BME Design-Spring 2023 - SAMUEL BARDWELL
Complete Notebook

PDF Version generated by

MAYA TANNA

on

May 02, 2023 @09:41 AM CDT

Table of Contents

Team contact Information

SAMUEL BARDWELL - Feb 01, 2023, 10:15 AM CST

Last Name	First Name	Role	E-mail	Phone	Office Room/Building
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Project description & PDS

SAMUEL BARDWELL - Feb 01, 2023, 10:17 AM CST

Course Number: BME 402

Project Name: Microscope Cell Culture 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 Department 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 coordinators, instructors and advises the design curriculum at UW-Madison.

SAMUEL BARDWELL - Apr 27, 2023, 2:38 PM CDT

Download

Product_Design_Specifications_Spring_2023.pdf (229 kB)

2/6/23 Client Meeting

SAMUEL BARDWELL - Feb 06, 2023, 11:27 AM CST

Title: Client Meeting

Date: 2/6/23

Present: Sam & Drew

Goals: To discuss semester plans with the client.

Content:

Expense Sheet

- Dr. P had some materials from the expense sheet and had ideas for cheaper versions
- Is aware of the expense sheet

Cells

- Incubator still not on

Incubator lid thoughts

- I2O glass in the chem building
- Maybe have conductive tape and solder wires to heat up the glass

More money for fabrication of another box?

- Yes this is doable

Conclusions/action items:

Need to figure out how to heat up the glass to reduce condensation. Dr. P wants to have the possibility of using time-lapses so condensation is still an issue.

1/27/2023 Advisor Meeting #1

MAYA TANNA - Jan 29, 2023, 12:03 PM CST

Title: Advisor Meeting #1

Date: 1/27/2023

Content by: Katie/Maya

Present: Whole Team

Goals: To document notes and plans from the meeting with Dr. Nimunkar

Content: See attachment.

Conclusions/action items: Use the schedule/plan to stay on top of important deadlines and make sure testing is consistent and troubleshooting occurs throughout the semester.

MAYA TANNA - Jan 29, 2023, 12:03 PM CST

Download

Advisor_Meeting_Notes_1_27.pdf (47.3 kB)

2/3/2023 Advisor Meeting #2

MAYA TANNA - Feb 03, 2023, 3:28 PM CST

Title: Advisor Meeting #2

Date: 2/2/2023

Content by: Maya

Present: Whole Team

Goals: To document notes and plans from the meeting with Dr. Nimunkar

Content: See attachment.

Conclusions/action items: Use the schedule/plan to stay on top of important deadlines and make sure testing is consistent and troubleshooting occurs throughout the semester.

MAYA TANNA - Feb 03, 2023, 3:28 PM CST

Download

Advisor_Meeting_2_3.pdf (39.5 kB)

2/10/2023 Advisor Meeting #3

MAYA TANNA - Feb 11, 2023, 1:39 PM CST

Title: Advisor Meeting #3

Date: 2/10/2023

Content by: Maya

Present: Whole Team

Goals: To document notes and plans from the meeting with Dr. Nimunkar

Content: See attachment.

Conclusions/action items: Use the schedule/plan to stay on top of important deadlines and make sure testing is consistent and troubleshooting occurs throughout the semester.

MAYA TANNA - Feb 11, 2023, 1:39 PM CST

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Advisor_Meeting_Notes_2_10.pdf (40.1 kB)

2/20/2023 Advisor Meeting #4

MAYA TANNA - Feb 20, 2023, 7:32 PM CST

Title: Advisor Meeting #4

Date: 2/20/2023

Content by: Maya

Goals: To document results from advisor meeting with Dr. Nimunkar

Content:

See attachment below.

Conclusions/action items: Use these action items to allocate work for each person in the coming week.

MAYA TANNA - Feb 20, 2023, 7:33 PM CST

Download

Advisor_Meeting_Notes_2_20.pdf (42.6 kB)

2/27/2023 Advisor Meeting #5

MAYA TANNA - Feb 27, 2023, 8:09 PM CST

Title: Advisor Meeting #5

Date: 2/27/2023

Content by: Maya

Goals: To document results from advisor meeting with Dr. Nimunkar

Content:

See attachment below.

