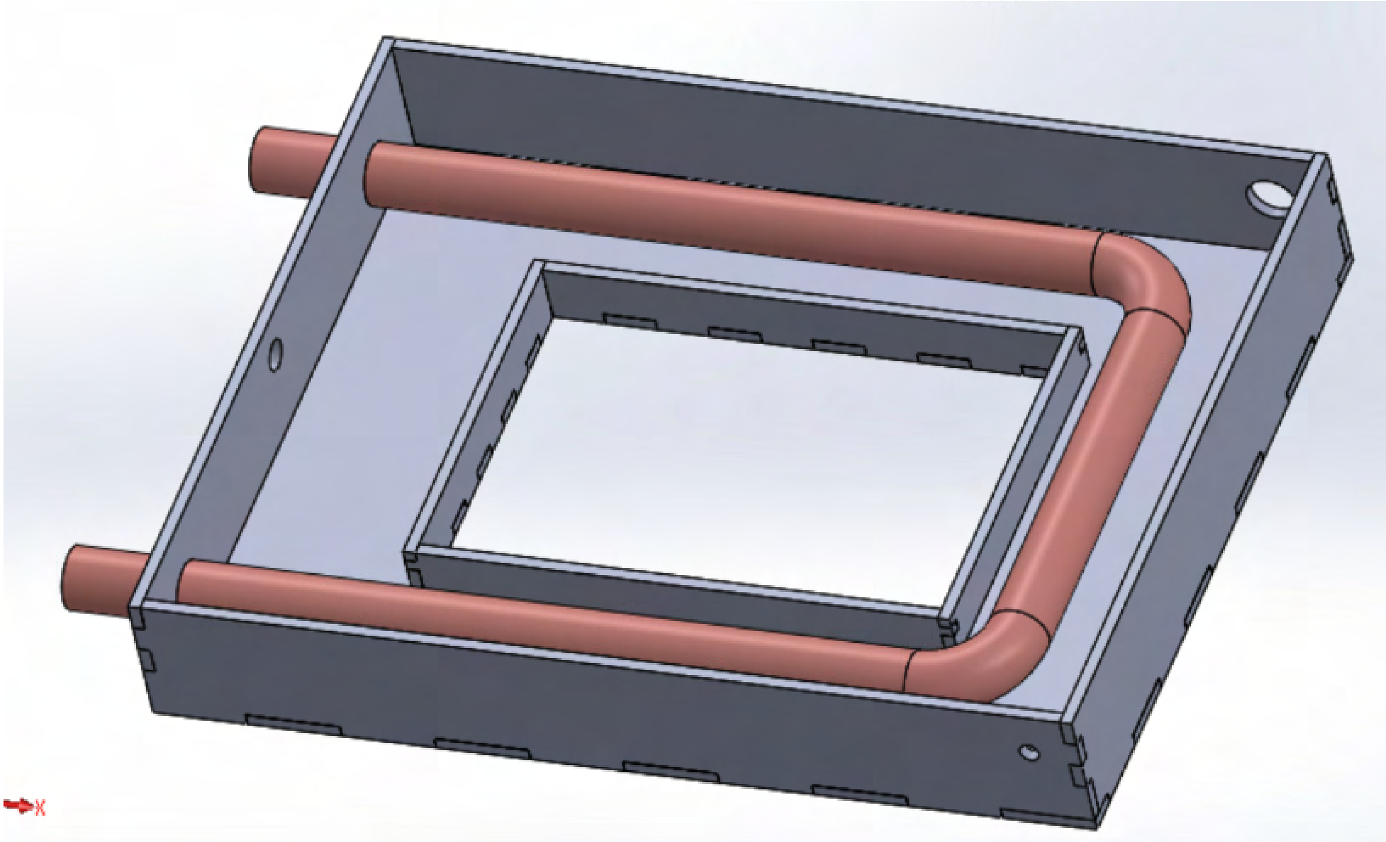


Figure 2: SOLIDWORKS drawing without the lid on the updated assembly.

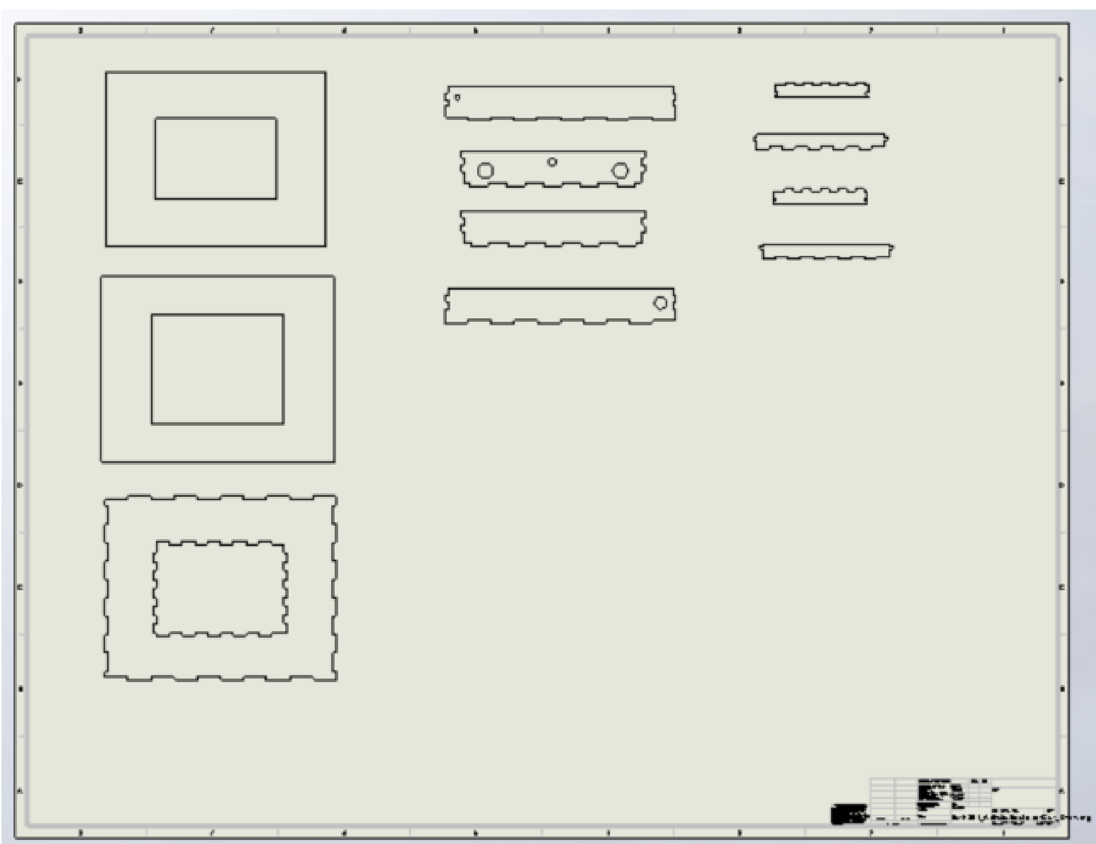


Figure 3: SOLIDWORKS drawing ready to be cut by the laser cutter with acrylic.

- Reviewed the executive summary.

Conclusions/action items:

Laser cut the acrylic box and fabricate necessary parts. Begin securing the sensors and inputs to the acrylic box. Continue working on CO_2 input control.

4/14/22 Progress Report 10

SAMUEL BARDWELL - Apr 13, 2022, 5:03 PM CDT

Title: Progress Report 10

Date: 4/13/22

Content by: Sam

Goals: To show my weekly progress and contributions to the project.

Content:

- Produced final drawings in order to laser cut the box

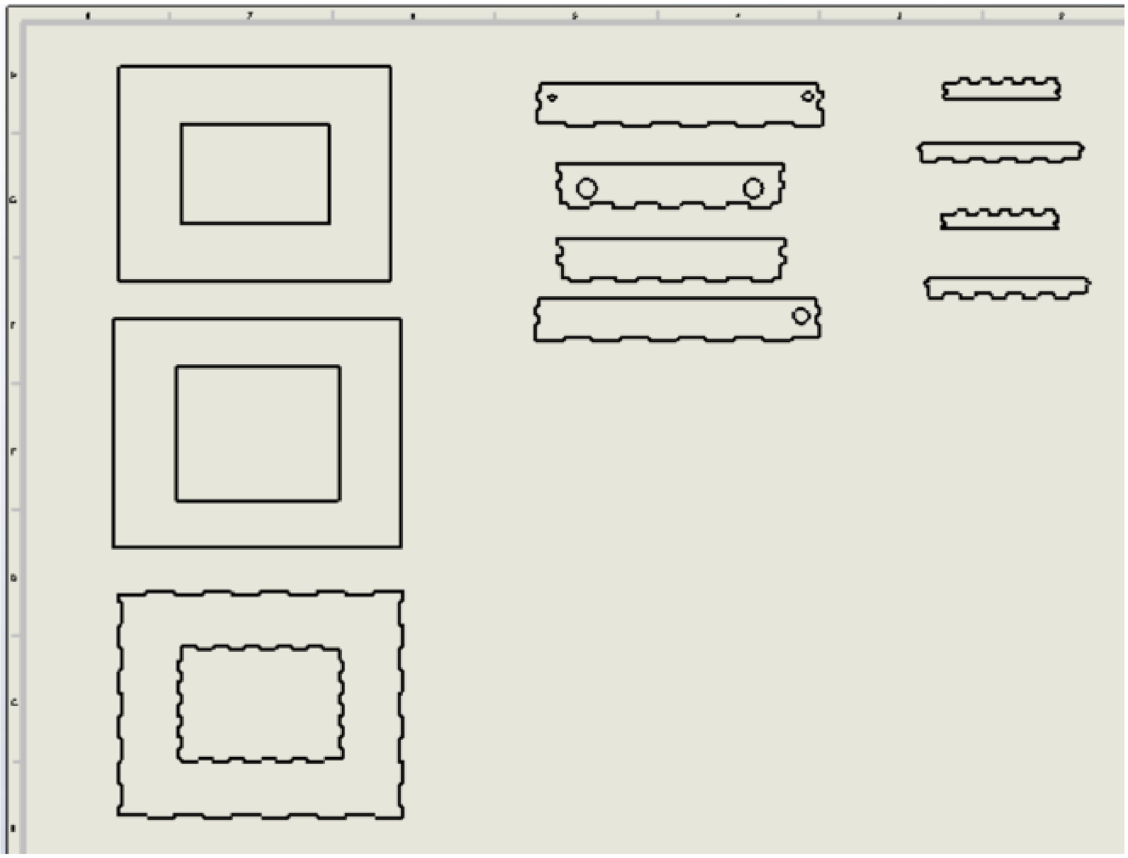


Figure 1: Final drawing before laser cutting the black acrylic.

- Laser cut black acrylic and assembled the box for the incubator.

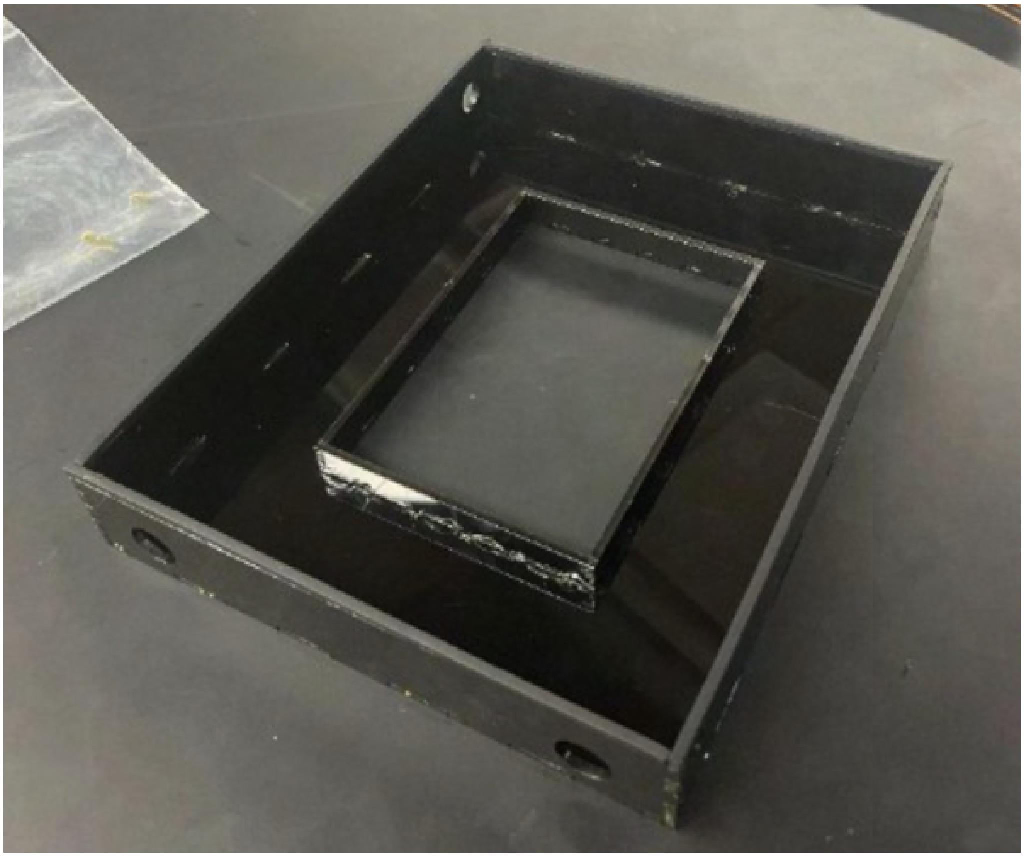


Figure 2: Assembled black acrylic box after being laser cut.

- Fabricated more of the copper tubing and added attachments for the heated water pump tubing.

Figure 3: Copper tubing with all necessary attachments for the water pump tubing.

Conclusions/action items:

Finalize the fabrication of the box and begin waterproof testing and then temperature and humidity testing of the box. Help with the CO_2 input fabrication and coding. Begin testing the box as a whole and possibly with live cells.

4/21/22 Progress Report 11

SAMUEL BARDWELL - Apr 20, 2022, 2:31 PM CDT

Title: Progress Report 11

Date: 4/21/22

Content by: Sam

Goals: To show my weekly progress and contributions to the project.

Content:

- Conducted waterproof testing on the copper tubing.

- Found out that hot glue, super glue, and electrical solder do not produce a waterproof seal on the copper.

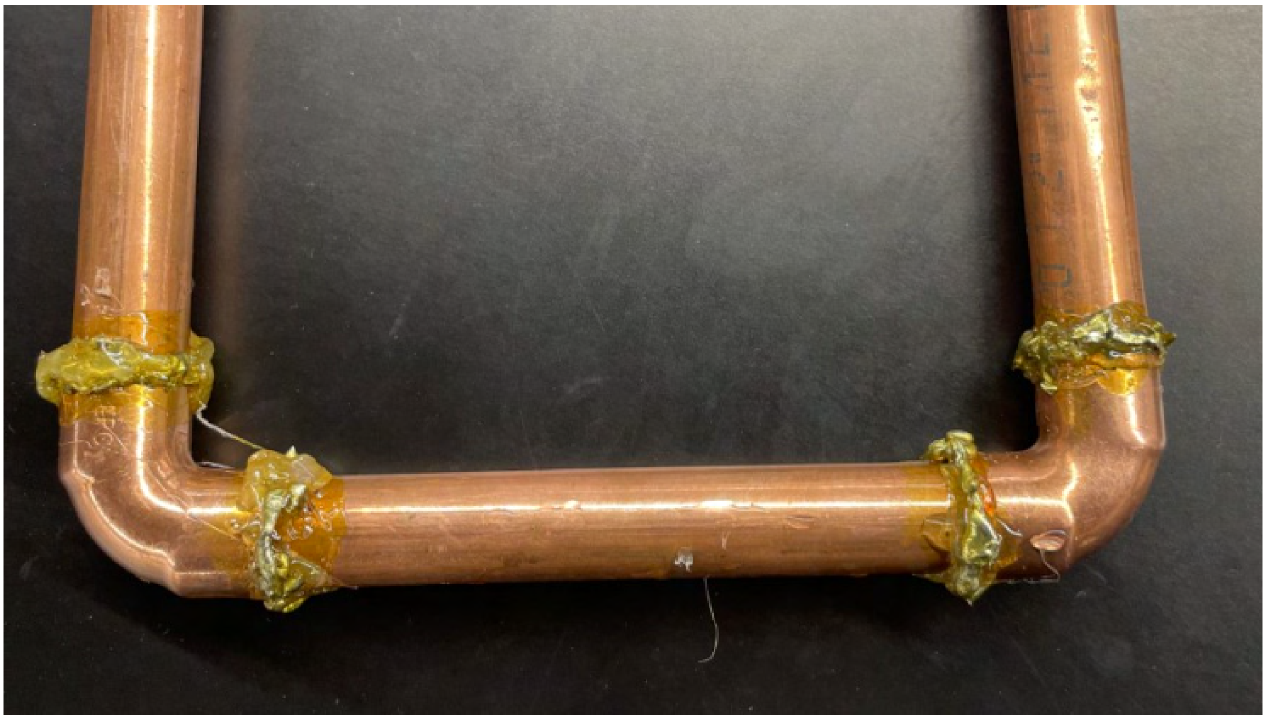


Figure 1: Photo of faulty hot glue, super glue, and electrical solder joints.

- Ended up using plumber solder and help from the TeamLab to secure the copper tubing.

Figure 2: Photo of plumbing soldered copper tubing within the incubator box.

- Conducting heat and humidity testing.

- Contributed to the executive summary and final report.

Conclusions/action items:

Begin working on final deliverables. Try to figure out CO_2 input before the end of the semester. Conduct more humidity testing and try to find the best way to not have condensation on the glass.

4/28/22 Progress Report 12

SAMUEL BARDWELL - Apr 27, 2022, 12:37 PM CDT

Title: Progress Report 12

Date: 4/28/22

Content by: Sam

Goals: To show my weekly progress and contributions to the project.

Content:

- Conducted recovery testing of the incubator.

- Contributed to the final report and presentation.

Specifically the final design sections.

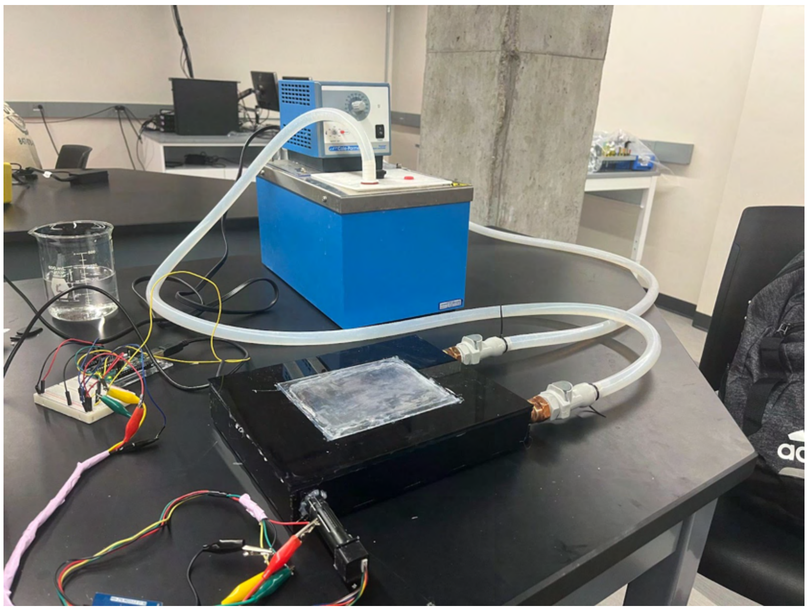


Figure 1: Whole Incubation Set-up

- Practiced the final presentation.

Conclusions/action items:

Complete all final deliverables and last day documents.

2/4/2022 Humidity Sensor

Katie Day - Feb 04, 2022, 4:39 PM CST

Title: Katie Day

Date: 2/4/2022

Content by: Katie Day

Present:

Goals: To research more about how to calculate humidity from temperature.

Content:

- Humidity Types
  - Absolute Humidity = total mass of water vaper/ volume of air
  - Relative Humidity = $(e/e_s) * 100$
    - $e = 6.11 * 10^{\frac{7.5T_d}{237.7+T_d}}$
      -
    - e_s =$6.11 * 10^{\frac{7.5T}{237.7+T}}$
  - $T_d = \frac{237.7log(\frac{e_s*rh}{611})}{7.5-log(\frac{e_s*rh}{611})}$
  - Thanks to much help from symbolab
    - rh = $10^{\frac{20.85e_s-9.99log(e_s)^2}{9.99log(e_s)-7.5}}$

Conclusions/action items:

Try using this equation in code

2/22/2022 Heat Transfer for Copper and Water Bed

Katie Day - Feb 22, 2022, 12:22 PM CST

Title: Heat Transfer for Copper and Water Bed

Date: 2/22/2022

Content by: Katie Day

Present:

Goals: To try to determine how long it will take to heat up the water bed based on the thermal conductivity of copper.

Content:

See attached files. Useful links:

https://en.wikipedia.org/wiki/Copper_in_heat_exchangers

http://www.matweb.com/tools/unitconverter.aspx?fromID=10&fromValue=118

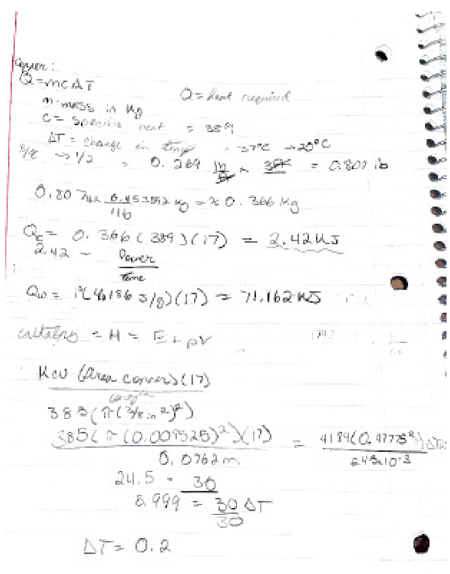
https://www.google.com/search?q=k+of+water&source=lmns&bih=569&biw=1280&rlz=1C1CHBF_enUS985US985&hl=en&sa=X&ved=2ahUKEwies7PF8pP2AhV1hGoFHXiRAkoQ_AUoAHoECAEQAA

https://study.com/academy/lesson/heat-transfer-through-conduction-equation-examples.html

Conclusions/action items:

If we heat up the water to 50*C running through the copper tubing than the water bath will hit 37*C within 7.5minutes.

Katie Day - Feb 22, 2022, 12:23 PM CST


Q = mcΔT
Q = heat required
m = mass in kg
ΔT = change in temp
Q_c = 0.366 (389)(17) = 2.42 kJ
Q_w = (4186 J/g)(17) = 71.162 kJ
ΔT = 0.2

Download

heat_transfer.pdf (535 kB)

2/10/2022 Competing Circuit Designs

Katie Day - Feb 10, 2022, 9:56 AM CST

Title: Competing Circuit Designs

Date: 2/10/2022

Content by: Katie Day

Present:

Goals: To try and find competing circuit designs that might be of use to us to streamline electronics.

Content:

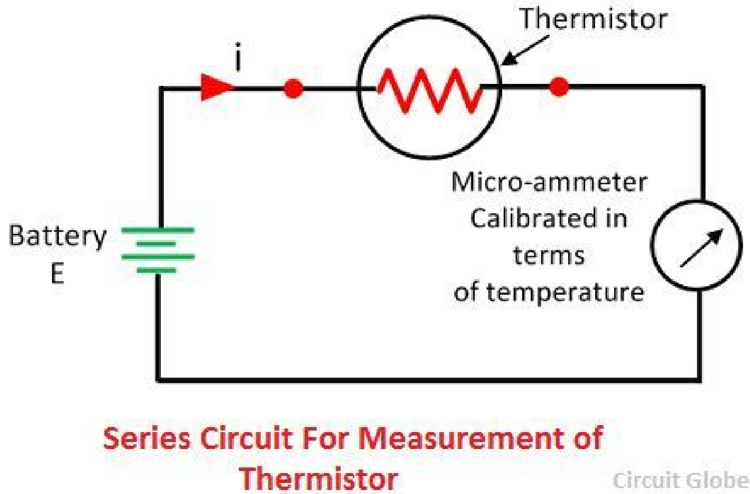
See attached file.

NDIR CO2 Sensor Operating Principles

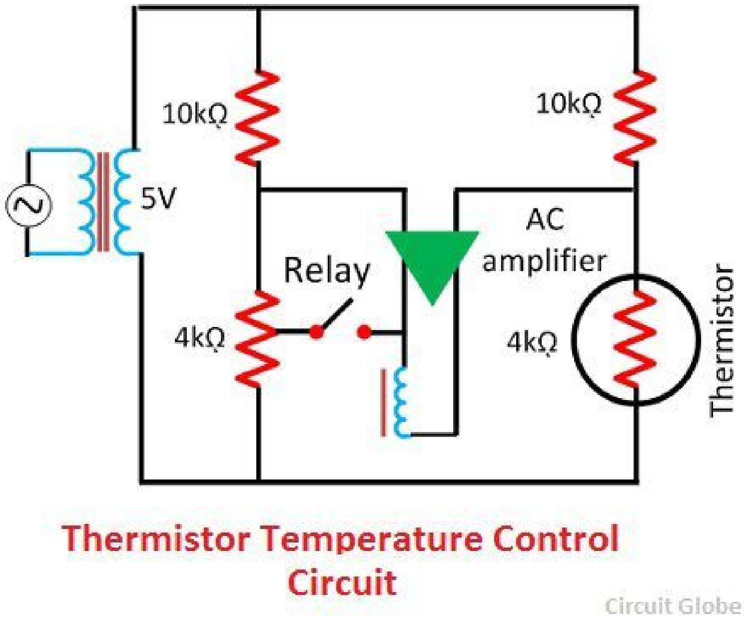
- Uses infrared light to detect CO2 gase
- Two dectectors and two optical filters of different wavelengths
- Relationship between infrared transmittance and gas concentration is expressed by Lamber-Beer Law
    - $T = I/I_0 = e^{-\varepsilon cd}$
- Exposure to high concentrations of target gas for a prolonged time would not result in irreversible sensitivity drift

Thermistor Circuit Design

- Resistance depends on external temperature



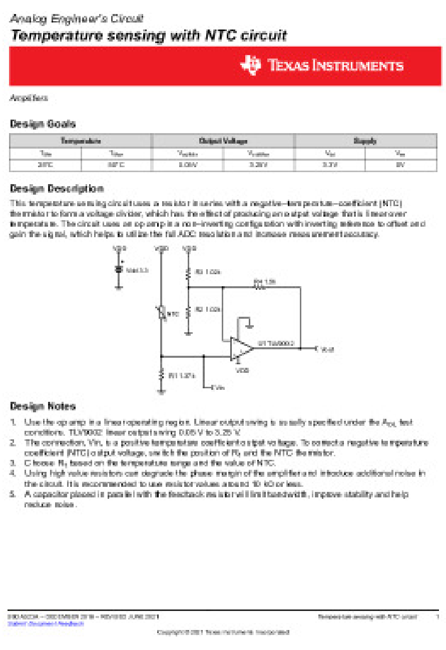
-
- Control of temperature with relay circuit (also generates heat with an accuracy of 0.00005*C



Conclusions/action items:

See if these circuits can be used to combine systems without overcomplicating things. Maybe try using an op amp?

Katie Day - Feb 10, 2022, 9:56 AM CST



Analog Engineer's Circuit

Temperature sensing with NTC circuit

TEXAS INSTRUMENTS

Amplifiers

Design Goals

Temperature		Output Voltage		Supply	
T_{Min}	T_{Max}	V_{outMin}	V_{outMax}	V_{cc}	V_{ee}
[illegible]	[illegible]	0.05V	3.25V	3.3V	0V

Design Description

This temperature sensing circuit uses a resistor in series with a negative–temperature–coefficient (NTC) thermistor to form a voltage divider, which has the effect of producing an output voltage that is linear over temperature. The circuit uses an op amp in a non-inverting configuration with inverting reference to offset and gain the signal, which helps to utilize the full ADC resolution and increase measurement accuracy.

Design Notes

1. Use the op amp in a linear operating region. Linear output swing is usually specified under the A_{OL} test conditions. TLV9002 linear output swing 0.05 V to 3.25 V.
2. The connection, Vin, is a positive temperature coefficient output voltage. To correct a negative temperature coefficient (NTC) output voltage, switch the position of R_1 and the NTC thermistor.
3. Choose R_1 based on the temperature range and the value of NTC.
4. Using high value resistors can degrade the phase margin of the amplifier and introduce additional noise in the circuit. It is recommended to use resistor values around 10 kΩ or less.
5. A capacitor placed in parallel with the feedback resistor will limit bandwidth, improve stability and help reduce noise.

[Download](#)

Thermistory_circuitry.pdf (496 kB)

2/22/2022 Stage Top Incubators

Katie Day - Feb 24, 2022, 9:25 AM CST

Title: Stage Top Incubators

Date: 2/22/2022

Content by: Katie Day

Present:

Goals: To research more stage top incubators that are currently on the market.

Content:

- Okolab Stage top incubator
    - Temp range: 3*C - 60*C
    - Chambers available for Xy stage/ piezo insert
        - Stage Platform Dimensions: **150x150mm**. Stage Height: 36mm.
    - Magnet locks that hold the plates in the correct position
    - Sliding lid
    - Temp sensor
    - CO2 sensor
    - Cost: 431.00 USD
- Elliot Scientific
    - Stage Top Incubator (DPMH)
        - 1-50*C
        - 0-20% Co2
        - quote requested.

Conclusions/action items:

Good to note that other stage top incubators are out there but are more costly.

2/28/2022 CO2 Valve Monitoring

Katie Day - Feb 28, 2022, 7:45 PM CST

Title: CO2 Valve Monitoring

Date: 2/28/2022

Content by: Katie Day

Present:

Goals: To try and come up with a way to monitor the flow of CO2 from a 100% CO2 tank.

Content:

See links for Youtube videos I used as inspiration.

- https://www.youtube.com/watch?v=An_A2XnI6IQ
- https://www.youtube.com/watch?v=An_A2XnI6IQ
- https://www.youtube.com/watch?v=f8B9plLAqGI

Idea:

- Use a DC motor and a rod with arms that go above and below the pressure gauge. Code the DC motor to move to the left or right (increasing or decreasing the tilt of one of the arms) to let more CO2 into the incubator or less depending on the reading from the CO2 sensor in the incubator.
- See drawing at the bottom for better clarity.

Conclusions/action items:

This could be a good way to measure CO2 output. See if Dr. Puccinelli or Dr. Kinney has legos or knix I could use to build the arms. I think that might be a cost effective way to build it. Or reach out to Dr. Nimunkar and see what he has on hand. Maybe even cut some wood scraps if we want something sturdier. First take a look at CO2 tank before starting purchasing.

Katie Day - Feb 28, 2022, 7:44 PM CST

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3/11/2022 WARF Presentation

Katie Day - Mar 10, 2022, 9:34 AM CST

Title: WARF Presentation

Date: 3/11/2022

Content by: WARF on Campus

Present:

Goals: WARF overview, protecting innovation, commercializing innovation, etc.

Content:

- WARF beginings
    - Created in 1925 to manage intellectual property related to Dr. Steenbock
    - Organized as a non profit
    - Proceeds support research at UW-Madison
    - Governed by an independent board of alumni
- Vision
    - Enable UW Madison research to solve the world problems
- Mission
    - To support scientific research within the UW-Madison COmmunity
- Cycle of Innovation
    - 6th overall in research funding
    - 350-400 invention disclosures each year
    - 2000 issued us patents with 700 pending
    - 50+ licenses annually
    - >1 bill products sold
- Protecting inoovation
    - Patents
        - machines and devices
        - compound
        - processes and methods
        - improvement s
    - Trademarks
        - Words and phases
        - Colors
        - pictures/logos
        - sound
    - Copyrights
        - Literary works
        - webpages
        - software programs
- Prior Art
    - "references" created before a specific date
        - by the inventor: >1 year before the filling date of the patent application
        - By another: before the filing date of the patnet application
    - Novelty and non-obviousness are evaluated based on prior art
    - Internationally, absolute novelty is typically required
- Public Disclosure and Prior Art
    - Examples of public disclosures of an invention
        - Journal pub
        - Talk or poster at conference/professional meeting
        - Non-confidential deparment seminar
        - Open thesis defense
        - Cataloged dissertation
        - Some funded grant abstracts
        - Description on an internet site
- Requirements for Patentability
    - Eligible

  - Useful
  - Enabled
  - Described
  - Novel
  - Non-obvious
- WARF's IP Management process
  - Disclosure your invention --> Disclosure committee meets monthly to review new disclosures--> patent application drafting, filing, and prosecution --> technology marketing ---> licensing
- Licensing Considerations for New Disclosure
  - Chance of licensing
    - potential applications, technology benefits and impact, state of market, etc
  - Timeline for licensing
  - Licensing strategy
  - Plan for next year
  - Revenue projections
- Licensing Innovation
  - WARD Provides
    - Exclusive or non-exclusive rights to make, use, sell, or import
  - Licensee Provides
    - Develop and commercialize
    - Reasonable Fees: upfront, royalties, milestones, etc
    - Fulfill obligations under Bayh-Dole
  - Timeline
    - Varies from months to years
    - Depends on technology and market readiness
- WARF's Accelerator Program
  - Milestone-based **validation funding** to speed promising technologies to a commercial license
    - **Goal:** Accelerate commercialization prospects for WARF IP
    - **Catalysts**: Expert Consultants with significant buisness experience
    - **Five Sectors**
      - Computer Science and Engineering
      - Med Devices and Healthcare
      - CleanTech
      - Food and Agriculture
      - Research Tools
    - REsults
      - 28 licenses / 6 paid options
      - 13 startups
      - $5.5M (45% of funding) in COE
- Finding a Licensee
  - INternal
    - INventor Contacts
    - Meetings
    - Sponsored Research
  - External
    - Technology descriptions on website
    - Publications
    - Technology portals
    - Targeted outreach
  - Inventor Startup
- Factors to consider in starting a company
  - Technology
  - Market
  - Management
  - Capital Requirement s
- Start-up Resources
  - Discovery to Product, a campus wide resource for entrpreneurship
  - Entrepreneurons - Seminar Series
  - Innovation Roadmap Series
  - UpStart Program for Minority and Women's Entrepreneurship
  - Law and Business Entrpreneurship Clinics

Conclusions/action items:

I think that our design has intellectual property as it is a low cost, novel, alternative to large costly microscope incubators that can be used in research labs, teaching environments, and other research applications all over the world.

3/21/2022 Initial Prototype Laser Cutting

Katie Day - Mar 21, 2022, 7:37 PM CDT

Title: Initial Prototype Laser Cutting

Date: 3/21/2022

Content by: Katie Day

Present: Katie Day and Sam Bardwell

Goals: To laser cut our initial prototype.

Content:

- Sam and I were not able to laser cut the initial prototype
- Problems
    - The rastoring is not going to work. It is too complex, takes too long, and is overall inefficient
    - When I transferred the drawing to illustrator I created too many paths causing the laser cutter to go over the same piece multiple times
    - The thickness was in pts not inches
    - The offset is slightly too large for what we need
- Successes
    - It does print and fit together (not well but nothing glue can't fix)
    - I still remember how to use the laser cutter
    - The box dimsensions and design will work
    - The cardboard was a great choice in material for the prototype

Conclusions/action items:

Go back to the makerspace tomorrow. Fix the paths, fix the thickness, decrease the offset, and laser cut the rest of the box to put together.

3/22/2022 Prototype Laser Cutting - Copy

Katie Day - Mar 22, 2022, 1:26 PM CDT

Title: Initial Prototype Laser Cutting

Date: 3/21/2022

Content by: Katie Day

Present: Katie Day and Sam Bardwell

Goals: To laser cut our initial prototype.

Content:

See attached file.

Conclusions/action items:

Fix the offset on the inside fillets because they are slightly too tight. Reprint with acrylic whenever we are ready.

Katie Day - Mar 22, 2022, 1:28 PM CDT

[Download](#)

IMG_6090.jpg (3.62 MB)

Katie Day - Mar 22, 2022, 1:28 PM CDT

Download

IMG_6091.jpg (3.42 MB)

3/30/2022 Flow Rate Calculations

Katie Day - Mar 30, 2022, 7:07 PM CDT

Title: Flow Rate Testing

Date: 3/30/2022

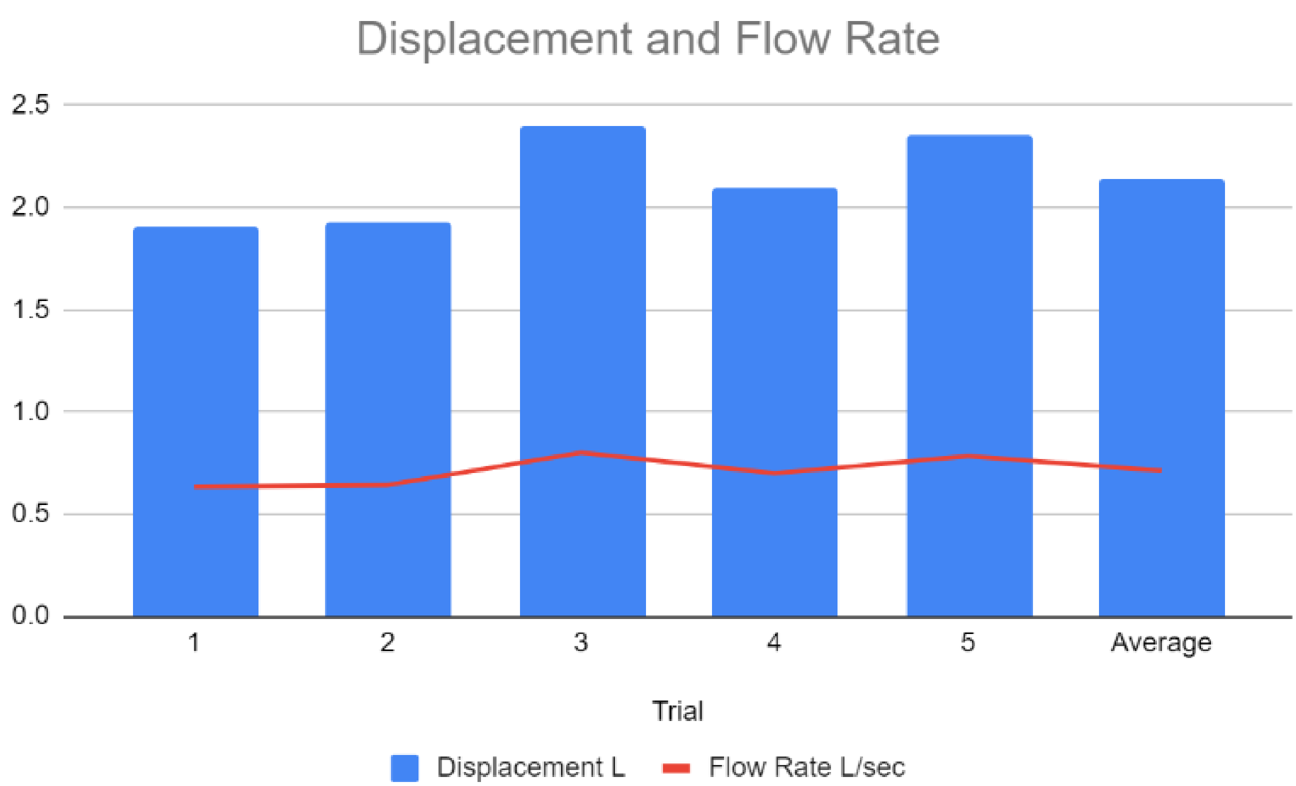
Content by: Katie Day

Present: Katie Day and Sam Bardwell

Goals: To calculate Flow rate of the CO2 tank via balloon trials.

Content:

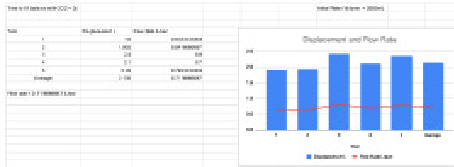
Testing was conducted using balloons and a 5L beaker. The beaker was initially filled with water, the balloon filled with CO2 for approximately 3 seconds, and then placed in the beaker to determine displacement. The following attachment contains the trials, averages, and flow rate calculations.



Conclusions/action items:

Use the flow rate calculations to determine how long the CO2 valve should be open for in order to fill the box with 5% CO2 at ~14PSI.

Katie Day - Mar 30, 2022, 7:05 PM CDT



Download

Flow_Rate_Calculations_-_Sheet1.pdf (56.1 kB)

4/5/2022 DC Motor Circuitry and Prelim Code

Katie Day - Apr 06, 2022, 3:23 PM CDT

Title: DC Motor

Date: 4/5/2022

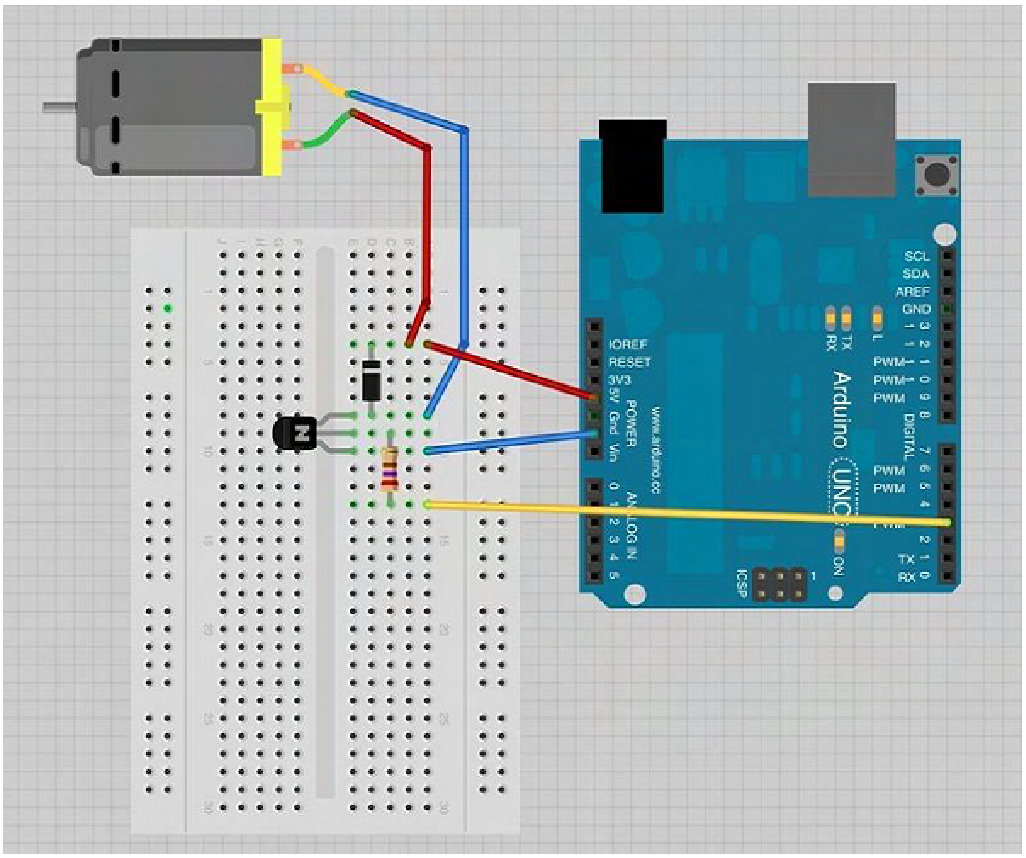
Content by: Katie Day

Present:

Goals: To build a working circuit and code a working DC motor so that it turns clockwise for three seconds, and counterclockwise for 3 seconds.

Content:

Circuit Diagram



Code:

```
const int pwm = 2 ; //initializing pin 2 as pwm
const int in_1 = 8 ;
const int in_2 = 9 ;
//For providing logic to L298 IC to choose the direction of the DC motor

void setup() {
  pinMode(pwm,OUTPUT) ; //we have to set PWM pin as output
  pinMode(in_1,OUTPUT) ; //Logic pins are also set as output
  pinMode(in_2,OUTPUT) ;
}

void loop() {
  //For Clock wise motion , in_1 = High , in_2 = Low
  digitalWrite(in_1,HIGH) ;
  digitalWrite(in_2,LOW) ;
  analogWrite(pwm,255) ;
```

```
  /* setting pwm of the motor to 255 we can change the speed of rotation
  by changing pwm input but we are only using arduino so we are using highest
  value to driver the motor */
  //Clockwise for 3 secs
  delay(3000) ;
  //For brake
  digitalWrite(in_1,HIGH) ;
  digitalWrite(in_2,HIGH) ;
  delay(1000) ;
  //For Anti Clock-wise motion - IN_1 = LOW , IN_2 = HIGH
  digitalWrite(in_1,LOW) ;
  digitalWrite(in_2,HIGH) ;
  delay(3000) ;
  //For brake
  digitalWrite(in_1,HIGH) ;
  digitalWrite(in_2,HIGH) ;
  delay(1000) ;
}
```

Conclusions/action items:

The DC motor circuit works.

Action Items:

- **3D print the motor attachment**
- **Test to see if it is strong enough to turn the valve on the CO2 tank**

4/11/2022 Incubation Chamber Fabrication

Katie Day - Apr 11, 2022, 8:25 PM CDT

Title: Incubation Chamber Fabrication

Date: 4/11/2022

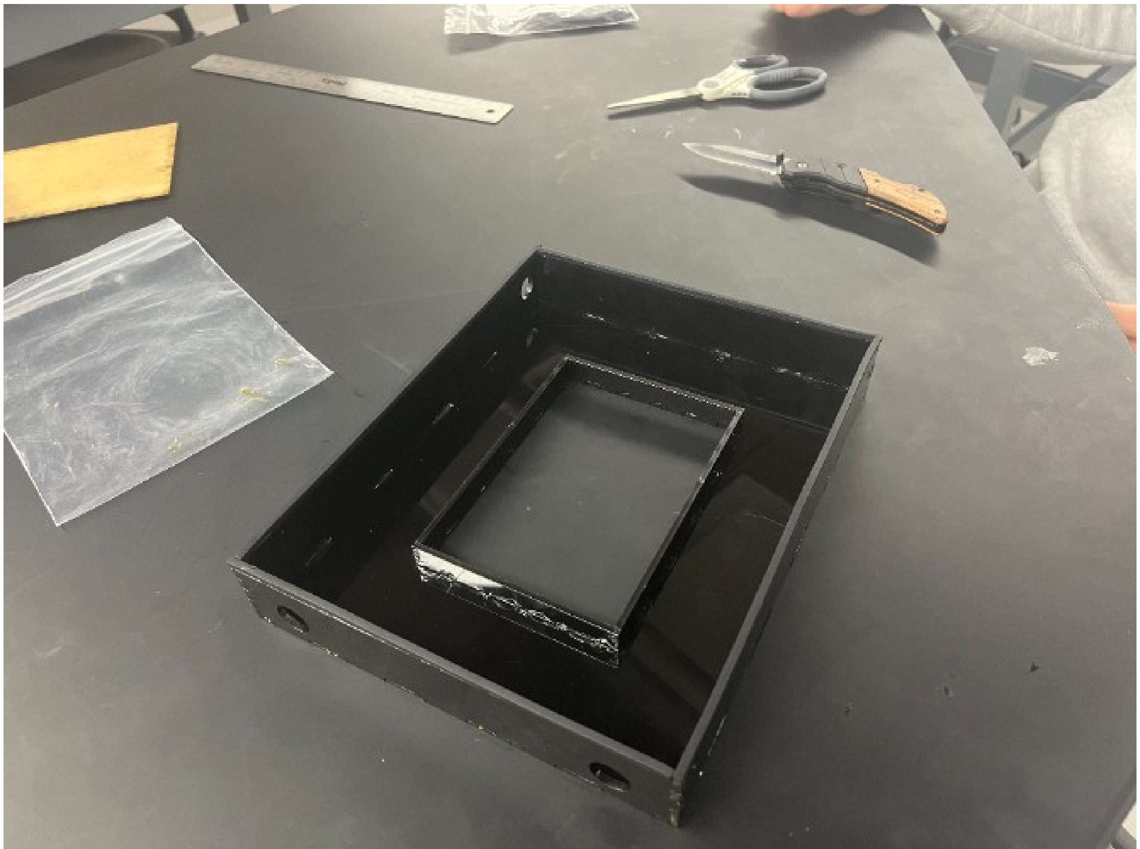
Content by: Katie Day and Sam Bardwell

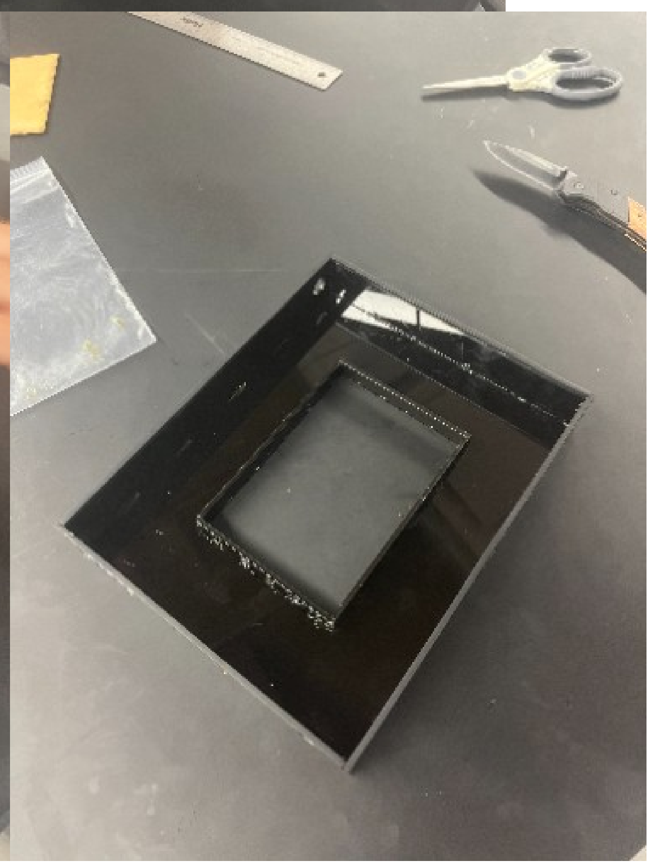
Present:

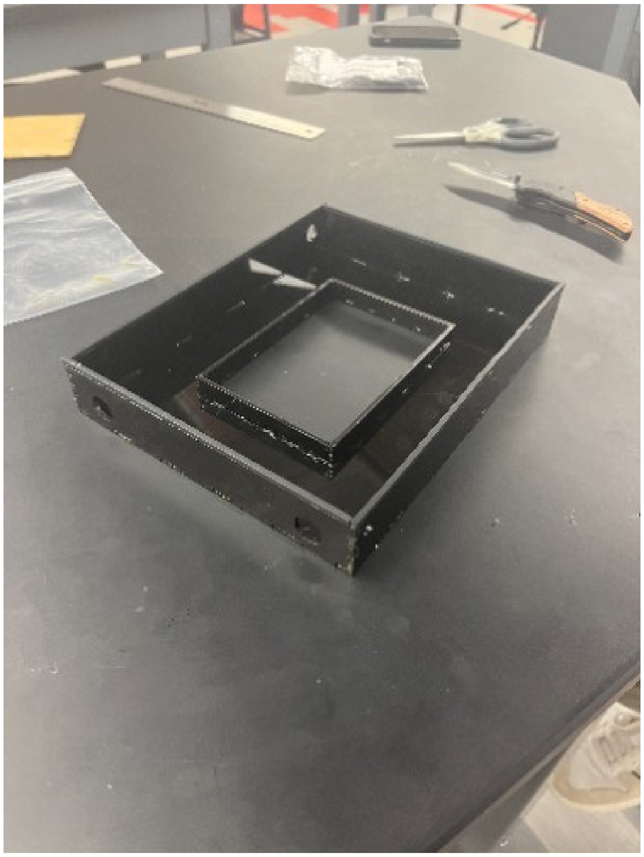
Goals: To fabricate, glue, and attach all elements of the incubation chamber.

Content:

See photos. The rubber lining was also added to the top.







Conclusions/action items:

Seal the box using caulk, file a bigger hole for the NDIR sensor, and consider spraying with an adhesive to ensure water tight.

4/21/2022 Completed Arduino Code

Katie Day - Apr 21, 2022, 12:42 PM CDT

Title: Completed Arduino Code

Date: 4/21/2022

Content by: Katie Day

Present:

Goals: To put all of the separate electronic elements onto one circuit and use one code to display all necessary values and perform all necessary functions.

Content:

See attached file.

```
//Combined Arduino Code for Temp, Hum, and CO2

//Concentration
#include <SoftwareSerial.h>
#include <NDIR_SoftwareSerial.h>

//Select 2 digital pins as SoftwareSerial's Rx and Tx. For example, Rx=2 Tx=3
NDIR_SoftwareSerial mySensor(2, 3);
double percent = mySensor.ppm/10000;

// temperature variables
int ThermistorPin = 0;
int Vo;
float R1 = 10000;
float logR2, R2, T, Tc, Tf;
float c1 = 1.009249522e-03, c2 = 2.378405444e-04, c3 = 2.019202697e-07;
float e_s;
float e_d;
float Td = 36.1;

//DC motor variables
const int pwm = 4;
const int in_1 = 8;
const int in_2 = 9 ;
//For providing logic to L298 IC to choose the direction of the DC motor

void setup()
{
    Serial.begin(9600);

    if (mySensor.begin()) {
       Serial.println("Wait 10 seconds for sensor initialization...");
        delay(10000);
    } else {
       Serial.println("ERROR: Failed to connect to the sensor.");
        while(1);
    }
   pinMode(pwm,OUTPUT) ; //we have to set PWM pin as output
   pinMode(in_1,OUTPUT) ; //Logic pins are also set as output
   pinMode(in_2,OUTPUT) ;

}

void loop() {
//  Temperature
  Vo = analogRead(ThermistorPin);
  R2 = R1 * (1023.0 / (float)Vo - 1.0);
```

```
  logR2 = log(R2);
  T = (1.0 / (c1 + c2*logR2 + c3*logR2*logR2*logR2));
  Tc = T - 271.15;
  Tf = (Tc * 9.0)/ 5.0 + 32.0;
  float hum =0;
  e_s = 6.11 * pow(10, ((7.5 * Tc)/(237.7 + Tc)));
  e_d = 6.11 * pow(10, ((7.5 * Td)/(237.7 + Td)));
  hum =exp((17.625*5.2)/(243.04+5.2))/exp((17.625*Tc)/(243.04+Tc)); //rel humidity


 Serial.print("Temperature: ");
 Serial.print(Tf);
 Serial.print(" F; ");
 Serial.print(Tc);
 Serial.println(" C");
 Serial.print("Relative Humidity: ");
 Serial.print((hum*1000)-30);
 Serial.println("%");
 delay(1000);

//Concentration
   if (mySensor.measure()) {
       Serial.print("CO2 Concentration is ");
       Serial.print(mySensor.ppm);
       Serial.println(" ppm");
       Serial.print("CO2 Percentage is ");
       Serial.print((mySensor.ppm/10000));
       Serial.println("%");

    } else {
        Serial.println("Sensor communication error.");
    }
   delay(1000);
//DC Motor
  if (mySensor.ppm < 60000){
   //For Clock wise motion , in_1 = High , in_2 = Low
   digitalWrite(in_1,HIGH) ;
   digitalWrite(in_2,LOW) ;
   analogWrite(pwm,255) ;
   /* setting pwm of the motor to 255 we can change the speed of rotation
   by changing pwm input but we are only using arduino so we are using highest
   value to driver the motor */
  }
  if (mySensor.ppm > 60000){
   //For Anti Clock-wise motion - IN_1 = LOW , IN_2 = HIGH
   digitalWrite(in_1,LOW) ;
   digitalWrite(in_2,HIGH) ;
  }else{
  //For brake
   digitalWrite(in_1,HIGH) ;
   digitalWrite(in_2,HIGH) ;
  }
}
```

Conclusions/action items:

Katie Day - Apr 21, 2022, 12:42 PM CDT

Download

Coding_Spring_22.ino (2.81 kB)

4/5/2022 Humidity Testing

Katie Day - Apr 06, 2022, 3:16 PM CDT

Title: Humidity Testing

Date: 4/5/2022

Content by: Katie Day

Present:

Goals: To test the accuracy of the humidity formula against the DHT22 humidity sensor.

Content:

The DHT22 and Thermistor both measured the humidity in ECB 1002 at ambient temperatures for 5 minutes. The resulting values and means were then compared via a t-Test.

See attached files.

Conclusions/action items:

There is no statistical significance between the DHT22 and Thermistor.

Katie Day - Apr 06, 2022, 3:16 PM CDT

Download

Misty_final_data.csv (1.75 kB)

Katie Day - Apr 06, 2022, 3:16 PM CDT

Download

Humidity_Test.csv (380 B)

4/5/2022 Temperature Testing (along with incubator Humidity Testing)

Katie Day - Apr 06, 2022, 3:18 PM CDT

Title: Temperature Testing

Date: 4/5/2022

Content by: Katie Day

Present:

Goals: To complete the testing protocols in order to determine the accuracy of the thermistor against the incubator in the teaching lab.

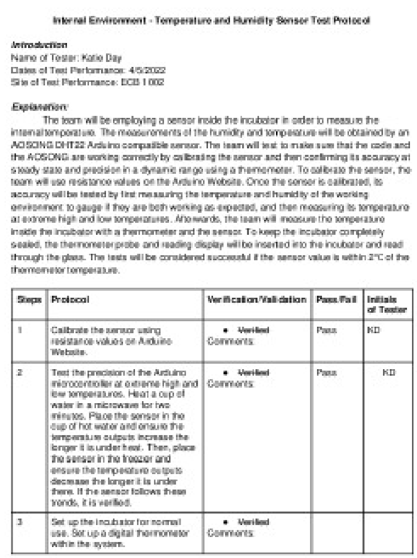
Content:

See attached files.

Conclusions/action items:

There is no statistical significance between the thermistor and the incubator readings.

Katie Day - Apr 06, 2022, 3:20 PM CDT



Internal Environment - Temperature and Humidity Sensor Test Protocol

Introduction
Name of Tester: Katie Day
Dates of Test Performance: 4/5/2022
Site of Test Performance: ECB 1002

Explanation:
The team will be employing a sensor inside the incubator in order to measure the internal temperature. The measurements of the humidity and temperature will be obtained by an AOSONG DHT22 Arduino compatible sensor. The team will test to make sure that the code and the AOSONG are working correctly by calibrating the sensor and then confirming its accuracy at steady state and precision in a dynamic range using a thermometer. To calibrate the sensor, the team will use resistance values on the Arduino Website. Once the sensor is calibrated, its accuracy will be tested by first measuring the temperature and humidity of the working environment to gauge if they are both working as expected, and then measuring its temperature at extreme high and low temperatures. Afterwards, the team will measure the temperature inside the incubator with a thermometer and the sensor. To keep the incubator completely sealed, the thermometer probe and reading display will be inserted into the incubator and read through the glass. The tests will be considered successful if the sensor value is within 2°C of the thermometer temperature.

Steps	Protocol	Verification/Validation	Pass/Fail	Initials of Tester
1	Calibrate the sensor using resistance values on Arduino Website.	• **Verified** Comments:	Pass	KD
2	Test the precision of the Arduino microcontroller at extreme high and low temperatures. Heat a cup of water in a microwave for two minutes. Place the sensor in the cup of hot water and ensure the temperature outputs increase the longer it is under heat. Then, place the sensor in the freezer and ensure the temperature outputs decrease the longer it is under there. If the sensor follows these trends, it is verified.	• **Verified** Comments:	Pass	KD
3	Set up the incubator for normal use. Set up a digital thermometer within the system.	• **Verified** Comments:		

Download

Katie_Temperature_Humdity_Testing.pdf (93.2 kB)

Katie Day - Apr 06, 2022, 3:20 PM CDT

Download

Temp_final_data.csv (673 B)

Katie Day - Apr 06, 2022, 3:19 PM CDT

Download

Temp_final_data.csv (673 B)

4/21/2022 Whole Incubator Temperature and Humidity Testing

Katie Day - Apr 26, 2022, 9:04 PM CDT

Title: Incubator Temperature and Humidity Testing

Date: 4/21/2022

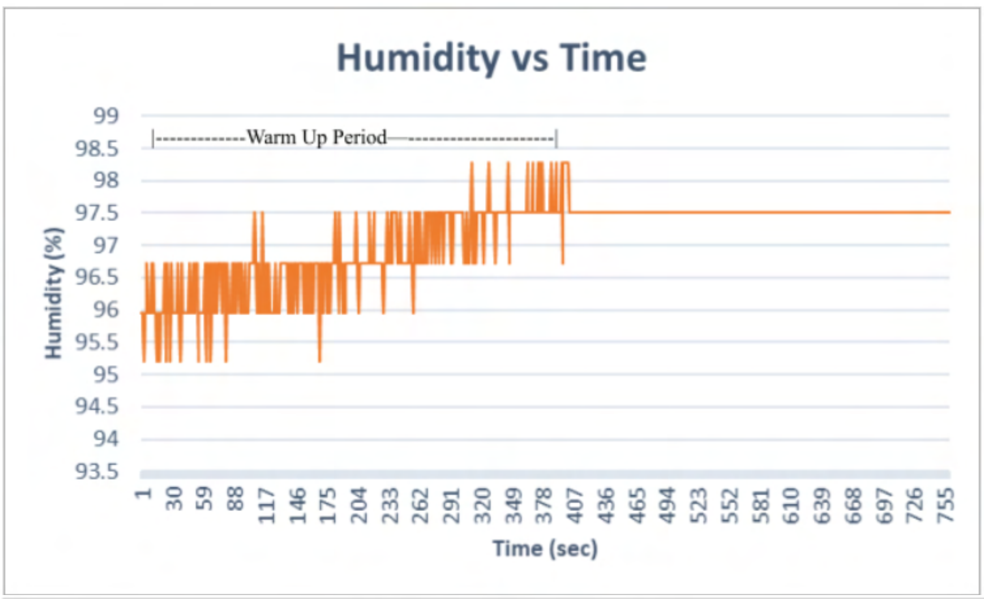
Content by: Katie Day, Maya Tanna, Bella Raykowski, Drew Hardwick, and Sam Bardwell

Present:

Goals: To test the internal environment of the incubator in regards to temperature and humidity.

Content:

- Temperature had an average temperature of 37.6℃, the dip in the graph represents turning the heated water pump down from it's warm up temperature of 40℃ to slightly below 34℃.
- Humidity testing was successful on the second try, after the formula was re-calibrated in the Arduino code. The results showed an average of 97.1% over the tested time interval.



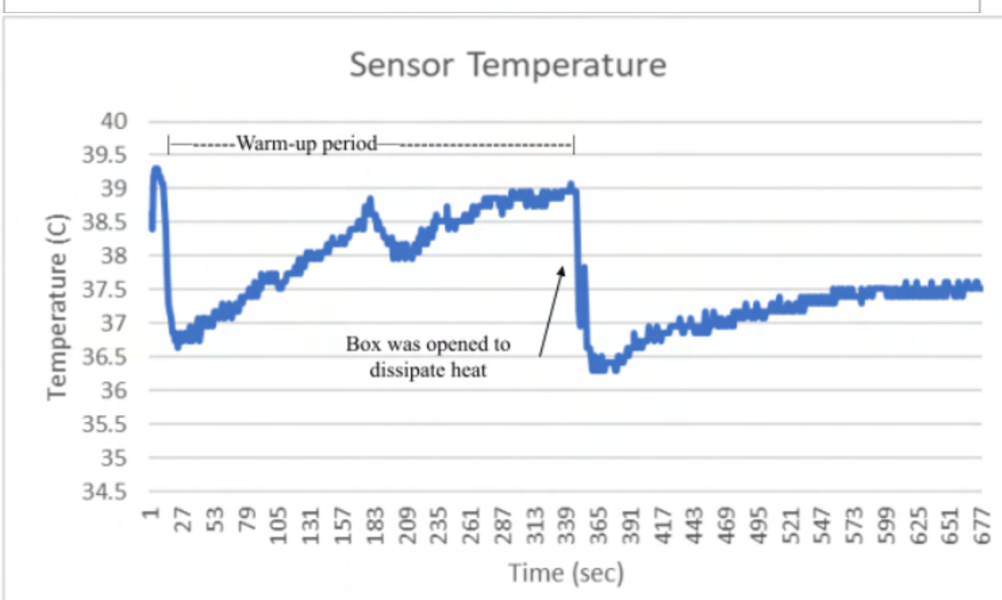


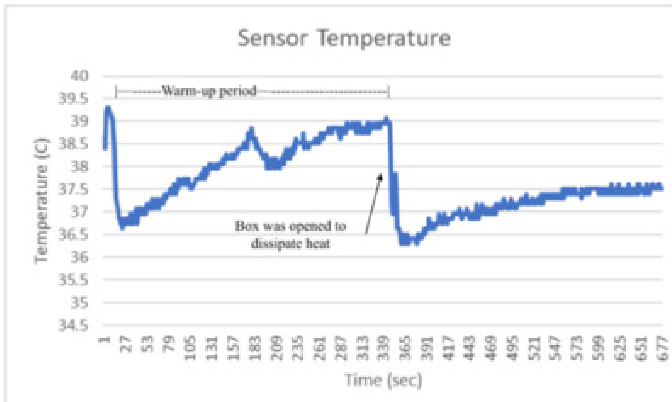
Figure 1: Sensor Humidity Results *Figure 2: Sensor Temperature Results*

See attached for raw data

Conclusions/action items:

Complete recovery testing.

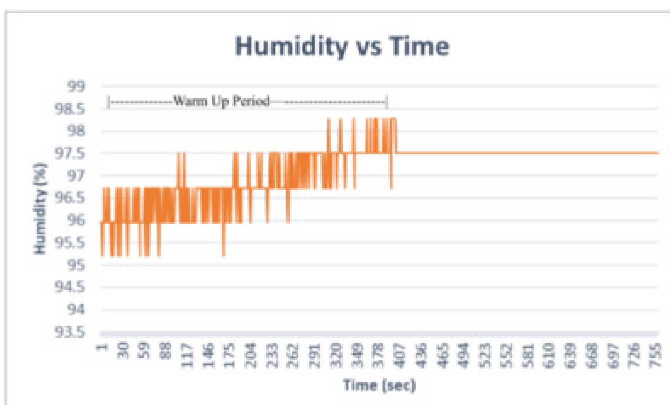
Katie Day - Apr 26, 2022, 9:04 PM CDT



Download

Sensor_temp_graph.png (74.9 kB)

Katie Day - Apr 26, 2022, 9:04 PM CDT



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Sensor_hum_graph.png (84.9 kB)

Katie Day - Apr 26, 2022, 9:04 PM CDT

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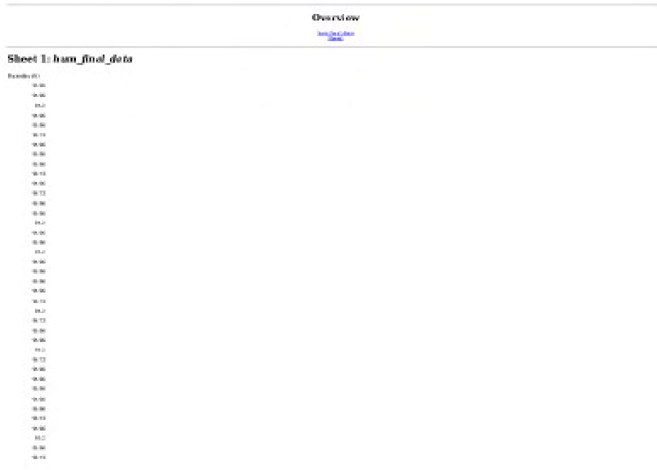
Incubator_temp_testing.csv (20.1 kB)

Katie Day - Apr 26, 2022, 9:04 PM CDT


Overview

Sheet 1: hum_final_data

Download

hum_final_data.xls (60.4 kB)

Katie Day - Apr 26, 2022, 9:04 PM CDT

Download

hum_final_data.csv (4.86 kB)

4/26/2022 Recovery Testing

Katie Day - Apr 26, 2022, 9:04 PM CDT

Title: Recovery Testing

Date: 4/26/2022

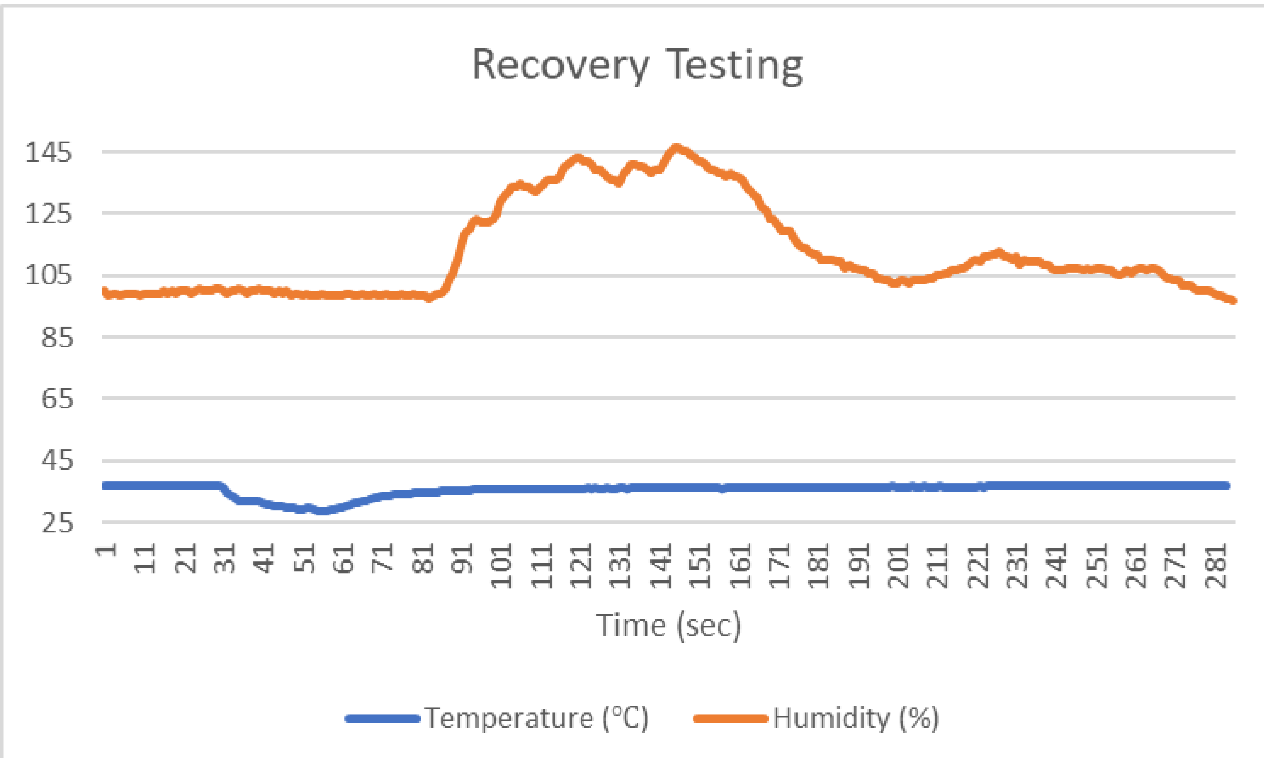
Content by: Katie Day, Maya Tanna, and Bella Raykowski

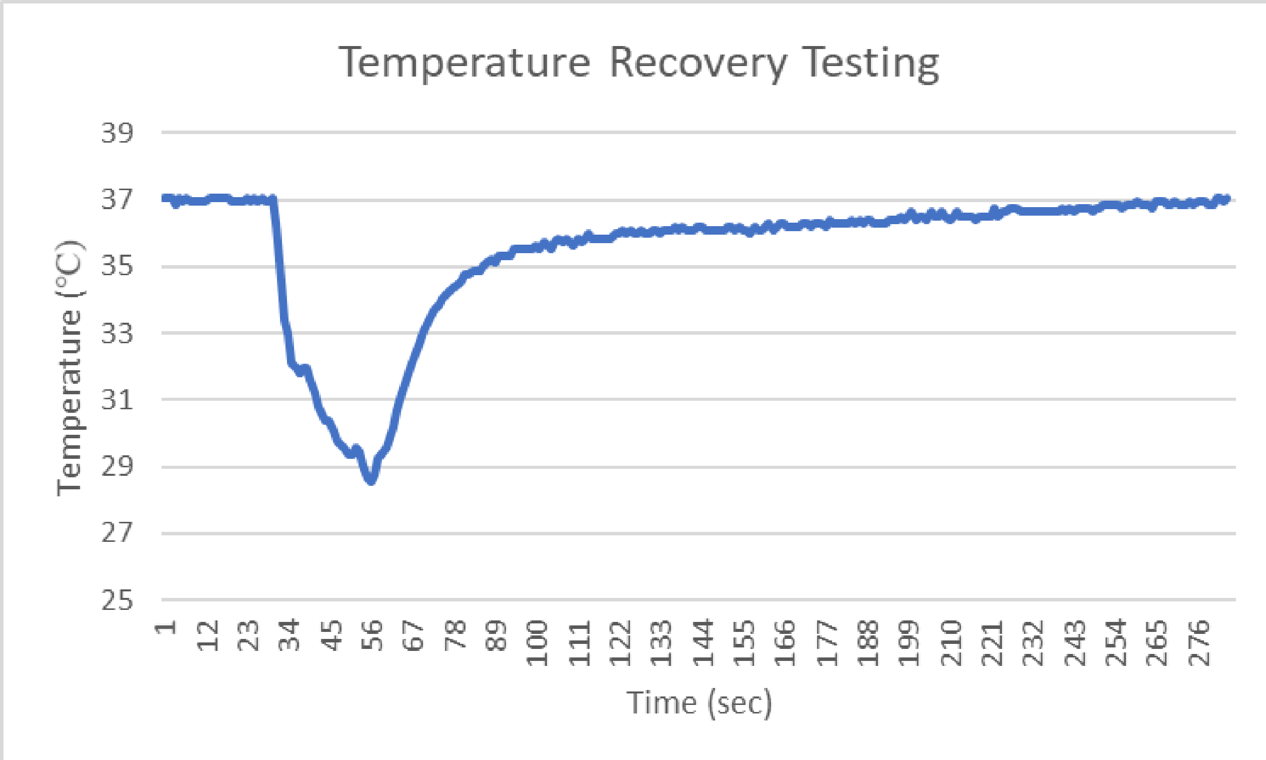
Present: Whole Group

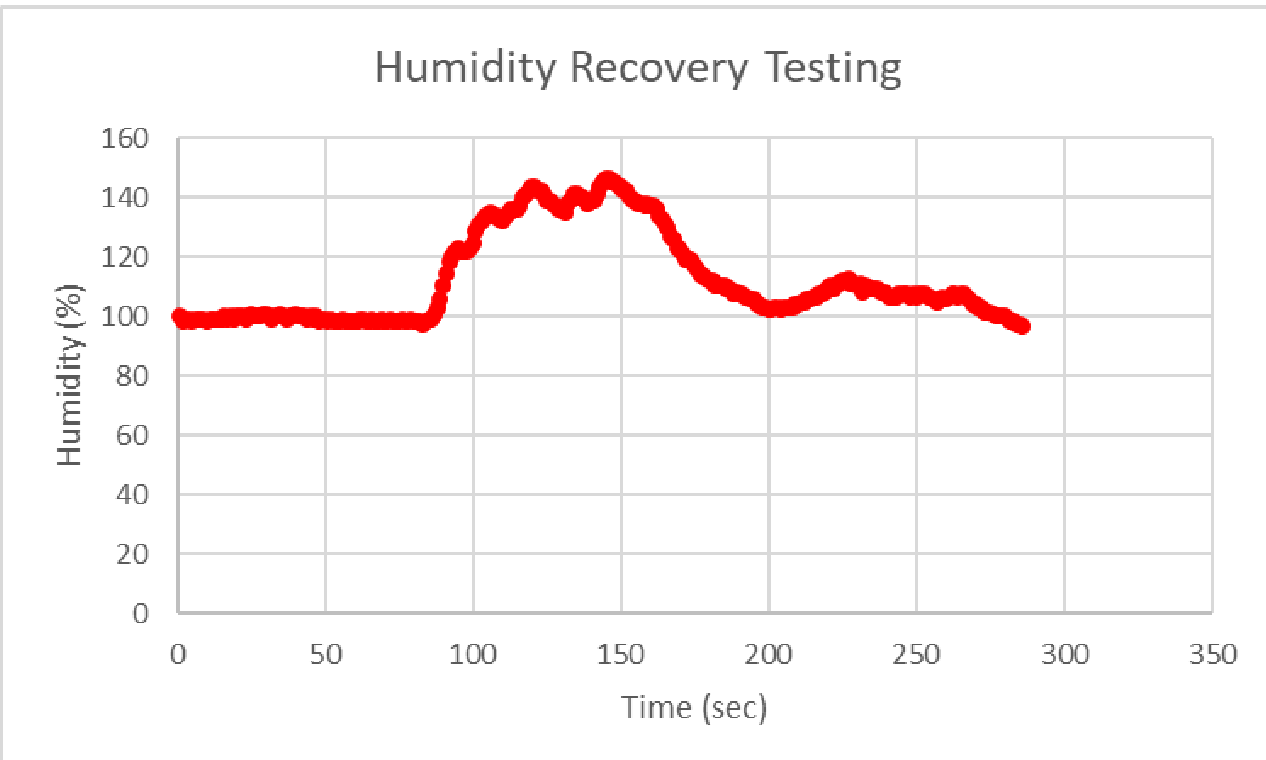
Goals: To determine the amount of time it takes the incubator to return to standard temperature and humidity after opening the box for a short amount of time.

Content:

See attached files.







Conclusions/action items:

The box meets the requirements outlined in the PDS, with an average recovery time of 3:30 per 30 seconds of disruption.

Katie Day - Apr 26, 2022, 9:04 PM CDT

Recovery Test Protocol Test 1

Introduction
Name of Tester: Maya & Katie
Dates of Test Performance: 04/26/2022
Site of Test Performance: ECB 1002

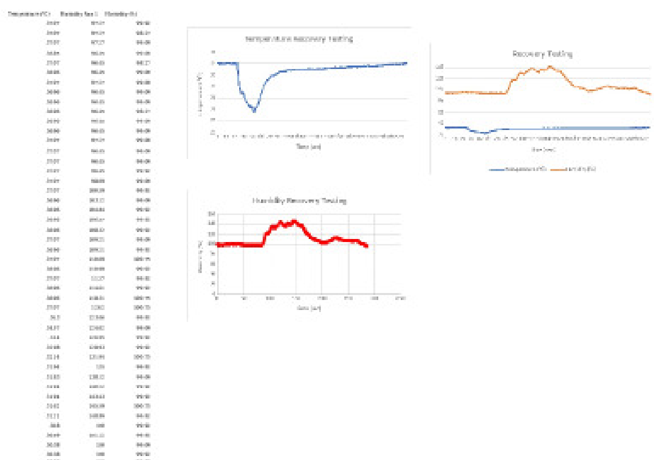
Explanation:
The team will test the recovery time of the incubator after it has been opened by timing how long it takes for the incubator to return to performance conditions (37°C, 5% CO_2, and >95% humidity). The maximum recovery time should not exceed five minutes after a 30 second exposure to the external environment.

Steps	Protocol	Verification/Validation	Pass/Fail	Tester Initials
1	Set up the incubator for normal use. Record internal conditions in the comments and verify that they fall within the correct ranges (37°C, 5% CO_2, and >95% humidity).	☑ Verified Comments: 37.07 C, 97.27%	Pass	KD/MT
2	Open the incubator for 30 seconds. Start stopwatch. Verify that the stopwatch is working.	☑ Verified Comments:	Pass	KD/MT
3	Record internal conditions in the comments at a time of 15 seconds after opening the incubator. Verify that the internal conditions deviate from the normal conditions recorded above.	☑ Verified Comments: 32.77 C, 100%	Pass	KD/MT
4	Close the incubator. Verify that the recovery time did not exceed 5 minutes after a 30 second exposure to the external environment. Record the time it took to revert back to optimal conditions in the comments.	☑ Verified Comments: It took a little over 3 min to recover from the temperature and humidity.	Pass	KD/MT

Download

Maya_Katie_Bella_Recovery_Testing.pdf (66.7 kB)

Katie Day - Apr 26, 2022, 9:04 PM CDT



Download

Recovery_Data.xlsx (35.7 kB)

9/12/2021 - Cell Culture Basics

Katie Day - Sep 12, 2021, 10:43 AM CDT

Title: Cell Culture Basics

Date: 9/12/2021

Content by: Katie McGovern

Present:

Goals: To research the basics of cell cultures to better understand how to build our incubator.

Content:

- Cell Culture: Growing Cells as Model Systems in Vitro
    - Cell culture: laboratory methods that enable the growth of cells in physiological conditions
        - most commonly used to study cell biology, replicate disease mechanisms, or investigate drug compounds
        - easy to manipulate genes and molecular pathways
        - culture systems removes interfering genetic or environmental variables
    - Safe Handling of Cell Lines
        - ACDP: national body managed by the Health and Safety Executive (HSE) that advises on hazards and risks to workers from exposure to pathogens during cell cultures
        - *consult biosafety levels (BSL) 1-4.*
    - Recommended Equipment for Cell Culture Labs Table 9.2
        -

Equipment	Purpose
Biosafety Cabinet	create sterile work surface
Humid CO2 incubator	provide a physiological environment for cell growth
Inverted light microscope	to asses cell morphology and count cells
fridge/freezers	store cells and cellular materials
Centrifuge	condense cells
Hemacytometer	count cells, determine growth kinetics and prepare suitable densities
Autoclave	sterilizator
Cell culture dishes	culture cells using flasks, petri dishes, 96 well plates
Vacuum pump	aspirate cell culture medium

-
    - Cell Cultures in Lab
        - Primary cells: directly isolated from human tissue (ex. fibroblasts from skin biopsies)
            - characterized as finite and rely on continuous supply of stocks since their proliferation ceases after a limited amount of cell divisions and cell expansion is often impossible
        - Transformed cells: can be generated either naturally or by genetic manipulator
        - Self-renewing cells: cells that carry the capacity to differentiate into a diversity of other cell types with long-term maintenance in vitro
            - ex. embryonic stem cells
    - Cell Culture Microenvironment
        - The Cell Culture Medium

      - create an environment that allows for max cell propagation is achieved through the **incubator (i.e. temperature, humidity, O2, and CO2 tensions**) and the basal cell culture medium and its supplements
        - Basal Cell culture medium: has carbs, vitamins, amino acids, minerals, growth factors, hormones, and components that control physicochemical properties such as the culture's pH and cellular osmotic pressure
          - serum as fetal bovine serum is added that provides cells with growth factors and hormones and acts as a carrier for lipids and enzymes and transportation of micronutrients and trace elements
    - Temperature, pH, CO2, and O2 Levels
      - temp: incubated at 36-37*C
        - can be achieved though tightly regulated and monitoring the temp of the environment
      - pH: 7.2-7.4
        - As the cells propagate, their growth requires energy supplied in the medium, for example in the form of glucose. When metabolized, its by-products include pyruvic acid, lactic acid, and CO_2. Since the pH level is dependent on the balance of CO_2 and HCO_3^- (bicarbonate), the addition of bicarbonate-based buffers to cell culture media can equilibrate the CO_2 concentrations.
      - CO2 tensions: 5-7% adjustable
    - Subculturing
      - when cell culture vessel reaches ~80% cells need to be transfered

Figure 9.3 Basic Science Methods for Clinical Researchers. 2017 : 151–172. Published online 2017 Apr 7. doi: 10.1016/B978-0-12-803077-6.00009-6

- Applications
  - Drug Development and Drug Testing: used to screen novel chemicals, cosmetics, and drug compounds for their efficacy and asses drug cytotoxicity in cell types
  - Virology and Vaccine Production: using mammalian cells researches can study the growth rates, development, and conditions required for the cycle of infectious diseases
  - Tissue Regeneration and Transplate: cell cultures with hIPSCs, embryonic stem cells, and adult stem cells can be studied for their regeneration properties for use in replacement tissues or organs
  - Genetic Engineering or Gene Therapy: allows for the study of the expression of specific genes and their impact on cells
- Encyclopedia Of Insects (second Edition) Chapter 39- Cell Culture
  - Cell Culture: technique in which cells are removed from an organism and placed in a fluid medium where, under proper conditions, cells can live and even grow.
    - cell growth is characterized by mitosis and differentiation
      - Differentiation: cells can change into specific types that are capable of functions analogous to tissues or organs in the organism

Conclusions/action items:

Cells need a hospitable environment in order to be studied. Incubators are commonly used and we will have to carefully monitor the system we create.

9/12/2021 CO2/Cell Culture Incubator Basics

Katie Day - Oct 03, 2021, 3:30 PM CDT

Title: Cell Culture Incubator Basics

Date: 9/12/2021

Content by: Katie McGovern

Present:

Goals: To understand the physiology of an incubator in order to replicate it at a lower price.

Content:

- Labcompare CO2/Cell Culture Incubator
    - Designed to maintain a constant temp and high humidity under a CO2 atmosphere
    - Temps: 4-50*C
        - controlled by a water bath circulating cabinet or by electric coils that give off heat
    - CO2: 0.3-19.9%
    - Use non-corrosive stainless steel interiors or antimicrobial copper surfaces
    - Auto decontamination using heat or UV
    - Humidity: 95-98%
    - Features of fancy ones:
        - programmable controls with password protection
        - temp alarms
        - CO2 alarms
        - door opening alarms
- Inexpensive low-oxygen incubators
    - Oxygen tension in mammillian tissues ranges from 1-6%
    - growing normal human diploid cells in 2% o2 extends their lifespance
    - Low Cost Incubator
        - Gas tank with O2, CO2, and N
        - Equipment:
            - Silicone vaccuum grease
            - Nalgene 2117 Stragith-side wide-mouth jars, polymethylpentene with white polypropylene screw-top lids, autoclavable
            - Size 15D silicone rubber stoppers
            - Bubble tubing
        - Procedure
            - First drill two half-inch holes into the clear bottoms of Nalgene 1,000-ml Straight-Side Wide-Mouth Jars (Fig. 2). Although this can be done by a bioengineering department, adequate holes are produced using a home drill press and a flat 1/2-inch wood drill bit.

            2 - Invert the jar so that the white plastic lid becomes the bottom of the incubator and the holes are at the top. Plug the holes with size 15D silicone rubber stoppers.

            3

- The lid has a small bump in its center that prevents dishes from lying flat on its surface. Form a flat surface by placing the lid from a 10-cm plastic petri dish on the white lid.

4. Coat the threads of the jar with silicone vacuum grease so that it closes smoothly and forms a gas-tight seal.

5. Bubble tubing provides a very convenient means of connecting the tank to the chambers. Cut one of the expanded sections before it tapers to the small diameter, providing the tubing with a good, snug fit into one of the 1/2-inch holes in order to flush the chambers.

6. Connect to a tank containing a special three-gas mix consisting of 2% oxygen, 5% CO_2 and 93% nitrogen.

7. Chambers must be re-gassed each time they are opened to observe or feed the cells. There is no need to re-gas unopened chambers (for example, if cloning cells, they can be left for several weeks without re-gassing).

- Wright, W., Shay, J. Inexpensive low-oxygen incubators. *Nat Protoc* **1,** 2088–2090 (2006). https://doi.org/10.1038/nprot.2006.374

- https://www.businesswire.com/news/home/20201009005417/en/CO2-Incubators-Market-Growth-of-Global-Life-Science-Market-to-Boost-the-Market-Growth-Technavio

Conclusions/action items:

Determine ways in which we can build sensors to deliver CO2 and keep the temperature and humidity in the right spots.

9/12/2021 EU Cell Culture Basics Handbook

Katie Day - Sep 12, 2021, 10:32 AM CDT

Title: EU Cell Culture Basics Handbook

Date: 9/12/2021

Content by: Katie McGovern

Present:

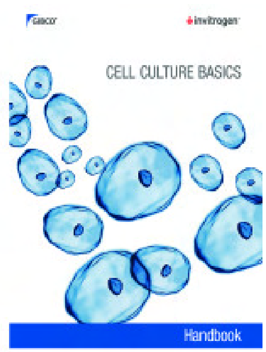
Goals: To learn about how cell cultures work in order to create a low cost incubator

Content: The EU's Cell Culture Basics Handbook

Conclusions/action items:

1. Refer to this handbook for logistics of creating cell plates and for incubator standards.

Katie Day - Sep 12, 2021, 10:32 AM CDT



Download

CellCultureBasicsEU.pdf (4.37 MB)

9/22/2021 Materials

Katie Day - Sep 23, 2021, 9:55 AM CDT

Title: Material Research

Date: 9/22/2021

Content by: Katie McGovern

Present:

Goals: To discover materials that are both insulators and transparent.