Conclusions/action items: Use these action items to allocate work for each person in the coming week.

MAYA TANNA - Feb 27, 2023, 8:09 PM CST

[Download](#)

Advisor_Meeting_Notes_2_27.pdf (40.9 kB)

3/7/2023 Advisor Meeting #6

MAYA TANNA - Mar 06, 2023, 6:39 PM CST

Title: Advisor Meeting #6

Date: 3/6/2023

Content by: Maya

Goals: To document results from advisor meeting with Dr. Nimunkar

Content:

See attachment below.

Conclusions/action items: Use these action items to allocate work for each person in the coming week.

MAYA TANNA - Mar 06, 2023, 6:40 PM CST

Download

Advisor_Meeting_Notes_3_6.pdf (39.3 kB)

3/10/2023 Advisor Meeting #7

MAYA TANNA - Mar 10, 2023, 12:35 PM CST

Title: Advisor Meeting #7

Date: 3/10/2023

Content by: Maya

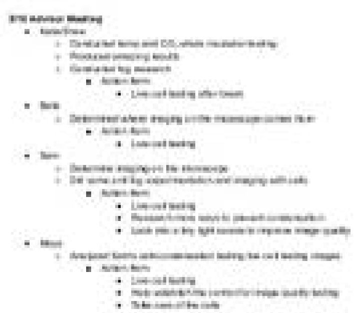
Goals: To document results from advisor meeting with Dr. Nimunkar

Content:

See attachment below.

Conclusions/action items: Use these action items to allocate work for each person in the coming week.

MAYA TANNA - Mar 10, 2023, 12:35 PM CST



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3_10_Advisor_Meeting.pdf (40.5 kB)

3/27/2023 Advisor Meeting #8

MAYA TANNA - Mar 27, 2023, 4:31 PM CDT

Title: Advisor Meeting #8

Date: 3/27/2023

Content by: Maya

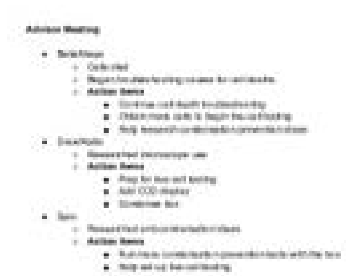
Goals: To document results from advisor meeting with Dr. Nimunkar

Content:

See attachment below.

Conclusions/action items: Use these action items to allocate work for each person in the coming week.

MAYA TANNA - Mar 27, 2023, 4:32 PM CDT



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3_27_Advisor_Meeting.pdf (38.4 kB)

4/3/2023 Advisor Meeting #9

MAYA TANNA - Apr 03, 2023, 7:19 PM CDT

Title: Advisor Meeting #9

Date: 4/3/2023

Content by: Maya

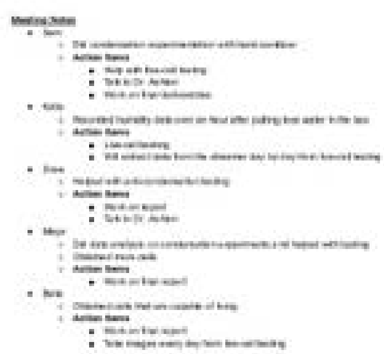
Goals: To document results from advisor meeting with Dr. Nimunkar

Content:

See attachment below.

Conclusions/action items: Use these action items to allocate work for each person in the coming week.

MAYA TANNA - Apr 03, 2023, 7:19 PM CDT



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Advisor_Meeting_Notes_4_3_23.pdf (39.4 kB)

4/10/2023 Advisor Meeting #10

MAYA TANNA - Apr 10, 2023, 4:30 PM CDT

Title: Advisor Meeting #10

Date: 4/10/2023

Content by: Maya

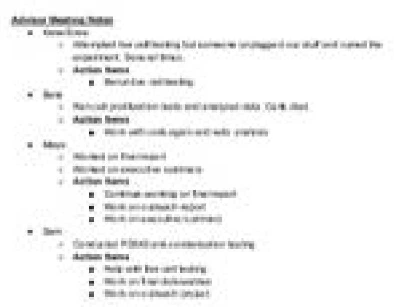
Goals: To document results from advisor meeting with Dr. Nimunkar

Content:

See attachment below.