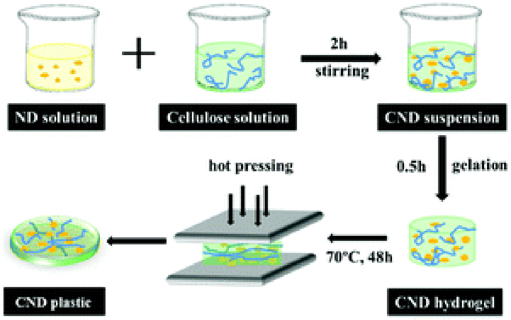
Content:

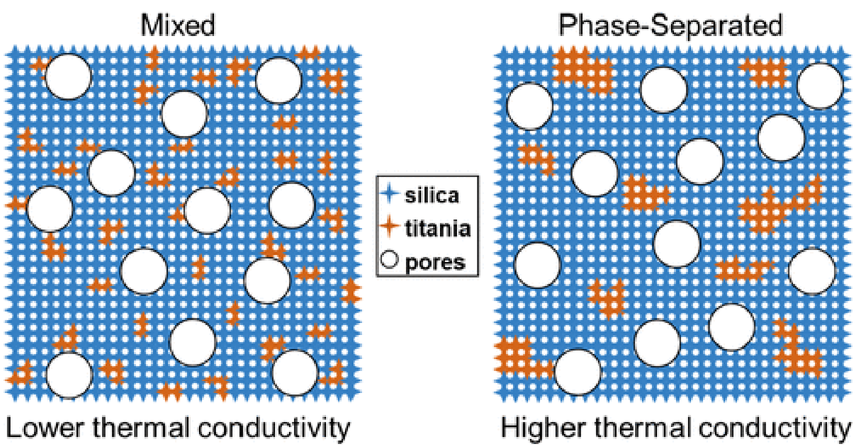
- Mechanical Properties of Zirconia Re-inforced Lithium Silicate Glass-Ceramic
    - Zirconia: enhanced mechanical properties of all-ceramic restorations
    - Lithium dislicate ceramic restoation
        - fabricated with a heat-pressed or CAD/CAM fabrication processes
        - enhanced translucency and different shades of lithium dislicate makes feasible anatomically contoured monolithic restorations --> displays a bluish color
    -

Materials	Fracture Toughness (MPa m^05)	Flexural Strength (MPa)	Characteristic Strength (MPa)	Weibull Modulus	Elastic Modulus (GPa)	Hardness (GPa)	Brittleness index (um^-1/2)
VS (Zirconia reinforced lithium silicate glass-ceramic)	2.31	443.63	460.74	13.41	70.44	6.53	2.84
IC(Lithium disilicate glass-ceramic)	2.01	348.33	361.82	12.49	60.61	5.45	2.72

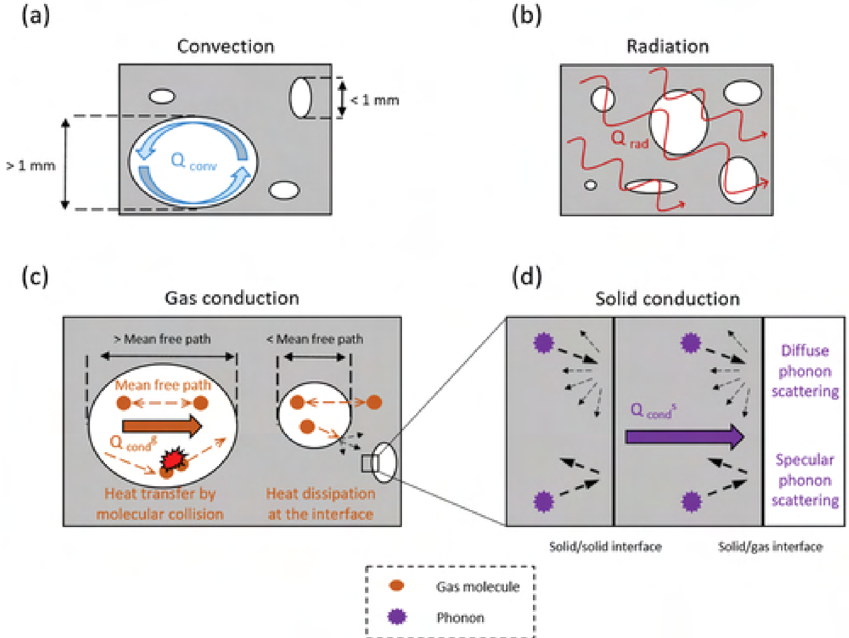
    - Conclusions
        - The VS zirconia reinforced lithium silicate glass-ceramic revealed higher mechanical properties (fracture toughness, flexural strength, elastic modulus, and hardness) compared with IC lithium disilicate glass-ceramic
        - According to Weibull distribution, VS glass-ceramic appears to be reliable for clinical use; however, clinical assessment is required to give reliable recommendations for dental practitioners
        - IC glass-ceramic revealed lower brittleness index compared with VS glass-ceramic and hence, IC glass-ceramic may have superior machinability.
- Optically Transparent Thermally Insulating Silica Aerogels for Solar Thermal Insulation
-
    - silica based aerogels coated on black surfaces have the potential to act as simple and inexpensive solar thermal collectors because of their high transmission to solar radiation and low transmission to thermal radiation
    - VTSS technology
        - places a selective surface inside a vacuum to limit convective and conductive losses --> cost of maintance is high
    - OTTI coating: transparent to solar radiation and opaque to IR
        - transmits sunlight to absorber while reducing the reradiation and convection heat losses from the hot absorber to the ambient

        - silica aerogels are mostly absorptive in thermal IR spectrum
            - absorption spectra of silica and other gaseous constituents such as H2O and CO2

- Aligned Cellulose/Nanodiamond plastics with high Thermal COnductivity
    - Plastic: orderly layered structure which cellulose is highly oriented along the in-plane direction and Nanodiamond disperses effectively to form an orderly connection with cellulose due to hydrogen bonding
    - Thermal conductivity = 5.37 Wm^-1K^-1 at 5 wt% filler content
    - 

- Examining the ROle of Atomic Scale Heterogeneity on the Thermal COnductivity of Transparent, Thermally Insulating Mesoporouus Silica-Titania Thin Films
    - Crystalline materials are often good conductors bc their long range atomic-scale order facilitates heat carrier propagation via lattice vibrations
    - Adding titania to silicate matrix lowers the thermal conductivity of the matrix as a result of introducing additional heat-carrier scattering centers
    - Materials that are the most chemically homogeneous with the most distrubuted scattering sites were more effcient at reducing heat carrier transport
    - 

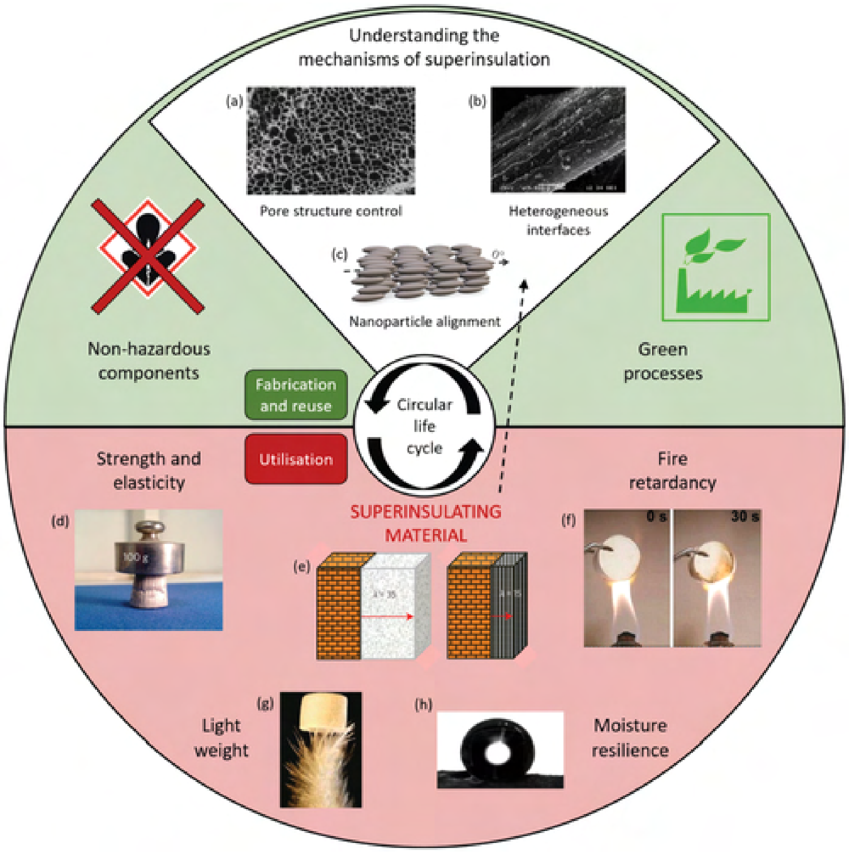
- Thermally Insulating Nanocellulose-Based Materials
    - Nanocellulose: rod-like partially crystallline cellulose nanparticles with diameters between 3-50nm and lengths from 100-several um, feature a combo of low density, high emodulus, low thermal expansion coefficient, and flexible surface chemistry

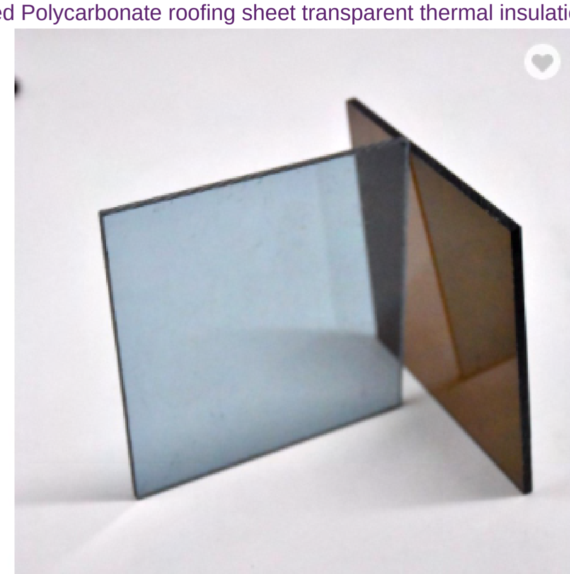
- 

    - Figure: the modes of heat transport in porous materials. Heat transfer by a) convection, b) radiation, c) gas conduction, including the coupling effects at the gas-solid interface, and d) solid conduction, highlighting diffuse and specular photon scattering at interphases
- Replacement of air with water through moisture uptake of hygroscopic materials (wood, cellulose, and CNMs) usually results in an increase of the heat conduction bc water has higher thermal conductivity that air
- Table 1: Thermal Conductivity of cellulose-, wood-, and CNM-based films

Material	Density (kg m^-3)	λa (mW m^-1 K^-1)	λr (mW m^-1 K^-1)	λa/λr	T (K)	RH (%)
Cellulose Iβ	1500-1600	900	240/500	3.8/1.8	298	N/A
CNC	1500-1600	5700	720	7.9	300	-
Partly crystalline cellulose in wood	1500-1600	1040	260	4.0	293	N/A
Wood fibers	1500-1600	766	430	1.8	293	N/A
Birch	680	323	214	1.5	294	30
Oak	753	270	160	1.7	293	30
Shear-oriented CNC films	N/A	530	220	2.4	300	-
TNW nanopaper	1090	2470	290	8.5	298	N/A
TOSNF nanopaper	1100	635	360	1.8	298	N/A

    - a) *a*-axis of the unit cell
    - b) *b*-axis of the unit cell
    - c) Under vacuum
    - d) Tunicate nanowhiskers
    - e) TEMPO-oxidized Sugi cellulose nanofiber.
- Aerogels with low density and pores smaller than the mean free path of air can display thermal conductivities significantly lower than value for air
- Silica aerogels consist of noncrystalline silica clustors that forms a 3D gel with pores smaller than 05nm and thermal conductivity is the same in all directiors and is sufficient to characterize the heat transfer properties for an isotropic material with a single value for thermal conductivity
- Oven drying fo wet CNM/cellulose-based foams or aerogels is a cost effective way of producing CNM-based thermally insulating materials --> can result in strongly distorted porous structures



-
    - Figure 9: Requirements for cellulose nanomaterial-based insulation materials
- Potentially use solar power insulating glasses --> like a mini-greenhouse for cells
    - Frosted Polycarbonate roofing sheet transparent thermal insulation sheets
        - 
    - High Transparent 8mm 10mm Twin Wall Thermal Insulation PC Lexan Polycarbonate Sheet for Home Swimming Pool Cover
        -

- Silica Aerogel 6mm Super Light Isulation Waterproof Sound deadening Mat

Conclusions/action items:

Look into greenhouse glass technology and make sure that we use a crystalline material.

10/8/2021 Optical Properties of Well Plates

Katie Day - Oct 18, 2021, 4:20 PM CDT

Title: Optical Properties of Well Plates

Date: 10/8/2021

Content by: Katie McGovern

Present:

Goals: To determine the optical properties of well plates so that they could be replicated with the incubator materials.

Content:

Optics for Testing:

- 96 Well Plates
  - Material: Polypropylene
    - Young's Modulus = 1.1-1.6
    - Optical Properties:
      - Gloss % = 75-90
      - Haze % = 11
      - Transparency % = 85-90

Conclusions/action items:

Replicate these conditions with the materials for the incubator design.

09/14/2021 Competing Designs

Katie Day - Sep 14, 2021, 10:32 AM CDT

Title: Competing Incubator Designs

Date: 9/14/2021

Content by: Katie McGovern

Present:

Goals: To discover what other kinds of incubators are on the market and why we are looking to improve them.

Content:

- ThermoFisher Scientific
    - Two chamber Types:
        - Direct Heat CO2 incubators
            - Heracell VIOS 160i CO@ INcubator with Coppor INterior Chambers
                - HEPA filtrations for ISO Class 5 air quality
                - Overnight Steri-Run for total sterilization
                - NOT AVAILABLE IN THE US
        - Forma Steri-Cult CO2 Incubator made of polished stainless steel
        - Water jacketed CO2 INcubators
            - Forma Series 3 Water Jacketed CO2 Incubators
                - Enhanced temp stability and univromite
                - HEPA filtration for **ISO Class 5** air quality
                - Intuitive iCAN touchscreen
- NuAire
    - Direct Heat
        - NU-5700
            - Touch panel control and monitoring of temp, CO2, humidity, and O2 lebels inside a 160L stainless steel chamber HEPA filtered to ISO Class 5
            - used for In-vitro cells
        - NU-5800
            - same thing as the 5700 but 200L
    - Water Jacket
        - NU-8600
            - 160L same thing but water jacketed design
- Biocompare
    - New Brunswick Galaxy 48R
        - Water jacketed
        - first to use fan-less, direct heat, and seamless chamber for low gas comsumption
    -

Conclusions/action items:

Need to request a quote to see how much these products actually cost and decide between a direct heat or water-jacketed design.

10/15/2021 ISO/TS 23565:2021

Katie Day - Dec 12, 2021, 2:21 PM CST

Title: ISO/TS 23565:2021

Date: 10/15/2021

Content by: Katie Day

Present:

Goals: To present standards that we must be aware of when creating our design.

Content:

ISO/TS 23565:2021; Biotechnology-Bioprocessing-General Requirements and Considerations for Equipment Systems used in the Manufacturing of Cells for Therapeutic Use

Notes:

- Doesn't apply to incubator, but important to note for other aspects of the design
- Applies for hardware, software, and consumables used in the manufactoring of cells i.e our arduino coding
- Used for tissue engineered product
- tubing, culture vessels or other containors
- also used for monitoring systems intended to control the internal environment.

14:00-17:00, "ISO/TS 23565:2021," *ISO*. https://www.iso.org/standard/76053.html (accessed Oct. 15, 2021).

Conclusions/action items:

Make sure Arduino circuitry and tubing materials are in check with this standard.

10/15/2021 ISO Standards Update

Katie Day - Dec 12, 2021, 2:25 PM CST

Title: ISO Standards Update

Date: 10/15/2021

Content by: Katie Day

Present:

Goals: To make a note of all 2021 updated ISO Standards that may be relevant in our project.

Content:

See link:

“ISO Update Supplement to ISOfocus,” 2021. Accessed: Dec. 12, 2021. [Online]. Available: https://www.iso.org/files/live/sites/isoorg/files/news/magazine/ISOupdate/EN/2021/ISOupdate_August_2021.pdf.

Conclusions/action items:

10/15/2021 ISO 19090:2018

Katie Day - Dec 12, 2021, 2:27 PM CST

Title: ISO 19090:2018

Date: 10/15/2021

Content by: Katie Day

Present:

Goals: To make note of another standard used in cell cultures.

Content:

See link for standard. Note that it is with animal cells, not human. Check what type of cells Dr. Puccinelli is working with.

14:00-17:00, "ISO 19090:2018," *ISO*. https://www.iso.org/standard/63936.html (accessed Oct 15, 2021).

Conclusions/action items:

10/15/2021 ISO 24998:2008

Katie Day - Dec 12, 2021, 2:30 PM CST

Title: ISO 24998:2008 Plastics Laboratory Ware

Date: 10/15/2021

Content by: Katie Day

Present:

Goals: To make note of another standard used for plastic lab ware when completing cell cultures, specifically petri-dishes.

Content:

See link attached.

14:00-17:00, “ISO 24998:2008,” *ISO*. https://www.iso.org/standard/42736.html (accessed Oct 15, 2021).

Conclusions/action items:

10/15/2021 CFR Title 21

Katie Day - Dec 12, 2021, 2:34 PM CST

Title: Code of Federal Regulations Title 21

Date: 10/15/2021

Content by: Katie Day

Present:

Goals: To familiarize myself with the code needed to be followed for the incubator.

Content:

See attached link:

"CFR - Code of Federal Regulations Title 21," *www.accessdata.fda.gov*. https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm?fr=864.2240 (accessed Oct. 15, 2021).

Notes:

Sec. 864.2240 is of most importance, speficially A where they mention the equipment codes for cell cultures.

Conclusions/action items:

09/23/2021 Katie and Sam Initial Design Idea

Katie Day - Sep 23, 2021, 10:41 AM CDT

Title: Katie and Sam Initial Design Idea

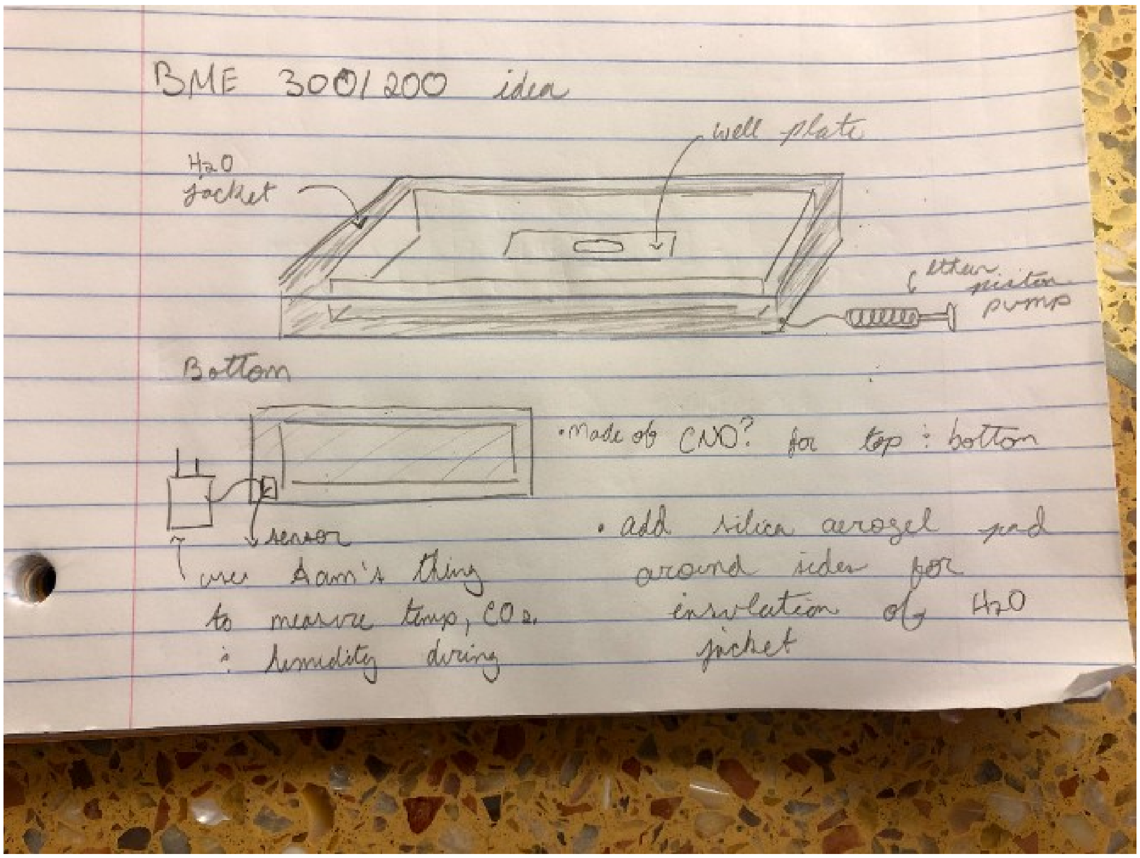
Date: 9/23/2021

Content by: Katie McGovern and Sam Bardwell

Present: Katie McGovern

Goals: To present an initial design idea based on element we have both individually researched

Content:



Conclusions/action items:

Formalize and present idea to the rest of the team

11/14/2021 Thermistor Code

Katie Day - Dec 03, 2021, 12:23 PM CST

Title: Thermistor Code (Arduino)

Date: 11/14/2021

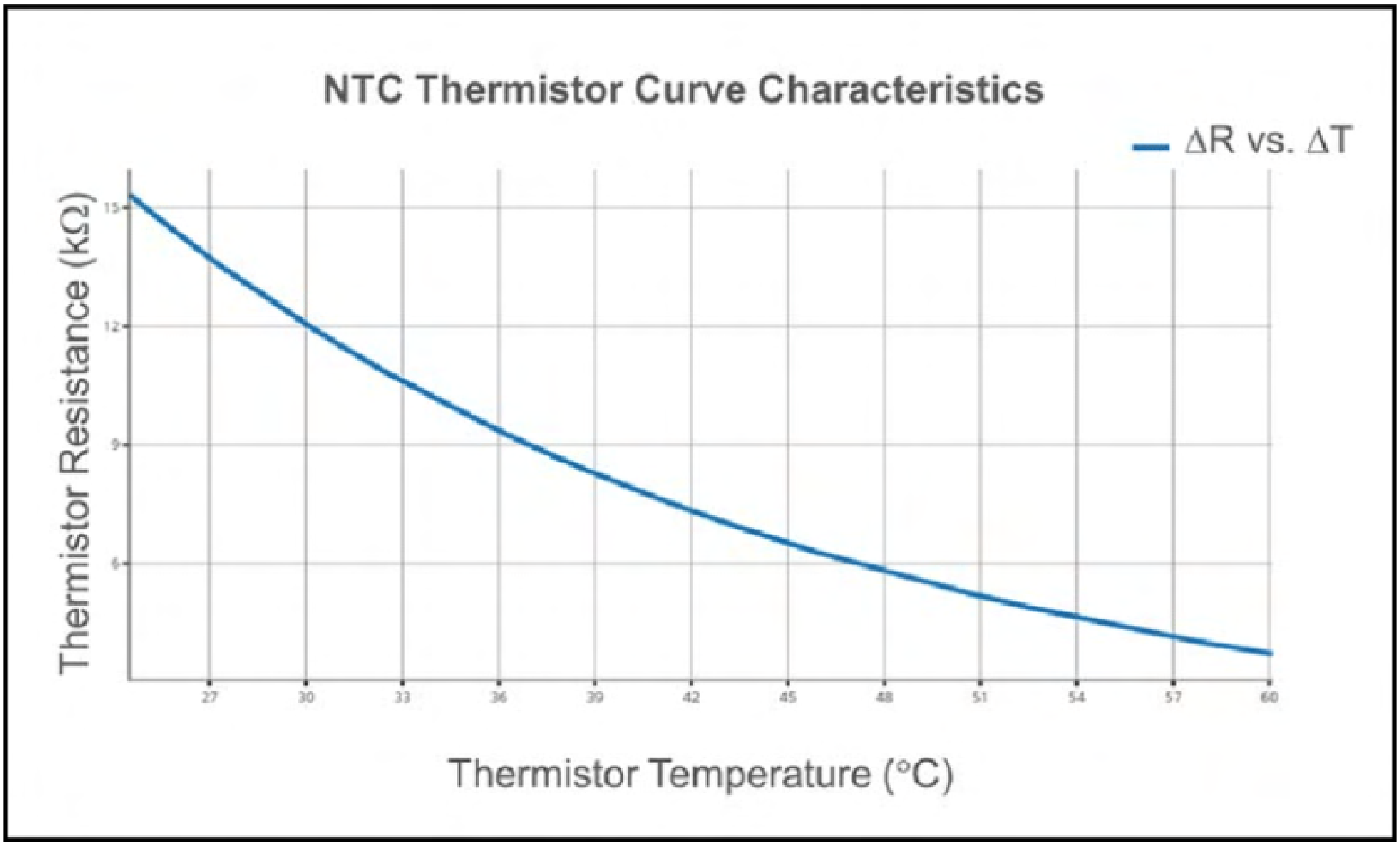
Content by: Katie Day and Olivia Jaekle

Present:

Goals: To create a code on Arduino that measures temperature and humidity with a thermistor.

Content:

See attached file. Calibration curve for thermistor attached below.



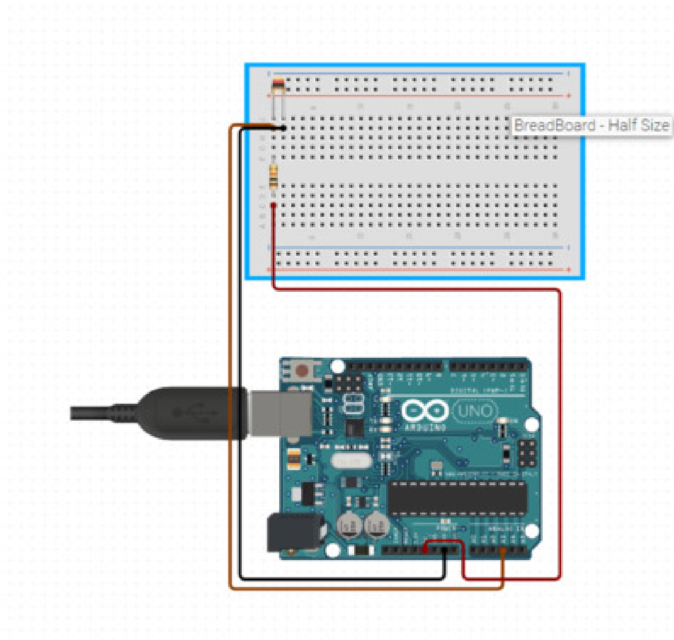
Conclusions/action items: Thermistor is working properly and outputs correct temperatures. Use in testing protocol next week with completed incubator prototype.

Katie Day - Nov 14, 2021, 8:28 PM CST

Download

thermistor.ino (745 B)

Katie Day - Dec 03, 2021, 12:23 PM CST



Download

Thermistor_Circuit_Diagram.PNG (82.8 kB)

11/14/2021 DHT22 Temperature and Humidity Code

Katie Day - Nov 14, 2021, 8:32 PM CST

Title: DHT22 Temperature and Humidity Code

Date: 11/14/2021

Content by: Katie Day and Olivia Jaekle

Present:

Goals: To create a code on Arduino that measures temperature and humidity with a DHT22 sensor.

Content:

See attached file.

Conclusions/action items:

1. Thank you to Dr. Nimunkar for ordering a proper DHT22 sensor and helping us with code.
2. Decide between thermistor applicator or DHT22.
3. If going with thermistor check humidity equation with values from the DHT22.

Katie Day - Nov 14, 2021, 8:31 PM CST

Download

DHT-22.ino (885 B)

11/14/2021 DHT22 Sensor Library

Katie Day - Nov 14, 2021, 8:37 PM CST

Title: DHT22 Sensor Library

Date: 11/14/2021

Content by: Katie McGovern

Present:

Goals: To get the DHT22 sensor to work properly.

Content:

In order for the DHT22 sensor to run properly a library of other files is needed. Attached are those files.

Conclusions/action items:

Katie Day - Nov 14, 2021, 8:38 PM CST

Download

code-of-conduct.md (5.83 kB) Download and put into libraries folder in Arduino.

Katie Day - Nov 14, 2021, 8:38 PM CST

Download

CONTRIBUTING.md (1.29 kB) Download and put into libraries folder in Arduino.

Katie Day - Nov 14, 2021, 8:38 PM CST

```
/*!
 *  @file DHT_U.cpp
 *
 *  Temperature & Humidity Unified Sensor Library
 *
 *  This is a library for DHT series of low cost temperature/humidity sensors.
 *
 *  You must have Adafruit Unified Sensor Library library installed to use this
 * class.
 *
 *  Adafruit invests time and resources providing this open source code,
 *  please support Adafruit andopen-source hardware by purchasing products
 *  from Adafruit!
 */
#include "DHT_U.h"

/*!
 *  @brief  Instantiates a new DHT_Unified class
 *  @param  pin
 *          pin number that sensor is connected
 *  @param  type
 *          type of sensor
 *  @param  count
 *          number of sensors
 *  @param  tempSensorId
 *          temperature sensor id
 *  @param  humiditySensorId
 *          humidity sensor id
 */
DHT_Unified::DHT_Unified(uint8_t pin, uint8_t type, uint8_t count,
                         int32_t tempSensorId, int32_t humiditySensorId)
    : _dht(pin, type, count), _type(type), _temp(this, tempSensorId),
      _humidity(this, humiditySensorId) {}

/*!
 *  @brief  Setup sensor (calls begin on It)
 */
void DHT_Unified::begin() { _dht.begin(); }

/*!
 *  @brief  Sets sensor name
 *  @param  sensor
 *          Sensor that will be set
 */
void DHT_Unified::setName(sensor_t *sensor) {
  switch (_type) {
  case DHT11:
    strncpy(sensor->name, "DHT11", sizeof(sensor->name) - 1);
    break;
  case DHT12:
    strncpy(sensor->name, "DHT12", sizeof(sensor->name) - 1);
    break;
  case DHT21:
    strncpy(sensor->name, "DHT21", sizeof(sensor->name) - 1);
    break;
  case DHT22:
    strncpy(sensor->name, "DHT22", sizeof(sensor->name) - 1);
    break;
  default:
    // TODO: Perhaps this should be an error?  However main DHT library doesn't
    // enforce restrictions on the sensor type value.  Pick a generic name for
    // now.
    strncpy(sensor->name, "DHT?", sizeof(sensor->name) - 1);
```

[Download]

DHT_U.cpp (6.44 kB) Download and put into libraries folder in Arduino.

Katie Day - Nov 14, 2021, 8:38 PM CST

```
/*!
 *  @file DHT_U.h
 *
 *  DHT Temperature & Humidity Unified Sensor Library<Paste>
 *
 *  Adafruit invests time and resources providing this open source code,
 *  please support Adafruit andopen-source hardware by purchasing products
 *  from Adafruit!
 *
 *  Written by Tony DiCola (Adafruit Industries) 2014.
 *
 *  MIT license, all text above must be included in any redistribution
 *
 *  Permission is hereby granted, free of charge, to any person obtaining a copy
 *  of this software and associated documentation files (the "Software"), to
 * deal in the Software without restriction, including without limitation the
 * rights to use, copy, modify, merge, publish, distribute, sublicense, and/or
 * sell copies of the Software, and to permit persons to whom the Software is
 *  furnished to do so, subject to the following conditions:
 *
 *  The above copyright notice and this permission notice shall be included in
 * all copies or substantial portions of the Software.
 *
 *  THE SOFTWARE IS PROVIDED "AS IS", WITHOUT WARRANTY OF ANY KIND, EXPRESS OR
 *  IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY,
 *  FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL THE
 *  AUTHORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER
 *  LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING
 * FROM, OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS
 * IN THE SOFTWARE.
 */

#ifndef DHT_U_H
#define DHT_U_H

#include <Adafruit_Sensor.h>
#include <DHT.h>

#define DHT_SENSOR_VERSION 1 /**< Sensor Version */

/*!
 *  @brief  Class that stores state and functions for interacting with
 * DHT_Unified.
 */
class DHT_Unified {
public:
  DHT_Unified(uint8_t pin, uint8_t type, uint8_t count = 6,
              int32_t tempSensorId = -1, int32_t humiditySensorId = -1);
  void begin();

  /*!
   *  @brief  Class that stores state and functions about Temperature
   */
  class Temperature : public Adafruit_Sensor {
  public:
    Temperature(DHT_Unified *parent, int32_t id);
    bool getEvent(sensors_event_t *event);
    void getSensor(sensor_t *sensor);

  private:
    DHT_Unified *_parent;
    int32_t _id;
  };
```

[Download]

DHT_U.h (3.08 kB) Download and put into libraries folder in Arduino.

Katie Day - Nov 14, 2021, 8:38 PM CST

```
/*!
 *  @file DHT.cpp
 *
 *  @mainpage DHT series of low cost temperature/humidity sensors.
 *
 *  @section intro_sec Introduction
 *
 *  This is a library for DHT series of low cost temperature/humidity sensors.
 *
 *  You must have Adafruit Unified Sensor Library library installed to use this
 * class.
 *
 *  Adafruit invests time and resources providing this open source code,
 *  please support Adafruit andopen-source hardware by purchasing products
 *  from Adafruit!
 *
 *  @section author Author
 *
 *  Written by Adafruit Industries.
 *
 *  @section license License
 *
 *  MIT license, all text above must be included in any redistribution
 */

#include "DHT.h"

#define MIN_INTERVAL 2000 /**< min interval value */
#define TIMEOUT                                                               \
  UINT32_MAX /**< Used programmatically for timeout.                          \
                   Not a timeout duration. Type: uint32_t. */

/*!
 *  @brief  Instantiates a new DHT class
 *  @param  pin
 *          pin number that sensor is connected
 *  @param  type
 *          type of sensor
 *  @param  count
 *          number of sensors
 */
DHT::DHT(uint8_t pin, uint8_t type, uint8_t count) {
  (void)count; // Workaround to avoid compiler warning.
  _pin = pin;
  _type = type;
#ifdef __AVR
  _bit = digitalPinToBitMask(pin);
  _port = digitalPinToPort(pin);
#endif
  _maxcycles =
      microsecondsToClockCycles(1000); // 1 millisecond timeout for
                                       // reading pulses from DHT sensor.
  // Note that count is now ignored as the DHT reading algorithm adjusts itself
  // based on the speed of the processor.
}

/*!
 *  @brief  Setup sensor pins and set pull timings
 *  @param  usec
 *          Optionally pass pull-up time (in microseconds) before DHT reading
 *starts. Default is 55 (see function declaration in DHT.h).
 */
void DHT::begin(uint8_t usec) {
```

Download

DHT.cpp (12 kB) Download and put into libraries folder in Arduino.

Katie Day - Nov 14, 2021, 8:38 PM CST

```
/*!
 *  @file DHT.h
 *
 *  This is a library for DHT series of low cost temperature/humidity sensors.
 *
 *  You must have Adafruit Unified Sensor Library library installed to use this
 * class.
 *
 *  Adafruit invests time and resources providing this open source code,
 *  please support Adafruit andopen-source hardware by purchasing products
 *  from Adafruit!
 *
 *  Written by Adafruit Industries.
 *
 *  MIT license, all text above must be included in any redistribution
 */

#ifndef DHT_H
#define DHT_H

#include "Arduino.h"

/* Uncomment to enable printing out nice debug messages. */
//#define DHT_DEBUG

#define DEBUG_PRINTER                                                          \
  Serial /**< Define where debug output will be printed.                       \
          */

/* Setup debug printing macros. */
#ifdef DHT_DEBUG
#define DEBUG_PRINT(...)                                                       \
  { DEBUG_PRINTER.print(__VA_ARGS__); }
#define DEBUG_PRINTLN(...)                                                     \
  { DEBUG_PRINTER.println(__VA_ARGS__); }
#else
#define DEBUG_PRINT(...)                                                       \
  {} /**< Debug Print Placeholder if Debug is disabled */
#define DEBUG_PRINTLN(...)                                                     \
  {} /**< Debug Print Line Placeholder if Debug is disabled */
#endif

/* Define types of sensors. */
static const uint8_t DHT11{11};  /**< DHT TYPE 11 */
static const uint8_t DHT12{12};  /**< DHY TYPE 12 */
static const uint8_t DHT21{21};  /**< DHT TYPE 21 */
static const uint8_t DHT22{22};  /**< DHT TYPE 22 */
static const uint8_t AM2301{21}; /**< AM2301 */

#if defined(TARGET_NAME) && (TARGET_NAME == ARDUINO_NANO33BLE)
#ifndef microsecondsToClockCycles
/*!
 * As of 7 Sep 2020 the Arduino Nano 33 BLE boards do not have
 * microsecondsToClockCycles defined.
 */
#define microsecondsToClockCycles(a) ((a) * (SystemCoreClock / 1000000L))
#endif
#endif

/*!
 *  @brief  Class that stores state and functions for DHT
 */
class DHT {
```

Download

DHT.h (3.22 kB) Download and put into libraries folder in Arduino.

Katie Day - Nov 14, 2021, 8:38 PM CST

```
###########################################
# Syntax Coloring Map For DHT-sensor-library
###########################################

###########################################
# Datatypes (KEYWORD1)
###########################################

DHT	KEYWORD1

###########################################
# Methods and Functions (KEYWORD2)
###########################################

begin	KEYWORD2
readTemperature	KEYWORD2
convertCtoF	KEYWORD2
convertFtoC	KEYWORD2
computeHeatIndex	KEYWORD2
readHumidity	KEYWORD2
read	KEYWORD2
```

Download

keywords.txt (529 B) Download and put into libraries folder in Arduino.

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Download

DHTtester.ino (2.68 kB) Download and put into libraries folder in Arduino.

11/14/2021 Adafruit Sensor Library

Katie Day - Nov 14, 2021, 8:45 PM CST

Title: Adafruit Sensor Library

Date: 11/14/2021

Content by: Katie McGovern

Present:

Goals:

Content:

In order for the DHT22 sensor library to work, the adafruit sensor library is needed. It is attached.

Conclusions/action items:

Katie Day - Nov 14, 2021, 8:45 PM CST

```
#include "Adafruit_Sensor.h"

/**************************************************************************/
/*!
    @brief  Prints sensor information to serial console
*/
/**************************************************************************/
void Adafruit_Sensor::printSensorDetails(void) {
  sensor_t sensor;
  getSensor(&sensor);
  Serial.println(F("------------------------------------"));
  Serial.print(F("Sensor:       "));
  Serial.println(sensor.name);
  Serial.print(F("Type:         "));
  switch ((sensors_type_t)sensor.type) {
  case SENSOR_TYPE_ACCELEROMETER:
    Serial.print(F("Acceleration (m/s2)"));
    break;
  case SENSOR_TYPE_MAGNETIC_FIELD:
    Serial.print(F("Magnetic (uT)"));
    break;
  case SENSOR_TYPE_ORIENTATION:
    Serial.print(F("Orientation (degrees)"));
    break;
  case SENSOR_TYPE_GYROSCOPE:
    Serial.print(F("Gyroscopic (rad/s)"));
    break;
  case SENSOR_TYPE_LIGHT:
    Serial.print(F("Light (lux)"));
    break;
  case SENSOR_TYPE_PRESSURE:
    Serial.print(F("Pressure (hPa)"));
    break;
  case SENSOR_TYPE_PROXIMITY:
    Serial.print(F("Distance (cm)"));
    break;
  case SENSOR_TYPE_GRAVITY:
    Serial.print(F("Gravity (m/s2)"));
    break;
  case SENSOR_TYPE_LINEAR_ACCELERATION:
    Serial.print(F("Linear Acceleration (m/s2)"));
    break;
  case SENSOR_TYPE_ROTATION_VECTOR:
    Serial.print(F("Rotation vector"));
    break;
  case SENSOR_TYPE_RELATIVE_HUMIDITY:
    Serial.print(F("Relative Humidity (%)"));
    break;
  case SENSOR_TYPE_AMBIENT_TEMPERATURE:
    Serial.print(F("Ambient Temp (C)"));
    break;
  case SENSOR_TYPE_OBJECT_TEMPERATURE:
    Serial.print(F("Object Temp (C)"));
    break;
  case SENSOR_TYPE_VOLTAGE:
    Serial.print(F("Voltage (V)"));
    break;
  case SENSOR_TYPE_CURRENT:
    Serial.print(F("Current (mA)"));
    break;
  case SENSOR_TYPE_COLOR:
    Serial.print(F("Color (RGBA)"));
    break;
```

Download

Adafruit_Sensor.cpp (2.34 kB) Download and add to libraries folder in Arduino.

Katie Day - Nov 14, 2021, 8:45 PM CST

```
/*
 * Copyright (C) 2008 The Android Open Source Project
 *
 * Licensed under the Apache License, Version 2.0 (the "License");
 * you may not use this file except in compliance with the License.
 * You may obtain a copy of the License at
 *
 * http://www.apache.org/licenses/LICENSE-2.0
 *
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 * distributed under the License is distributed on an "AS IS" BASIS,
 * WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.
 * See the License for the specific language governing permissions and
 * limitations under the License.
 */

/* Update by K. Townsend (Adafruit Industries) for lighter typedefs, and
 * extended sensor support to include color, voltage and current */

#ifndef _ADAFRUIT_SENSOR_H
#define _ADAFRUIT_SENSOR_H

#ifndef ARDUINO
#include <stdint.h>
#elif ARDUINO >= 100
#include "Arduino.h"
#include "Print.h"
#else
#include "WProgram.h"
#endif

/* Constants */
#define SENSORS_GRAVITY_EARTH (9.80665F) /**< Earth's gravity in m/s^2 */
#define SENSORS_GRAVITY_MOON (1.6F)      /**< The moon's gravity in m/s^2 */
#define SENSORS_GRAVITY_SUN (275.0F)     /**< The sun's gravity in m/s^2 */
#define SENSORS_GRAVITY_STANDARD (SENSORS_GRAVITY_EARTH)
#define SENSORS_MAGFIELD_EARTH_MAX                                           \
  (60.0F) /**< Maximum magnetic field on Earth's surface */
#define SENSORS_MAGFIELD_EARTH_MIN                                           \
  (30.0F) /**< Minimum magnetic field on Earth's surface */
#define SENSORS_PRESSURE_SEALEVELHPA                                         \
  (1013.25F) /**< Average sea level pressure is 1013.25 hPa */
#define SENSORS_DPS_TO_RADS                                                  \
  (0.017453293F) /**< Degrees/s to rad/s multiplier                          \
                  */
#define SENSORS_RADS_TO_DPS                                                  \
  (57.29577793F) /**< Rad/s to degrees/s  multiplier */
#define SENSORS_GAUSS_TO_MICROTESLA                                          \
  (100) /**< Gauss to micro-Tesla multiplier */

/** Sensor types */
typedef enum {
  SENSOR_TYPE_ACCELEROMETER = (1), /**< Gravity + linear acceleration */
  SENSOR_TYPE_MAGNETIC_FIELD = (2),
  SENSOR_TYPE_ORIENTATION = (3),
  SENSOR_TYPE_GYROSCOPE = (4),
  SENSOR_TYPE_LIGHT = (5),
  SENSOR_TYPE_PRESSURE = (6),
  SENSOR_TYPE_PROXIMITY = (8),
  SENSOR_TYPE_GRAVITY = (9),
  SENSOR_TYPE_LINEAR_ACCELERATION =
      (10), /**< Acceleration not including gravity */
  SENSOR_TYPE_ROTATION_VECTOR = (11),
```

Download

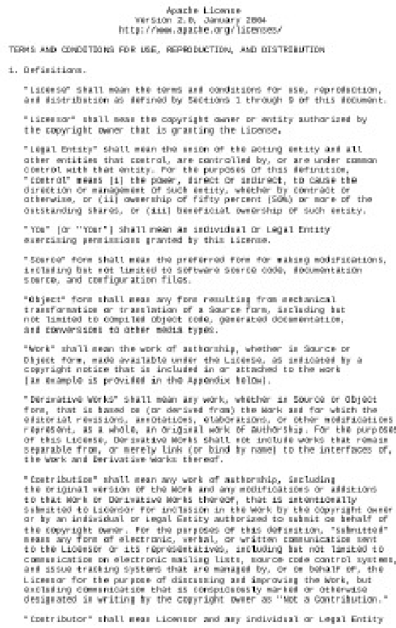
Adafruit_Sensor.h (7.78 kB) Download and add to libraries folder in Arduino.

Katie Day - Nov 14, 2021, 8:45 PM CST

Download

library.properties (380 B) Download and add to libraries folder in Arduino.

Katie Day - Nov 14, 2021, 8:45 PM CST



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sensortest.ino (4.17 kB) Download and add to libraries folder in Arduino.

11/14/2021 MH-Z16 CO2 Monitor Code

Katie Day - Nov 14, 2021, 8:48 PM CST

Title: MH-Z16 NDIR CO2 Monitoring Code

Date: 11/14/2021

Content by: Katie McGovern

Present:

Goals: To create a code in Arduino that allows the MH-Z16 NDIR CO2 monitor to work.

Content:

See attached file.

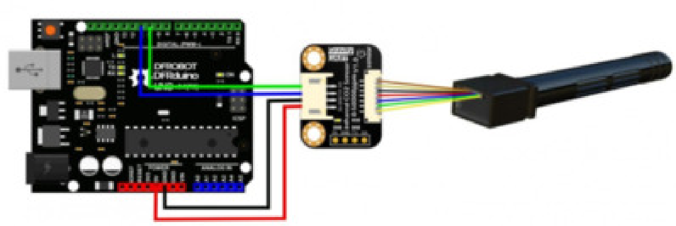
Conclusions/action items: Test the CO2 sensor using the testing protocols created by Maya and Caroline. Figure out a way to convert ppm to percentage.

Katie Day - Dec 03, 2021, 12:25 PM CST

Download

ReadConcentration.ino (888 B)

Katie Day - Dec 03, 2021, 12:25 PM CST



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MH_Z16_Circuit_Diagram.PNG (155 kB)

12/03/2021 Thermistor Testing

Katie Day - Dec 07, 2021, 7:43 PM CST

Title: Thermistor Testing

Date: 12/3/2021

Content by: Katie, Olivia, Maya, and Caroline

Present: Katie and Olivia

Goals: To test the accuracy of our thermistor against an incubator.

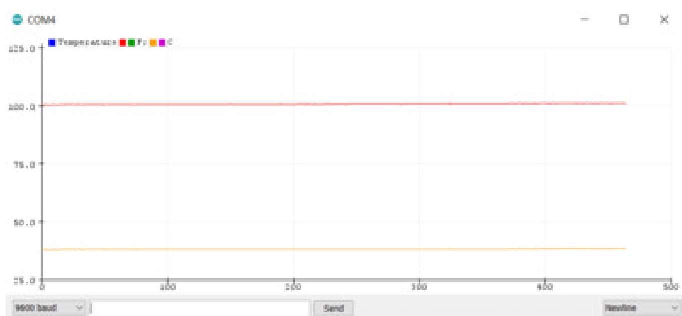
Content:

Testing protocol written by Maya and Caroline and performed by Olivia and me. Results are below.

Conclusions/action items:

Thermistor is working properly and ready for implementation.

Katie Day - Dec 03, 2021, 12:28 PM CST



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Misty_In_Incubator_10-min.PNG (15.4 kB)

12/03/2021 CO2 Testing

Katie Day - Dec 07, 2021, 7:42 PM CST

Title: CO2 Testing

Date: 12/3/2021

Content by: Katie, Olivia, Maya, and Caroline

Present: Katie and Olivia

Goals: To test the CO2 sensor to make sure that it is working properly.

Content:

Attached our the results of our testing, testing protocols written by Maya and Caroline, performed by Olivia and me.

Conclusions/action items:

The CO2 sensor is ready for incorporation into the incubator.

Katie Day - Dec 03, 2021, 3:22 PM CST

Download

concentration.csv (2.43 kB)

Katie Day - Dec 07, 2021, 7:42 PM CST

Download

concentration_graphs.csv (2.34 kB)

12/03/2021 Humidity Testing

Katie Day - Dec 07, 2021, 7:47 PM CST

Title: Humidity Testing

Date: 12/3/2021

Content by: Katie and Olivia

Present: Katie and Olivia

Goals: To test the accuracy of our humidity formula against the DHT22 sensor

Content:

Humidity data gathered over time in order to perform ttest to determine statistically significance compared to the DHT22 sensor.

Conclusions/action items:

Send data to caroline, olivia, and maya for analysis.

Katie Day - Dec 07, 2021, 7:48 PM CST

Download

Misty_Humidity_Data.csv (1.55 kB)

Katie Day - Dec 07, 2021, 7:48 PM CST

Download

Combined_Humidity_Data.csv (4.23 kB)

Katie Day - Dec 07, 2021, 7:48 PM CST

DHT22 Humidity (%)	Misty Humidity (%)
12.7	12.07
12.7	12.07
12.7	12.07
12.6	11.72
12.6	11.27
12.6	11.27
12.6	11.27
12.6	11.37
12.6	11.37
12.6	11.37
12.6	11.37
12.7	11.27
13.5	11.72
13.6	12.07
13.5	12.42
13.2	12.78
13.3	12.78
13.2	12.78
13.1	12.78
13	12.78
12.9	12.78
12.9	12.78
12.8	12.78
12.7	12.42
12.7	12.42
12.6	12.07
12.6	11.72
12.6	11.72
12.6	11.27
12.6	11.27
12.5	11.27
12.5	11.37
12.5	11.27
12.5	11.72
12.5	11.72
12.6	11.72
12.6	12.07
12.6	12.42
12.6	12.42
12.6	12.78
12.6	12.78
12.6	12.78
12.6	12.78
12.6	12.78
12.6	12.42
12.6	12.78
12.5	12.78
12.5	12.42
12.5	12.42
12.5	12.07
11.7	12.07
12.4	11.72
12.4	11.72
12.4	11.72
12.4	11.37
12.4	11.72
12.4	12.07
12.4	12.42
12.4	12.07
12.4	12.07
12.4	11.72
12.4	11.27

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Combined_Humidity_Data.txt (2.08 kB)

Katie Day - Dec 07, 2021, 7:48 PM CST

Download

DHT22_Humidity_Data.csv (441 B)

12/07/2021 Group Testing Protocols

Katie Day - Dec 07, 2021, 7:37 PM CST

Title: Group Testing Protocols

Date: 12/07/2021

Content by: Maya Tanna and Caroline Craig

Present: Katie McGovern and Olivia Jaekle

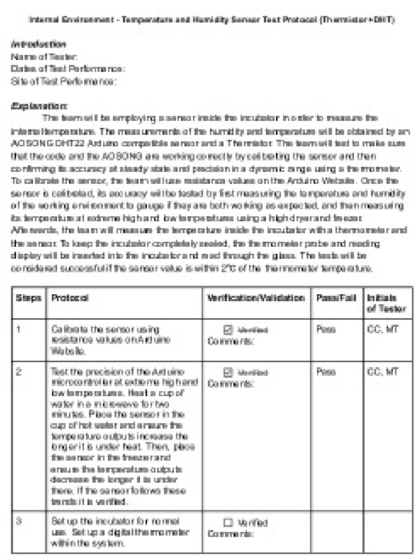
Goals: To create testing protocols and verify that the elements of our design are working as expected, accurately, and precisely.

Content: The Testing Protocols and the parts of the protocol that were able to be evaluated during the semester.

Conclusions/action items:

The temperature, humidity, CO2, and optics are all working as expected.

Katie Day - Dec 07, 2021, 7:37 PM CST



Internal Environment - Temperature and Humidity Sensor Test Protocol (Thermistor+DHT)

Introduction
Name of Tester:
Dates of Test Performance:
Site of Test Performance:

Explanation:
The team will be employing a sensor inside the incubator in order to measure the internal temperature. The measurements of the humidity and temperature will be obtained by an AOSONG DHT22 Arduino compatible sensor and a Thermistor. The team will test to make sure that the code and the AOSONG are working correctly by calibrating the sensor and then confirming its accuracy at steady state and precision in a dynamic range using a thermometer. To calibrate the sensor, the team will use resistance values on the Arduino Website. Once the sensor is calibrated, its accuracy will be tested by first measuring the temperature and humidity of the working environment to gauge if they are both working as expected, and then measuring its temperature at extreme high and low temperatures using a high dryer and freezer. Afterwards, the team will measure the temperature inside the incubator with a thermometer and the sensor. To keep the incubator completely sealed, the thermometer probe and reading display will be inserted into the incubator and read through the glass. The tests will be considered successful if the sensor value is within 2°C of the thermometer temperature.

Steps	Protocol	Verification/Validation	Pass/Fail	Initials of Tester
1	Calibrate the sensor using resistance values on Arduino Website.	☑ ~~Verified~~ Comments:	Pass	CC, MT
2	Test the precision of the Arduino microcontroller at extreme high and low temperatures. Heat a cup of water in a microwave for two minutes. Place the sensor in the cup of hot water and ensure the temperature outputs increase the longer it is under heat. Then, place the sensor in the freezer and ensure the temperature outputs decrease the longer it is under there. If the sensor follows these trends it is verified.	☑ ~~Verified~~ Comments:	Pass	CC, MT
3	Set up the incubator for normal use. Set up a digital thermometer within the system.	☐ Verified Comments:		

Download

Group_Testing_Protocols.pdf (92.6 kB)

12/07/2021 Incubator Fabrication

Katie Day - Dec 07, 2021, 7:57 PM CST

Title: Incubator Fabcrication

Date: 12/07/2021

Content by: Katie McGovern

Present: Katie McGovern and Sam Bardwell

Goals: To fabricate the incubator.