Conclusions/action items: Use these action items to allocate work for each person in the coming week.

MAYA TANNA - Apr 10, 2023, 4:31 PM CDT



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Advisor_Meeting_4_10_23.pdf (40.2 kB)

4/17/2023 Advisor Meeting #11

MAYA TANNA - Apr 17, 2023, 4:56 PM CDT

Title: Advisor Meeting #11

Date: 4/17/2023

Content by: Maya

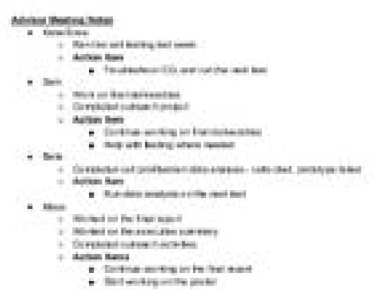
Goals: To document results from advisor meeting with Dr. Nimunkar

Content:

See attachment below.

Conclusions/action items: Use these action items to allocate work for each person in the coming week.

MAYA TANNA - Apr 17, 2023, 4:57 PM CDT



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Advisor_Meeting_4_17.pdf (40.2 kB)

4/21/2023 Advisor Meeting #12

MAYA TANNA - Apr 21, 2023, 12:36 PM CDT

Title: Advisor Meeting #12

Date: 4/21/2023

Content by: Maya

Goals: To document results from advisor meeting with Dr. Nimunkar

Content:

See attachment below.

Conclusions/action items: Use these action items to allocate work for each person in the coming week.

MAYA TANNA - Apr 21, 2023, 12:36 PM CDT

Download

4_21_Advisor_Meeting_Notes.pdf (39.4 kB)

2/2/23 Progress Report 1

Drew Hardwick - May 01, 2023, 4:32 PM CDT


Microscope Cell Incubator

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

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cell_incubator-progress_report_1.pdf (81.4 kB)

2/9/23 Progress Report 2

Drew Hardwick - May 01, 2023, 4:32 PM CDT

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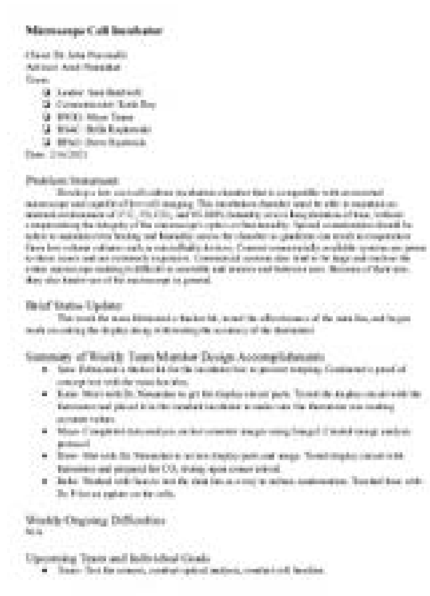
cell_incubator-progress_report_2.pdf (82.1 kB)

2/16/23 Progress Report 3

Drew Hardwick - May 01, 2023, 4:33 PM CDT



Microscope Cell Incubator

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

Weekly/Ongoing Difficulties

Upcoming Team and Individual Goals

Download

cell_incubator-progress_report_3.pdf (80.4 kB)

2/23/23 Progress Report 4

Drew Hardwick - May 01, 2023, 4:36 PM CDT


Microscope Cell Incubator

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

Weekly Ongoing Difficulties

Download

cell_incubator-progress_report_4.pdf (86 kB)

3/2/23 Progress Report 5

Drew Hardwick - May 01, 2023, 4:36 PM CDT

Microscope Cell Incubator

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

Weekly/Ongoing Difficulties

N/A

Upcoming Team and Individual Goals

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cell_incubator-progress_report_5.pdf (80 kB)

3/9/23 Progress Report 6

Drew Hardwick - May 01, 2023, 4:38 PM CDT

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cell_incubator-progress_report_6.pdf (80.1 kB)

3/23/23 Progress Report 7

Drew Hardwick - May 01, 2023, 4:38 PM CDT

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cell_incubator-progress_report_7.pdf (79.1 kB)

3/30/23 Progress Report 8

Drew Hardwick - May 01, 2023, 4:40 PM CDT

Microscope Cell Incubator

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

Weekly/Ongoing Difficulties

Upcoming Team and Individual Goals

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cell_incubator-progress_report_8.pdf (80.3 kB)

4/6/23 Progress Report 9

Drew Hardwick - May 01, 2023, 4:43 PM CDT

Microscope Cell Incubator

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

Weekly/Ongoing Difficulties

Upcoming Team and Individual Goals

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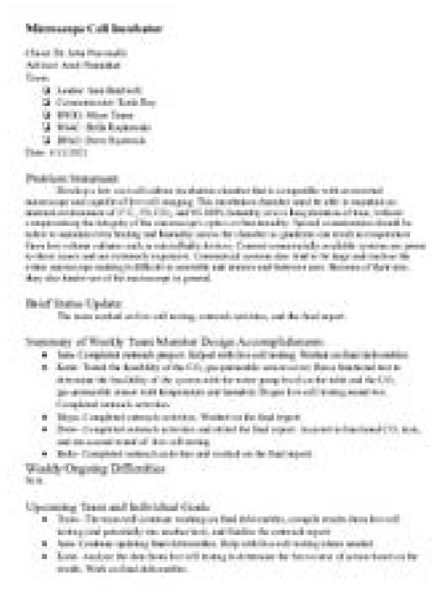
cell_incubator-progress_report_9.pdf (79.8 kB)

4/13/23 Progress Report 10

Drew Hardwick - May 01, 2023, 4:44 PM CDT

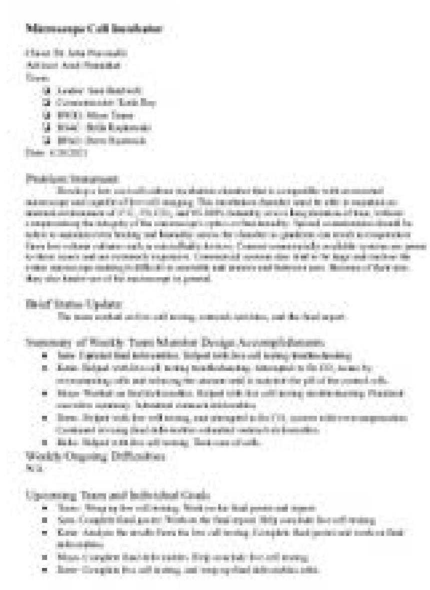


Download

cell_incubator-progress_report_10.pdf (79.6 kB)

4/20/23 Progress Report 11

Drew Hardwick - May 01, 2023, 4:46 PM CDT



Microscope Cell Incubator

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

Weekly Ongoing Difficulties

N/A

Upcoming Team and Individual Goals

[Download](#)

cell_incubator-progress_report_11.pdf (78.8 kB)

4/27/23 Progress Report 12

Drew Hardwick - May 01, 2023, 4:46 PM CDT


Microscope Cell Incubator

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

Weekly/Ongoing Difficulties

N/a

Upcoming Team and Individual Goals

Download

cell_incubator-progress_report_12.pdf (77.3 kB)

2/1/23 - CO2 Redesign

Drew Hardwick - Feb 01, 2023, 1:57 PM CST

Title: CO2 Redesign

Date: 2/1/23

Content by: Drew

Present: Drew and Katie

Goals: Meet with Dr. Nimunkar to go over our CO2 regulatory system

Content:

- Reviewed Data sheets for sandbox NDIR MH-Z16 CO2 sensor and determined viability of sensor
    - Data Sheet: https://sandboxelectronics.com/wp-content/uploads/2018/08/Z16DS.pdf
    - After reviewing data sheet we determined that the AnalogRead() function should be sufficient in our case, and we should not have to establish I2C as previously thought!!!!!
- Refined Current CO2 sensing code, and then tested withe Multimeter to ensure sensor was reading in atmosphere which it was (0ppm)
    - This makes sense since ppm reading is set to integers, so very hard to make atmosphere of entire room reach 1ppm CO2
- Next we moved on to looking at Beefcake Relay and Solenoid Valve.
- Tested Solenoid on Multimeter and wall outlet to ensure required 12V being supplied, which it was for both
- We then connected the entire system and took a look at the Arduino code
    - For some reason, our code last semester was out of order, and simple changes and suggestions from a more experienced microcontroller user like Dr. Nimunkar was greatly helpful.
- Our System finally works all from 1 microcontroller, and if statement should be able to me modified to be adaptive to incubator environment
- Katie and I went back to lab to fiddle with If statement after our meeting with Dr. Nimunkar concluded
- We determined that even after blowing direct CO2 from the tank/solenoid on the NDIR sensor, sensor communication error is what resulted
- We believe that we need to purchase a new NDIR MH-Z16 sensor to avoid this and continue with accurate CO2 regulation
    - Current sensor is AT LEAST 2-3 years (maybe more) old, and it has been used by our team and other teams in the past
    - Its inaccuracy is likely a signal it is time for replacement
    - We will buy the exact same sensor that we currently have, just a newer model.
- Link for new NDIR sensor (~$70): https://sandboxelectronics.com/?product=mh-z16-ndir-co2-sensor-with-i2cuart-5v3-3v-interface-for-arduinoraspeberry-pi

Conclusions/action items:

- Order new NDIR, and test CO2 reading ASAP when it arrives

Katie Day - Feb 01, 2023, 2:24 PM CST

Download

Coding_Spring_2023.ino (1.24 kB)

2/6/2023 ESP8266 Coding

Katie Day - Feb 06, 2023, 5:22 PM CST

Title: ESP8266 Coding

Date: 2/6/2023

Content by: Katie Day

Present:

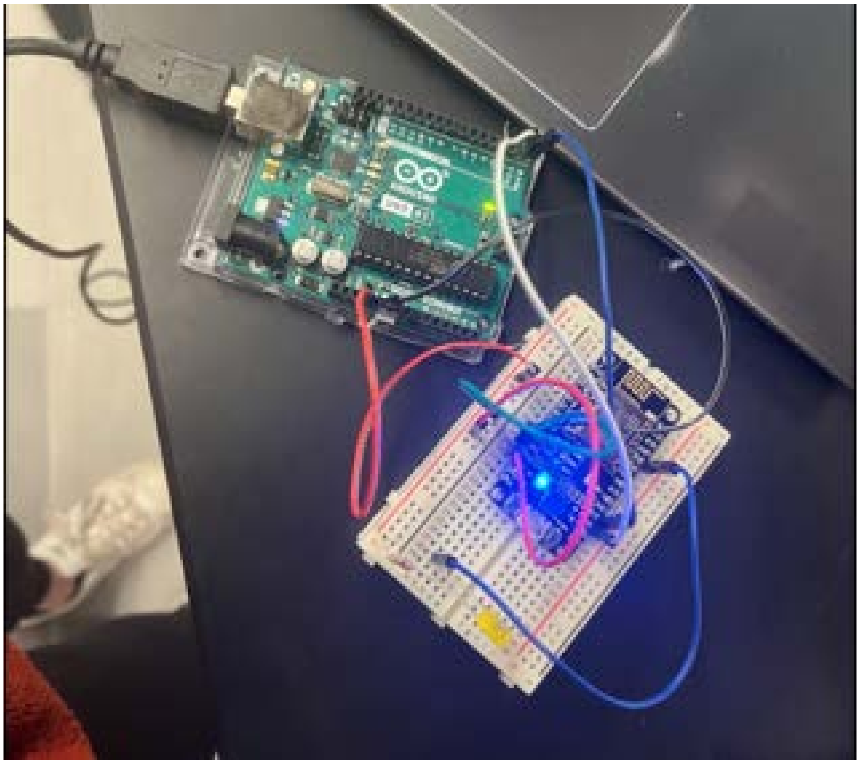
Goals: To try to code the ESP8266 so that it would transmit wifi.