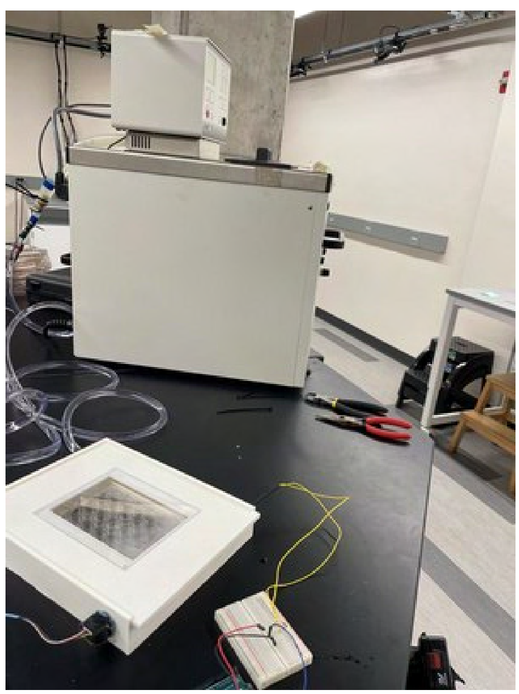
Content:

The box was fabricated by first drilling 3/8 inch diameter holes in the front of the box and then using a circular file to expand them so that the barbed connectors could fit in the incubator. They were then hot glued. The glass was hot glued onto the small divot made for them in the design. A 1/4 inch hole was drilled on the bottom right corner for the thermistor and filed with a circular file. A 1/2 inch hole was drilled and expanded via circular file for the CO2 sensor to fit in. The CO2 sensor and the thermistor were hot glued into place. The 3/8x1/4 inch tubing was wrapped in a circular fashion along the interior of the box and connected to the barbed vacuum connectors. They were then secured by zip ties. They were connected to a 1/2x3/8 inch tubing that was secured via zip ties to both the connector and the hot water pump. Then roughly 16 oz of water was poured into the incubator.

Conclusions/action items:

The PLA material needs to be changed as it was difficult to drill into, very brittle, and appeared to be leaking in random places.

Katie Day - Dec 07, 2021, 7:52 PM CST



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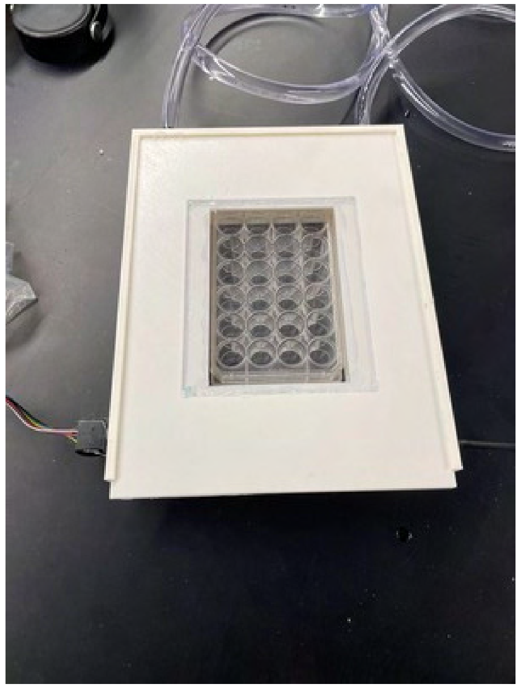

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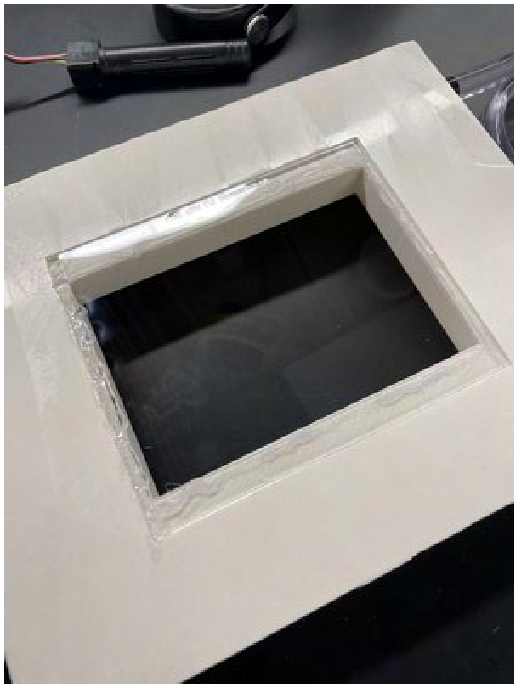

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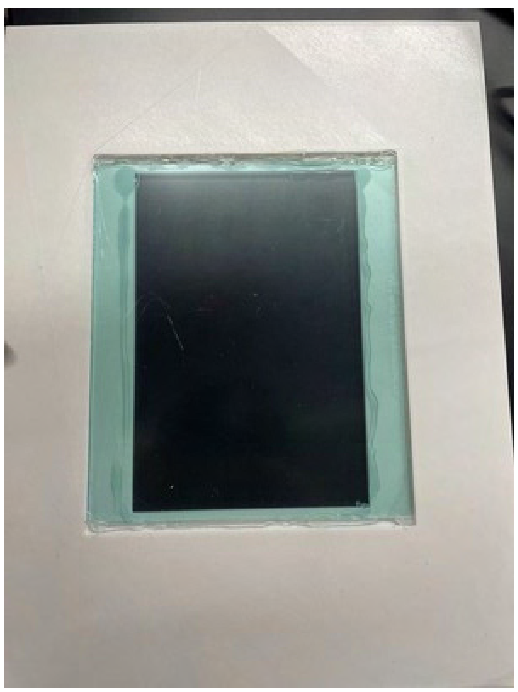

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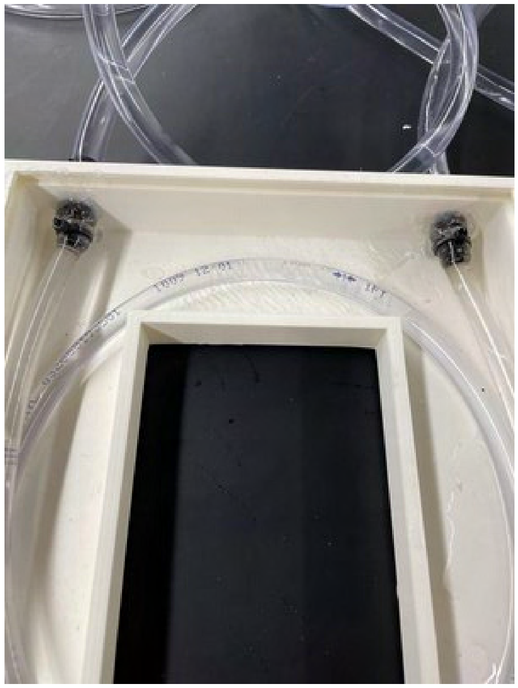

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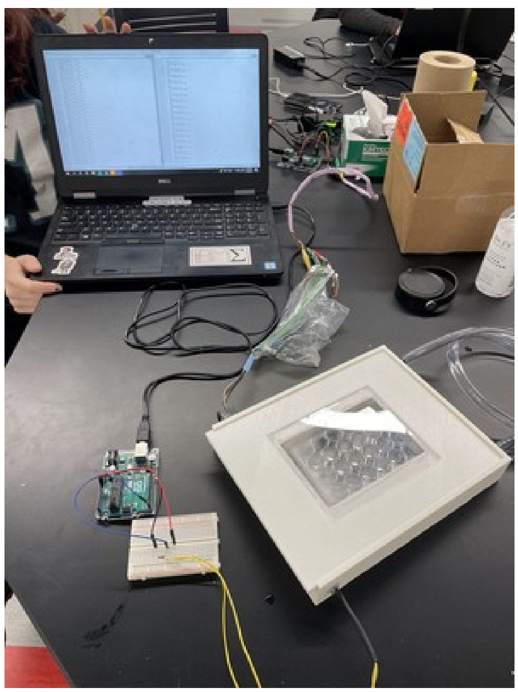

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IMG_5895.jpg (693 kB)

12/07/2021 Attempted Incubator Testing

Katie Day - Dec 07, 2021, 8:00 PM CST

Title: Attempted Incubator Testing

Date: 12/07/2021

Content by: Katie McGovern and Sam Bardwell

Present: Katie McGovern and Sam Bardwell

Goals: To initially determine whether or not our incubator was working as expected.

Content: Data collected during testing.

Conclusions/action items:

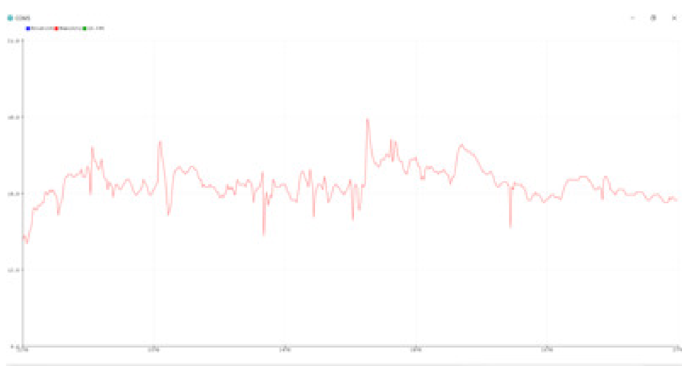
1. Polyethelene tubing acted more as an insulator than a conductor and would not heat up the water bath to the desired temperature. Need to use a metal tube.
2. PLA box was leaking slightly. It is unclear where or how it is leaking as it has been sealed via hot glue and zipties.
3. Glass did fog up after about 30 minutes so we will need to figure out how to demist the glass.

Katie Day - Dec 07, 2021, 8:01 PM CST

Download

Incubator_Temp_Over_Time.csv (5.1 kB)

Katie Day - Dec 07, 2021, 8:01 PM CST



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Incubator_Temp_Over_Time.PNG (68.7 kB)

Katie Day - Dec 07, 2021, 8:01 PM CST

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Incubator_Temp_Hum_Over_Time.csv (5.1 kB)

Katie Day - Dec 07, 2021, 8:01 PM CST

Download

Actual_Inc_HUm_Data.csv (2.19 kB)

02/01/2022 Preventing Cell Culture Contamination with Copper CO2 Incubators

MAYA TANNA - Feb 01, 2022, 9:26 PM CST

Title: Preventing Cell Culture Contamination with Copper CO2 Incubators

Date: 02/01/2022

Content by: Maya

Present: Maya

Goals: To document findings from this interesting article on copper incubator systems

Content:

Findings

- Copper inhibits the growth of lots of different microorganisms (bacteria, fungi, algae, and yeast)
  - Ions bind to contaminant and disrupt key proteins/processes
- Copper acts as a microcide - antibacterial only in the presence of glucose and oxygen
  - Reduces bacteria/algae in cooling systems/towers
  - Plumbing pipes reduce bacteria
  - Aquacides and pesticides reduce several other organisms
- Copper in incubators
  - Reduces microbes in a wide variety of equipment
  - Copper wire/sulfate significantly inhibit microbial growth
  - Reduce spread of contaminants
  - Proven antimicrobial properties

Cite: A. Dippel, “APN_LECT_PRECON_1007.qxd,” p. 2.

Conclusions/action items: I don't think this would be that useful for where we're at in the project currently, but it was a cool article to read and interesting to learn about full-on copper incubator systems. It's different from our project because we're just trying for copper tubing rather than the whole incubator be copper. This could definitely be a cool thing to consider in future years though to prevent contamination across the whole system.

MAYA TANNA - Feb 01, 2022, 9:27 PM CST

Preventing Cell Culture Contamination with Copper CO_2 Incubators

Download

Flyer-Heracell-cu-AN-LECO2-PRECON-11071.pdf (235 kB)

02/01/2022 Thermal Properties of Copper

MAYA TANNA - Feb 01, 2022, 9:51 PM CST

Title: Thermal Properties of Copper

Date: 02/01/2022

Content by: Maya

Present: Maya

Goals: To document specifications from this article on the thermal properties of copper

Content:

Findings

- Copper is soft, malleable (able to be bent with a hammer), and ductile (able to deform without losing toughness)
  - Has a very high conductivity (thermally and electrically)
- Melting point is 1084.62 C, boiling point is 2562 C
- Thermal conductivity of Copper is 401 W/(m*K)
  - Thermal conductivity is a measure of a substance's ability to transfer heat through a material via conduction
  - Need to use Fourier's Law for any calculations (works for any state of matter)
- Coefficient of thermal expansion is 16.5 um/(m*K)
  - Thermal expansion is the tendency of matter to change its dimensions in response to a change in temperature
- Density is 8.92 g/cm3

**Important formulas to use for thermal calculations are included in the article

Cite: “Copper - Thermal Properties - Melting Point - Thermal Conductivity - Expansion,” *Material Properties*, Nov. 01, 2020. https://material-properties.org/copper-thermal-properties-melting-point-thermal-conductivity-expansion/ (accessed Feb. 01, 2022).

Conclusions/action items: We are going to switch our tubing to copper, which is why this research is necessary. However, we may need to do more calculations this semester in order to verify that heat is being distributed evenly throughout the entire incubator system, so these equations and specifications were important to look at.

02/06/2022 Ensuring CO2 Function

MAYA TANNA - Feb 06, 2022, 10:15 AM CST

Title: Ensuring CO_2 Function

Date: 02/06/2022

Content by: Maya

Present: Maya

Goals: To document information on how to ensure that CO_2 sensors are reading gas values and functioning normally

Content:

Findings

- Avoid contamination and don't use antibiotics/antimycotics - instead, improve sterile techniques and come up with a system to regularly clean the incubator
- Main source of incubator contamination is the entry of microorganisms through the access door/entry region
  - Wear gloves
  - Minimize the time the entry pathway is open
  - Wipe the entry pathway with 70% ethanol
  - Change out water weekly
- Need to keep CO_2 levels at 5% to maintain the cell medium at a physiological pH
  - Even though CO_2 sensors aim to maintain the desired CO_2 level, the calibration may shift over time from the set point
  - Easiest and most accurate method to measure CO_2 is a gas analyzer - Fyrite instrument (can also measure O_2 if needed)
    - Downside: way too expensive
  - Automatically zero the sensor monthly
- Temperature requirement of 37 C
  - Check with a calibrated thermometer - open the outer and inner incubator doors and tape the thermometer to the inside of the glass door so the temperature can be read from the outside when the glass door is closed
- Humidity requirement of 95-100%
  - Keep water in the tray on the bottom of the incubator
    - Downside: potential source of contamination

Cite: May 20 and 2013, “How to Make Sure Your CO2 Incubator Is Working Properly.” http://www.biocompare.com/Bench-Tips/137449-How-to-Make-Sure-Your-CO2-Incubator-Is-Working-Properly/ (accessed Feb. 06, 2022).

Conclusions/action items: This was an informative article on how to maintain cleanliness within the incubator which will be very useful closer to the end of the project when we have a final working product, but it's still good to know as we build because then some of this can be included in the testing protocols in order to ensure a safe and clean product. We haven't done much work with CO_2 so we're really going to have to look into that since a CO_2 gas analyzer is significantly over our $100 budget.

02/13/2022 Standard Tolerance Values

MAYA TANNA - Feb 13, 2022, 12:40 PM CST

Title: Standard Tolerance Values

Date: 02/13/2022

Content by: Maya

Present: Maya

Goals: To document CO_2 tolerance values

Content:

Findings

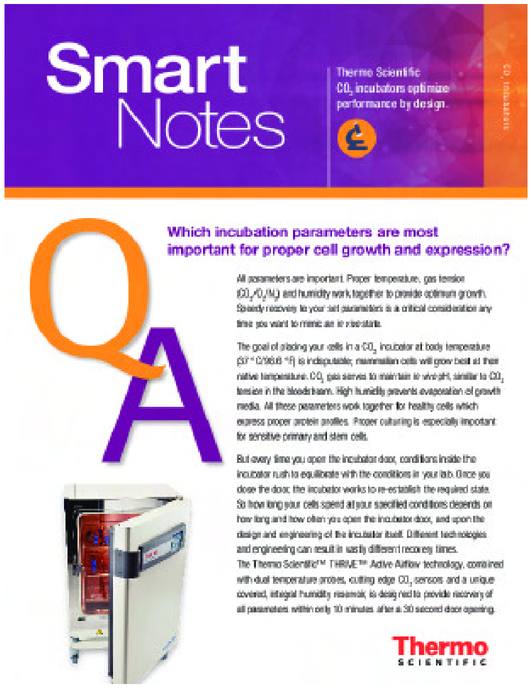
- CO_2 Tolerance Value
  - CO_2 is typically kept between 3-7% depending on the application and culture
    - About a 2% tolerance value from 5%
  - Our sensor: MH z16 NDIR
- Temperature Tolerance Value
  - Temp is typically kept between 37-39 degrees C
- Humidity Tolerance Value
  - Typically kept between 85-95% - Thermo Fisher Scientific recommendation

Conclusion: This research was necessary so we could include these tolerance values in our technical reports to ensure we are following typical industry standards.

Cite: "Why is CO2 Safety Important for Incubators?," *AZoSensors.com*, Jan. 17, 2020. https://www.azosensors.com/article.aspx?ArticleID=1872 (accessed Feb. 13, 2022).

B. C. Coops, "Incubation: Everything You Need To Know About Incubator Heat and Humidity," *Backyard Chicken Coops*. https://www.backyardchickencoops.com.au/blogs/learning-centre/everything-you-need-to-know-about-heat-and-humidity (accessed Feb. 13, 2022).

MAYA TANNA - Feb 13, 2022, 12:40 PM CST



Smart Notes

Thermo Scientific CO_2 incubators optimize performance by design.

QA

Which incubation parameters are most important for proper cell growth and expression?

All parameters are important. Proper temperature, gas tension (CO_2/O_2/N_2) and humidity work together to provide optimum growth. Speedy recovery to your set parameters is a critical consideration any time you want to mimic an in vivo state.

The goal of placing your cells in a CO_2 incubator at body temperature (37 °C/98.6 °F) is indisputable; mammalian cells will grow best at their native temperature. CO_2 gas serves to maintain in vivo pH, similar to CO_2 tension in the bloodstream. High humidity prevents evaporation of growth media. All these parameters work together for healthy cells which express proper protein profiles. Proper culturing is especially important for sensitive primary and stem cells.

But every time you open the incubator door, conditions inside the incubator rush to equilibrate with the conditions in your lab. Once you close the door, the incubator works to re-establish the required state. So how long your cells spend at your specified conditions depends on how long and how often you open the incubator door, and upon the design and engineering of the incubator itself. Different technologies and engineering can result in vastly different recovery times.

The Thermo Scientific™ THRIVE™ Active Airflow technology, combined with dual temperature probes, cutting edge CO_2 sensors and a unique covered, integral humidity reservoir, is designed to provide recovery of all parameters within only 10 minutes after a 30 second door opening.

Thermo SCIENTIFIC

Download

PF-CO2-SMARTNOTE-EN.pdf (574 kB)

02/06/2022 Self-Installing Incubator Monitoring System

MAYA TANNA - Feb 06, 2022, 10:31 AM CST

Title: Self-Installing Incubator Monitoring System

Date: 02/06/2022

Content by: Maya

Present: Maya

Goals: To document information on how to install CO2 sensors with a tutorial from TetraScience

Content:

Findings

- Prep
    - Make sure there is an available power outlet within 6 feet/get a power strip
    - Ensure access to the top of the freezer/refrigerator
- Each TetraScience link comes with:
    - Monitor (AnyLink)
    - Power supply
    - 2x antennas
    - USB sensor and probe

- Tutorial
    - Screw the wifi antenna onto the Link connect it to power
        - 4 indicator lights - power, run, net, warn

- CO2 (images of each step are included in the article)
    - Mount the sensor on the side wall of the incubator (use a 3M dual Lock hook-and-loop fastener)

      - Place the sensor at least halfway to the back wall of the incubator
    - Pass the cable through the sensor port to the back of the incubator
    - Place a stopper on the port once cables have been fed through
    - Connect the USB adapter into the temp sensor
    - Insert the ends of the sensors' cables into the provided USB splitter
    - Insert splitter into the USB port on the AnyLink monitor
    - Place the link on top of the incubator with its antennae pointing up
- Key tip: remove sensors before sterilizing incubator with 70% ethanol

Cite: “Self-installing Incubator Monitoring,” *TetraScience*. https://tetrascience.zendesk.com/hc/en-us/articles/360029774512-Self-installing-Incubator-Monitoring (accessed Feb. 06, 2022).

Conclusions/action items: This article is helpful because it includes steps to connecting a CO2 sensor to the incubator and then displaying the results on a monitor, but in terms of cost effectiveness, I don't think this would fit within our $100 budget. Maybe we can follow similar steps but look for cheaper materials or come up with an entirely new approach. Once I go into ECB to look at the CO2 tank/sensor, I will have a better idea how we can try to connect all the pieces together.

02/12/2022 CO2 Progress from Previous Semesters

MAYA TANNA - Feb 27, 2022, 3:54 PM CST

Title: CO2 Progress from Previous Semesters

Date: 02/12/2022

Content by: Maya

Present: Maya

Goals: To document progress with CO2 sensors from previous semesters

Content:

Findings

- Fall 2020 / Spring 2021 Team
    - Worked on reading CO2 tank values on an Arduino, but never tested it
    - Used a solenoid valve to regulate distribution of CO2 in the incubator
- Spring 2017 Team
    - Got CO2 working!
    - Need to look more into this
- Maybe switch to plastic tubing because that's what the successful team used - just make sure to use really thick tubing
    - Do plastic tubing on the outside and copper tubing inside the box so heat can be dissipated inside the box and our temperature/humidity values can be more accurate

Conclusion: Since the spring 2017 team got CO2 working, I want to look more into what they did as well as use actual connectors with threading in the box in order to ensure heat is conserved as much as possible. In the future, I need to read the 2017 final report and look at the CO2 tank in person to determine possible connection ideas.

MAYA TANNA - Feb 12, 2022, 6:18 PM CST

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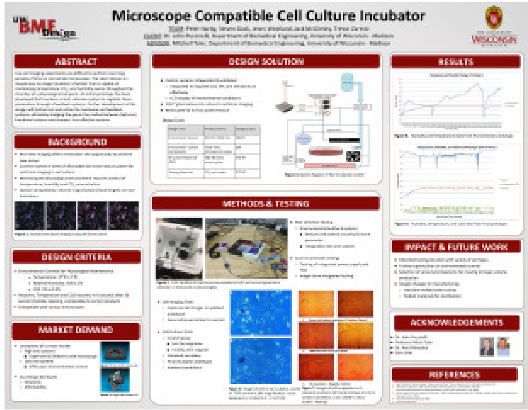
Spring_2021_Final_Poster.pdf (684 kB)

MAYA TANNA - Feb 12, 2022, 6:56 PM CST



Download

Spring_2017_Final_Poster.pdf (1.72 MB)

02/15/2022 Heat Transfer Calculations

MAYA TANNA - Feb 15, 2022, 8:38 PM CST

Title: Heat Transfer Calculations

Date: 02/15/2022

Content by: Maya

Present: Maya

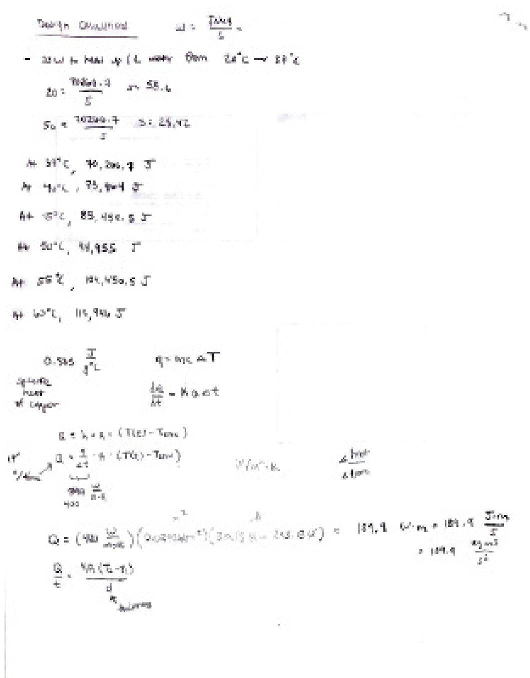
Goals: To document heat transfer calculations/ideas done during team meeting

Content:

See attachment below

Conclusion: These calculations are necessary because we can calculate the time it would take to heat the incubator to a certain temperature as much heat would be lost and what temperature we should keep the incubator at to account for any minor losses. We did not finish calculations, but we will revisit these at a future date.

MAYA TANNA - Feb 15, 2022, 8:40 PM CST



Download

Heat_Transfer_Calculations.pdf (162 kB)

02/27/2022 CO2 Connection Ideas

MAYA TANNA - Feb 27, 2022, 3:57 PM CST

Title: CO2 Connection Ideas

Date: 02/27/2022

Content by: Maya

Present: Maya

Goals: To document CO2 connection ideas for the incubator system

Content:

CO2 Ideas

- Look up a gas solenoid that can plug into tubing and plug into Arduino as a pwm input
  - PWM - pulse width modulation (essentially, this allows the finite control of the solenoid valve so that we can control the level of CO2 in the chamber)
- If we can't find a gas solenoid that will plug directly into the Arduino (i.e. takes a 5V output), then search for one that takes a 12V or 24V source
  - Buy a 12V or 24V wall connector to an AC connector
  - Strip the AC connector for the positive and negative connections, then purchase a relay that allows for the voltage to be controlled with a select signal input from a digital or analog write command from the Arduino
  - Or if the valve's electronics allow, a MOSFET (transistor) circuit to control current to the valve and slowly control the valve to open or close
- How to connect CO2 tank to the incubator
  - Drill holes in the acrylic about the approximate diameter of the connector diameter
  - Use a tap to create threading for the connector to screw into
  - Use teflon tape around the connector to make sure there is an airtight seal
- 
  - Barbs

Conclusion: These ideas will be useful once we get more hands-on with the CO2 tank and decide how specifically to connect the sensor to the incubator to accurately read CO2 values. Next steps are to start working with CO2.

03/25/2022 Show and Tell Feedback

MAYA TANNA - Mar 25, 2022, 1:25 PM CDT

Title: Show and Tell Feedback

Date: 3/25/2022

Content by: Maya

Present: Whole Team

Goals: To get feedback on our call-to-action and generate more ideas for future directions of the project

Content:

Call-to-Action:

- Need help with preventing leakage in the box and making the box more waterproof.
  - We are worried that the joint connections will have leakages.
- Or if anyone knows anything on how to regulate CO2 - it needs to stay at 5% (a continuous stream won't work, we need something to open and close the valve).
- Or if anyone knows where to get a cheap DC motor that's not Amazon

Ideas:

- Different type of resin - look for something more waterproof
- Some kind of glue and a lot of it
- Liquid rubber can help with the seal and keeping it watertight
  - More insulating and can be used with a fluorescent microscope
- Flex seal
- Have a constant motor that pumps CO2 in, and then have another motor that pumps it out
  - This would be difficult, may need a vacuum
  - Would be hard to maintain because you would have to keep changing out the tanks (would waste a lot of CO2)
- Look at a blueprint or data sheet for an actual incubator
- Rubber caulk
  - Can line the tip with the edge so you don't have to waste excess material
- Can you weld acrylic?
  - Yes, you can
- Acrylic cement/sealer
- Put foam/insulation film around the box to help preserve the heat
- Use a servomotor
- Use a solenoid valve
  - Build a mechanism such that the solenoid cuts off the flow
- Get a big block of acrylic and use it to cover any holes
- Use a tarp material for the inside

Conclusions/action items:

Consider the potential solutions at the next team meeting.

04/08/2022 Executive Summary Draft 1

MAYA TANNA - Apr 21, 2022, 12:57 PM CDT

Title: Executive Summary Draft 1

Date: 04/08/2022

Content by: Maya, Katie

Present: Maya, Katie

Goals: To document the first draft of the executive summary

Content:

See attached file.

Conclusions/action items: Make edits to this based on advisor feedback and submit in a few weeks.

MAYA TANNA - Apr 21, 2022, 12:59 PM CDT

Microscopic Cell Culture Incubator

BME Design Excellence Award

Sam Bardwell, Katie Day, Maya Tanna, Drew Hardwick, Bella Raykowski

The goal of the project was to develop a low cost cell culture incubation chamber that is compatible with an inverted microscope and capable of keeping cells alive during imaging. This incubation chamber must be able to maintain an internal environment of 37°C, 5% CO_2, and 95-100% humidity over the course of 1 week, without compromising the integrity of the microscope's optics or functionality. Special consideration must be taken to maintain even heating and humidity across the chamber as gradients can result in evaporation from low volume cultures such as microfluidic devices. Current commercially available systems are prone to these issues and are extremely expensive.

There are currently two categories of competing designs. Commercial stand-alone incubators and, less popular, commercially available stage top incubators, both of which range from $500-$40,000[1]. The most popular Thermo Fisher design is the Heracell VIOS 160i CO2 Incubator with Copper Interior Chambers, which has HEPA filtration for ISO Class 5 air quality and an overnight Steri-Run for total sterilization [2]. Commercially available stage-top incubators include those from Okolab and Elliot scientific, which have had great success in maintaining a homogeneous environment in terms of temperature and CO2 percentage [3,4].

The design process has been broken down into three main parts: circuitry, fabrication, and testing. Due to the importance of maintaining a precise internal environment for cell growth, a thermistor, NDIR CO_2 sensor, and a DC motor have been implanted for the purpose of monitoring and inputting temperature, humidity, and CO_2. The thermistor is waterproof, automatically monitors temperature, and additionally has been coded to monitor humidity. The NDIR sensor monitors the CO_2 volume and percentage inside the box. The DC motor, which is paired with a 3D printed attachment, is used to adjust the flow of 100% CO_2 from a tank so the incubator only contains 5% CO_2 at all times. The resulting final design includes a hinge-top acrylic box incubator, fabricated via laser cutting black acrylic. The current prototype is a 245x195x40mm black acrylic box with two polycarbonate glass plates on the top and bottom to allow for optical use of an inverted microscope, a top lid with a rubber lining that is secured via latches, two feet of copper tubing circling the inside, an internal water bath, and holes for the sensors and polyethylene tubing that will deliver 5% CO_2 from the 100% tank, as controlled by the DC motor. The copper tubing will allow for sufficient heat transfer to the water bath, because of high thermal transfer properties, in order to maintain an internal environment of 37°C and 95-100% humidity. The acrylic was chosen as it will provide the best internal environment, reduce the majority of leakage, and is cost efficient.

Testing protocols were written and conducted on sensory accuracy, optical clarity, and the internal environment. All sensors were tested against a commercially available incubator in the teaching lab and were determined to have no statistical significance between the sensor and incubator values. Optical clarity tests showed that there was no optical difference between slides when under the polycarbonate glass, as compared to without glass. The internal environment of the incubator was tested to ensure homogeneity and cell viability, along with recovery testing.

The low cost aspect of the incubator makes it more accessible for research labs, educational institutions, and companies to conduct live cell imaging. More users will be able to image live cells, which could greatly advance the field of pharmaceuticals, virology, and vaccine production, and genetic engineering/gene therapy.

Download

Executive_Summary.pdf (65.9 kB)

04/21/2022 Executive Summary Final

MAYA TANNA - Apr 21, 2022, 1:01 PM CDT

Title: Executive Summary Final

Date: 04/22/2022

Content by: Maya, Katie

Present: Maya, Katie

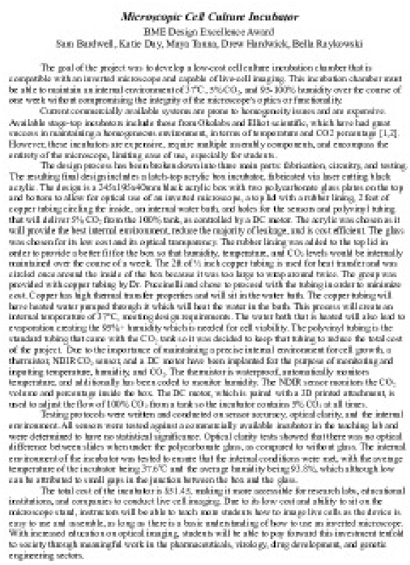
Goals: To document the final executive summary

Content:

See attached file.

Conclusions/action items: Submit to BME design website.

MAYA TANNA - Apr 21, 2022, 1:01 PM CDT



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The goal of the project was to develop a low-cost cell culture incubation chamber that is compatible with an inverted microscope and capable of live-cell imaging. This incubation chamber must be able to maintain an internal environment of 37°C, 5% CO_2, and 95-100% humidity over the course of one week without compromising the integrity of the microscope's optics or functionality.

Current commercially available systems are prone to homogeneity issues and are expensive. Available stage-top incubators include those from Okolabs and Elliot scientific, which have had great success in maintaining a homogeneous environment, in terms of temperature and CO2 percentage [1,2]. However, these incubators are expensive, require multiple assembly components, and encompass the entirety of the microscope, limiting ease of use, especially for students.

The design process has been broken down into three main parts: fabrication, circuitry, and testing. The resulting final design includes a latch-top acrylic box incubator, fabricated via laser cutting black acrylic. The design is a 245x195x40mm black acrylic box with two polycarbonate glass plates on the top and bottom to allow for optical use of an inverted microscope, a top lid with a rubber lining, 2 feet of copper tubing circling the inside, an internal water bath, and holes for the sensors and polyvinyl tubing that will deliver 5% CO_2 from the 100% tank, as controlled by a DC motor. The acrylic was chosen as it will provide the best internal environment, reduce the majority of leakage, and is cost efficient. The glass was chosen for its low cost and its optical transparency. The rubber lining was added to the top lid in order to provide a better fit for the box so that humidity, temperature, and CO_2 levels would be internally maintained over the course of a week. The 2ft of ½ inch copper tubing is used for heat transfer and was circled once around the inside of the box because it was too large to wrap around twice. The group was provided with copper tubing by Dr. Puccinelli and chose to proceed with the tubing in order to minimize cost. Copper has high thermal transfer properties and will sit in the water bath. The copper tubing will have heated water pumped through it which will heat the water in the bath. This process will create an internal temperature of 37°C, meeting design requirements. The water bath that is heated will also lead to evaporation creating the 95%+ humidity which is needed for cell viability. The polyvinyl tubing is the standard tubing that came with the CO_2 tank so it was decided to keep that tubing to reduce the total cost of the project. Due to the importance of maintaining a precise internal environment for cell growth, a thermistor, NDIR CO_2 sensor, and a DC motor have been implanted for the purpose of monitoring and inputting temperature, humidity, and CO_2. The thermistor is waterproof, automatically monitors temperature, and additionally has been coded to monitor humidity. The NDIR sensor monitors the CO_2 volume and percentage inside the box. The DC motor, which is paired with a 3D printed attachment, is used to adjust the flow of 100% CO_2 from a tank so the incubator contains 5% CO_2 at all times.

Testing protocols were written and conducted on sensor accuracy, optical clarity, and the internal environment. All sensors were tested against a commercially available incubator in the teaching lab and were determined to have no statistical significance. Optical clarity tests showed that there was no optical difference between slides when under the polycarbonate glass, as compared to without glass. The internal environment of the incubator was tested to ensure that the internal conditions were met, with the average temperature of the incubator being 37.6°C and the average humidity being 93.8%, which although low can be attributed to small gaps in the junction between the box and the glass.

The total cost of the incubator is $51.45, making it more accessible for research labs, educational institutions, and companies to conduct live cell imaging. Due to its low cost and ability to sit on the microscope stand, instructors will be able to teach more students how to image live cells as the device is easy to use and assemble, as long as there is a basic understanding of how to use an inverted microscope. With increased education on optical imaging, students will be able to pay forward this investment tenfold to society through meaningful work in the pharmaceuticals, virology, drug development, and genetic engineering sectors.

Download

Executive_Summary_1_.pdf (65.2 kB)

02/27/2022 Testing Protocol Template Revisions

MAYA TANNA - Feb 27, 2022, 4:06 PM CST

Title: Testing Protocol Template Revisions

Date: 02/27/2022

Content by: Maya

Present: Maya

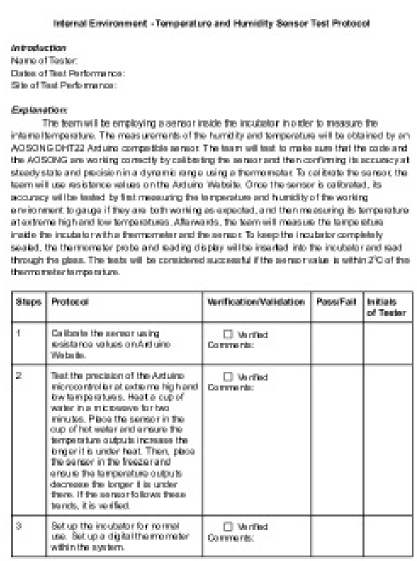
Goals: To document revisions made to the testing protocol template in order to better reflect current information

Content:

See attached file.

Conclusions/action items: Begin testing wherever possible, likely with optical imaging testing/microscopy. Help other areas of the project so they can get to the testing stage and then lead that. We may need to calibrate the CO2 sensor and this may take a while since calibrating CO2 is harder than calibrating temperature. This is usually done with a fyrite - check with Dr. Puccinelli if he has one available in the teaching lab and do more research about this.

MAYA TANNA - Feb 27, 2022, 3:52 PM CST



Internal Environment - Temperature and Humidity Sensor Test Protocol

Introduction
Name of Tester:
Dates of Test Performance:
Site of Test Performance:

Explanation:
The team will be employing a sensor inside the incubator in order to measure the internal temperature. The measurements of the humidity and temperature will be obtained by an AOSONG DHT22 Arduino compatible sensor. The team will test to make sure that the code and the AOSONG are working correctly by calibrating the sensor and then confirming its accuracy at steady state and precision in a dynamic range using a thermometer. To calibrate the sensor, the team will use resistance values on the Arduino Website. Once the sensor is calibrated, its accuracy will be tested by first measuring the temperature and humidity of the working environment to gauge if they are both working as expected, and then measuring its temperature at extreme high and low temperatures. Afterwards, the team will measure the temperature inside the incubator with a thermometer and the sensor. To keep the incubator completely sealed, the thermometer probe and reading display will be inserted into the incubator and read through the glass. The tests will be considered successful if the sensor value is within 2°C of the thermometer temperature.

Steps	Protocol	Verification/Validation	Pass/Fail	Initials of Tester
1	Calibrate the sensor using resistance values on Arduino Website.	☐ Verified Comments:		
2	Test the precision of the Arduino microcontroller at extreme high and low temperatures. Heat a cup of water in a microwave for two minutes. Place the sensor in the cup of hot water and ensure the temperature outputs increase the longer it is under heat. Then, place the sensor in the freezer and ensure the temperature outputs decrease the longer it is under there. If the sensor follows these trends, it is verified.	☐ Verified Comments:		
3	Set up the incubator for normal use. Set up a digital thermometer within the system.	☐ Verified Comments:		

Download

Testing_Protocols_Template_.pdf (479 kB)

03/24/2022 Optical Testing Images

MAYA TANNA - Mar 25, 2022, 9:58 AM CDT

Title: Optical Testing Images

Date: 03/24/2022

Content by: Maya

Present: Maya/Bella

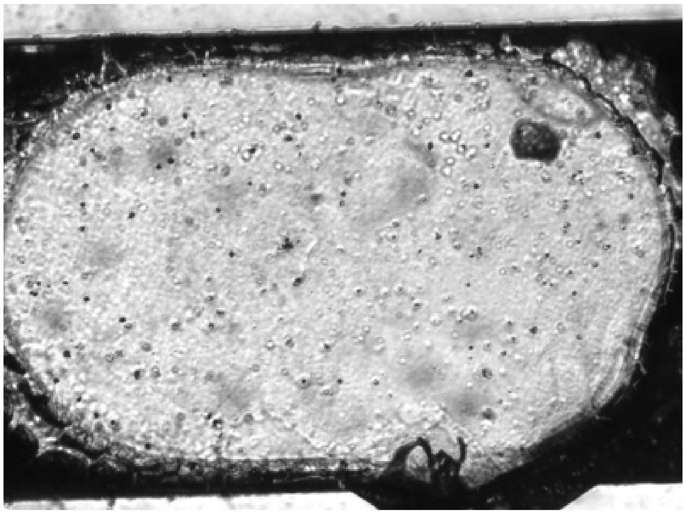
Goals: To provide images from the microscope to complete optical testing

Content:

See attached files.

Conclusions/action items: Next steps are to do image analysis via ImageJ and make conclusions on microscope focus quality based on those results.

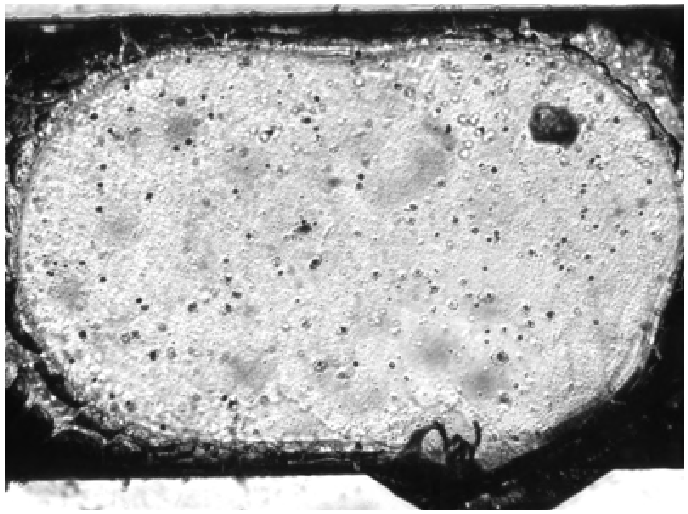
MAYA TANNA - Mar 25, 2022, 9:59 AM CDT



Download

test_2_with_glass.jpg (777 kB)

MAYA TANNA - Mar 25, 2022, 9:59 AM CDT



[Download]

test_2_without_glass.jpg (824 kB)

MAYA TANNA - Mar 25, 2022, 9:59 AM CDT

[Download]

test_with_sheet.jpg (178 kB)

MAYA TANNA - Mar 25, 2022, 9:59 AM CDT

Download

test_without_sheet.jpg (190 kB)

03/25/2021 Optical Testing Protocol Results

MAYA TANNA - Mar 25, 2022, 10:01 AM CDT

Title: Optical Testing Protocol Results

Date: 03/25/2022

Content by: Maya

Present: Maya/Bella

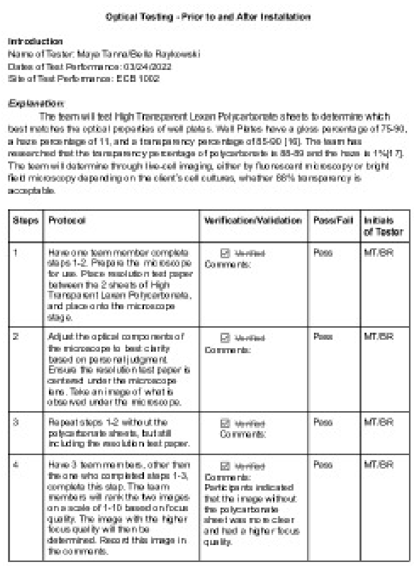
Goals: To document optical testing protocol results

Content:

See attached file.

Conclusions/action items: Next steps are to do image analysis via ImageJ and make conclusions on microscope focus quality based on those results, as well as complete testing wherever possible on other components of the system.

MAYA TANNA - Mar 25, 2022, 10:02 AM CDT



Optical Testing - Prior to and After Installation

Introduction
Name of Tester: Maya Tanna/Bella Raykowski
Dates of Test Performance: 03/24/2022
Site of Test Performance: ECB 1002

Explanation:
The team will test High Transparent Lexan Polycarbonate sheets to determine which best matches the optical properties of well plates. Well Plates have a gloss percentage of 75-90, a haze percentage of 11, and a transparency percentage of 85-90 [16]. The team has researched that the transparency percentage of polycarbonate is 88-89 and the haze is 1%[17]. The team will determine through live-cell imaging, either by fluorescent microscopy or bright field microscopy depending on the client's cell cultures, whether 88% transparency is acceptable.

Steps	Protocol	Verification/Validation	Pass/Fail	Initials of Tester
1	Have one team member complete steps 1-2. Prepare the microscope for use. Place resolution test paper between the 2 sheets of High Transparent Lexan Polycarbonate, and place onto the microscope stage.	☑ Verified Comments:	Pass	MT/BR
2	Adjust the optical components of the microscope to best clarity based on personal judgment. Ensure the resolution test paper is centered under the microscope lens. Take an image of what is observed under the microscope.	☑ Verified Comments:	Pass	MT/BR
3	Repeat steps 1-2 without the polycarbonate sheets, but still including the resolution test paper.	☑ Verified Comments:	Pass	MT/BR
4	Have 3 team members, other than the one who completed steps 1-3, complete this step. The team members will rank the two images on a scale of 1-10 based on focus quality. The image with the higher focus quality will then be determined. Record this image in the comments.	☑ Verified Comments: Participants indicated that the image without the polycarbonate sheet was more clear and had a higher focus quality.	Pass	MT/BR

Download

Maya_Bella_Optical_Testing_1_.pdf (63.8 kB)

03/25/2022 Testing Protocol Template Revisions

MAYA TANNA - Mar 25, 2022, 1:04 PM CDT

Title: Testing Protocol Template Revisions

Date: 03/25/2022

Content by: Maya

Present: Maya

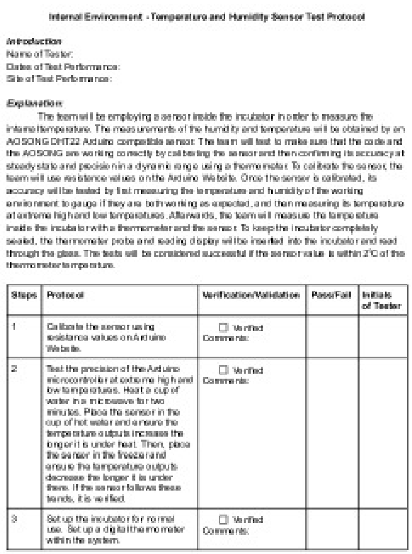
Goals: To document revisions made to the testing protocol template in order to better reflect current information

Content:

See attached file.

Conclusions/action items: Continue testing wherever possible. Help other areas of the project so they can get to the testing stage and then lead that.

MAYA TANNA - Mar 25, 2022, 1:04 PM CDT



Internal Environment - Temperature and Humidity Sensor Test Protocol

Introduction
Name of Tester:
Dates of Test Performance:
Site of Test Performance:

Explanation:

The team will be employing a sensor inside the incubator in order to measure the internal temperature. The measurements of the humidity and temperature will be obtained by an AOSONG DHT22 Arduino compatible sensor. The team will test to make sure that the code and the AOSONG are working correctly by calibrating the sensor and then confirming its accuracy at steady state and precision in a dynamic range using a thermometer. To calibrate the sensor, the team will use resistance values on the Arduino Website. Once the sensor is calibrated, its accuracy will be tested by first measuring the temperature and humidity of the working environment to gauge if they are both working as expected, and then measuring its temperature at extreme high and low temperatures. Afterwards, the team will measure the temperature inside the incubator with a thermometer and the sensor. To keep the incubator completely sealed, the thermometer probe and reading display will be inserted into the incubator and read through the glass. The tests will be considered successful if the sensor value is within 2°C of the thermometer temperature.

Steps	Protocol	Verification/Validation	Pass/Fail	Initials of Tester
1	Calibrate the sensor using resistance values on Arduino Website.	☐ Verified Comments:		
2	Test the precision of the Arduino microcontroller at extreme high and low temperatures. Heat a cup of water in a microwave for two minutes. Place the sensor in the cup of hot water and ensure the temperature outputs increase the longer it is under heat. Then, place the sensor in the freezer and ensure the temperature outputs decrease the longer it is under there. If the sensor follows these trends, it is verified.	☐ Verified Comments:		
3	Set up the incubator for normal use. Set up a digital thermometer within the system.	☐ Verified Comments:		

Download

Testing_Protocols_Template_1_.pdf (478 kB)

03/26/2022 Optical Testing ImageJ Analysis

MAYA TANNA - Mar 26, 2022, 12:47 PM CDT

Title: Optical Testing ImageJ Analysis

Date: 03/26/2022

Content by: Maya

Present: Maya

Goals: To document the ImageJ analysis and results for the final report with data included

Content:

See below.

Conclusions/action items: Continue testing wherever possible. Help other areas of the project so they can get to the testing stage and then lead that.

Optical Testing Results (Prior and After Installation)

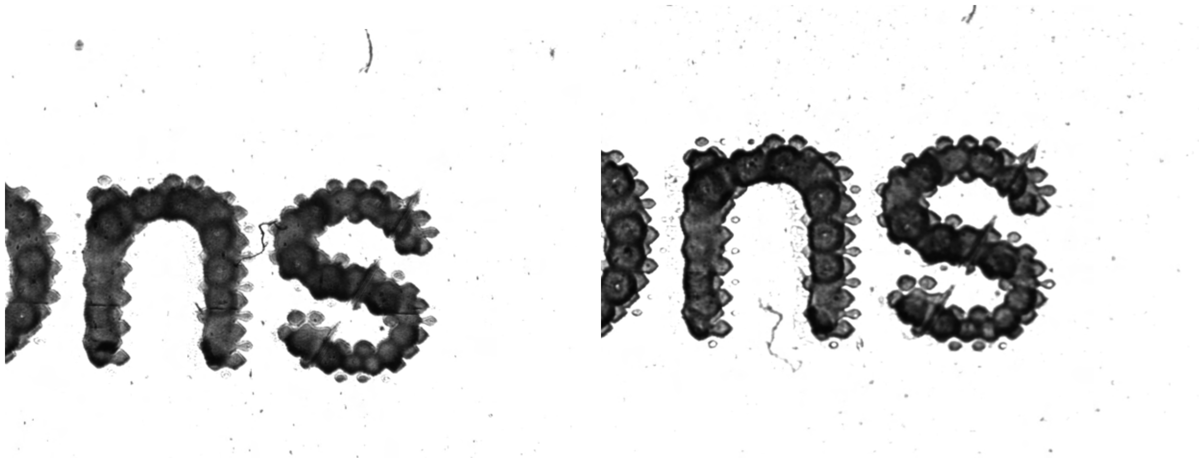


Figure 1. Microscope images with and without polycarbonate sheet. The image of the film paper without the polycarbonate sheet has more clarity and a greater focus quality based on qualitative analysis.

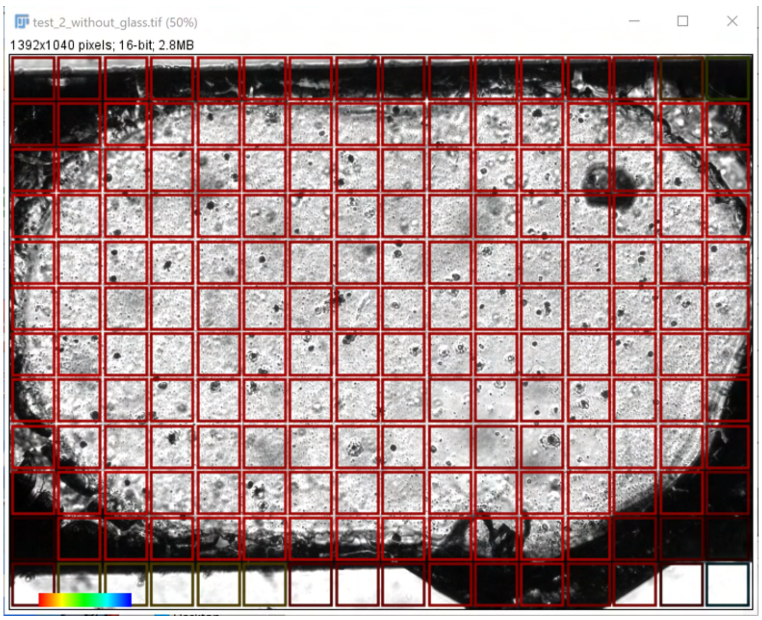


Figure 2: Optical analysis from ImageJ of microscopic cells with glass (left) and without glass (right)

Table 3: Table displaying the number of red (in focus), green (mid focus), and blue (out of focus) squares shown in each image above

	Microscope Image with Glass	**Microscope Image without Glass**
Red Squares	190	185
Green Squares	2	6
Blue Squares	0	1
Total	192	192

The two optical testing images above show boxes around the image that outline the clarity and quality of that part of the image. According to the color scale shown at the bottom of both images, the red end of the spectrum indicates that the image is in focus at a specific region, while the blue end of the spectrum indicates that the image is out of focus at a given region. Results from this test show that the image without the glass had a slightly higher, yet very similar focus quality compared to the image with the glass present. Similarly, 100% of randomly selected subjects expressed no difference in clarity between the two optical images. As seen above, the microscope image with glass has slightly more red squares (in focus) and fewer blue squares (out of focus), causing to have a slightly higher focus quality. However, the two images have very similar values as for each color type as demonstrated in Table 3.

04/19/2022 Temperature and Humidity Data

MAYA TANNA - Apr 21, 2022, 1:09 PM CDT

Title: Temperature and Humidity Data

Date: 04/19/2022

Content by: Maya

Present: Whole Team

Goals: To document excel files from temperature and humidity testing

Content:

See attached files.

Conclusions/action items: Next steps are to include results and graphs in final deliverables. Temperature testing was successful (average was 37.65 C), but humidity testing was slightly lower than expected because of gaps in the glass on the top plate.

MAYA TANNA - Apr 21, 2022, 1:06 PM CDT

Download

Incubator_temp_testing.csv (20.1 kB)

MAYA TANNA - Apr 21, 2022, 1:06 PM CDT

Download

bad_hum_data.csv (1.26 kB)

04/26/2022 Recovery Testing Results

MAYA TANNA - Apr 26, 2022, 7:21 PM CDT

Title: Recovery Testing Results

Date: 04/26/2022

Content by: Maya/Katie

Present: Whole Team

Goals: To document results from recovery testing

Content:

See attached file.

Conclusions/action items: Next steps are to include results and graphs in final deliverables. Recovery testing was very successful as it took around 3 minutes for the incubator box to revert back to normal, homeostatic conditions.

MAYA TANNA - Apr 26, 2022, 7:20 PM CDT

Recovery Test Protocol Test 1

Introduction
Name of Tester: Maya & Katie
Dates of Test Performance: 04/26/2022
Site of Test Performance: ECB 1002

Explanation:
The team will test the recovery time of the incubator after it has been opened by timing how long it takes for the incubator to return to performance conditions (37°C, 5% CO_2, and >95% humidity). The maximum recovery time should not exceed five minutes after a 30 second exposure to the external environment.

Steps	Protocol	Verification/Validation	Pass/Fail	Tester Initials
1	Set up the incubator for normal use. Record internal conditions in the comments and verify that they fall within the correct ranges (37°C, 5% CO_2, and >95% humidity).	☑ Verified Comments: 37.07 C, 97.27%	Pass	KD/MT
2	Open the incubator for 30 seconds. Start stopwatch. Verify that the stopwatch is working.	☑ Verified Comments:	Pass	KD/MT
3	Record internal conditions in the comments at a time of 15 seconds after opening the incubator. Verify that the internal conditions deviate from the normal conditions recorded above.	☑ Verified Comments: 32.77 C, 100%	Pass	KD/MT
4	Close the incubator. Verify that the recovery time did not exceed 5 minutes after a 30 second exposure to the external environment. Record the time it took to revert back to optimal conditions in the comments.	☑ Verified Comments: It took a little over 3 min to recover from the temperature and humidity.	Pass	KD/MT

Download

Maya_Katie_Bella_Recovery_Testing.pdf (66.7 kB)

05/03/2022 Testing Protocol Template Revisions

MAYA TANNA - May 03, 2022, 7:11 PM CDT

Title: Testing Protocol Template Revisions

Date: 05/03/2022

Content by: Maya

Present: Maya

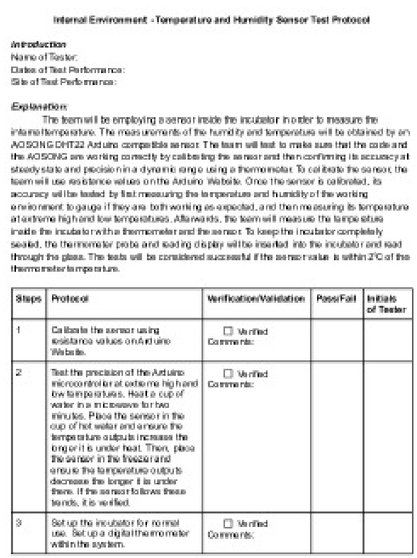
Goals: To document revisions made to the testing protocol template in order to better reflect current information

Content:

See attached file. (Cell Viability Test Protocol was added)

Conclusions/action items: Continue testing wherever possible next semester. Help other areas of the project so they can get to the testing stage and then lead that.

MAYA TANNA - May 03, 2022, 7:10 PM CDT



Internal Environment - Temperature and Humidity Sensor Test Protocol

Introduction
Name of Tester:
Dates of Test Performance:
Site of Test Performance:

Explanation:
The team will be employing a sensor inside the incubator in order to measure the internal temperature. The measurements of the humidity and temperature will be obtained by an AOSONG DHT22 Arduino compatible sensor. The team will test to make sure that the code and the AOSONG are working correctly by calibrating the sensor and then confirming its accuracy at steady state and precision in a dynamic range using a thermometer. To calibrate the sensor, the team will use resistance values on the Arduino Website. Once the sensor is calibrated, its accuracy will be tested by first measuring the temperature and humidity of the working environment to gauge if they are both working as expected, and then measuring its temperature at extreme high and low temperatures. Afterwards, the team will measure the temperature inside the incubator with a thermometer and the sensor. To keep the incubator completely sealed, the thermometer probe and reading display will be inserted into the incubator and read through the glass. The tests will be considered successful if the sensor value is within 2°C of the thermometer temperature.

Steps	Protocol	Verification/Validation	Pass/Fail	Initials of Tester
1	Calibrate the sensor using resistance values on Arduino Website.	☐ Verified Comments:		
2	Test the precision of the Arduino microcontroller at extreme high and low temperatures. Heat a cup of water in a microwave for two minutes. Place the sensor in the cup of hot water and ensure the temperature outputs increase the longer it is under heat. Then, place the sensor in the freezer and ensure the temperature outputs decrease the longer it is under there. If the sensor follows these trends, it is verified.	☐ Verified Comments:		
3	Set up the incubator for normal use. Set up a digital thermometer within the system.	☐ Verified Comments:		

Download

Testing_Protocols_Template_2_.pdf (95.7 kB)

02/01/2022 Lab Training

MAYA TANNA - Feb 01, 2022, 9:08 PM CST

Title: Biosafety and Chemical Safety Training

Date: 02/01/2022

Content by: Maya Tanna

Present: Maya Tanna

Goals: To document biosafety and chemical safety training

Content:

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

This certifies that Maya Tanna has completed training for the following course(s):

Expand All Collapse All

Course	Assignment	Completion	Expiration
Biosafety 102: Bloodborne Pathogens for Laboratory and Research	Biosafety 102: Bloodborne Pathogens Safety in Research Quiz 2021	1/14/2022	
Biosafety 105: Biosafety Cabinet Use	Biosafety 105: Biosafety Cabinet Use Quiz	1/14/2022	
Biosafety 106: Autoclave Use	Biosafety 106: Autoclave Use: Safety and Efficacy - Verification Quiz	1/22/2021	
Biosafety 107: Centrifuge Safety	Biosafety 107: Centrifuge Safety Verification Quiz	1/14/2022	
Biosafety Required Training	Biosafety Required Training Quiz	1/17/2021	
Chemical Safety: Cryogen Safety Training	Part 1 Final Quiz	1/22/2021	
Chemical Safety: Cryogen Safety Training	Part 2 Final Quiz	1/22/2021	
Chemical Safety: Fume Hood Safety Training	Fume Hood Final Quiz	1/17/2021	
Chemical Safety: Personal Protective Equipment	PPE Final Quiz	1/14/2022	
Chemical Safety: The OSHA Lab Standard	Final Quiz	3/24/2021	
Laser Safety 2021-2022	Laser Safety Quiz	1/20/2022	

Data Last Imported: 01/02/2022 09:05 PM

Conclusions/action items: Do more training and get a Green Pass Certification from the TEAM Lab.

03/13/2022 WARF Lecture

MAYA TANNA - Mar 13, 2022, 10:51 AM CDT

Title: WARF Lecture

Date: 03/13/2022

Content by: Maya

Present: Maya

Goals: To document notes and takeaways from the WARF lecture

Content:

Notes

- Beginnings
    - Created in 1925 to manage intellectual property related to the work of Dr. Harry Steenbock
    - Organized as a nonprofit, functionally integrated supporting organization
    - Proceeds support research at UW-Madison
    - Governed by an independent board of UW-Madison alumni with expertise in a variety of fields
- Vision
    - Enable research to solve the world's problems
- Mission
    - To support scientific research by providing financial support, actively managing assets, and moving innovations to the marketplace for a financial return and global impact
- Cycle of Innovation
    - 6th overall in research funding
    - 350-400 invention disclosures each year
- UW Research & Discovery --> IP Protection (patents) --> Licensing & Startups --> Funding to Support Research & Discovery
- Protecting Innovation
    - Patents - machines and devices, compounds, processes and methods, improvements
    - Trademarks - words and phrases, colors, pictures or logos, sound
    - Copyrights - literary works, webpages, software programs
- Prior Art
    - "References" created before a specific date
        - By the inventor: >1 year before the filing date of the patent application
        - By another: before the filing date of the patent application
    - Novelty and non-obviousness are evaluated based on the prior art
    - Internationally, absolute novelty is typically required
- Requirements of Patentability
    - Eligible
    - Useful
    - Enabled
    - Described
    - Novel
    - Non-Obvious
    - Examination = assessment of the invention
    - Based on statutory requirements and application of prior art
- Licensing Considerations for New Disclosures
    - Chance of licensing

        - Potential applications, technology benefits, and impact, state of the market, WARF's history in licensing
    - Timeline for licensing
        - Stage of the technology, patent status, position in WARF's portfolio
    - Licensing strategy
        - Companies (existing or start-up), exclusive vs. non field limitations
    - Plan for the next year
        - Further technology development, proactive marketing, marketing materials
    - Revenue projections
        - Early revenue, patent reimbursement, lifetime royalty projections
- Licensing Innovation
    - WARF Provides:
        - Exclusive or non-exclusive rights to make, use, sell, or import
    - Licensee Provides:
        - Develop and commercialize
        - Reasonable fees: upfront, royalties, milestones, etc.
        - Fulfill obligations under Bayh-Dole
    - Timeline
        - Varies from months to years
        - Depends on technology and market readiness
- Factors to Consider in Starting a Company
    - Technology
    - Market
    - Management
    - Capital requirements

Conclusions/action items: This information is important because we will need to think about how our design has intellectual properties and whether or not we should consider patenting our final product. Our design may have intellectual property, because we may choose to patent it since there are not many low-cost cell culture incubators in the field. The main incubators in the field are produced by large companies such as Thermo Fisher Scientific, so our product may be useful when considering smaller, more cost-efficient incubators in the BME teaching labs on campus, as well as potential research labs at UW and other universities.

04/01/2022 Tong Distinguished Entrepreneur Lecture

MAYA TANNA - Apr 01, 2022, 12:51 PM CDT

Title: Tong Distinguished Entrepreneur Lecture

Date: 04/01/2022

Content by: Maya

Present: Maya

Goals: To document notes and takeaways from the Tong Distinguished Entrepreneur lecture

Content:

Notes

- Entrepreneur: a person who organizes and operates a business or businesses, taking on greater than normal financial risks in order to do so
  - One who organizes, manages, and assumes the risks of a business or enterprise
- Real definition
  - An innovator or developer who recognizes and seizes opportunities; converts those opportunities into workable options
- What good is an idea if it remains an idea?
  - Try. Experiment. Iterate. Fail. Try again. Change the world. - Simon Sinek
- Intent: treating complex skin defects
  - Standard treatment options for severe burns require harvest of uninjured skin creating painful donor sites
  - Large TSBA: insufficient donor skin available, serial re-harvest
- Entrepreneurs are characterized by a need for achievement or an achievement orientation, which is a drive to excel, advance, and grow
- Time and health are two precious assets that we don't recognize and appreciate until they have been depleted

Conclusions/action items: This was a very inspiring lecture and incredible advice was given on taking risks, surrounding yourself with a good support system, and having the purpose of serving others without spreading yourself too thin. Looking forward, I will be more open to taking risks and making sure I surround with people who want to see me succeed and will help me along the way.

02/03/2022 Maya's Progress Report 1

MAYA TANNA - Feb 01, 2022, 9:51 PM CST

Title: Maya's Progress Report 1

Date: 02/03/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Updated website with team picture and team roles
- Did research on electrical/thermal properties of copper
- Did research on how copper prevents contamination within incubator systems
- Found some formulas on Fourier transforms/thermal conductivity for us to use later on
- Helped brainstorm questions for client meeting with Dr. Puccinelli
- Uploaded team progress report to the website

Goals

- Make any necessary edits to the PDS based on client feedback
- Make any potential edits to testing protocols
- Redo optical testing since we don't need any other part of the system to complete it
- Update the website and help wherever else it is needed

Conclusions/action items: Action items are stated as goals in the content above.

02/10/2022 Maya's Progress Report 2

MAYA TANNA - Feb 08, 2022, 7:17 PM CST

Title: Maya's Progress Report 2

Date: 02/10/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Updated website with PDS and team progress report for the week
- Did research on ensuring an effective CO_2 sensor setup with the incubator
- Did research on how to connect the CO_2 sensor to an incubator system in an industry incubator (TetraScience)
- Helped with updating the PDS

Goals

- Work on testing protocols
- Redo optical testing once access to the lab is granted
- Update the website and help wherever else it is needed (lots of help will probably be needed with CO_2)

Conclusions/action items: Action items are stated as goals in the content above.

02/17/2022 Maya's Progress Report 3

MAYA TANNA - Feb 15, 2022, 8:44 PM CST

Title: Maya's Progress Report 3

Date: 02/17/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Updated website with team progress report for the week
- Helped create design matrices for fabrication design and CO2 design
- Researched CO2 progress from previous semesters
- Researched standard industry tolerance values for internal environmental conditions
- Worked on heat transfer calculations with Sam and Bella

Goals

- Work on testing protocols
- Redo optical testing once access to the lab is granted
- Update the website and help wherever else it is needed (lots of help will probably be needed with CO2 and sensors)
- Prepare for preliminary design presentations

Conclusions/action items: Action items are stated as goals in the content above.

02/24/2022 Maya's Progress Report 4

MAYA TANNA - Feb 24, 2022, 1:42 PM CST

Title: Maya's Progress Report 4

Date: 02/24/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Updated website with team progress report for the week
- Helped contribute to preliminary deliverables

Goals

- Work on testing protocols
- Redo optical testing once access to the lab is granted
- Update the website and help wherever else it is needed (lots of help will probably be needed with CO2 and sensors)
- Help with preliminary report

Conclusions/action items: Action items are stated as goals in the content above.

03/03/2022 Maya's Progress Report 5

MAYA TANNA - Feb 27, 2022, 3:48 PM CST

Title: Maya's Progress Report 5

Date: 03/03/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Worked on the testing section of the preliminary report
- Reviewed and updated testing protocols to reflect current information
- Uploaded preliminary report to website and Canvas, as well as weekly progress report

Goals

- Complete testing wherever possible
- Help with incubator fabrication or the sensor aspects of the project
- Start working to hook up CO2 to the incubator

Conclusions/action items: Action items are stated as goals in the content above.

03/10/2022 Maya's Progress Report 6

MAYA TANNA - Mar 08, 2022, 7:19 PM CST

Title: Maya's Progress Report 6

Date: 03/10/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Helped brainstorm ideas for CO_2 connections to the incubator
- Reviewed material purchasing requests
- Updated website with progress report

Goals

- Complete testing wherever possible
- Help with incubator fabrication or the sensor aspects of the project
- Start working to hook up CO2 to the incubator once we have access to the CO2 tank

Conclusions/action items: Action items are stated as goals in the content above.

03/24/2022 Maya's Progress Report 7

MAYA TANNA - Mar 23, 2022, 4:57 PM CDT

Title: Maya's Progress Report 7

Date: 03/24/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Planning to do optical testing at the end of the week with Bella
- Helped prepare for Show and Tell elevator pitch
- Updated website with progress report

Goals

- Complete testing wherever possible
- Conduct image analysis for optical tests, and write up results to be included in the next report
- Help wherever needed to get the team to the testing stage.

Conclusions/action items: Action items are stated as goals in the content above.

03/31/2022 Maya's Progress Report 8

MAYA TANNA - Mar 29, 2022, 7:20 PM CDT

Title: Maya's Progress Report

Date: 03/31/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Completed optical testing with Bella and Caroline
  - Collected images from the microscope
  - Analyzed images qualitatively and quantitatively
  - Completed ImageJ analysis and optical testing section of the final report (results were highly accurate)
- Updated testing protocol template to reflect current information
- Documented feedback from Show and Tell
- Looked into using a MOSFET and a solenoid valve to regulate CO2
- Updated website with progress report

Goals

- Test out the electrical components
- Help with statistical analysis
- Discuss CO2 regulation with the team

Conclusions/action items: Action items are stated as goals in the content above.

04/07/2022 Maya's Progress Report 9

MAYA TANNA - Apr 10, 2022, 5:22 PM CDT

Title: Maya's Progress Report 9

Date: 04/07/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Reviewed testing results from electrical components
- Updated website with progress report

Goals

- Help with CO2 design
- Do more testing where possible, as well as statistical analysis
- Discuss CO2 regulation with the team

Conclusions/action items: Action items are stated as goals in the content above.

04/14/2022 Maya's Progress Report 10

MAYA TANNA - Apr 12, 2022, 7:34 PM CDT

Title: Maya's Progress Report 10

Date: 04/14/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Reviewed testing results from electrical components
- Started the final poster for the poster session and started making updates to better reflect current information
- Updated website with progress report

Goals

- Work with Katie and Bella to complete whole box testing
  - Potentially even recovery testing if we get far enough
- Work on final report and deliverables
- Help with executive summary if needed.

Conclusions/action items: Action items are stated as goals in the content above.

04/21/2022 Maya's Progress Report 11

MAYA TANNA - Apr 21, 2022, 10:42 AM CDT

Title: Maya's Progress Report 11

Date: 04/21/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Finished, reviewed, and submitted the executive summary for the Design Excellence Award
- Tested the incubator to make sure it was waterproof, and the test succeeded with no leakage
- Helped test temperature and humidity and found an average temp of 37.6 C and slightly less successful humidity testing due to some gaps in the glass on the top plate
- Worked on the final report and poster
- Uploaded necessary files to the website

Goals

- Help with CO_2 if necessary
- Do recovery testing on the whole box system
- Work on the final deliverables

Conclusions/action items: Action items are stated as goals in the content above.

04/28/2022 Maya's Progress Report 12

MAYA TANNA - Apr 26, 2022, 7:24 PM CDT

Title: Maya's Progress Report 12

Date: 04/28/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Completed recovery testing system with Katie and Bella
- Worked on the final report and poster
- Uploaded necessary files to the website

Goals

- Review and submit final deliverables

Conclusions/action items: Action items are stated as goals in the content above.

Metal Thermal Properties Research - 2/8/22

Drew Hardwick - Feb 09, 2022, 2:25 PM CST

Title: Thermal Properties of Copper Wire

Date: 2/8/22

Content by: Drew Hardwick

Present: N/A

Goals: Learn more about how well Copper can hold/transfer heat

Content:

- The heat transfer characteristics of a solid material are measured by a property called the thermal conductivity, k (or λ), measured in W/m.K. It is a measure of a substance's ability to transfer heat through a material by conduction. Note that Fourier's law applies for all matter, regardless of its state (solid, liquid, or gas), therefore, it is also defined for liquids and gases.

- Thermal conductivity of Copper is 401 W/(m·K).
- Thermal conductivity of Silver is 419 W/(m·K).

- Both Copper and Silver have high thermal conductivities (copper slightly less so) but copper is much cheaper than silver, which is why it is used in refrigerants.
- Copper seems like the best logical choice for our incubator, especially if we can use flexible copper wire and wrap it around within our well to try and evenly heat the water well as best as possible.

- Linear thermal expansion coefficient of Copper is 16.5 µm/(m·K)
- Thermal expansion is generally the tendency of matter to change its dimensions in response to a change in temperature. It is usually expressed as a fractional change in length or volume per unit temperature change.

- This expansion is something to look into, but since the units are µm/(m·K) I assume that the expansion due to heating will be negligible within the well. The only place we might have to worry about it is where the tubing enters the well. We do not want to make this opening too large and have leakage issues, but we also do not want to make it too small and have the tube expand slightly and potentially damage the copper tubing or acrylic well

References:

[] "Copper - Thermal Properties - Melting Point - Thermal Conductivity - Expansion," *Material Properties*, Nov. 01, 2020. https://material-properties.org/copper-thermal-properties-melting-point-thermal-conductivity-expansion/ (accessed Feb. 08, 2022).

Conclusions/action items:

- Look into expansion of copper wire, and what it will do at 37℃

CO2 Input Research - 2/20/22

Drew Hardwick - Mar 02, 2022, 8:28 AM CST

Title: CO2 Input Research

Date: 2/20/22

Content by: Drew Hardwick

Present: N/A

Goals: Research how difficult diluting CO2 is

Content:

- The team is deciding whether CO2 input would be best as 100% CO2 input controlled by a valve and allowed to diffuse throughout the well, or a previously diluted 5% input pumped in to fill the tank
- I personally think that pumping in the 5% CO2 could lead to issues, as we would have to completely fill the atmosphere within the well to accomplish the intended 5% CO2 atmosphere, and this could cause other issues by increasing the pressure to much
    - If we want to pursue the diluted idea, I think we should select a higher %, maybe roughly 15-25% so that we don't have to worry about pressure complications
        - Calculations needed to determine max pressure withstandable, and what % CO2 will be needed to keep the pressure below this threshold
- For the 100% input and diffusion, we will need to calculate the well area, and determine how long it will take the CO2 to diffuse
    - Gases like molecular oxygen and carbon dioxide have excellent permeability coefficients, and diffuse across a lipid bilayer membrane at a rate of **2-3 mm/sec**, approximately one hundred times as quickly as water.
    - Do math of area (with water in well) that gas will need to travel/diffuse over
- Tank Price must also be considered:
- Both Tanks can be rented instead of purchased to reduce total price
- Will renting a lesser percent cost more or be more difficult to procure?

References:

[]P. D. Wagner, “Vascular transit times in the lung,” *Journal of Applied Physiology*, vol. 79, no. 2, pp. 380–381, Aug. 1995, doi: 10.1152/jappl.1995.79.2.380.

[]N. C. Staub, J. M. Bishop, and R. E. Forster, “Importance of diffusion and chemical reaction rates in O_2 uptake in the lung,” *Journal of Applied Physiology*, vol. 17, no. 1, pp. 21–27, Jan. 1962, doi: 10.1152/jappl.1962.17.1.21.

Conclusions/action items:

- Look into developing diffusion and pressure equations, determine prices, and select easier idea

Reflection on Last Semester's Progress - 2/9/22

Drew Hardwick - Mar 02, 2022, 7:10 AM CST

Title: Reflection on Last Semester's Progress

Date: 2/9/22

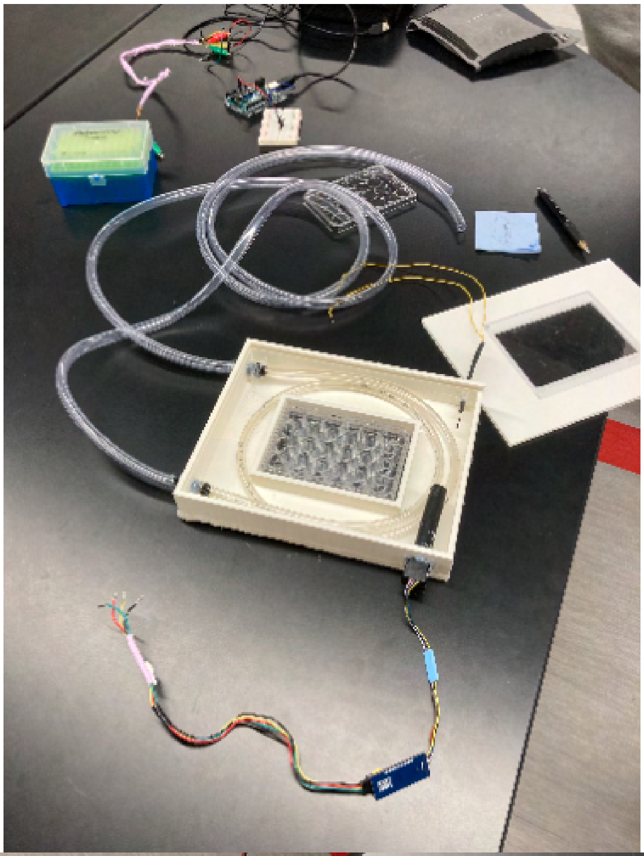
Content by: Drew Hardwick

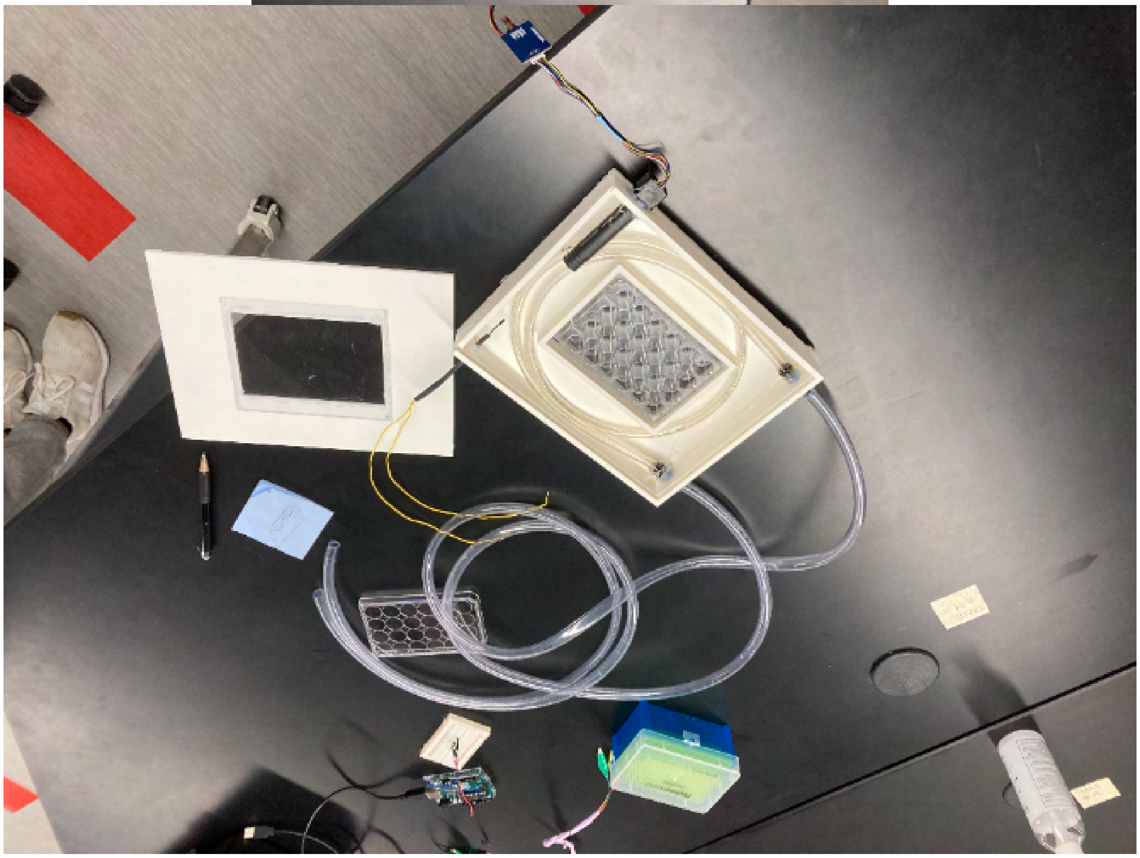
Present: Sam Bardwell

Goals: See the teams previous work from last semester

Content:

SETUP:





Figures 1/2: Experimental Setup from Last Semester

REFLECTION:

- Sam showed me all parts of the experiment, including the extra pieces from previous teams they didn't use and the heated water pump
- He showed me how the current prototype functions and how the testing was conducted
- He also showed me the target microscope this product is intended for

- Overall I thought the team made significant progress last semester, and the design can definitely be improved upon this semester
- The material was clearly an issue - not air/watertight at all!!
- Reaching the target number of 37 degrees C, 5% CO2 and 95-100% humidity should be the primary goal of the semester
  - To reach this a CO2 input system must be developed - I will attempt to take this on as my primary contribution to the team
  - Insulation and heating must also be improved
- I have some worried about reusing parts from last semester
  - While it would be nice to reuse sensors like thermistor and CO2 sensor from the project last semester will we be able to remove them from the current project without damaging them??

Conclusions/action items:

- I now have firm understanding of last semester's and previous year's work, and should be ready to take on this challenge.

Metal Tubing Research - 2/5/22

Drew Hardwick - Feb 09, 2022, 2:25 PM CST

Title: Metal Tubing Research

Date: 2/5/22

Content by: Drew Hardwick

Present: N/A

Goals: Find Potential Metal Tubing and evaluate properties that make it a potential selection

Content:

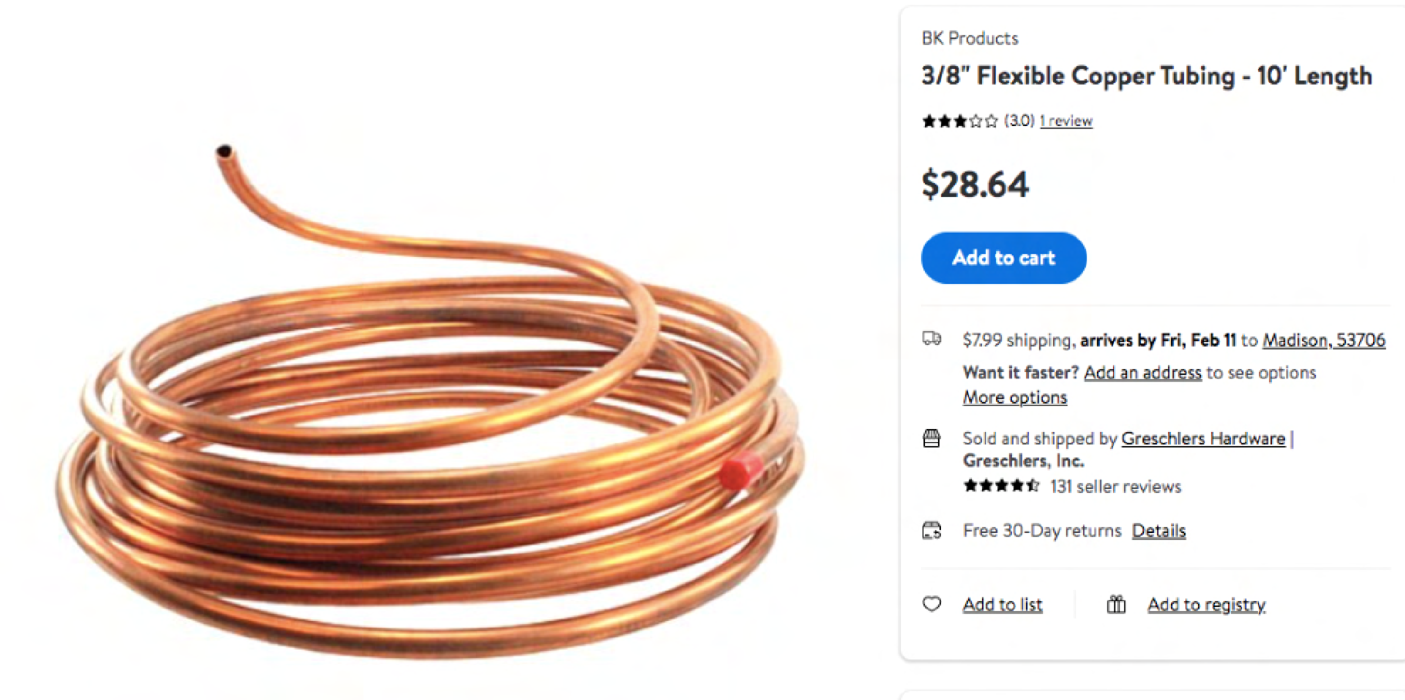


Figure (1): Flexible Copper Wire Available for Purchase at Walmart

This flexible copper wire is available in bulk for relatively cheap, for $28.64, and it is 3/8" diameter, and 10' long

It is intended for use in HVAC or refrigeration, so it should do well maintaining and dealing with high temperatures.

1/4" diameter is also available for purchase.

The thermal properties of copper need to be further researched. Water's high specific heat means that the water will take a lot of constant heat to maintain its temperature at the desired value

The copper pipes will have to be as evenly distributed throughout the well as possible also to ensure that the water in the well is being as evenly heated as possible.

References:

[] "3/8" Flexible Copper Tubing - 10' Length," *Walmart.com*. https://www.walmart.com/ip/3-8-Flexible-Copper-Tubing-10-Length/141597672 (accessed Feb. 05, 2022).

Conclusions/action items:

Continue research on possible materials, but this product is a possibility - better than other metal products I could find on internet.

Research potential issues with rusting in copper pipes. Will they be ok transporting water, would the copper have to be protected? would rust even occur?

Acrylic Research 2/9/22

Drew Hardwick - Feb 09, 2022, 4:56 PM CST

Title: Acrylic Material Research

Date: 2/7/22

Content by: Drew Hardwick

Present: N/A

Goals: Learn more about Acrylic material

Content:

- Acrylic material was recommended for use by the client, Dr. Puccinelli.
- Both regular Acrylic and mirrored Acrylic are available for purchase in the UW makerspace:

Material Name	Category	Safe for Raster?	Safe for Vector Engraving?	Safe for Vector Cut?	Notes
100% Cotton	Fabrics	Yes	Yes	Yes	
100% Silk	Fabrics	Yes	Yes	Yes	
100% Wool	Fabrics	Yes	Yes	Yes	Wool felt is safe to cut but has a bad odor. Please bag all scraps and cut pieces immediately after cutting.
3form Chroma	No settings currently	Yes	Yes	Yes	
Acrylic	Plastics	Yes	Yes	Yes	For sale in Makerspace
Mirrored Acrylic	Plastics	Yes	Yes	Yes	Mirrored acrylic must be masked off with mirrored side face down
Muslin	Fabrics	Yes	Yes	Yes	

Table 1: Acrylics available at the UW-Madison Makerspace

- Mirrored acrylic is reflective like a glass mirror, but much lighter and stronger. There is no point in mirroring our incubator, so regular acrylic will be fine for our purposes

- **General Laser Processing Tips for Acrylic**

  1) Never leave your machine unattended when working with acrylic. Many materials are susceptible to igniting, but acrylic - in all its different forms - has been shown to be especially flammable when cut with the laser. As a general rule, you should never run your laser - using any material - if you are not present.

  2) Make sure to choose the right type of acrylic for your application. Remember, cast acrylic is better for engraving, while extruded acrylic is better suited for laser cutting.

  3) Elevate the acrylic - using Epilog's Pin Table or other supports - to eliminate backside reflection.

- **What types of acrylic projects can you make?**

  Acrylic is a durable and practical material for laser processing. The variety of colors and textures make this material ideal for all kinds of things:

  - Point of purchase signage
  - Directional signage
  - Earrings/pendants/buttons
  - **Containers/boxes**
  - Cake/cupcake toppers
  - Custom awards
  - Holiday ornaments
  - And much more!

References:

[] "Acrylic Cutting and Engraving with a Laser Machine - Epilog Laser." https://www.epiloglaser.com/how-it-works/applications/laser-cutting-acrylic/ (accessed Feb. 09, 2022).
[] "Laser Cutter," *UW Makerspace*. https://making.engr.wisc.edu/laser-cutters-2/ (accessed Feb. 09, 2022).

Conclusions/action items:

- Speak to Makerspace staff about laser print process/certification

CO2 Valve Research 2/25/22

Drew Hardwick - Mar 02, 2022, 8:21 AM CST

`Title: CO2 Potential Valves

Date: 2/25/22

Content by: Drew Hardwick

Present: N/A

Goals: Look at CO2 system Valve options

Content:

Previous Semester's:

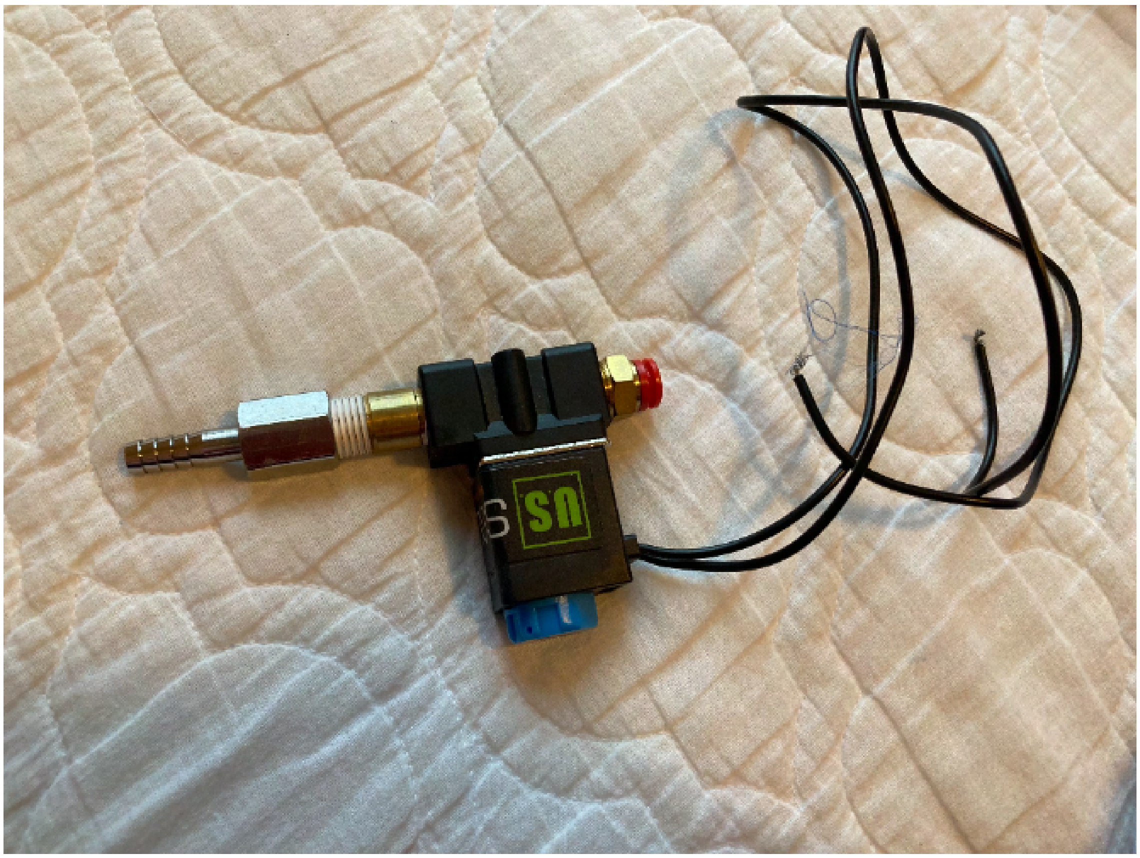


Figure 1: Previous Team's Valve

- This Valve from *US Solid* was in our locker as a part from a previous team's work
- I could not find this product on the *US Solid* website, so I believe it might not be in production anymore
    - Since I could not find it online, I am currently still unsure of what exactly its function/capabilities are
- Need to ask a makerspace staff member to analyze it

Potential Solenoid Valve Controlled Through Arduino:

- The Solenoid Valve described below is for the input of water, but could it be repurposed or modified with a different attachment/slightly different schematic for CO2?
- Parts:
    - DN15 Solenoid Valve or 12V Solenoid Valve
    - Arduino UNO
    - Solderless Breadboard
    - TIP120 Darlington Transistor
    - 1k Ohm Resistor
    - 1N4001 Diode

  - Hookup wires (male/male)
- Schematic:

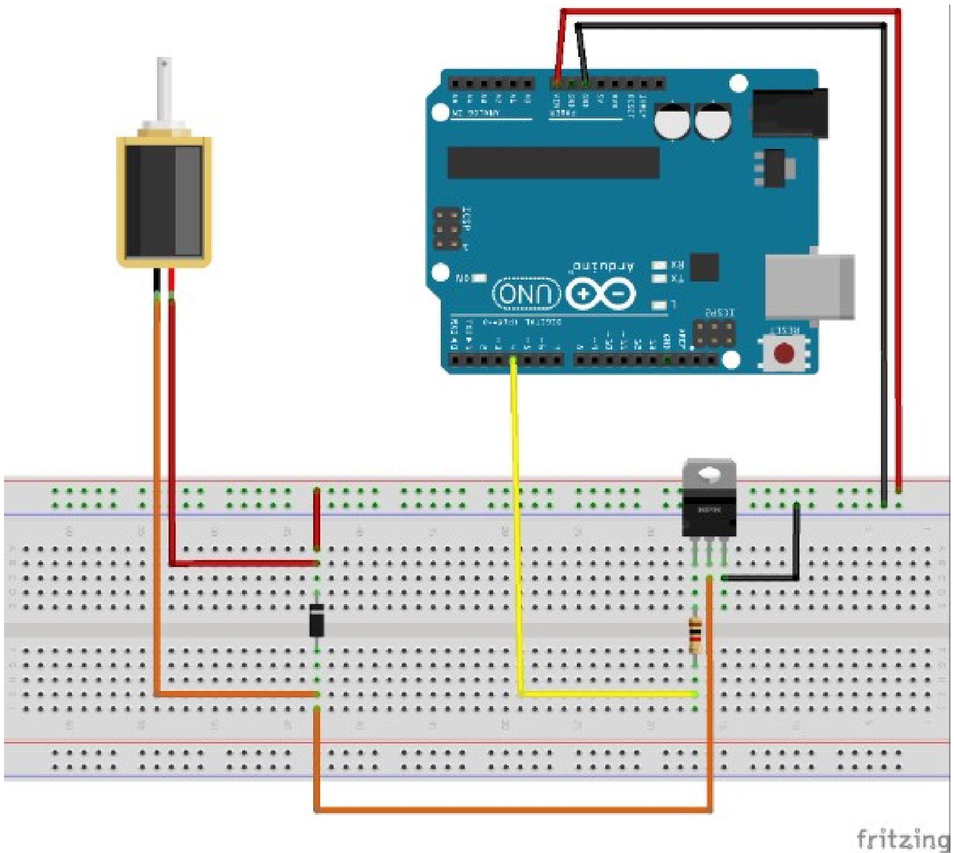


Figure 2: Solenoid Valve Schematic Diagram

- The solenoid works with anywhere between 6-12V which is too high to use with the standard Arduino 5V
- To get around this problem we will be using a 9V power supply – the solenoid will operate at 9V while the Arduino's built in voltage regulator will turn that 9V into the 5V that it needs to operate
- To gain access to the raw voltage going into the DC barrel jack on the Arduino Uno we will use the "Vin" pin located next to the ground pin on the Arduino.
  - Connect one of the jumper wires to the "Vin" pin on the Arduino and running it over to the positive rail on the side of the solderless breadboard
  - Next, run a wire from the Ground pin on the Arduino over to the negative rail on the solderless breadboard.
- Do not plug ANY other pins from the Arduino into the positive rail on the breadboard.
- Connections to solenoid do not matter, does not care +/-

- Snubber diodes help eliminate transient voltages caused when a magnetic coil (such as those found in a motor, relay, or solenoid) suddenly loses power. Without this diode in place the transient voltage spikes can damage other elements of the circuit.