Content:

I followed directions from this webpage: https://randomnerdtutorials.com/how-to-install-esp8266-board-arduino-ide/#:~:text=Install%20ESP8266%20Add%2Don%20in%20Arduino%20IDE&text=Open%20the%20Boards%20Manager.,installed%20after%20a%20few%20seconds.

It had a problem connecting just to the ESP when running a basic Blink Test Code for an LED. I'm not sure what I am doing wrong. Here is the error message.

esptool.py v3.0
Serial port COM4
Connecting........_____....._____....._____....._____....._____....._____.....____
_
A fatal esptool.py error occurred: Failed to connect to ESP8266: Timed out waiting for packet header



Conclusions/action items:

Book meeting with Dr. Nimunkar to see where I am going wrong.

2/17/23 - Display Fabrication/Coding

Katie Day - Feb 20, 2023, 5:14 PM CST

Title: Display Fabrication

Date: 2/15/23 & 2/17/23

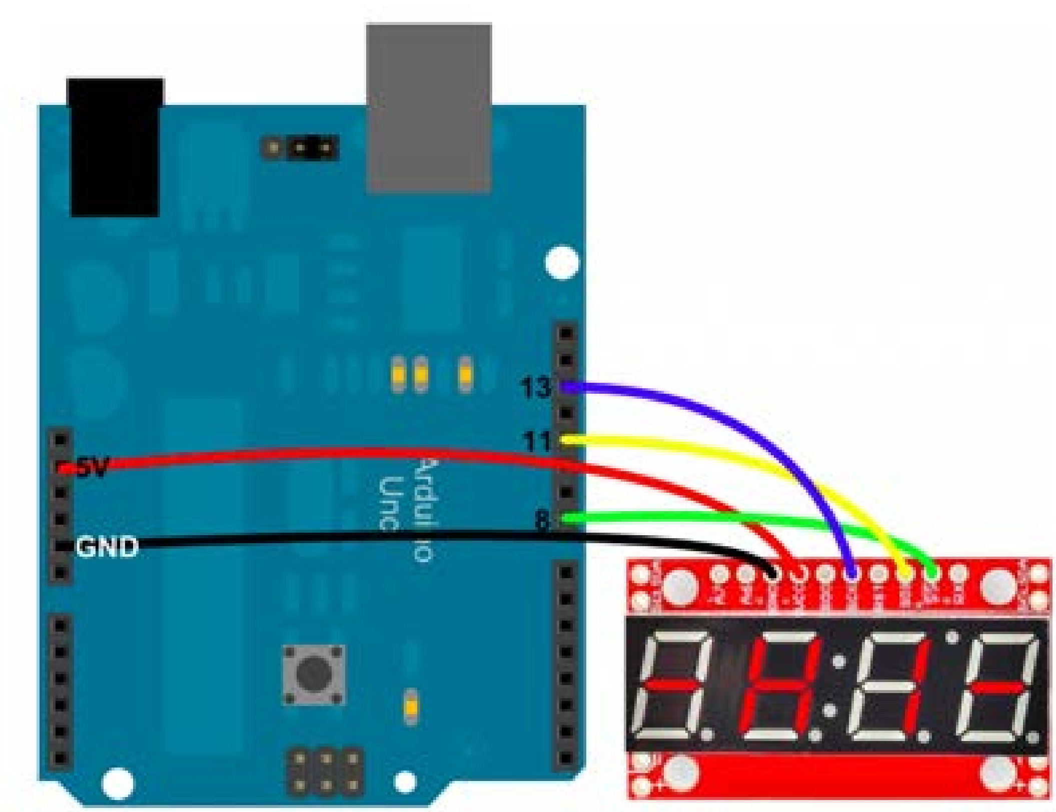
Content by: Katie Day, Drew Hardwick

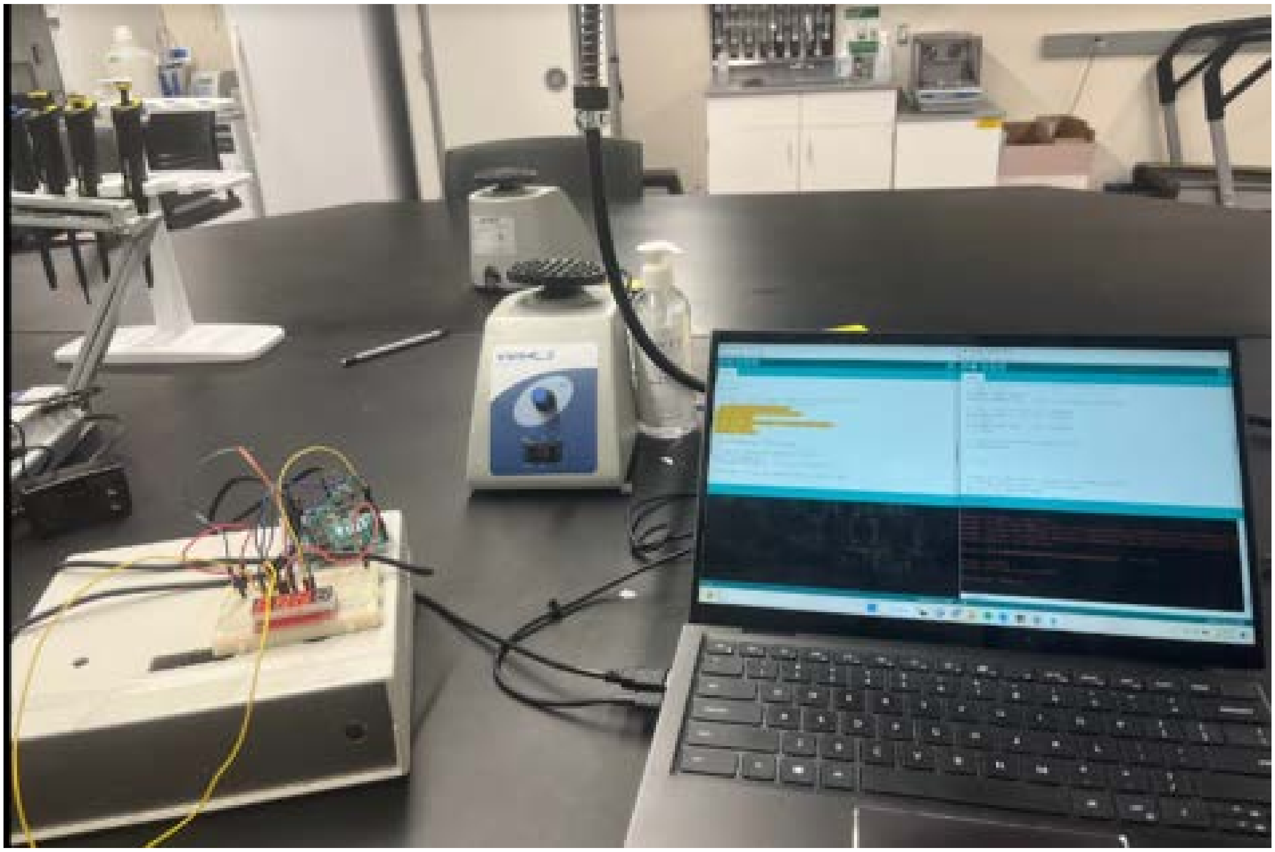
Present: Drew Hardwick, Katie Day