- The snubber is placed from the negative side of the coil to the positive side. Since diodes only allow current to flow in one direction we need to make sure we get this right, otherwise it will be a dead short between power and ground.

- Ensure the side with the White stripe is connected to power/positive side of the solenoid

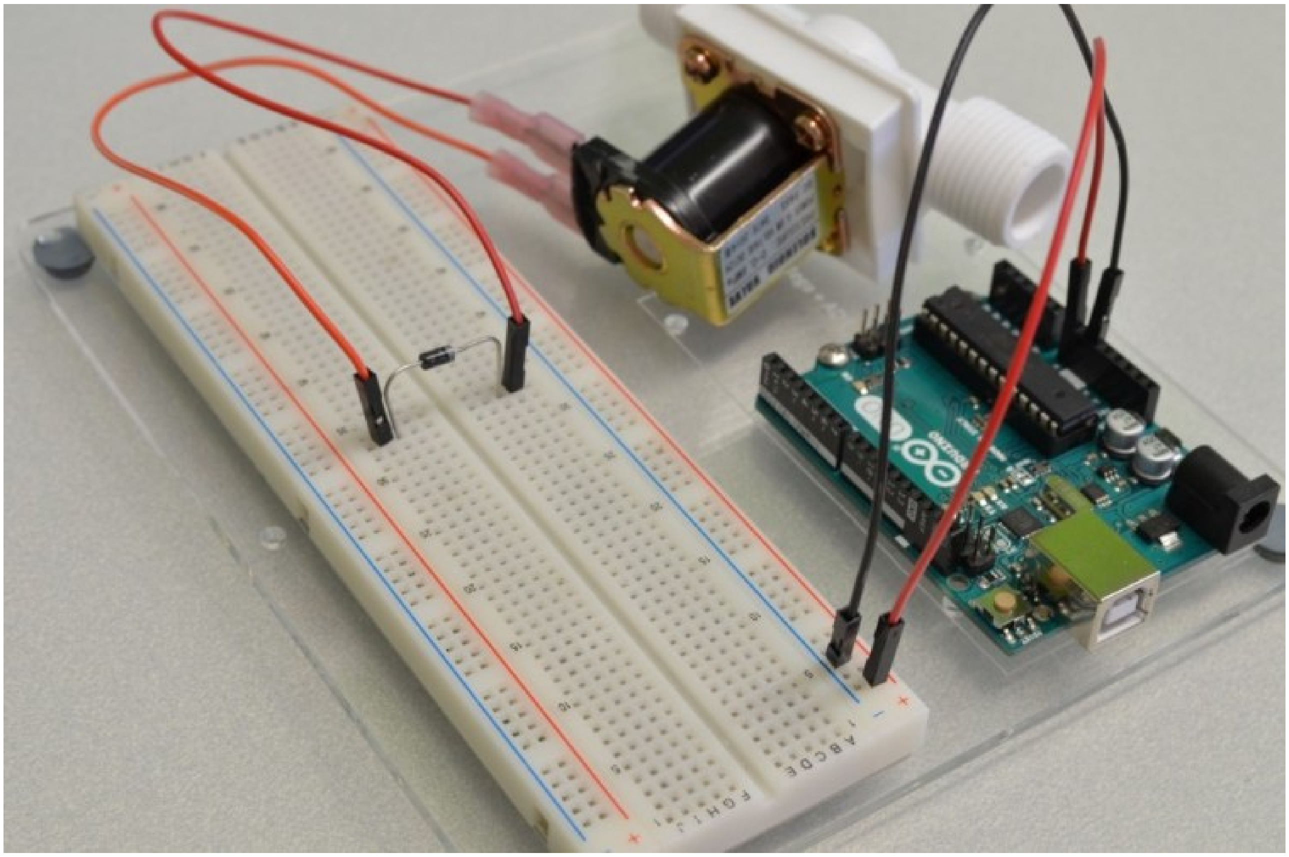


Figure 3: Setup thus far

- Place the transistor and the base resistor as shown in figure 4
- Connect the Arduino, connect the solenoid, and plug into ground - final setup shown below:

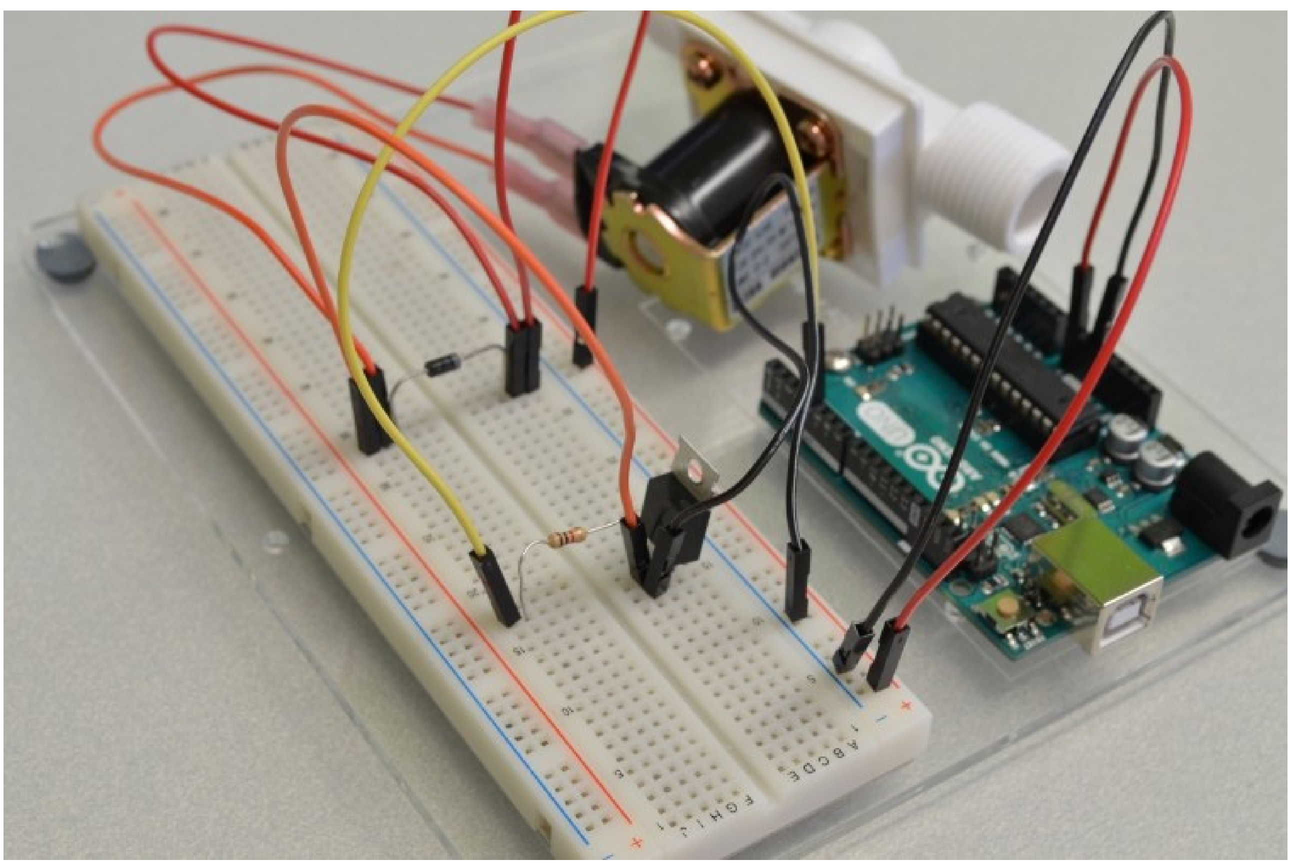


Figure 4: Final Solenoid Valve Arduino Setup

- Start writing/testing the code, which can be found at https://bc-robotics.com/tutorials/controlling-a-solenoid-valve-with-arduino/

<u>Reflection:</u>

- I am not an Arduino expert or a Robotics master, so I do not really know how feasible this design is, or how much work it would be to tweak it to fit our needs
- I thought it seemed like a doable setup, with mostly parts we have from our sparkplug electronics kits, and it seemed simple enough that it could be modified if need be
- Speak to the makerspace to get an expert's thoughts/opinions on how to tackle this issue

References:

[] “Controlling A Solenoid Valve With Arduino,” *BC Robotics*. https://bc-robotics.com/tutorials/controlling-a-solenoid-valve-with-arduino/ (accessed Mar. 02, 2022).

Conclusions/action items:

- Speak to makerspace staff member about currnet valve
- Speak to makerspace about adjusting solenoid for CO2 input
- Talk to team about possible solenoid

Preliminary Purchasing Order 3/9/22

Drew Hardwick - May 03, 2022, 6:34 PM CDT

Title: Preliminary Purchasing Order

Date: 3/9/22

Content by: Drew Hardwick

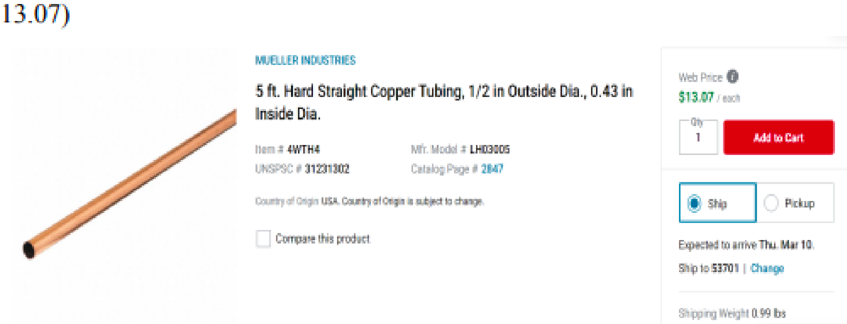
Present: Everyone

Goals: Get preliminary purchasing order submitted and ordered before spring break

Content:

- The team wanted to get a jump start on fabrication and not be limited by not having the parts we require so we decided to order the parts before spring break so that they will (hopefully) be delivered during the break and that way the team can get fabricating when we return
- As BPAG I recorded and approved all purchasing requests, and created document to summarize and send to client (attached)

- Below is the Copper tubing (selected for its high thermal conductivity) that the team plans to run heated water through to heat up the water bath and internal environment:
- 2. Copper tubing ($13.07)

a. 

- FIGURE 1: Copper tubing purchased
- UPDATE: The team originally sought to purchase copper tubing, but this cost was eliminated as the client had extra copper tubing of the desired diameter handy

- Below are the transparent insulation sheets which will be used on the top and bottom of the incubator to allow the microscope optics and lighting to be used properly while also maintaining a 37℃ temperature.

3. Polycarbonate Transparent Thermal Insulation Sheets (x4)

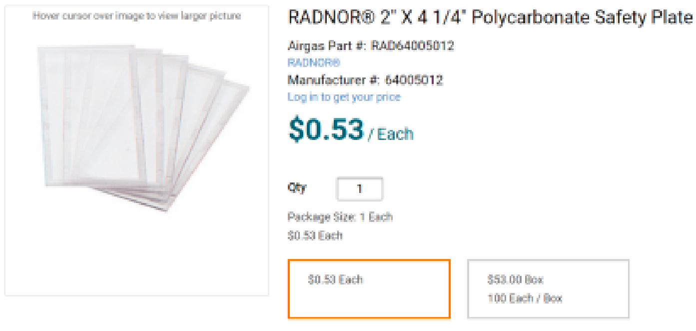
a. 

FIGURE 3: Glass Viewing Sheets

- UPDATE: According to the client, these sheets did come in the preliminary order, but the team never received them with the rest of the order, or were able to locate them, so the glass plates from last semester's prototype were used in the final prototype
  - These glass sheets were removed with a heat gun from the TEAM lab to melt the hot glue that had previously kept them in place

- Below is the Acrylic Contact Cement ordered to glue together the acrylic pieces of the final prototype

4. Acrylic Contact Cement, Clear (x2)

a. 

FIGURE 3: Acrylic Contact Cement ordered

- This acrylic cement was deemed necessary to purchase over ordinary glue due to its acrylic specific properties so that the prototype will be as sturdy and well built as possible

- Below is the Rubber lining purchased to keep the box lid stationary, and to prevent leakage between the lid and the well:

5. Buna-N Square Cord: Std, Black, 0.133 in : 1/8 in, 5 ft Overall Lg, 70A, 0°F to 210°F

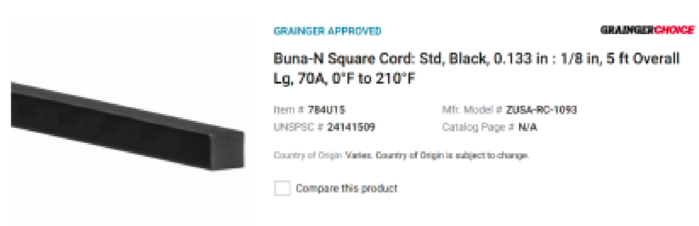


FIGURE 4: Rubber Lining

- UPDATE: This lining was originally supposed to provide a seal and a soft surface for the lid to clamp down upon, but after initial acrylic fabrication, the client expressed his opinion that the lid did not need clamps to keep a tight seal with its weight and the rubber lining
    - This rubber was also repurposed and glued to the bottom of the box as "legs" so that the bottom glass would not scratch on the table it was resting on and would be elevated by these rubber "legs"
-

Conclusions/action items:

1. Getting these Items ordered the week prior to spring break will allow fabrication to begin after spring break
2. The acrylic will be printed at the Makerspace its cost added to the total along with any other prints and other future expenses

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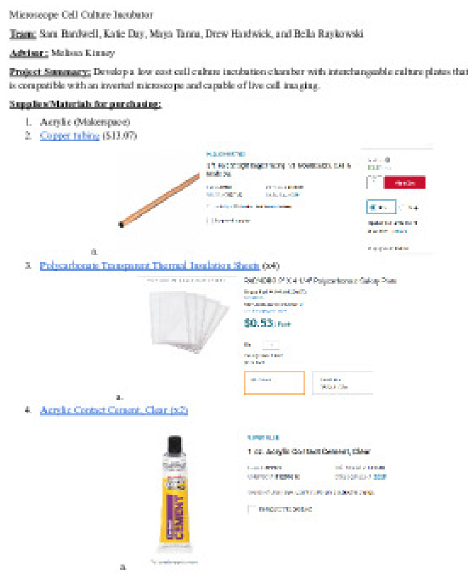
Drew Hardwick - May 03, 2022, 6:34 PM CDT


Microscope Cell Culture Incubator

Team: Sara Hardwell, Katie Day, Maya Tanna, Drew Hardwick, and Bella Raykowski

Advisor: Melissa Kinney

Project Summary: Develop a low cost cell culture incubation chamber with interchangeable culture plates that is compatible with an inverted microscope and capable of live cell imaging.

Supplies/Materials for purchasing:

1. Acrylic (Makerspace)
2. Copper tubing ($13.07)
    a.
3. Polycarbonate Transparent Thermal Insulation Sheets (x4)
    a.
4. Acrylic Contact Cement, Clear (x2)
    a.

Download

Materials_Purchasing_Request_-_Microscope_Cell_Culture_Incubator.pdf (610 kB)

Waterproofing Acrylic Research 4/4/22

Drew Hardwick - May 03, 2022, 8:15 PM CDT

Title: Waterproof Caulk Research

Date: 4/4/22

Content by: Drew Hardwick

Present: N/A

Goals: Determine which kind of Caulk to use to seal interior of box

Content:

- An issue the team has been tackling recently is how to properly seal the interior of the box where the water bath will rest
- Last semester, there was no lining because the box was 3D printed from PLA Plastic in one piece, but there was leakage due to suspected micropores in the PLA plastic
- This semester, acrylic is being used to minimize these micropores, and better insulate the internal environment, but because this material must be laser cut in 2D pieces and then glued together into a 3D object, there could be leakage at these connection points so the team wants to line the box interior with some sealant.
- Caulk was suggested by a classmate at the Show and Tell session and, having worked with caulk before I believe that this is the best material option
- I do also know there are multiple types of caulk so I want to research and see what type would be best for our situation

- Acrylic Latex Caulk
    - Also called painter's caulk, this is probably what most people think of when they think of caulk.
    - the cheapest type of caulk in most stores - meant to cover small holes and cracks and then be painted over
    - Adheres very well to wood, drywall, and masonry - meant for interior use only, and it usually cannot create a water-tight seal.
    - Most common/cheap caulk, but NOT USABLE for our design because of waterproofing aspect
- Acrylic Tile Sealant
    - This caulk comes in tiny tubes and is meant for patching holes and gaps between tiles in areas that are prone to mold and mildew
    - It is essentially a way to keep the tile well-sealed in between applications of a more durable sealant, and it should not be used as a primary sealant.
    - NOT VIABLE, we need a primary sealant
- Siliconized Acrylic Sealant
    - Siliconized acrylic combines the easy application of acrylic with the added durability of silicon
    - It is slightly more difficult to clean up than pure acrylic, but it is more durable and it provides a water-tight seal
    - It is even suitable for outdoor use, although it is not necessarily the best choice for outdoor applications
    - This could be a potential option for us
- Pure Silicone
    - This is one of the **most durable and water-tight** caulks that is made
    - It is ideal for bathrooms, especially sinks and toilets, because it adheres very well to **non-porous surfaces**
    - Once applied, it will **last for decades**, too.
    - This is the IDEAL caulk for our use

- TEAM lab does have silicone caulk for rental along with a caulk gun, so I believe that this should be the route taken by the team at this point
- I watched a youtube video (below) on how to use a caulk gun and properly seal with caulk so that I am prepared to rent the caulk/caulk gun from the TEAM lab and waterproof the interior of the box ASAP, as the caulk takes a long time (over 24 hours) to fully dry, so we want to get it applied ASAP so we can begin testing.
- https://www.youtube.com/watch?v=FnZmYW-P8wU&t=21s

References:

[1] "Types Of Caulk For Buildings," *Waterproof Caulking & Restoration*, Dec. 16, 2019. https://waterproofcaulking.com/types-of-caulk-to-use-on-commercial-buildings/ (accessed April 04, 2022).

[2] Ace Hardware, *How To Use a Caulk Gun - Ace Hardware*, (Dec. 24, 2012). Accessed: April 04, 2022. [Online Video]. Available: https://www.youtube.com/watch?v=FnZmYW-P8wU

Final Purchasing List 5/3/21

Drew Hardwick - May 03, 2022, 7:37 PM CDT

Title: Final Purchasing List

Date: 5/3/21

Content by: Drew Hardwick

Present: N/A

Goals: As BPAG, Review Final Purchasing List

Content:

Final Materials and Expenses:

m	Description	Manufacturer	Part Number	Date	QTY	Cost Each	Total	Link
ımponent 1								
ɔlycarbonate Transparent Thermal Insulation Sheets	2"x4.25" clear Polycarbonate safety plate for covering cells while viewing	Airgas	RAD64005012	3/9/22	4	$0.53	$2.12	Link
ımponent 2								
Acrylic Contact Cement	1 oz Clear Contact Cement to mount clasps and assemble acrylic box	Grainger	3EHR7	3/9/22	2	$2.73	$5.46	Link
ımponent 3								
Buna-N Square Rubber Cord	5ft, ⅛" x ⅛", 70A, 0℃ - 210℃ square rubber cord to prevent leakage with clasp lid	Grainger	784U15	3/9/22	1	$4.86	$4.86	Link
ımponent 4								
ırd Wood	36x24x ⅛ Hard wood that was used to fabricate the prototype	UW Makerspace	1	3/21/2022	1	$2.50	$2.50	Link
ımponent 5								
ırd Wood	18x24x ⅛ Hard wood that was used to fabricate the prototype	UW Makerspace	1	3/21/2022	1	$1.25	$1.25	Link
ımponent 6								
ırbed Adapter	Barbed x MNPT Adapter, Polyethylene, ⅜ in barb size, natural used to connect copper tubing to heated water tank	Grainger	1	3/29/2022	10	$1.26	$12.63	Link
ımponent 7								
ıck Acrylic	Black Acrylic used to fabricate the incubation chamber 18x24 sheet with ½ inch thickness	UW Makerspace	1	4/11/2022	1	$21.50	$21.50	Link
ımponent 8								
ɔ print DC motor attachment	PVA plastic used to fabricate the DC motor attachment for the regulation of CO_2 input into the incubation chamber	UW Makerspace	1	4/11/2022	1	$2.72	$2.72	Link
ımponent 9								
C Motor	Actual motor used for CO2 regulation	UW Makerspace	1	4/11/2022	1	$2.00	$2.00	Link
ɔTAL:	$53.54							

- The First 3 items remain unchanged from their purchase in the preliminary order
- The Wood was purchased as a proof of design expense to confirm that our CAD laser cutting images would fit together nicely. The Wood Prototype is shown below:

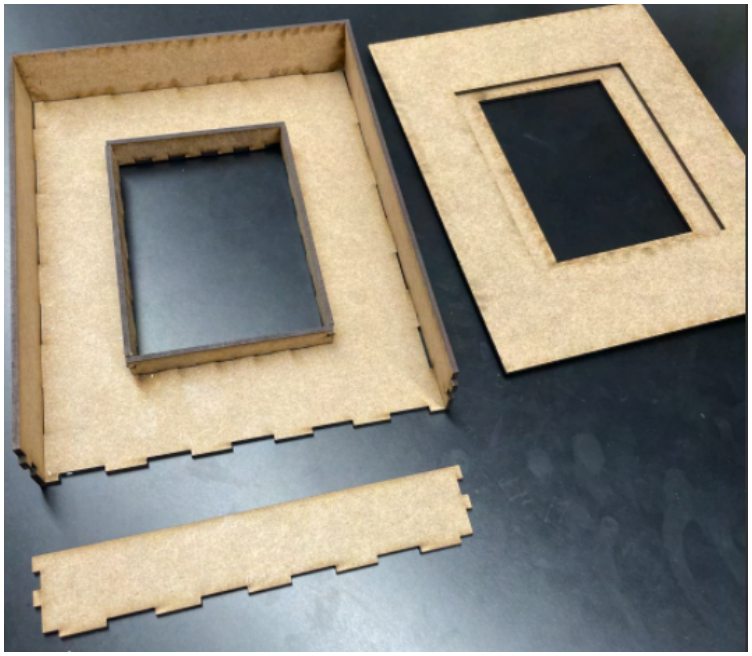


FIGURE 1: Wood Prototype

- The barbed adaptor was purchased to connect the plastic heated water pump tubing to the copper tubing on the interior of the incubator with no leakage, but this barbed attachment was abandoned due to poor fit, and a hose adaptor provided by the client was used instead. The purchased barbed adaptor is shown below

FIGURE 2: Barbed Adaptor Purchased

- Below are the Hose Adaptors provided by the client (on the final prototype):

FIGURE 3: Hose-like Adaptors provided by client

- Both the Black Acrylic and PLA plastic for the actual incubator exterior and the CO2 motor attachment respectively were purchased from the Makerspace on the client's purchasing account and the prototypes are shown below:

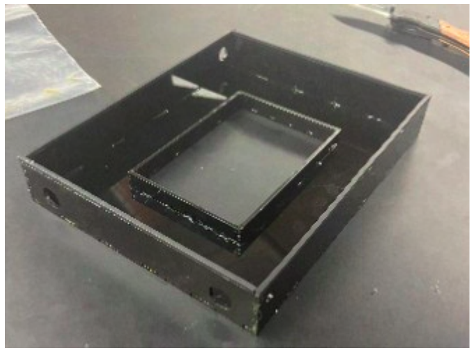


FIGURE 4: Final Acrylic Laser Cut Incubator Housing

FIGURE 5: Final 3D Printed PLA Plastic Valve holder:

- The DC motor was also purchased from the Makerspace window on the client's purchasing account and is shown below

FIGURE 6: Makerspace bought DC motor

- TOTAL BUDGET: $53.54
- This is well under our budget and gives the team some money to spend to improve the product in future semesters ($46.46)
- This total price tag is not taking into account the items given to us from the client (like the copper piping and the hose adaptors), and from last semester (like the sensors)
  - We estimate the total, all in price after purchasing these to be around $150

Laser Cutting Research - 2/10/22

Drew Hardwick - Feb 10, 2022, 11:50 AM CST

Title: Laser Cutting Research

Date: 2/10/22

Content by: Drew Hardwick

Present: N/A

Goals: Learn More about Laser Cutting

Content:

- Laser cutting is mainly a thermal process in which a focused laser beam is used to melt material in a localised area. A co-axial gas jet is used to eject the molten material and create a kerf. A continuous cut is produced by moving the laser beam or workpiece under CNC control.
- A laser cutter is a prototyping and manufacturing tool used primarily by engineers, designers, and artists to cut and etch into flat material. Laser cutters use a thin, focused laser beam to pierce and cut through materials to cut out patterns and geometries specified by designers.
  - Apart from cutting, laser cutters can also raster or etch designs onto work pieces by heating up the surface of the workpiece, thus burning off the top layer of the material to change its appearance where the raster operation was performed.
- The laser originates from a laser resonator, which sends out a beam of intense light through reflects through a system of mirrors to the cutting head.
- Within the cutting head, the laser is focused through a lens and narrowed down to an extremely thin, concentrated beam. This beam is projected down at the material and can cut or raster the raw stock, which I'll cover in more detail later.
  - The cutting head is usually mounted on what is called an XY gantry, which is a mechanical system driven usually by belt or chain that allows for the precise movement of cutting head within a given rectangular area, which is the size of the work bed.
- The gantry allows the laser head to move back and forth and forward and back over the work piece so that it can make precise cuts anywhere on the bed. In order for the laser to actually cut, the focal point of the lens, where the laser would be at its finest, needs to be on the surface of the material it is cutting through.
  - All laser cutters require a focusing procedure before making their cuts to ensure that the laser cuts well.
- During a cutting operation, the cutting head fires a continuous laser at the material to slice through it. In order to know where to cut, the laser cutter driver reads all of the vector paths in the designed piece. Once you send your file to a laser cutter, only lines that register as only hairline or vector graphics with the smallest possible line thickness will be cut by the laser.
- Rastering is a lot different than vector cutting; instead of cutting all the way through the workpiece, the laser will burn off the top layer of the material you are cutting to create two color (and sometimes grayscale) images using the raster effect.
  - In order to raster materials, the laser will usually be set to a lower power than it would when vector cutting material, and instead of shooting down a pulsing beam, it creates fine dots at a selected DPI (dots per inch) so that the laser doesn't really cut all the way through.
- laser cutters have defined material ranges and limitations.
  - While some of this is due to the power it takes to cut through certain materials, some of the material limitations come from the gases that certain materials make when burned or cut with a laser.
  - Other materials can be cut, but respond poorly to heat and may shrivel or melt.
  - Like any other machining technology, there are definitely things that you can and can't do on a laser cutter.

MAKERSPACE SPECS:

Make	Model	Qty	Features	Permit Required		
Universal	ILS9.150D-150	1	150W (2x75W) lasers, 36" x 24" x 12" bed	Lab Orientation + Laser Cutter 1 Upgrade	Manufacturer's Manual	Specs

Click here for a complete list of equipment.

- Laser Processing Area = 36" x 24"
- Maximum material cut depth = .5"

Software

You will need a 2D vector file, which can have the following file types: .dxf, .ai, .pdf

These files can be generated from multiple software packages including:

- 3D (CAD): Solidworks, Onshape, Fusion 360
- 2D: Illustrator, Gravit, Inkscape

The Makerspace has a computer available for file prep – just look for the file prep station near the laser cutter. CAE login not required.

Figure (1): Laser Cutter Specifications from UW Makerspace Website

References:

[] “Laser Cutter,” *UW Makerspace*. https://making.engr.wisc.edu/laser-cutters-2/ (accessed Feb. 09, 2022).

[] printeraction, “Laser Cutting Basics,” *Instructables*. https://www.instructables.com/Laser-Cutting-Basics/ (accessed Feb. 10, 2022).

[] “Laser Cutting - Cutting Processes.” https://www.twi-global.com/technical-knowledge/job-knowledge/cutting-processes-laser-cutting-052.aspx (accessed Feb. 10, 2022).

Conclusions/action items:

- Look into getting Laser 1 Upgrade

Motor Purchasing and Circuitry Meeting - 3/23/22

Drew Hardwick - May 03, 2022, 8:02 PM CD

Title: Motor Purchasing and Circuitry Meeting

Date: 3/23/22

Content by: Drew

Present: Drew and Katie

Goals: Meet with Dr. Amit Nimunkar to discuss the CO2 circuitry, and see about motor purchasing at UW Makerspace

Content:

- Katie and I spoke with Dr. Nimunkar after his Instrumentation class, and he confirmed that our arduino DC motor circuit schematic diagram should work properly
- Then Katie and I spoke with the UW Makerspace checkout window and confirmed that they do sell DC motors
  - However, the DC motors that they sell are very small and cheap ($2.00)
  - There is concern that a motor this size will not supply enough torque to properly open and close the CO2 valve
    - Also limited by 5v output of arduino uno
- Other, more powerful DC motors I researched on Grainger are extremely expensive:
- The smallest Stepper Motor (internal gearbox, only can turn when power is supplied to it) on Grainger is still upwards of $2

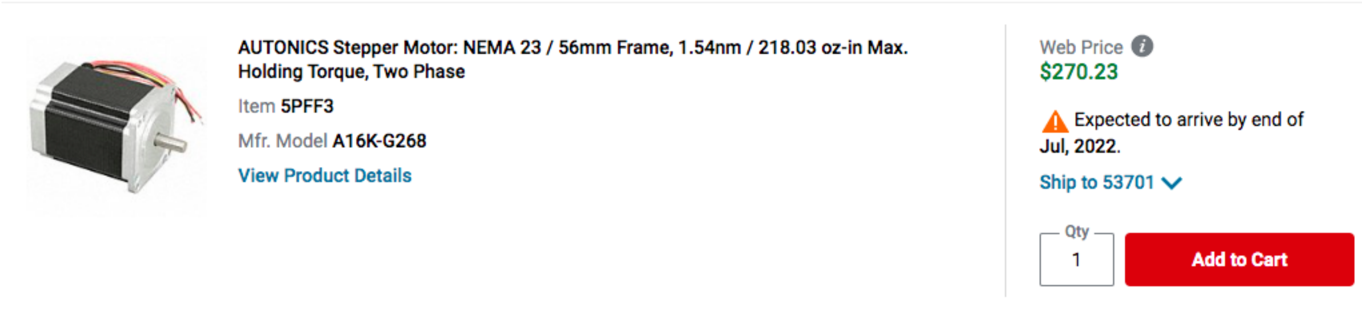


FIGURE 1: Stepper Motor for Purchase on Grainger

- This is very far out of our budget, and while we could find much cheaper, larger DC motors out there, we had trouble finding any reasonably priced motors on any approved purchasing site
- Because of this, we decided that for budgeting purposes, it was best to purchase the small DC motor from the Makerspace and see if it could work first, and then if not, reevaluate and take a new course of action
- Below is the motor we purchased:

FIGURE 2: DC motor ($2.00) from UW Makerspace

Conclusions/action items:

- Motor is purchased, begin fabricating motor attachment and circuit

Copper Bending Research 3/25/22

Drew Hardwick - May 03, 2022, 8:13 PM CDT

Title: Metal work research

Date: 3/25/22

Content by: Drew

Present: N/A

Goals: Determine best way to bend Copper tube

Content:

- The current copper pipe that our client gave us is 1/2" diameter and about 4ft long
- It needs to be bent to a right angle at 2 places to fit inside our water bath
- Need to research how can this be done:

- ## Tips For Bending Copper Pipe

- Pipe Support: Supporting the copper pipe along the entire length of its bend is key to a consistent shape - support can either be inside/outside the pipe.
- Bend Slowly: Bending the copper pipe quickly might crimp it, even if properly supported - ripples may develop on the inside of the curve - always bend slowly.

- ## Use a Spring to Bend the Pipe

- Tube-bending springs fit in the copper pipe and act as support to better distribute the force
- Bends as extreme as 180 degrees are possible with tube springs
- Tube springs come in kits of various sizes that fit copper pipes ranging from 1/4-inch to 5/8-inch diameter.

- ## Use Sand or Salt to Bend the Pipe

- Dense materials packed inside the copper pipe produce an effect much like pipe bending springs
- This prevent any single area from receiving all of the bending force - the force is distributed along the entire length of the curve
- Not helpful for our purposes

- ## Use Ice to Bend the Pipe

- Like sand and salt, water is another dense material that can be used to fill a copper pipe for bending
  - water is denser in its fluid state than as ice, freezing the water helps to better contain it in the copper pipe
- Once again, not particularly useful for our purposes

- ## Use a Pipe Bending Tool to Bend the Pipe

- A pipe bender is a small, inexpensive, dedicated tool that bends various sizes of copper and other soft metal pipes to a set radius
- Shaped like a set of pliers, a pipe bender allows for the insertion of pipes down the middle. A marked gauge indicates the angle of the bend, from 0 up to 90 degrees

- The secret of pipe benders is that the top part of the tool—the shoe—travels along with the bend, ensuring a smooth curve.
- The TEAM lab website indicates they have Pipe benders available for free use (with a paid materials fee)
  - This is definitely the easiest and most precise way to bend our metal pipe, and we should pursue this plan of action first

References:

[1] "How to Bend Copper Pipe 4 Ways," *The Spruce*. https://www.thespruce.com/how-to-bend-copper-pipe-5081971 (accessed March 25, 2022).

[2] "Tool Checkout," *TEAM Lab*. https://teamlab.engr.wisc.edu/services/tool-checkout (accessed March 25, 2022).

Copper Bending Session - 3/28/21

Drew Hardwick - May 03, 2022, 8:30 PM CDT

Title: Copper Bending in TEAM Lab

Date: 3/28/22

Content by: Drew

Present: Drew and Sam

Goals: Fabricate the Copper piping interior

Content:

- We began by checking out the pipe benders at the TEAM lab
  - Sam had his materials fee paid for this semester, so the rental cost nothing towards our project budget
- Our first attempt went poorly, as we initially chose the wrong size pipe bender
  - We thought that the copper pipe was 1/2" diameter, but upon bending our copper pipe we found that it did not fit properly in the 1/2" pipe benders and the pipe was pinched
  - This caused our first attempt to fracture the pipe
  - We remeasured with digital calipers and found that the INNER diameter was the assumed 1/2", but the OUTER diameter was 5/8"
  - We swapped out for the correct OUTER diameter pipe bender and tried again
- The second try went much better and we were able to bend the pipe to the desired 90 degrees
- HOWEVER: the rounding of the pipe was too long
  - we calculated that when doubled with another 90 degree bend on the other side, the width of the copper pipe would be too wide and it would not fit with in the incubator water well
- Sam and I were able to find copper L joints in the lab for no additional cost, and we decided to cut the copper pipe and solder it to the copper L joints instead of bending it
- The Final result is shown below

FIGURE 1: Cut copper pipe and L joints inside cardboard prototype to showcase fit (Yet to be soldered together)

Conclusions/action items:

- Solder the Copper piping parts together to prevent leakage

SOLIDWORKS CO2 Valve Holder Design 4/6/22

Drew Hardwick - May 03, 2022, 9:32 PM CDT

Title: CO2 Valve Attachment Initial SOLIDWORKS Design

Date: 4/6/22

Content by: Drew

Present: N/A

Goals: Get a preliminary 3D model prepared for the Valve Attachment

Content:

- My idea for this design was to modify a part I had printed for my design course last semester:
    - I designed and drafted a "tuning-fork"-esque part in SOLIDWORKS last semester
    - This design was also meant to attach to a DC motor via a long shaft and rotate to wrap a nylon seatbelt around the end
- My initial SOLIDWORKS template (from last semester) is shown below:

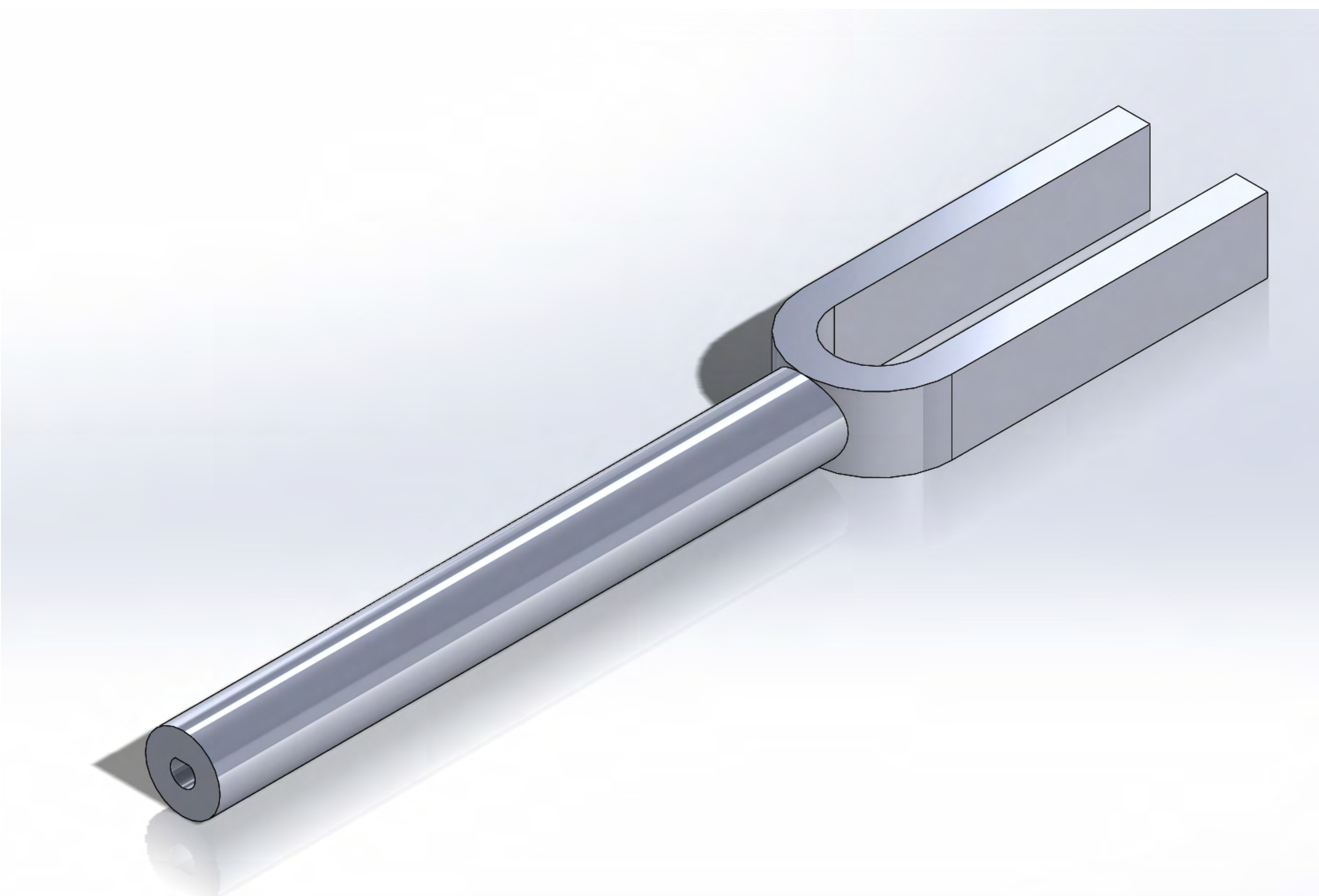


FIGURE 1: Tuning fork from BME 300 on SOLIDWORKS

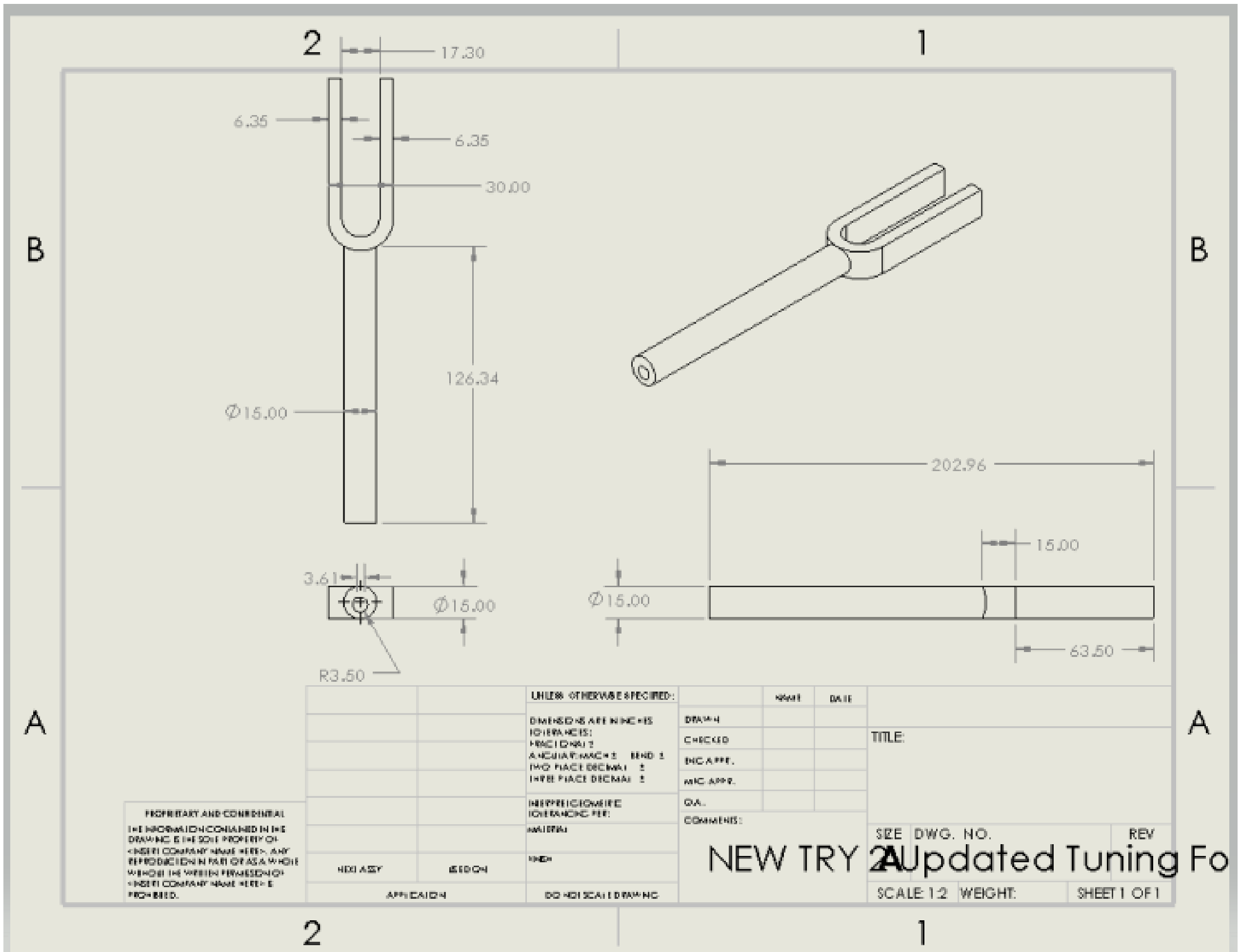


FIGURE 2: Tuning Fork Drawing

- Then I was able to edit this template to add 2 more arms, get rid of the hole for the motor in the base (with our small motor it will be easier to just drill the right diameter hole ourselves)
- The arms had to be spaced at the proper diameter of the valve (32.64mm)

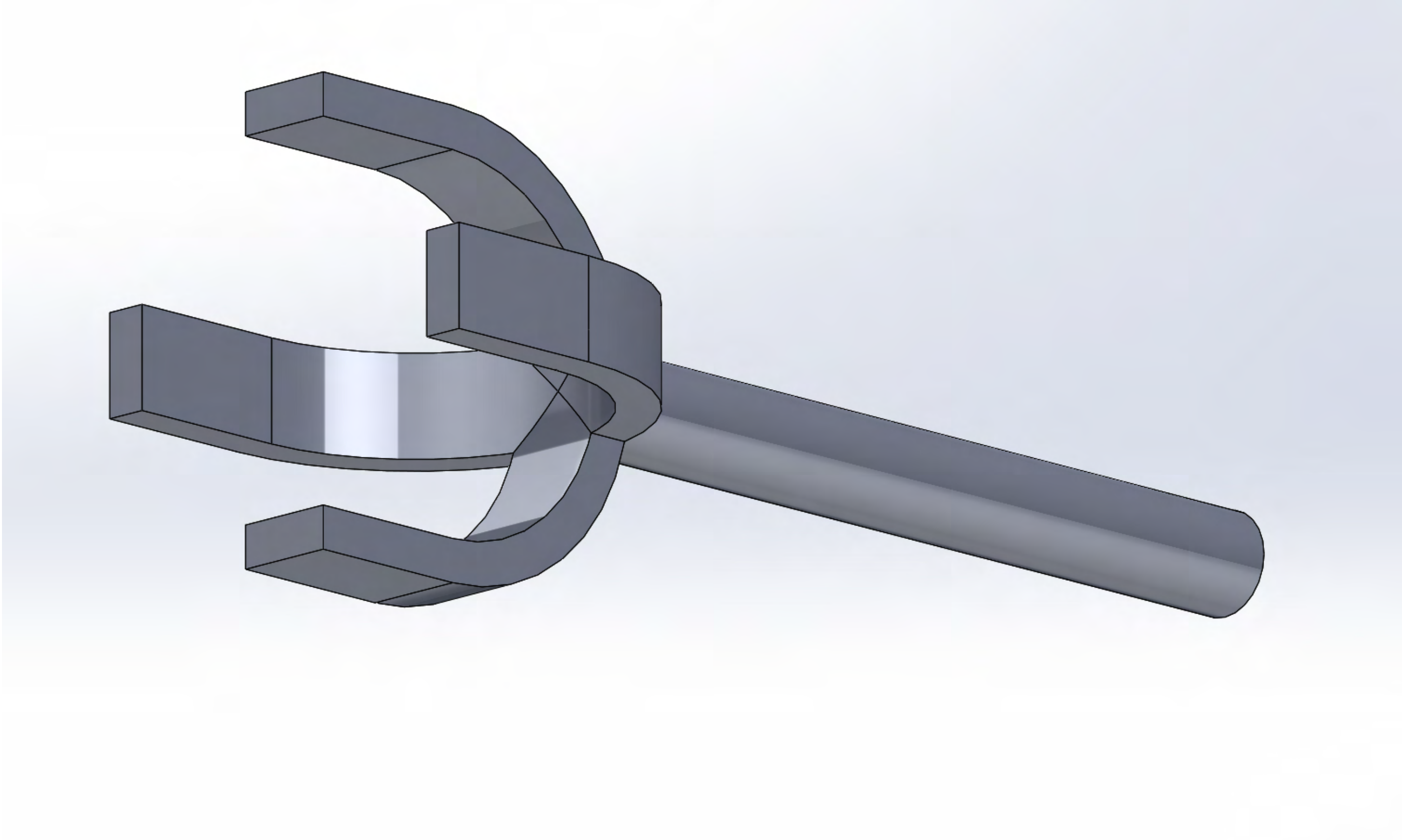


FIGURE 3: Initial Valve Connector SOLIDWORKS Design

Conclusions/action items:

- Begin Printing this piece for testing

SOLIDWORKS CO2 Valve Holder Editing Session 4/8/22

Drew Hardwick - May 03, 2022, 10:09 PM CDT

Title: SOLIDWORKS CO2 Valve Holder Editing Session

Date: 4/8/22

Content by: Drew

Present: N/A

Goals: Edit current SOLIDWORKS Draft

Content:

- As I thought more and more about the application of the valve, and how it would be used on a constant basis, I came to the realization that it needed to be beefed up
- The arms are far too thin in my original design and they are susceptible to stress fractures due to the constant torque and shear stress placed upon them
- The fix to this is to make them much thicker
- I also decided to make the base thicker to just beef up the entire design and prevent any possible fractures.
- The New SOLIDWORKS file (with dimensions in mm) is shown below:

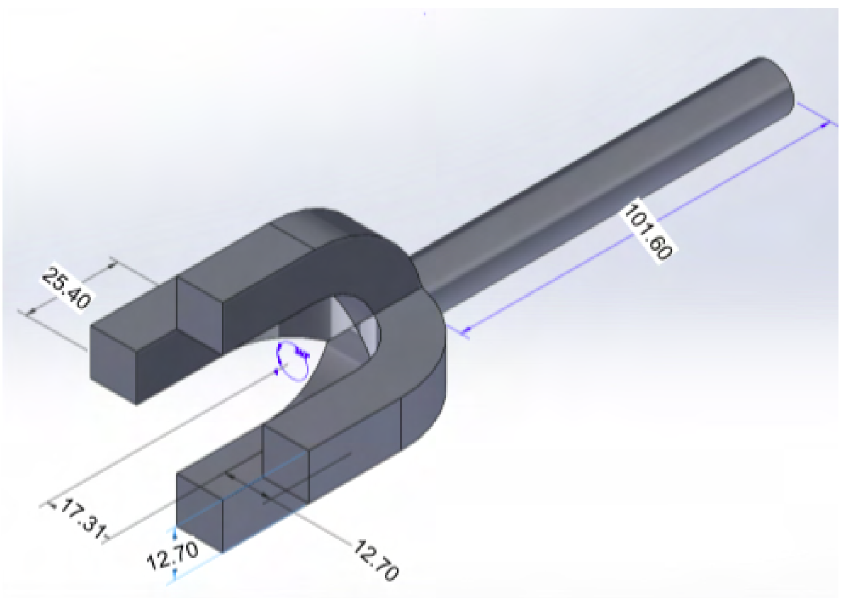


FIGURE 1: SOLIDWORKS image of edited Valve holder with dimensions in mm

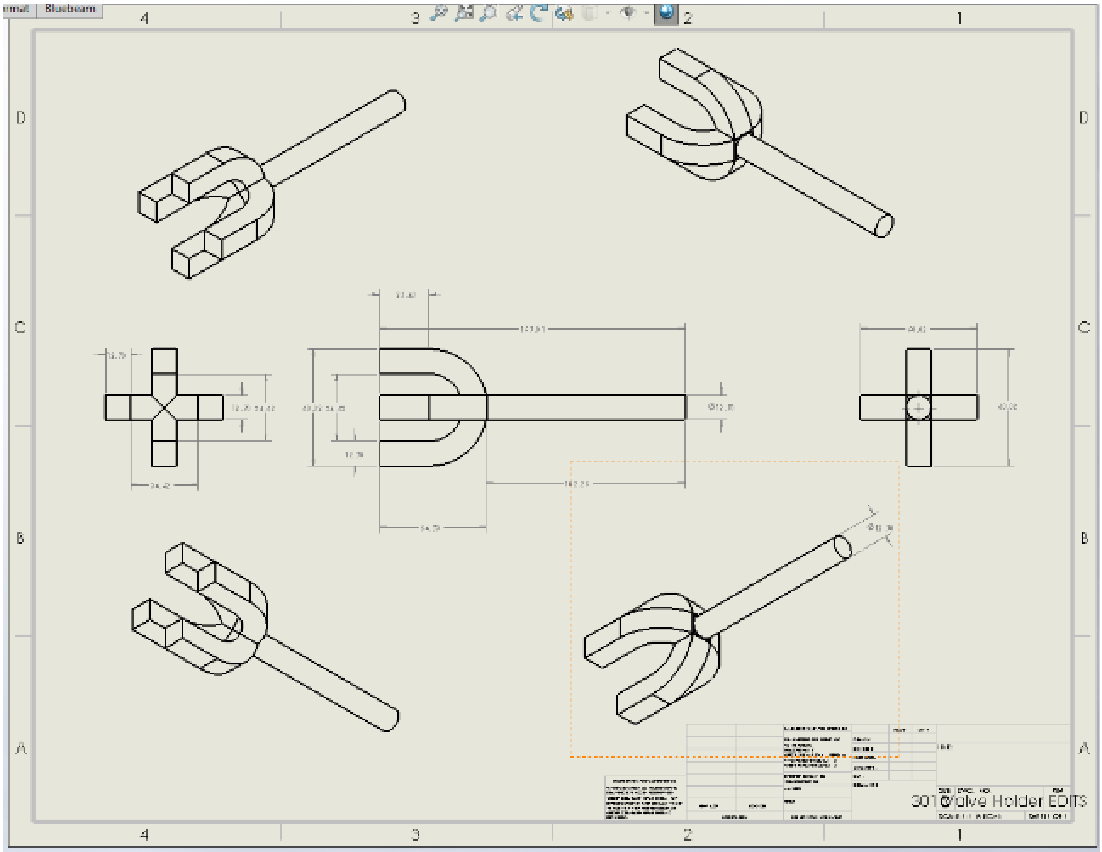


FIGURE 2: Edited Part Drawing with dimensions (in mm)

- This change caused a few kinks that took me a while to fix on solidworks
  - when the arm cross sectional area increased, it decreased the distance between them, so that the valve diameter would not be able to fit within the grasp of the holder
  - Because of this I basically had to redesign the piece from scratch

Conclusions/action items:

- Piece should be ready for printing
- 3D print ASAP

CO2 Valve Holder Printing 4/12/22

Drew Hardwick - May 03, 2022, 10:36 PM CDT

Title: CO2 Attachment Printing

Date: 4/12/22

Content by: Drew

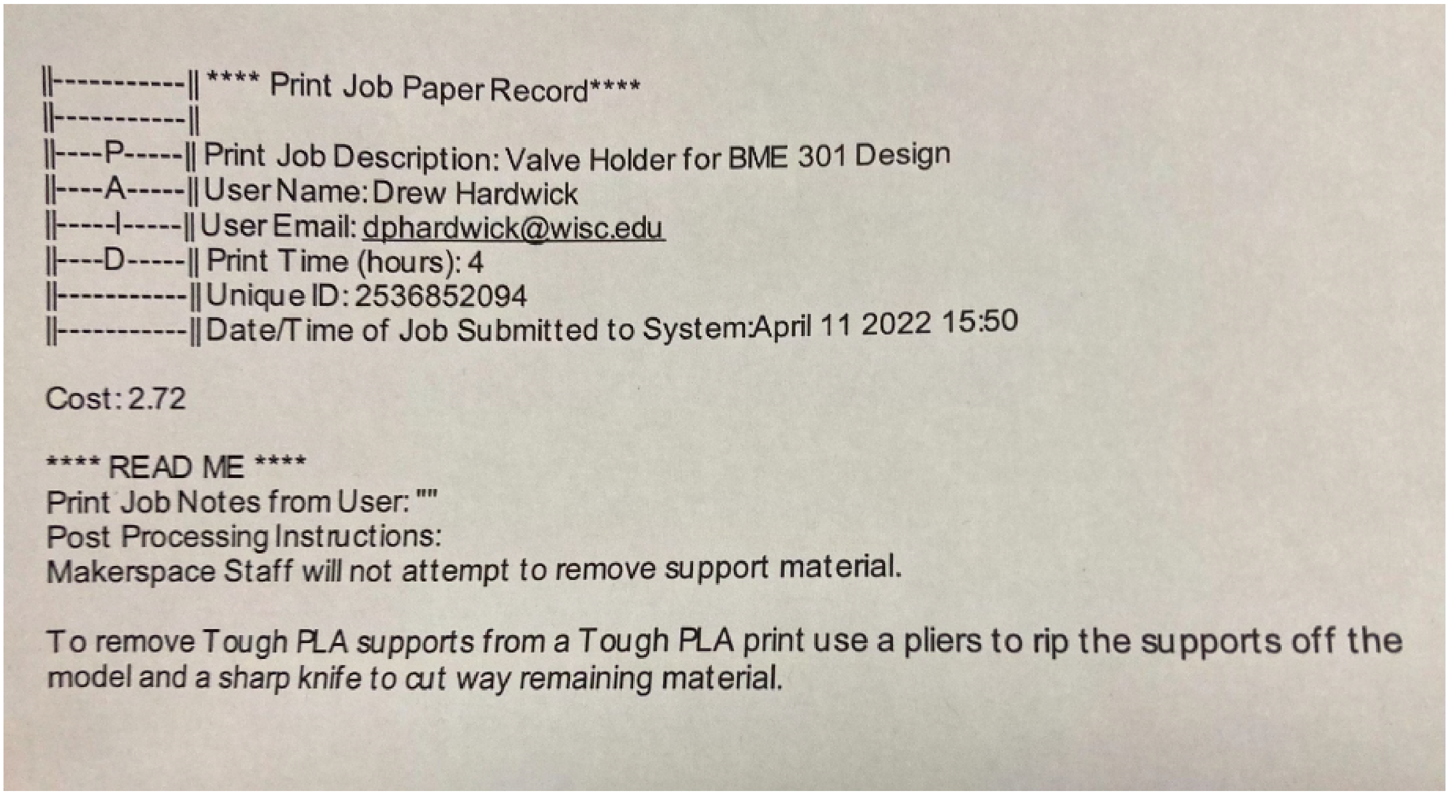
Present: N/A

Goals: Print the Attachment Piece

Content:

- The 3D printing process at the UW Makerspace was relatively straightforward and occured with no complications
- I chose to print in PLA Plastic due to its relative strength, cheapness and accessibility
- I chose to print in Black PLA Plastic to match the black acrylic of the box
- The print took roughly 4 hours, cost $2.72, and was super easy to clean up after it was completed
- Below is an image of the final print, and the print job receipt

FIGURE 1: Final 3D printed Valve Attachment



||-----------|| **** Print Job Paper Record****
||-----------||
||----P-----|| Print Job Description: Valve Holder for BME 301 Design
||----A-----|| User Name: Drew Hardwick
||----I-----|| User Email: dphardwick@wisc.edu
||----D-----|| Print Time (hours): 4
||-----------|| Unique ID: 2536852094
||-----------|| Date/Time of Job Submitted to System:April 11 2022 15:50

Cost: 2.72

**** READ ME ****
Print Job Notes from User: ""
Post Processing Instructions:
Makerspace Staff will not attempt to remove support material.

To remove Tough PLA supports from a Tough PLA print use a pliers to rip the supports off the model and a sharp knife to cut way remaining material.

FIGURE 2: Receipt

Conclusions/action items:

- Test apparatus

Caulking Final Prototype - 4/12/22

Drew Hardwick - May 03, 2022, 10:43 PM CDT

Title: Waterproofing Final Prototype

Date: 4/12/22

Content by: Drew

Present: Everyone

Goals: Waterproof the acrylic box

Content:

- With the box finally fabricated, the team meeting this week focused on getting the prototype assembled
- Katie and Sam worked on soldering the copper tubes together, while I worked on Caulking the interior of the acrylic frame
- based on my previous research, I was able to rent a caulk gun and silicone caulk from the TEAM lab
- After rewatching a youtube video to refresh myself on how to use the caulk gun, I started lining the box
- Both the outer edge, and the inner edge where the culture well sits had to be waterproofed to prevent leakage
- After applying a constant stream of caulk to all edges, I used q-tips to spread the caulk and make sure all parts of the crease are evenly coated.
- A sample of the caulk lining can be seen below:

FIGURE 1: Caulk Lining (DRIED)

- This Caulk lining takes over 24 hours to dry, so the team will wait for it to dry, and then conduct leakage testing to see if the well is truly water proofed

Conclusions/action items:

- Test seal when caulk is dried

CO2 Past Teams' Progress 2/15/22

Drew Hardwick - Feb 22, 2022, 11:07 AM CST

Title: Past Teams' Progress on CO2

Date: 2/15/22

Content by: Drew Hardwick

Present: N/A

Goals: Figure what went wrong with 2017 design (and other years), and how we can adapt/improve

Content:

2020:

- Never appeared to actually fabricate or test CO2

2017:

- A feedback control loop was used to adjust the CO2 injection rate and temperature appropriately, depending on the input from sensors.
  - Code was designed to cause larger additions and thus larger increases in CO2 or temperature following openings of the chamber.
  - This system also allowed for much smaller adjustments to be made during regular operation.
- To test environmental control in the preliminary prototype, temperature, humidity, and CO2 measurements were taken over the course of about 6 hours.
- The primary difficulty encountered during culture was stability of CO2 concentration.
  - While the MHZ –16 was specified to measure with a 200 ppm accuracy and the data in Figure 1 (below) shows relatively steady state CO2 measurement of 50,000 ppm (5%), during cell culture media was observed to yellow.
  - This indicates a rise above the set pH of 7.4 and was the likely factor behind decreases wound healing observed in the test sample.
  - The results of this testing suggest that the MHZ-16 were not stable in measurement. As a result, the feedback loop controlled by its output allowed for fluctuations in concentration.

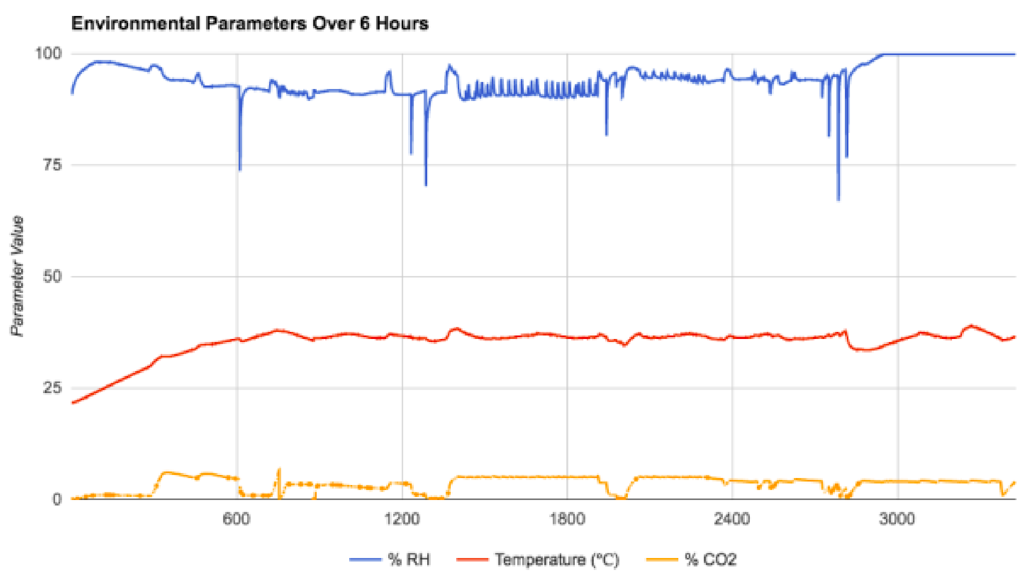


Figure 1: 2017 team environmental testing results

- A second difficulty encountered in CO2 control was the lack of control over pressure behind the CO2 valve.
  - The pressure gauge was manually controlled and as a result, made it difficult to achieve consistent feedback control when opening the solenoid valve to increase CO2 concentration.
- The design that has been created is able to sense and alter chamber temperature, humidity, and CO2 to relevant physiological conditions based on environmental changes

- However, longer-term environmental tests and adjustments to the CO_2 buffering must be performed prior to application in research

2016:

- While testing proved the control system accuracy and stability over time, the CO_2 set point, 0.65%, was significantly below the desired specification of 5%.
- Could have injected enough CO_2 to reach this concentration in the chamber, the sensor that was purchased was unable to detect any amount of CO_2 greater than 1%
- Increasing this set point will be a trivial test once a new sensor with a higher concentration limit has be obtained.

Conclusions/action items:

- The team is using the same CO_2 sensor as purchased by the 2017 team, so potentially tweaking their design to allow for more easy buffering is a possibility

Arduino CO2 Incubator Possible Design - 2/18/22

Drew Hardwick - Feb 22, 2022, 12:00 PM CST

Title: Arduino CO2 DIY Incubator

Date: 2/18/22

Content by: Drew Hardwick

Present: N/A

Goals: Learn more about possible arduino setups

Content:

DIY CO2 Incubator - Arduino and Circuits:

- The electronics and code are primitive
  - An Arduino UNO simply monitors temperature and CO2 content and turns on/off the heaters or open/closes the solenoid valve as necessary to maintain the various setpoints
  - It works and mammalian cells can be grown and differentiated
- The Arduino is essentially operating four simple circuits:
  - Control of a 12V DC fan
  - Reading temperature sensors
  - Reading the CO2 sensor
  - Relay control to supply 12V to the heaters (on/off) or to the solenoid (open/closed).
- NOTE: images below do not show 12V power supply - Using a DC barrel adaptor, connect a 12V supply to one set of rails and the Arduino 5V to the other (with common ground) - images indicate which set of rails the 12V supply should be connected to.

ARDUINO CODE CAN ALL BE DOWNLOADED!!! GOOD STARTING POINT AT LEAST!!

Fan:

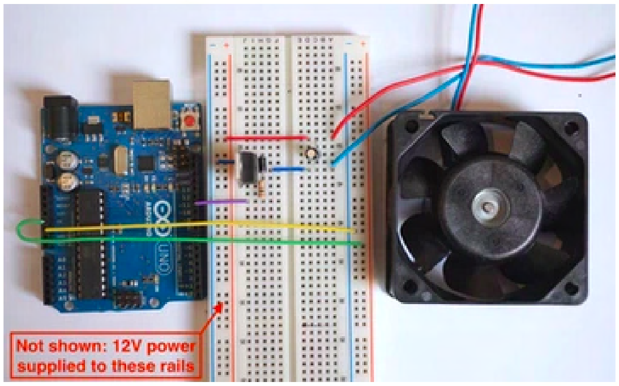


Figure 1: Circuit for Fan Control

- Fan helped to keep the atmosphere well mixed and the temperature fairly stable.

CO2 Sensor:

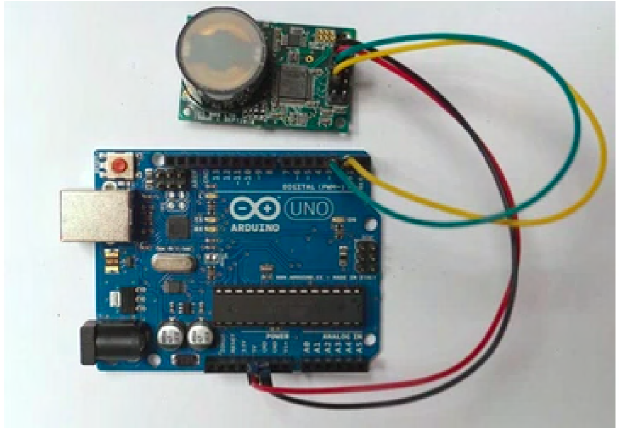


Figure (2): CO2 Sensor and Arduino Control

- For CO2 sensing, used NDIR based sensor from co2meter.com (GC-0017, 0-20%)
  - There are only 4-pins to care about on the sensor (GND, 3.3-5.5VDC, Rx, Tx) and its very easy to hook up
- An Arduino library was developed for this CO2 sensor so not much work to get it up and running
- Checked the calibration by exposing the sensor to a commercial premix of 5%/95% CO2/Air gas from BOC
  - Upon exposure to the 5% CO2 premixed gas, obtained CO2 readings from 3 different sensors by placing each sensor inside of an airtight container with a gas inlet and a syringe acting as an small outlet
  - Under pressure, flooded the premixed gas into the box and started recording
  - For each sensor, made three 180sec recordings and then averaged all 9 measurements together to produce the plot below

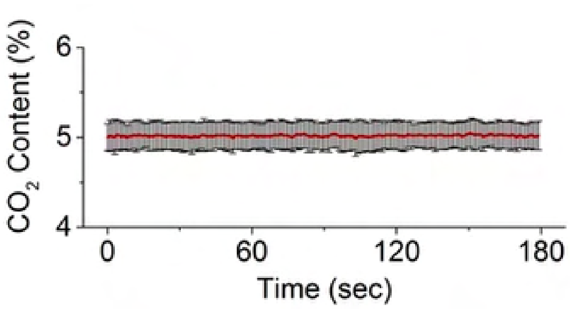


Figure (3): CO2 sensor testing

-
  - On average, exposure to a commercial premixed gas of 5%/95% CO2/Air, resulted in a stable CO2 reading of 5.01±0.15%. This is well within the noise characteristics of the sensor.

Control over Solenoid (CO2 input):

- employed two identical relay switches to supply 12V power to the heaters or the solenoid
- pictures and code here are for a single relay, so will have to double up
- using a pretty standard SPDT relay from sparkfun which is very easy to setup. This one is the 5-pin variety so note that the wring will change very slightly for 6-pin SPDT relays. There are also lots of pre-built relay modules out there that are simple to implement.
- Controlling relay is very easy
  - Setting an Arduino digital pin HIGH allows one to employ a transistor to trigger the relay switch with 5V from the Arduino
  - Once the switch has been triggered, 12V power can supply your load
  - Setting the digital pin LOW closes the switch - Therefore, the relays can be used to selectively supply power to a heater or to a solenoid

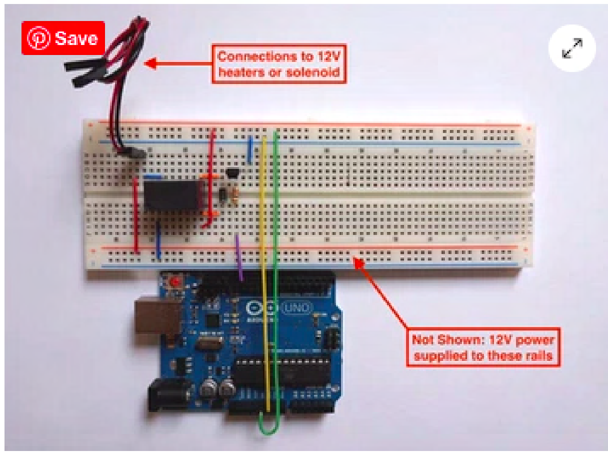


Figure (4): Solenoid arduino setup

Perfboard Setup:

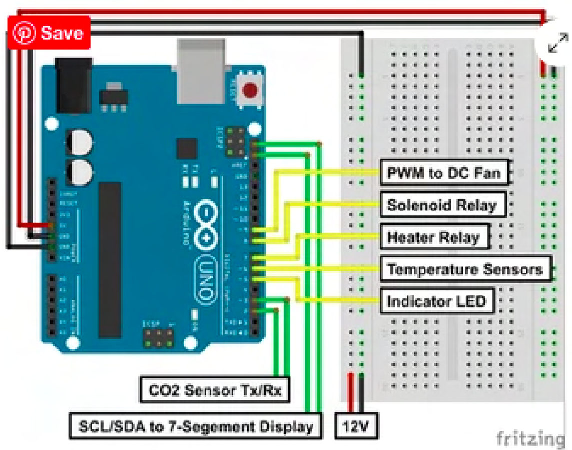


Figure (5): Perfboard setup

- Can eliminate all temperature elements (have own heating method)

CO2 Control Results:

- When the CO2 content of the incubator drops below 80% of setpoint (for example 3.5% with a setpoint of 5%), the solenoid opens allowing CO2 to rapidly fill the incubator
- If the CO2 level is above 80% of the setpoint (for example 4.5% with a setpoint of 5%), the solenoid only opens for 0.2 sec, closes and another reading is taken
    - This cycle continues until the setpoint is reached. This approach allows the CO2 content to step up to the setpoint and minimizes over-shooting.
- All the parameters (setpoint, thresholds, relay on times) modulating the control of the system are defined by the user
    - The default values in the Arduino control code work well for the incubator being described here
    - Values for the Temperature and CO2 setpoints (36.9 and 4.8, respectively), thresholds (0.98 and 0.8, respectively) and on times (1000 and 200, respectively) were chosen to achieve a stable reading of 37°C and 5% CO2

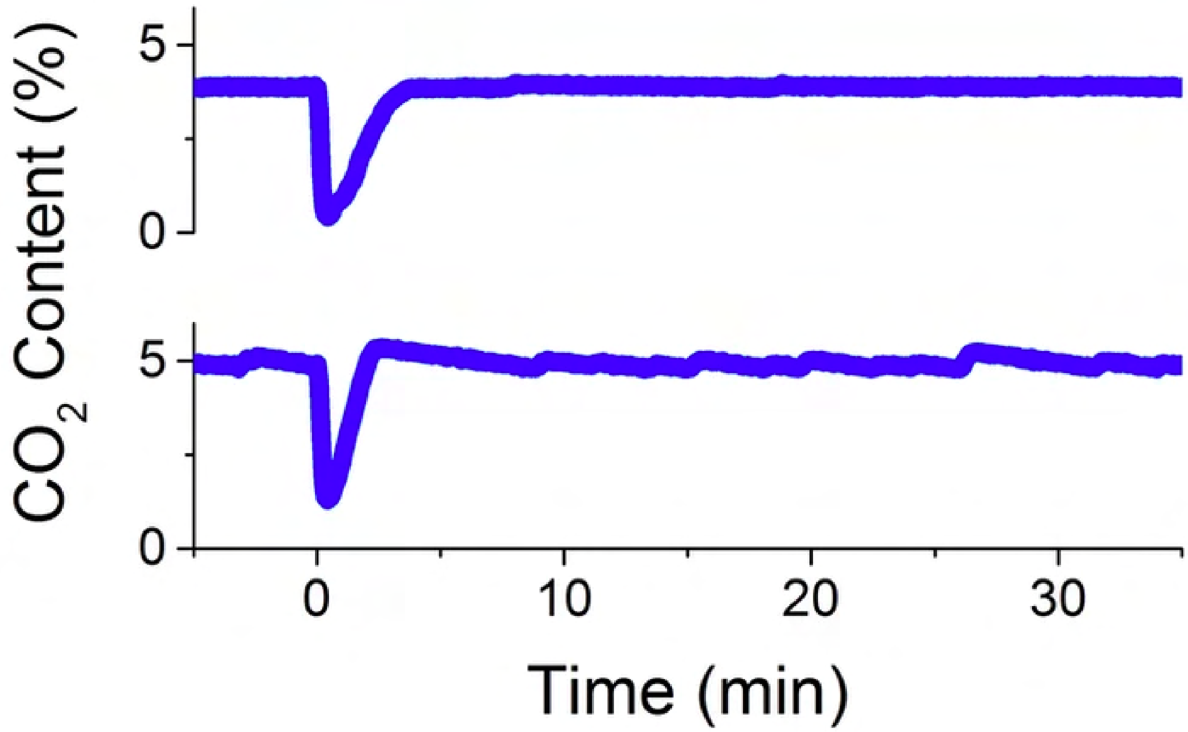


Figure (6): CO2 Testing Results

- Opening the door of either incubator results in a rapid decrease in CO2, approaching regular atmospheric levels
- Surprisingly, the recovery time of both incubators was observed to be quite similar, however the DIY incubator did tend to display a small overshoot
  - What is clear from the data, is that the commercial incubator was able to maintain a more stable CO2 content over time
  - The DIY incubator displays fluctuations of about ±0.2% (in other words, ~4% of the target value of 5%)
  - In this case, the average stabilized CO2 level in the middle of the incubator was ~4.9%
- mammalian cells (mouse cell lines and primary human cells) did not appear to be affected by the small CO2 fluctuations that were observed in the DIY system.

Conclusions/action items:

- This is very good starting reference point for CO2 sensing
- Speak with Katie and see what she thinks and if temperature/humidity unit could be integrated with this

References:

[] A. Pelling, "DIY CO2 Incubator - Arduino and Circuits," *pellinglab*, Dec. 14, 2014. https://www.pellinglab.net/post/diy-diy-co2-incubator-arduino-and-circuits (accessed Feb. 18, 2022).

CO2 Valve Holder Brainstorm Session 4/5/22

Drew Hardwick - May 03, 2022, 9:01 PM CDT

Title: CO2 Valve Holder Brainstorm Session

Date: 4/5/22

Content by: Drew H

Present: N/A

Goals: Brainstorm possible solutions/attachments to regulate CO2

Content:

- After Seeing the CO2 tank, which was finally delivered to the lab, during our team meeting, we had to figure out the easiest way to regulate CO2
- Although after speaking to the client, I realized a solenoid Valve would be most likely the most effective way to regulate CO2, we would also have to purchase new parts and develop a new circuit, so as a team we decided to try and continue with the DC motor idea
- This means controlling a DC motor from the Makerspace with a micro-controller, and 3D printing a valve piece that will attach to the motor and valve on each end and turn the master CO2 valve to open/close CO2 flow into the incubator when the motor spins
- I am tackling 3D modeling and printing this piece, and shown below are a couple preliminary sketches:

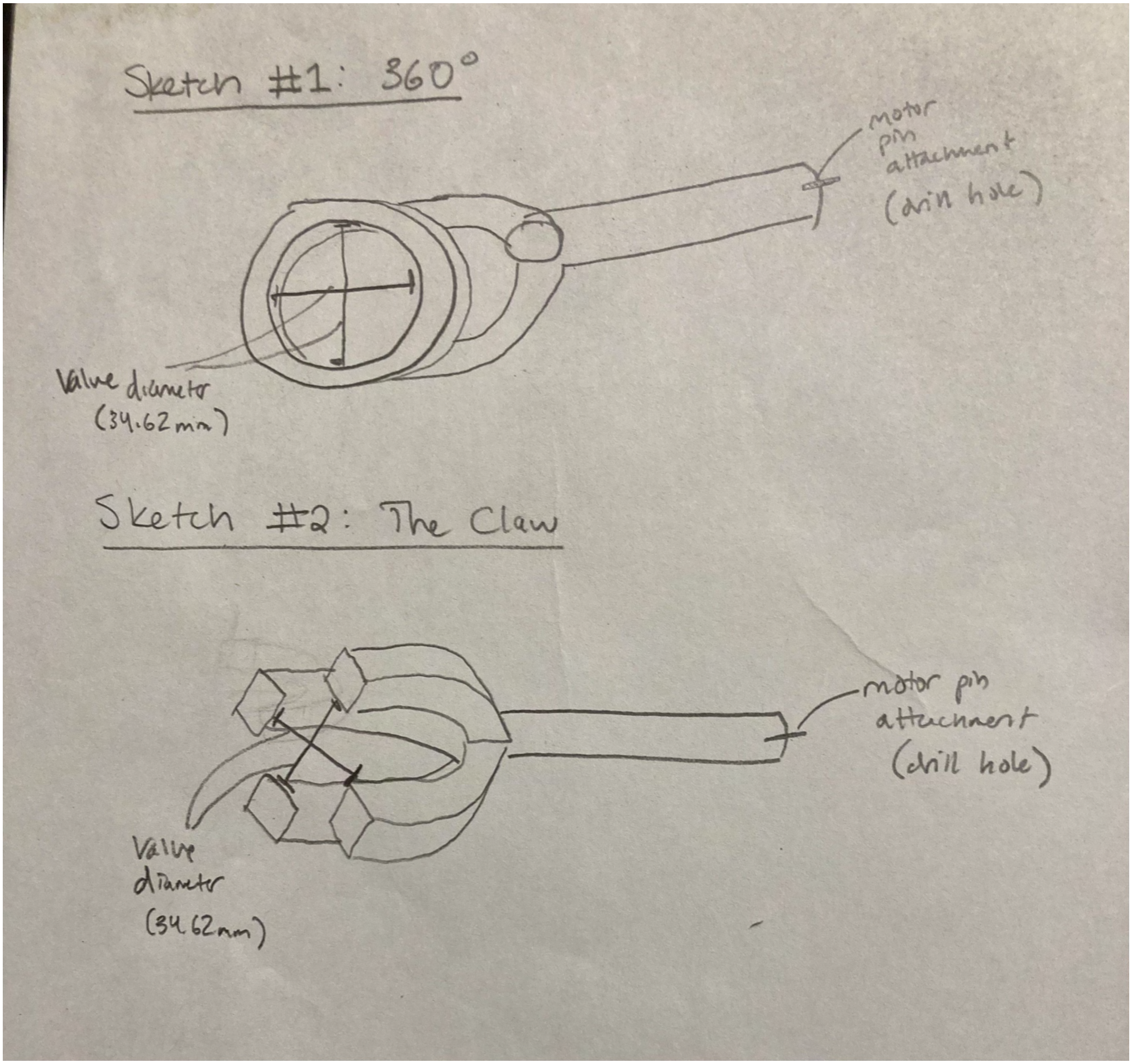


FIGURE 1: Design Sketches for CO2 Valve Adaptor

- The first Design I thought would be best for actually gripping the Valve due to it gripping the valve like a sleeve at all 360 degrees
  - It would have greater surface area contact and frictional contact with the valve than the second design, as well as being less brittle since the torque will be more evenly distributed
- The 2nd Design would be easier to draft in SOLIDWORKS and would be easier to modify if the fit to the valve is not absolutely perfect
  - If the first design doesn't fit perfectly to the valve or it slips at all, it will be hard to tighten without creating a completely new piece
  - The second design will hopefully have a little more give and flexibility/room for error despite being more likely to fracture because the arms can be pinched in to grip the valve by an elastic outer force (like a rubber band)
- After attempting to model on SOLIDWORKS I selected the second design due to it being much easier to model and due to it being more easily modified

Conclusions/action items:

- Finish SOLIDWORKS images and print part

Temperature, Humidity and Leakage Testing - 4/19/22

Drew Hardwick - May 03, 2022, 11:24 PM CDT

Title: Temperature, Humidity and Leakage Testing

Date: 4/19/22

Content by: Drew

Present: Everyone

Goals: Test Temperature reading, Humidity reading, and Leakage in the well at our weekly team meeting

Content:

Temperature/Humidity:

- The incubator was initially warmed up using a heated water pump, which pumped water at 55℃, for approximately 5 minutes, until it was lowered to about 34℃.
- The results from testing the incubator's temperature over approximately ten minutes showed an average temperature of 37.6℃.

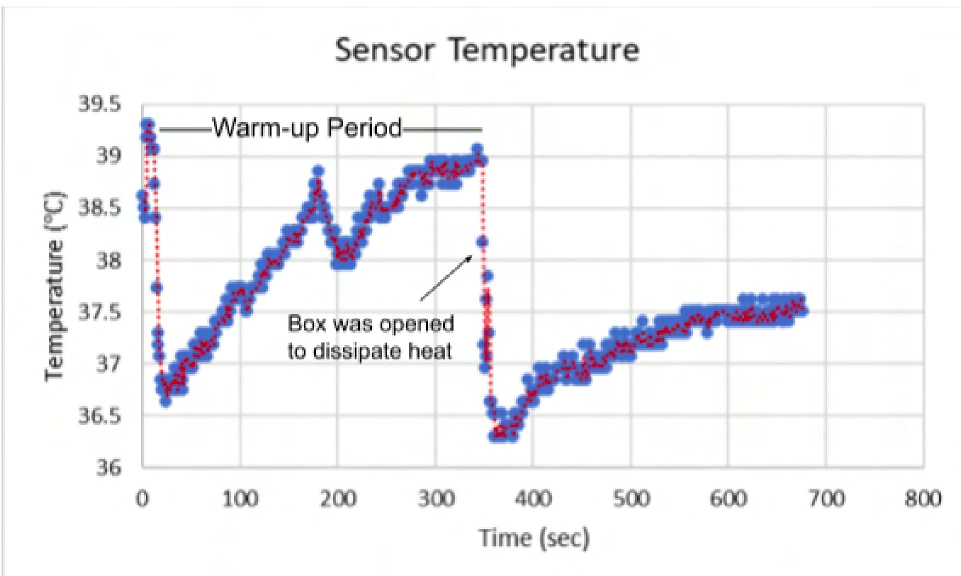


FIGURE 1: Full Incubator Temperature Testing results

- Humidity testing was set up under the same conditions (initially it was recorded with the temperature testing but the humidity formula had to be revised so it was conducted separately)
- An average humidity of 97.1% was found to be maintained over the 10 min testing interval

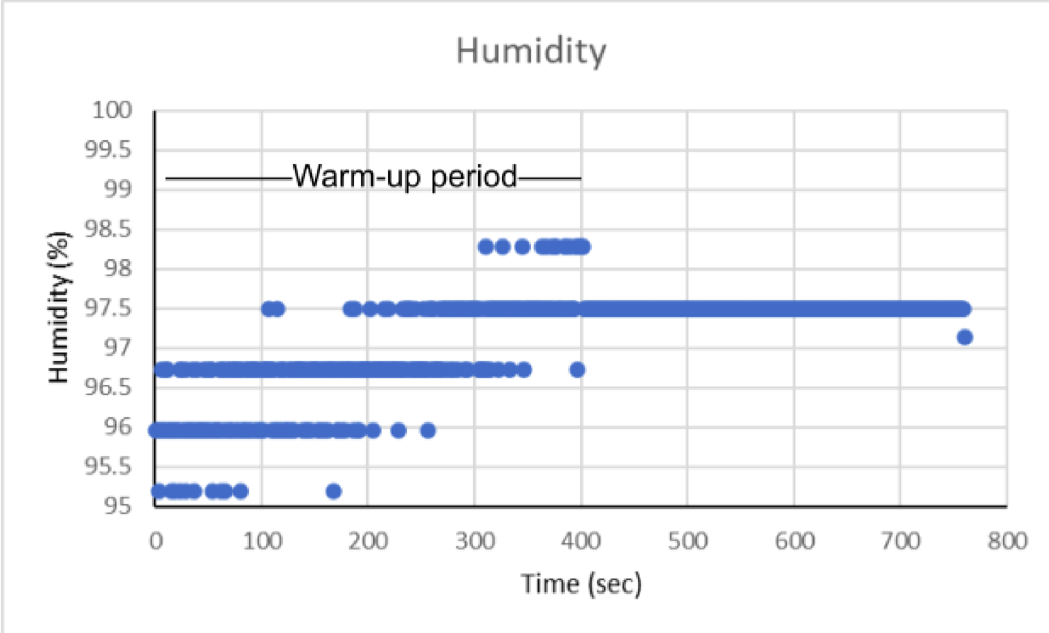


FIGURE 2: Full Incubator Humidity Testing results

- Leakage testing was also conducted (prior to temperature and humidity testing) by simply filling the incubator with the water bath and seeing if any leakage occurred
- We found no leakage at any point during all tests!!!
- This means the Silicone Caulk sealant worked!

FIGURE 3: Leakage testing Setup

Conclusions/action items:

- Work on deliverables and conduct CO_2 and recovery testing next week
- Temperature and humidity are working properly!!! (better than expected)
- No leakage as well !!!

CO2 and Recovery Testing - 4/26/21

Drew Hardwick - May 04, 2022, 12:04 AM CDT

Title: CO2 and Recovery Testing

Date: 4/26/21

Content by: Drew

Present: Everyone

Goals: Test recovery and CO2 at weekly team meeting

Content:

<u>CO2 Testing</u>

- The 3D printed DC motor attachment was glued to the DC motor which was plugged into the micro controller
- The micro controller was able to spin the printed attachments easily, and at high speeds, but when tested with the application of slight resistance (ones finger) the system stopped spinning
    - This lead us to think that the torque from this cheap, small motor will not be sufficient
- We decided to test this anyways, and the 3D printed attachment was fixed on the CO2 valve
- When we executed the code from the micro controller, we confirmed our suspicions
    - The motor did not have the power to turn the valve at all
    - Furthermore, the motor was not attached to the breadboard by anything other than the studs, and when power was supplied to the motor, the torque was enough to break off the studs powering the motor, but not to turn valve

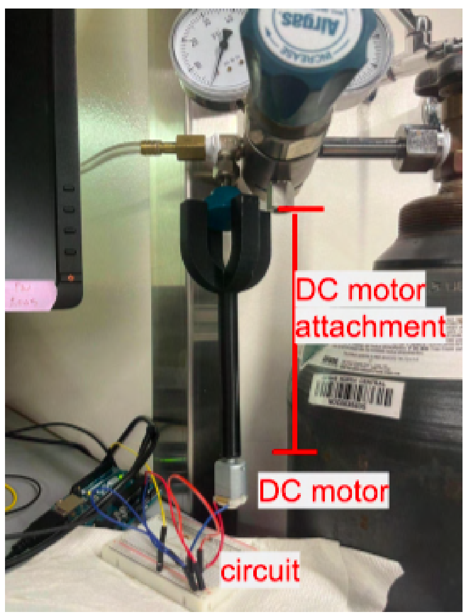


FIGURE 1: CO2 Testing Setup

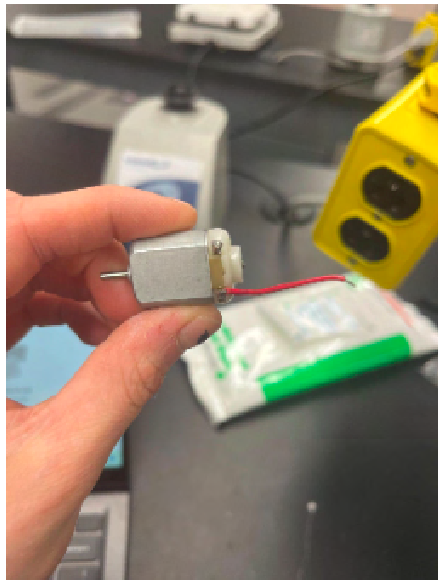


FIGURE 2: Broken DC Motor

- Because of the motor breaking, the team was unfortunately unable to collect any meaningful CO2 data (other than testing the CO2 sensors)

<u>Recovery Testing:</u>

- Recovery testing was completed in order to assess how well the incubator responds to a disturbance in the environment (like opening the lid for example)
- The first recovery test showed that after 30 seconds of disruption in the incubation chamber the temperature was able to reach optimal conditions within approximately 3 min
- The second recovery test showed that after 30 seconds of disruption in the incubation chamber the humidity was able to reach optimal conditions after 3 min 23 sec
- Humidity values during testing went over 100% however, which is not theoretically possible
  - Supersaturation caused this we concluded
  - We also concluded that although the values are over 100%, the recovery testing was still accurate and showed optimal recovery time.

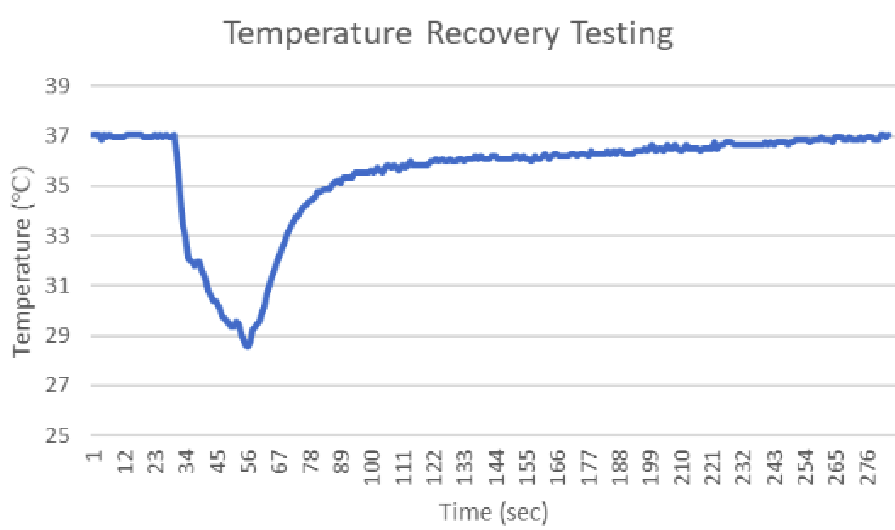


FIGURE 3: Temperature Recovery Testing results

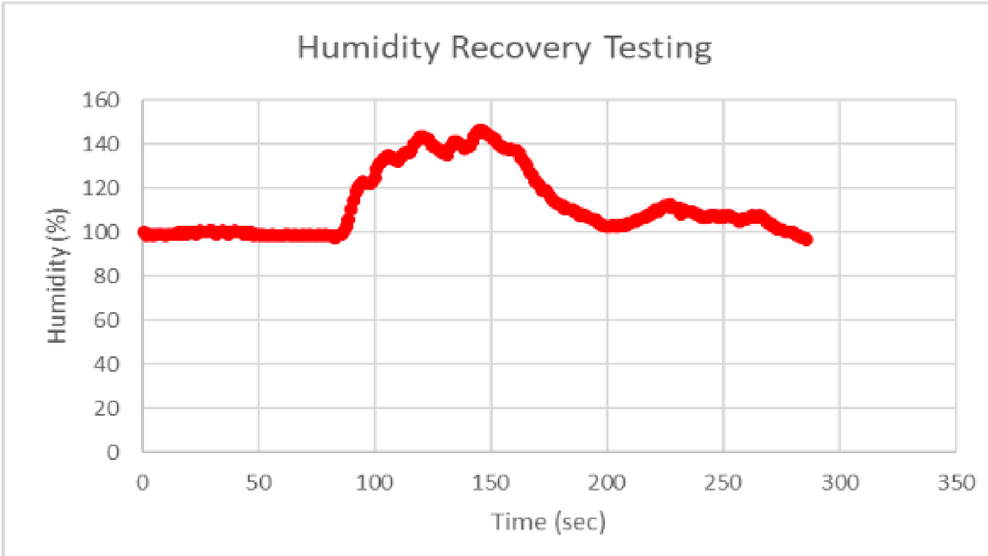


FIGURE 4: Humidity Recovery Testing results

Conclusions/action items:

- Recovery Testing Worked well
- CO2 testing needs entire redesign

WARF Lecture Notes - 3/11/22

Drew Hardwick - Mar 20, 2022, 9:47 PM CDT

Title: WARF Lecture Notes and Conclusions

Date: 3/11/22

Content by: Drew Hardwick

Present: N/A

Goals: Learn about what WARF is and what they do

Content:

- WARF is non profit not affiliated with university, except for chancellor seat on board
- aim to support scientific research and thought within the university with funds and exposure
- UW 6th overall in university research funding, 300-400 invention disclosures each year and close to 3000 patents throughout the history of WARF (1 billion $ of sales each year)
- WARF has given over 3 Billion $ back to UW and over 200 Million $ back to inventors as royalties
- Patents
    - machines, devices, compounds, methods, improvements
- Trademarks
    - words, phrases, colors, pictures, logos, sound
- Copyrights
    - literally works, webpages, software
- Prior Art = anything ever done before your invention concerning your invention/ideas
- US patent = time expensive and 30000$
- License = contract with company allowing company to use patent
    - WARF Accelerator program - milestone based validation funding to speed promising technologies to a commercial license

Conclusions/action items:

I think that our design can definitely qualify for intellectual property in the future when we get it up and running since there really is no cheap, portable incubator alternative on the market now. If we could market our final product as a kit for use in labs like the teaching lab, where everything needed to get the portable, reliable, cheap cell culture incubator running is within the kit, that would be a product like no other out there now, and we could definitely pursue a patent.

Bioentrepreneurship Lecture Notes - 1/1/22

Drew Hardwick - Apr 01, 2022, 12:25 PM CDT

Title: Bioentrepreneurship Lecture Notes

Date: 1/1/22

Content by: Drew Hardwick

Present: N/A

Goals: Learn as much as possible

Content:

- entrepreneur = person who organizes/operates business, taking on greater financial risks to do so
    - innovator or developer who recognizes/seizes opportunities and capitalizes on those opportunities adding time, value or funds
- StrataGraft skin substitute takes 20 years to reach approval
    - Tissue engineering a slow process!
-

Conclusions/action items:

2/10/22- A hot water supply as the source of Legionella pneumophila in incubators of a neonatology unit

Bella Raykowski - Mar 01, 2022, 8:13 PM CST

Title: A hot water supply as the source of Legionella pneumophila in incubators of a neonatology unit

Date: 2/10/22

Content by: Bella Raykowski

Goal: Understand how the water system could pose a contamination risk

Content:

- The humidification/water trays of 5 incubators were colonized with Legionella pneumophila, serogroup 1

- Legionelle pneumophila is a thin, aerobic, pleomorphic, flagellated, non-spore-forming bacteria. L. pneumophila is the causative agent of Legionnaires' disease

- Bacteriological analysis of the water in the humidification trays showed very large numbers of heterotrophic bacteria

- Two hot water systems supply the unit, either of which is used to add water to the humidification trays:

(A) is maintained at about 60 °C

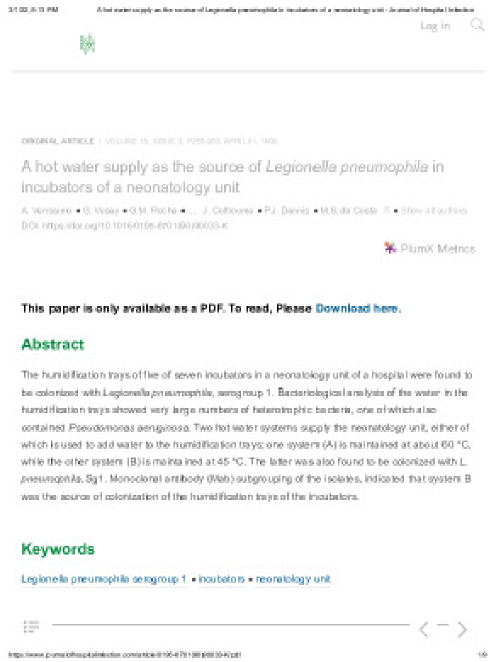
(B) is maintained at 45 °C.

- B was found to be colonized with L. pneumophila. Monoclonal antibody (Mab) subgrouping indicated it was the source of colonization of the humidification trays of the incubators.

Conclusion: We may need to test to make sure that our water system stays sterilized as to not pose a risk to the cell culture

Citation: A. Veríssimo, G. Vesey, G.M. Rocha, G. Marrão, J. Colbourne, P.J. Dennis, M.S. da Costa, A hot water supply as the source of Legionella pneumophila in incubators of a neonatology unit, Journal of Hospital Infection, Volume 15, Issue 3, 1990, Pages 255-263, ISSN 0195-6701, https://doi.org/10.1016/0195-6701(90)90033-K.

Bella Raykowski - Mar 01, 2022, 8:14 PM CST



Log in

ORIGINAL ARTICLE

A hot water supply as the source of *Legionella pneumophila* in incubators of a neonatology unit

PlumX Metrics

This paper is only available as a PDF. To read, Please Download here.

Abstract

The humidification trays of five of seven incubators in a neonatology unit of a hospital were found to be colonized with *Legionella pneumophila*, serogroup 1. Bacteriological analysis of the water in the humidification trays showed very large numbers of heterotrophic bacteria, one of which also contained *Pseudomonas aeruginosa*. Two hot water systems supply the neonatology unit, either of which is used to add water to the humidification trays; one system (A) is maintained at about 60 °C, while the other system (B) is maintained at 45 °C. The latter was also found to be colonized with *L. pneumophila*, Sg1. Monoclonal antibody (Mab) subgrouping of the isolates, indicated that system B was the source of colonization of the humidification trays of the incubators.

Keywords

Legionella pneumophila serogroup 1 • incubators • neonatology unit

Download

A_hot_water_supply_as_the_source_of_Legionella_pneumophila_in_incubators_of_a_neonatology_unit_-_Journal_of_Hospital_Infection.pdf (150 kB)

2/14/22- The Thermal Conductivity of Common Tubing Materials Applied in a Solar Water Heater Collector

Bella Raykowski - Mar 01, 2022, 9:10 PM CST

Title: The Thermal Conductivity of Common Tubing Materials Applied in a Solar Water Heater Collector

Date: 2/14/22

Content by: Bella Raykowski

Goal: Understand how the conductivity of copper wiring works

Content:

- Thermal conductivity is the amount of energy required to increase the temperature of the liquid inside the tubing to the same temperature on the exterior of the tubing (the rate at which heat is transferred through a material)

- Different materials have different thermal conductivity rates, and this is based upon the molecular structure

- Transfer rate is also influenced by the thickness of the material

Piping	Material	W/mK
Steel	Carbon Steel	54
Copper	Copper	401
PEX	Cross-linked High-density Polyethylene	0.51
CPVC	Chlorinated Polyvinyl Chloride	0.14
PE	Polyethylene	0.38
PVC	Polyvinyl Chloride	0.19

- The table from the article above shows a ranking of common materials used in thermal conductivity

- Fourier’s law examines the transfer of heat through a solid material.

$q = k A \, dT / s$

q = heat transferred per unit time (W, Btu/hr)

A = heat transfer area (m^2, ft^2)

k = thermal conductivity of the material

dT = temperature difference across the material

s = material thickness (m, ft)

Conclusion: We can use Fourier's law to find the heat transferred per unit of time for our copper wire. This article also solidifies the idea that we should use copper wire.

Citation:

Patterson, John E., and Ronald J. Miers. "The thermal conductivity of common tubing materials applied in a solar water heater collector." 46th ASC Annual International Conference, Wentworth Institute of Technology, ed T. Sulbaran (Boston, MA). 2010.

Bella Raykowski - Mar 01, 2022, 9:11 PM CST

The Thermal Conductivity of Common Tubing Materials Applied in a Solar Water Heater Collector

John E. Patterson, Ph.D. and Ronald J. Miers, Ph.D.
Western Carolina University
Cullowhee, North Carolina

Key Words: Solar, Collector, Tubing, Thermal, Materials

Introduction

Thermal Conductivity

[Download](#)

CPRT192002010.pdf (203 kB)

2/22/22- Advantages of laser machine cutting acrylic

Bella Raykowski - Mar 01, 2022, 10:20 PM CST

Title: Advantages of laser machine cutting acrylic

Date: 2/22/22

Content by: Bella Raykowski

Goal: Understand the pros and cons of acrylic for our box design

Content:

- Advantages: fast speed, high accuracy, and accurate positioning

- Factors that limit cutting speed: thickness, the thermal expansion coefficient of materials, the output power of the laser

- The process outlined in this article allows for smooth and neat edges with no need for any subsequent cleaning and polishing. The laser principle is the high strength, natural tempering edge, then there are no cracks.

Conclusion: Laser cutting acrylic is looking like the best option for this project due to the accuracy, cost, and the fact that it doesn't crack easily, which was a problem with last year's design.

Citation: "Advantages of Laser Machine Cutting Acrylic (Organic Glass)-Arthas." XTLASER, 26 July 2017, https://www.xtlaser.com/advantages-laser-machine-cutting-acrylic-organic-glass/#:~:text=Cutting%20acrylic%20(organic%20glass)%20with,it%20has%20an%20irreplaceable%20role.

Bella Raykowski - Mar 01, 2022, 10:18 PM CST


INDUSTRY NEWS

2017-07-26

Advantages of laser machine cutting acrylic (organic glass)-Arthas

Advantages of laser mach cutting acrylic

laser machine cutting acrylic.Laser cutting machine is one of the representative works of laser technology. Now it has an impressive performance in every different industry.

Laser cutting is applicable to all kinds of materials. So what are its applications and advantages in cutting acrylic (organic glass)? Today, Let me introduce that in detail.

Cutting acrylic (organic glass) with laser cutting machine has obvious advantages . Such as fast speed, high accuracy and accurate positioning. It used in acrylic craft gifts, acrylic display frame, acrylic picture frame, display products, packaging boxes and other

12KW+ LASER CUTTING LASER WELDING LASER CLEANING LASER MARKING

LANGUAGE

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Advantages_of_laser_machine_cutting_acrylic_organic_glass_-Arthas___XTLASER.pdf (265 kB)

3/1/22- Why is CO2 Used in the Incubation Industry?

Bella Raykowski - Mar 01, 2022, 11:30 PM CST

Title: Why is CO2 Used in the Incubation Industry?

Date: 3/1/22

Content by: Bella Raykowski

Goal: Understand why we need CO2 in the incubator

Content:

- Carbon dioxide is used in incubators to maintain the pH in the cell cultures. (how though?)

- Combined with maintaining a consistent temperature and humidity levels, the CO2 is usually kept between 3-7%.

- To ensure accuracy and to ensure extremely tight tolerances and specifications, occasional or constant checks of readings are a key for quality and tolerance controls.

- A common CO2 monitor is the Incubator IR CO2 Sensor.

- The (MH-100) Incubator IR CO2 Sensor is specifically designed to monitor and detect carbon dioxide levels in cell incubators to manage ideal cell and tissue growth.

- The CO2 sensor may be placed directly in the incubation chamber to allow accurate readings

Conclusion: We need the CO2 in order to maintain the proper pH and although we already have a sensor we could also try using one of the sensors listed above.

Citation: CO2Meter, Sponsored Content by. “Why Is CO2 Used in the Incubation Industry?” News, 19 Oct. 2020, https://www.news-medical.net/whitepaper/20200117/Why-is-CO2-Used-in-the-Incubation-Industry.aspx.

Bella Raykowski - Mar 01, 2022, 11:31 PM CST

[Download]

Why_is_CO2_Used_in_the_Incubation_Industry_.pdf (920 kB)

5/3/2022- Cell Viability Staining

Bella Raykowski - May 03, 2022, 3:30 PM CDT

Title: Cell Viability Staining

Date: 5/3/2022

Content by: Bella

Goals: To research what types of stains/dyes can be used in viability staining

Content:

Hoechst:

- is a blue fluorescent stain for the DNA and nuclei of cells

- can be used in fixed and live-cell imaging (we would start with daily live-cell imaging)

- emits between 460-490 nm (blue range)

- it binds into the groove of DNA and is brighter for dead cells than live cells

- store at 4 degrees C and protect it from light (it will become bleached over time if has prolonged exposure to light)

- price: $112.00 for 5 mL (yikes)

Calcein AM:

- a cell-permeant dye that can determine cell viability in eukaryotic cells (will need to check what types of cells we are using)

- is a green florescent stain for live cells

- emits between 488-520 nm (green range)

- store at -5 to -30 degrees C

- price: $317.00 for 1 mg (that's a lot of money)

Propidium Iodide:

- is a red nuclear and chromosome counterstain that is not permeant to live cells and therefore is used to stain dead cells

- PI binds to the DNA through intercalating between the bases

- emits between 535-617 nm (red range)

- store at room temperature and protect it from light (photobleaching)

- price: $166.00 for 100 mg

Conclusions/action items:

Citations: These stains will theoretically work for testing the viability of our prototype but will need to check with Dr. P to determine what cells we will be using. Will also need to ask him if these would be included in the budget or if he already has some that we can borrow. If not I can ask my PI if I can use some of our aliquotes since we already have these stains.

https://www.thermofisher.com/order/catalog/product/62249

https://www.thermofisher.com/order/catalog/product/C1430

https://www.thermofisher.com/order/catalog/product/P1304MP

5/3/2022- Biosafety level 2 standards

Bella Raykowski - May 03, 2022, 9:58 PM CDT

Title: Biosafety Level 2 Standards

Date: 5/3/2022

Content by: Bella

Goals: Understand what the biosafety level 2 requirements are in order to ensure that our design meets them

Content:

- BSL2 labs work with infectious agents, toxins, and cells therefore the guidelines must mediate the risk of exposures

- these labs must have handwashing sinks, eye washing stations, doors that lock, the ability to decontaminate lab waste, and an autoclave

- people just wear PPE such as lab coats, gloves, eye protection, and face shields

- incubators must maintain a temperature of 37 degrees C, 95% humidity, and 5% CO_2 in order to provide an adequate microenvironment for cells

- many types of incubators have special features like decontamination programs, locking mechanisms, alarms, digital displays, and transparent doors

- our incubator will have a "transparent" door but won't include locks, alarms, or displays

- they must utilize 1 airflow tech: gravity convection, mechanical convection, or dual convection

- gravity convection: there are no fans or anything that moves the air; it follows the law of physics (heat rises and cool air falls); will have less temperature uniformity but will have less drying over time

- mechanical convection: aka forced air; uses an integrated fan to move air inside the chamber; has a very even temperature distribution across the chamber

- dual convection: combines both gravity and mechanical convection; the user decides the mode that is best for their experiment

Conclusions: Testing has shown that our prototype meets the temp and humidity requirements but we were not able to test CO_2. Our prototype utilizes the gravity convection method since there is no fan. We will need to keep our eye on making sure there is an even temperature across the box but being as it much smaller than a standard incubator we should be ok.

2/10/22- Micro-CO2-Incubator for Use on a Microscope

Bella Raykowski - Feb 10, 2022, 8:56 PM CST

Title: Micro CO2 Incubator for use on a Microscope

Date: 2/10/22

Content by: Bella Raykowski

Goal: Understand how this design works and pull ideas from it for our design

Content:

- The incubator consists of 3 toroidal rings anodized with a black aluminum-oxide film and a 2-turn canthal wire wound around the middle ring that produces heat.

- The top ring fits over the middle ring, leaving open an inner circular gas duct and a narrow slit all along the inner surface of the ring just above the side of the culture dish.

- A polyvinylchloride (PVC) support ring with a metal top fits around the incubator so that thermistors attached to small magnets can be placed in or around the incubator.

- The PVC insulating ring under the incubator prevents heat loss to the object holder of the microscope.

- Between the center and side of the culture dish the gas can be used to maintain the partial pressure of gasses in the culture medium.

- By directing a suitable gas mixture at a flow rate of 0.5-2.0 1/min over the oil layer, the pH of a bicarbonate-buffered medium and its partial O2 pressure can be maintained.

Conclusion: We could try leaving an empty space where we pump the CO2 in at the desired concentration of 5%

Citation:

Can Ince, Dirk L. Ypey, Martina M.C. Diesselhoff-Den Dulk, Jacques A.M. Visser, Arie De Vos, Ralph Van Furth, Micro-CO2-incubator for use on a microscope, Journal of Immunological Methods, Volume 60, Issues 1–2, 1983, Pages 269-275, ISSN 0022-1759, https://doi.org/10.1016/0022-1759(83)90354-X.

5/4/2022 Ibidi Stage Top Incubator

Bella Raykowski - May 04, 2022, 11:12 AM CDT

Title: Ibidi Stage Top Incubator

Date: 05/04/2022

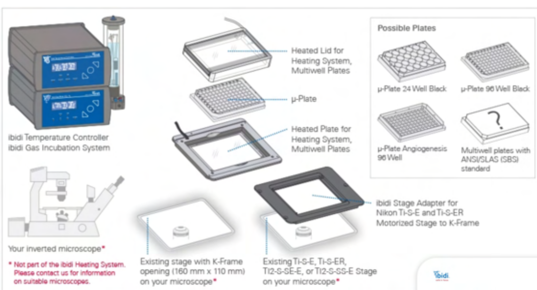
Content by: Bella

Goals: To document a product that is direct competition to our design

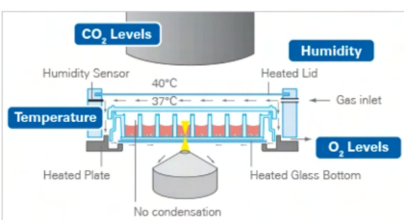
Content:

- this is a stage top incubator that works with an inverted microscope and has CO2 control

- has a constant high relative humidity by humidifying the gas mixture before it enters the incubator



- there are 2 systems available: one for a slide/dish and one for well plates



- the lid is heated which prevents condensation in order to not intervene with the microscope optics

- this creates a temp gradient from top to bottom which also ensures a constant temp across the box

Conclusions: This incubator has a lot of similar aspects to ours but is very expensive. We could utilize the heated lid design in our prototype in order to prevent condensation

Link: https://ibidi.com/stage-top-incubators/232-ibidi-stage-top-incubation-system-multi-well-plates-k-frame-co2.html

3/1/22- Math calculations for heat transfer

Bella Raykowski - Mar 01, 2022, 11:16 PM CST

Title: Math calculations for heat transfer

Date: 3/1/22

Content by: Bella Raykowski

Content:

- see attached file

Conclusion: We can use Newton's Law of Cooling to determine the heat transfer out of the copper tubing

Bella Raykowski - Mar 01, 2022, 11:16 PM CST

Water heating math

20 watts to heat 1 L of water 20°C to 37°C

Watts = J/sec

70,000 J

$20W = \frac{70000 J}{x \text{ sec}}$

x = 3,500 sec = 58 min

@ 37°C is 70,266 J
40°C is 75,969 J
45°C is 85,454 J
50°C is 94,955 J
55°C is 104,450 J
60°C is 113,946 J

Newtons Law of cooling

$Q = \frac{q}{\Delta T} \cdot A \cdot (T(t) - T_{env})$

Q = rate of heat transfer out of body
q = heat flux
ΔT = diff in temp between a solid surface

heat transfer coeff = 400 W / meter Kelvin

Download

heat_transfer_math.pdf (3.6 MB)

4/26/2022 Solenoid Valve

Bella Raykowski - May 03, 2022, 3:02 PM CDT

Title: Solenoid Valve research

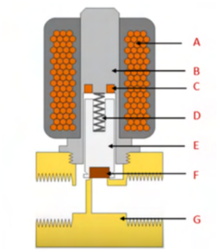
Date: 04/26/2022

Content by: Bella

Goals: To research how a solenoid valve works since our DC motor broke

Content:

- A solenoid is an electric coil that has a plunger in the center that can block the flow of gas and liquids



- A: an electromagnetically inductive coil that moves the plunger

- C: the shading ring which prevents/limits the vibrations from the AC coils

- D: the spring that must be overcome in order to move the plunger

- E: the plunger that does the actual blocking of flow

- F: the seal that prevents leakage when closed

- this valve type can be used in both high and low pressures as well as small and large flow rates

- a 2-way solenoid valve (what we would use) allows the flow into and then out of the valve

- a normally closed (NC) solenoid valve (what we would use) is closed until a current is sent to the coil (A) in order to move the plunger (E)

- we would need to code the circuitry to open and close very quickly

- Direct-acting: typically used in small flow rate setups because the max pressure and flow are related to the tubing diameter and the magnetic force of the valve

- they have no min pressure therefore their range is 0 bar - whatever the max allowed is

- Indirect-acting: uses the pressure differential over the ports in order to open and close the valve and therefore requires a min pressure ~0.5 bar

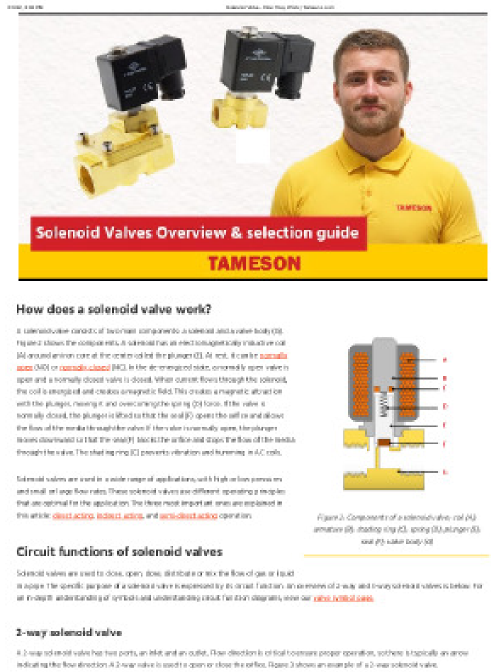
- can withstand a large flow rate

- semi-direct-acting: combines direct and indirect; can work at 0 bar but still handle high flow rates

Conclusions/action items: Finances pertaining, I think that a semi-direct-acting solenoid would work the best because it seems to be the best of both worlds but I don't think we will have a high flow rate so we could get away with using a direct one. Will now need to look into the cost of this type of valve and if it will fit in our $100 budget.

Citation: https://tameson.com/solenoid-valve-types.html

Bella Raykowski - May 03, 2022, 3:03 PM CDT


Solenoid Valves Overview & selection guide

TAMESON

How does a solenoid valve work?

Circuit functions of solenoid valves

2-way solenoid valve

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Solenoid_Valve_-_How_They_Work___Tameson.com.pdf (1.05 MB)

4/26/2022 Fog Resistant Glass

Bella Raykowski - May 03, 2022, 9:06 PM CDT

Title: Fog Resistant glass

Date: 04/26/2022

Content by: Bella

Goals: To research possible fog-resistant glass that could be used in the prototype

Content:

- we had an issue with the glass paneling fogging up and condensation impairing the optics; to combat this we attempted to use a waterproofing spray however we ended up making the glass translucent instead of transparent

- MIT has developed an anti-fogging, glare-free, self-cleaning glass made out of nanotextures

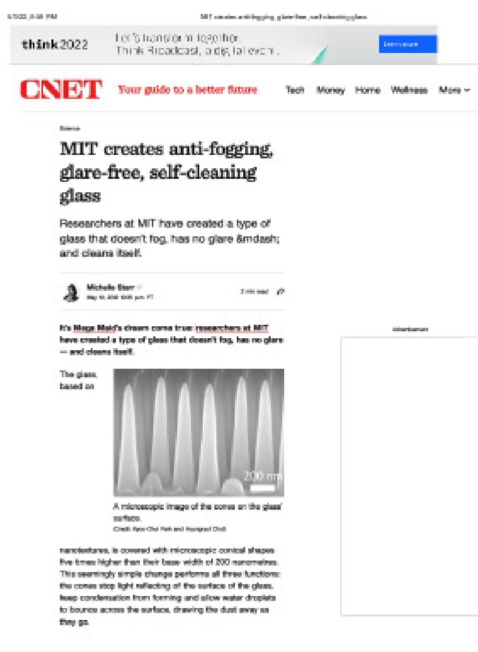
- it is covered with microscopic conical indents with the intent that it stops light refracting on the surface, keeps condensation from forming, bounces water droplets off the surface which draws dust away

- it is fabricated with several fine layers with one of those layers being photo-resistant

Conclusion: if we can purchase this glass and it is within our $100 budget then it could provide a really good option for our fogging problem while maintaining the optics of the microscope

Citation: Starr, Michelle. “MIT Creates Anti-Fogging, Glare-Free, Self-Cleaning Glass.” CNET, CNET, 11 May 2012, https://www.cnet.com/science/mit-creates-anti-fogging-glare-free-self-cleaning-glass/.

Bella Raykowski - May 03, 2022, 8:59 PM CDT



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MIT creates anti-fogging, glare-free, self-cleaning glass

Researchers at MIT have created a type of glass that doesn't fog, has no glare — and cleans itself.

Michelle Starr

It's Mega Maid's dream come true: researchers at MIT have created a type of glass that doesn't fog, has no glare — and cleans itself.

The glass, based on nanotextures, is covered with microscopic conical shapes five times higher than their base width of 200 nanometres. This seemingly simple change performs all three functions: the cones stop light reflecting off the surface of the glass, keep condensation from forming and allow water droplets to bounce across the surface, drawing the dust away as they go.

A microscopic image of the cones on the glass' surface.

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MIT_creates_anti-fogging_glare-free_self-cleaning_glass.pdf (1.63 MB)

4/26/2022 Fog Resistant Spray

Bella Raykowski - May 03, 2022, 9:33 PM CDT

Title: Fog Resistant Spray

Date: 4/26/2022

Content by: Bella

Goals: To research possible fog-resistant glass that could be used in the prototype

Content:

- common anti-fog treatments exist such as balms, drops, sprays, and wipes which work to repel fog

- New York Times tested 3 anti-fog drops, 2 anti-fog sprays, and 1 anti-fog wipe

- They found that Ultra Clarity's Defog It drops to be the most effective although it does require reapplication and can leave streaks

- it is applied by dropping the solution onto the lens and then using the wipe to spread it evenly across the glass

- this product is $16 on amazon and is therefore within our budget; can be used up to 100 times

Conclusions: This could be a potential option for fog proofing our glass however it will likely need to be applied right before imaging and testing must be done in order to ensure that any streaks won't interfere with the microscope optics.

Citation: “The Best Anti-Fog for Glasses and a Mask.” The New York Times, The New York Times, 1 Mar. 2021, https://www.nytimes.com/wirecutter/reviews/best-anti-fog-glasses-and-mask/.

Bella Raykowski - May 03, 2022, 9:34 PM CDT

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HEALTH & FITNESS · CORONAVIRUS COVERAGE

The Best Anti-Fog for Glasses and a Mask

By Tracy Vence

Published March 1, 2021

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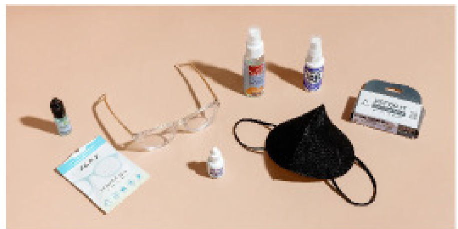

Foggy glasses—caused by a mismatch between the temperature of your breath and the surrounding environment—can range from a mild annoyance to a vision-clouding hazard, and the problem is all the more common now with the daily wearing of face masks. Long used for occupational safety and recreat

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The_Best_Anti-Fog_for_Glasses_and_a_Mask_in_2022___Reviews_by_Wirecutter.pdf (8.92 MB)

3/25/2022 Optical Testing Protocol

Bella Raykowski - May 03, 2022, 12:56 PM CDT

Title: Optical Testing Protocol Results

Date: 03/25/2022

Content by: Bella

Present: Bella and Maya

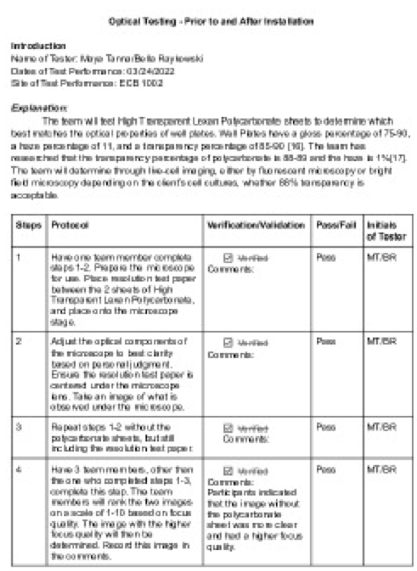
Goals: To complete the optical testing by taking images with and without the glass of our prototype

Content:

See attached file.

Conclusions/action items: Now we must analyze these images using ImageJ in order to conclude whether or not there is a significant difference between the quality of the image taken with the class compared to without. This will determine whether our glass sheet interferes with the optics of the microscope.

Bella Raykowski - May 03, 2022, 12:56 PM CDT



Optical Testing - Prior to and After Installation

Introduction
Name of Tester: Maya Tanna/Bella Raykowski
Dates of Test Performance: 03/24/2022
Site of Test Performance: ECB 1002

Explanation:
The team will test High Transparent Lexan Polycarbonate sheets to determine which best matches the optical properties of well plates. Well Plates have a gloss percentage of 75-90, a haze percentage of 11, and a transparency percentage of 85-90 [16]. The team has researched that the transparency percentage of polycarbonate is 88-89 and the haze is 1%[17]. The team will determine through live-cell imaging, either by fluorescent microscopy or bright field microscopy depending on the client's cell cultures, whether 88% transparency is acceptable.

Steps	Protocol	Verification/Validation	Pass/Fail	Initials of Tester
1	Have one team member complete steps 1-2. Prepare the microscope for use. Place resolution test paper between the 2 sheets of High Transparent Lexan Polycarbonate, and place onto the microscope stage.	☑ Verified Comments:	Pass	MT/BR
2	Adjust the optical components of the microscope to best clarity based on personal judgment. Ensure the resolution test paper is centered under the microscope lens. Take an image of what is observed under the microscope.	☑ Verified Comments:	Pass	MT/BR
3	Repeat steps 1-2 without the polycarbonate sheets, but still including the resolution test paper.	☑ Verified Comments:	Pass	MT/BR
4	Have 3 team members, other than the one who completed steps 1-3, complete this step. The team members will rank the two images on a scale of 1-10 based on focus quality. The image with the higher focus quality will then be determined. Record this image in the comments.	☑ Verified Comments: Participants indicated that the image without the polycarbonate sheet was more clear and had a higher focus quality.	Pass	MT/BR

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Maya_Bella_Optical_Testing_-_Google_Docs.pdf (67.4 kB)

3/25/2022 Optical Testing Images

Bella Raykowski - May 03, 2022, 1:04 PM CDT

Title: Optical Testing Images

Date: 03/24/2022

Content by: Bella

Present: Bella and Maya

Goals: To document the images taken by the microscope to for optical testing

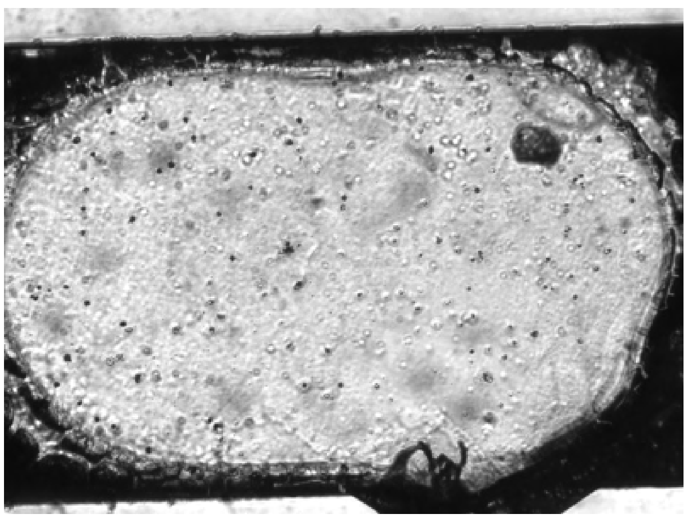
Content:

Bella took the images and Maya will analyze them using ImageJ

See attached files.

Conclusions/action items: Next is to analyze the images using ImageJ and conclude whether or not the glass impacts the microscope focus quality.

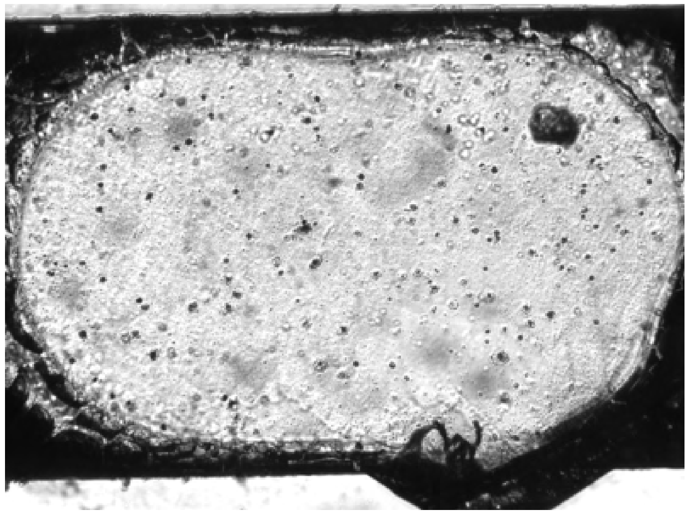
Bella Raykowski - May 03, 2022, 1:05 PM CDT



Download

test_2_with_glass.jpg (777 kB)

Bella Raykowski - May 03, 2022, 1:05 PM CDT



Download

test_2_without_glass.jpg (824 kB)

Bella Raykowski - May 03, 2022, 1:05 PM CDT

Download

test_with_sheet.jpg (178 kB)

Bella Raykowski - May 03, 2022, 1:05 PM CDT

Download

test_without_sheet.jpg (190 kB)

4/26/2022 Recovery Testing

Bella Raykowski - May 03, 2022, 2:38 PM CDT

Title: Recovery Testing Results

Date: 04/26/2022

Content by: Bella, Maya, Katie

Present: Whole Team

Goals: To record the results from recovery testing (minus CO2)

Content:

See attached file.

Conclusions/action items: Using this data we can now generate graphs and figures for our final deliverables in order to show how temperature and humidity recover after the box has been opened. We found that it will take about 3 minutes for the box to return to the desired conditions.

Bella Raykowski - May 03, 2022, 2:39 PM CDT

Recovery Test Protocol Test 1

Introduction
Name of Tester: Maya & Katie
Dates of Test Performance: 04/26/2022
Site of Test Performance: ECB 1002

Explanation:
The team will test the recovery time of the incubator after it has been opened by timing how long it takes for the incubator to return to performance conditions (37°C, 5% CO_2, and >95% humidity). The maximum recovery time should not exceed five minutes after a 30 second exposure to the external environment.

Steps	Protocol	Verification/Validation	Pass/Fail	Tester Initials
1	Set up the incubator for normal use. Record internal conditions in the comments and verify that they fall within the correct ranges (37°C, 5% CO_2, and >95% humidity).	☑ Verified Comments: 37.07 C, 97.27%	Pass	KD/MT
2	Open the incubator for 30 seconds. Start stopwatch. Verify that the stopwatch is working.	☑ Verified Comments:	Pass	KD/MT
3	Record internal conditions in the comments at a time of 15 seconds after opening the incubator. Verify that the internal conditions deviate from the normal conditions recorded above.	☑ Verified Comments: 32.77 C, 100%	Pass	KD/MT
4	Close the incubator. Verify that the recovery time did not exceed 5 minutes after a 30 second exposure to the external environment. Record the time it took to revert back to optimal conditions in the comments.	☑ Verified Comments: It took a little over 3 min to recover from the temperature and humidity.	Pass	KD/MT

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Maya_Katie_Bella_Recovery_Testing_-_Google_Docs.pdf (77.4 kB)

5/3/2022 Cell Culture Protocol

Bella Raykowski - May 03, 2022, 12:40 PM CDT

Title: Cell Culture protocol

Date: 05/03/2022

Content by: Bella

Present: Bella

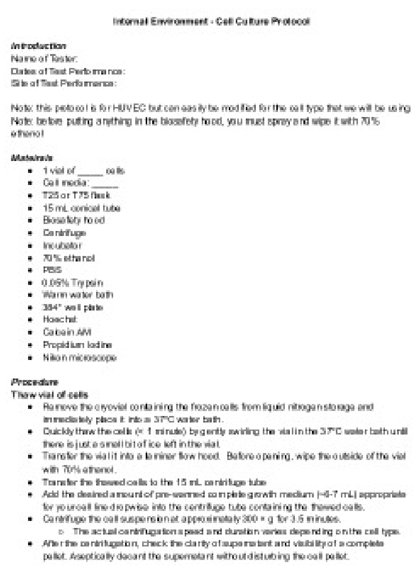
Goals: To create a preliminary protocol for how to culture cells for next semester

Content:

See attached file.

Conclusions/action items: Begin cell testing wherever possible next semester. Help other areas of the project so they can get to the testing stage and then lead that. We will need to discuss with Dr. P what types of cells we will be using, the type of media they need, what size well plate, and if the 3 stains I have listed will work/can we get them.

Bella Raykowski - May 03, 2022, 12:41 PM CDT



Internal Environment - Cell Culture Protocol

Introduction
Name of Tester:
Dates of Test Performance:
Site of Test Performance:

Note: this protocol is for HUVEC but can easily be modified for the cell type that we will be using
Note: before putting anything in the biosafety hood, you must spray and wipe it with 70% ethanol

Materials

- 1 vial of _____ cells
- Cell media: _____
- T25 or T75 flask
- 15 mL conical tube
- Biosafety hood
- Centrifuge
- Incubator
- 70% ethanol
- PBS
- 0.05% Trypsin
- Warm water bath
- 384* well plate
- Hoechst
- Calcein AM
- Propidium Iodine
- Nikon microscope

Procedure
Thaw vial of cells

- Remove the cryovial containing the frozen cells from liquid nitrogen storage and immediately place it into a 37°C water bath.
- Quickly thaw the cells (< 1 minute) by gently swirling the vial in the 37°C water bath until there is just a small bit of ice left in the vial.
- Transfer the vial it into a laminar flow hood. Before opening, wipe the outside of the vial with 70% ethanol.
- Transfer the thawed cells to the 15 mL centrifuge tube
- Add the desired amount of pre-warmed complete growth medium (~6-7 mL) appropriate for your cell line dropwise into the centrifuge tube containing the thawed cells.
- Centrifuge the cell suspension at approximately 300 × g for 3.5 minutes.
  - The actual centrifugation speed and duration varies depending on the cell type.
- After the centrifugation, check the clarity of supernatant and visibility of a complete pellet. Aseptically decant the supernatant without disturbing the cell pellet.

[Download](#)

Cell_Culture_Protocol_-_Google_Docs.pdf (80.8 kB)

5/3/2022 Cell Staining Testing Protocol

Bella Raykowski - May 03, 2022, 12:44 PM CDT

Title: Cell Staining Testing Protocol Template

Date: 05/03/2022

Content by: Bella

Present: Bella

Goals: To create a preliminary testing protocol about how to test the cell viability of our prototype vs the standard incubator

Content:

See attached file.

Conclusions/action items: Begin testing wherever possible next semester. We will need to talk to Dr. P about being able to get the dyes I have mentioned and whether they will be included in the $100 project budget. If not I may be able to get a small sample from my lab since we do this type of staining often. This test will require someone to go into the lab every day and change the media, stain a well, and image the cells.

Bella Raykowski - May 03, 2022, 12:44 PM CDT

Internal Environment - Temperature and Humidity Sensor Test Protocol

Introduction
Name of Tester:
Dates of Test Performance:
Site of Test Performance:

Explanation:
The team will be employing 3 stains in order to quantify the live vs dead cells in order to determine if the prototype can maintain cell viability compared to a standard incubator. The images of the cells will be taken using the Nikon scope in the teaching lab. The control will be the well plate that is cultured in the standard incubator in order to provide a base line on appropriate cell death over the course of a week. Another well plate will be cultured inside the prototype at the same time as the control over the course of a week. Hoechst, calcein AM, and propidium iodine (PI) will be used to 1-2 wells each day to stain the nuclei, live cells, and dead cells respectively. Using image J, the team will be able to quantify the ratio of live to dead cells in order to compare the 2 plates and track cell death over the course of the week. Tests will be considered successful if there is no significant difference between the live to dead cell ratio between the control and the prototype.

Steps	Protocol	Verification/Validation	Pass/Fail	Initials of Tester
1	Day 0: viability stain 1 well from the control and the prototype	☐ Verified Comments:		
2	Day 1: viability stain 1 well from the control and the prototype	☐ Verified Comments:		
3	Day 2: viability stain 1 well from the control and the prototype	☐ Verified Comments:		
4	Day 3: viability stain 1 well from the control and the prototype	☐ Verified Comments:		
5	Day 4: viability stain 1 well from the control and the prototype	☐ Verified Comments:		
6	Day 5: viability stain 1 well from the control and the prototype	☐ Verified Comments:		
7	Day 6: viability stain 1 well from the control and the prototype	☐ Verified Comments:		

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Testing_Protocol_Cell_Viability_-_Google_Docs.pdf (60.5 kB)

5/3/2022 Full Testing Protocol (updated)

Bella Raykowski - May 03, 2022, 9:02 PM CDT

Title: Testing Protocol Template Revisions

Date: 05/03/2022

Content by: Bella

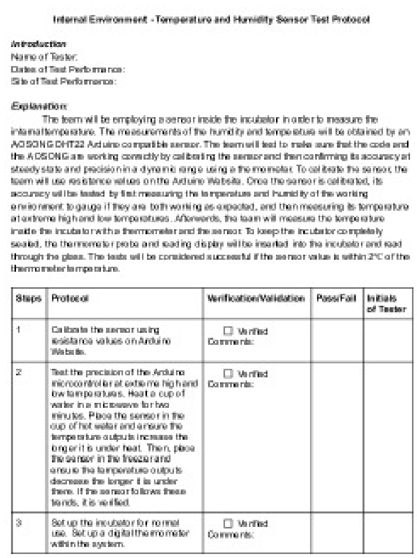
Goals: Update the testing protocol template in order to better reflect current and proposed tests

Content:

See attached file

Conclusions/action items: Continue testing wherever possible next semester and hopefully we will be able to do a week-long cell viability test.

Bella Raykowski - May 03, 2022, 9:03 PM CDT



Internal Environment - Temperature and Humidity Sensor Test Protocol

Introduction
Name of Tester:
Dates of Test Performance:
Site of Test Performance:

Explanation:
The team will be employing a sensor inside the incubator in order to measure the internal temperature. The measurements of the humidity and temperature will be obtained by an AOSONG DHT22 Arduino compatible sensor. The team will test to make sure that the code and the AOSONG are working correctly by calibrating the sensor and then confirming its accuracy at steady state and precision in a dynamic range using a thermometer. To calibrate the sensor, the team will use resistance values on the Arduino Website. Once the sensor is calibrated, its accuracy will be tested by first measuring the temperature and humidity of the working environment to gauge if they are both working as expected, and then measuring its temperature at extreme high and low temperatures. Afterwards, the team will measure the temperature inside the incubator with a thermometer and the sensor. To keep the incubator completely sealed, the thermometer probe and reading display will be inserted into the incubator and read through the glass. The tests will be considered successful if the sensor value is within 2°C of the thermometer temperature.

Steps	Protocol	Verification/Validation	Pass/Fail	Initials of Tester
1	Calibrate the sensor using resistance values on Arduino Website.	☐ Verified Comments:		
2	Test the precision of the Arduino microcontroller at extreme high and low temperatures. Heat a cup of water in a microwave for two minutes. Place the sensor in the cup of hot water and ensure the temperature outputs increase the longer it is under heat. Then, place the sensor in the freezer and ensure the temperature outputs decrease the longer it is under there. If the sensor follows these trends, it is verified.	☐ Verified Comments:		
3	Set up the incubator for normal use. Set up a digital thermometer within the system.	☐ Verified Comments:		

Download

Testing_Protocols_Template_-_Google_Docs.pdf (119 kB)

03/01/2022 Lab Training

Bella Raykowski - Mar 01, 2022, 8:04 PM CST

Title: Training Documentation

Date: 03/01/2022

Content by: Bella Raykowski

Goal: Show proof of documentation of any lab training

Content:

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

This certifies that Bella Raykowski has completed training for the following course(s):

Expand All Collapse All

Course	Assignment	Completion	Expiration
2020-21 HIPAA Privacy & Security Training	HIPAA Quiz	4/9/2021	
Biosafety 102: Bloodborne Pathogens for Laboratory and Research	Biosafety 102: Bloodborne Pathogens Safety in Research Quiz 2021	8/12/2021	
Biosafety Required Training	Biosafety Required Training Quiz	3/13/2021	

Data Last Imported: 03/01/2022 07:50 PM

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

This certifies that Bella Raykowski has completed training for the following course(s):

Expand All Collapse All

Course	Assignment	Completion	Expiration
Chemical Safety: The OSHA Lab Standard	Final Quiz	3/26/2021	
Good Clinical Practice for Drug/Device Researchers	Good Clinical Practice	9/3/2021	9/2/2024
UW Social & Behavioral Course	Basic/Refresher Course - Human Subjects	9/3/2021	9/2/2024

Data Last Imported: 03/01/2022 07:50 PM

Conclusion: I have completed training for HIPPA Privacy and Security Training, Biosafety 102, Biosafety Required Training, Chemical Safety, Good Clinical Practice for Drub/Device Researchers, UW Social and Behavioral Course

03/18/2022 WARF Lecture

Bella Raykowski - Mar 20, 2022, 8:43 PM CDT

Title: WARF Lecture

Date: 3/18/2022

Content by: Bella Raykowski

Goal: Understand patents and how my design project could be taken on as a patent in the WARF portfolio

Content:

Beginnings:

- WARF was founded in 1925 by Dr. Steenbock in order to help manage and patent intellectual property

- is separate from the university but has proceeds go towards research at the university

- the patent process can cost around $30,000 years and take between 3-5 years, WARF takes on these costs

Vision:

- allow for research to help solve the problems of the world and to support this research financially and move products to market

Protecting innovation:

- patents: covers machines, devices, compounds, processes, and methods

- trademarks: covers words, colors, pictures, logos, sound

- copyrights: covers literature, webpages, and software programs

- trade secrets: hardest to cover and once the secret is out there there is no protection

Prior art:

- anything that could pertain to your invention that has been released before a patent

- for the researcher, this is any presentations or papers that occurred more than a year before filling

- for anything else, this is anything released before the filling date

- must keep this in mind when presenting any inventions or discoveries before the filling has occurred

Requirements of patentability:

- eligible, useful, enabled, described, novel, non-obvious

- the patent office then examines the claim in order to ensure it meets each of the requirements

Licensing considerations:

- chance of licensing: can be impacted by the potential applications, tech benefits, and the current state of the market

- timeline: where is the current technology in its timeline (how developed is it), the patent status, and what level priority is it to WARF

- strategy: which companies would want this tech and do you make the licensing exclusive

- plan for the next year: how is the tech going to develop in the near future and what is the marketing going to be

- revenue: what is the royalty projections and the patent reimbursement

Start-up considerations:

- is the tech enough to start its own company or can it not stand alone (ex: MRI machine code)

- is there a big enough market to warrant a start-up

- how will people management occur/hiring

Conclusion: Knowing about patents and what WARF can do for us student innovators is important because then we are aware of where these design projects could lead to. It is also important when you are working on a longer-term design project to be aware of the idea of the prior art may cause issues for patents in the future. The designs we make in this class are our intellectual property and for our projects specifically, it has the potential to be patent since there are no low-cost microscope incubators on the market. However, this project has been worked on over numerous semesters which means there is a lot of prior art working against us.

2014/11/03-Entry guidelines

John Puccinelli - Sep 05, 2016, 1:18 PM CDT

Use this as a guide for every entry

- Every text entry of your notebook should have the **bold titles** below.
- Every page/entry should be **named starting with the date** of the entry's first creation/activity, subsequent material from future dates can be added later.

You can create a copy of the blank template by first opening the desired folder, clicking on "New", selecting "Copy Existing Page...", and then select "2014/11/03-Template")

Title: Descriptive title (i.e. Client Meeting)

Date: 9/5/2016

Content by: The one person who wrote the content

Present: Names of those present if more than just you (not necessary for individual work)

Goals: Establish clear goals for all text entries (meetings, individual work, etc.).

Content:

Contains clear and organized notes (also includes any references used)

Conclusions/action items:

Recap only the most significant findings and/or action items resulting from the entry.

2014/11/03-Template

John Puccinelli - Nov 03, 2014, 3:20 PM CST

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items: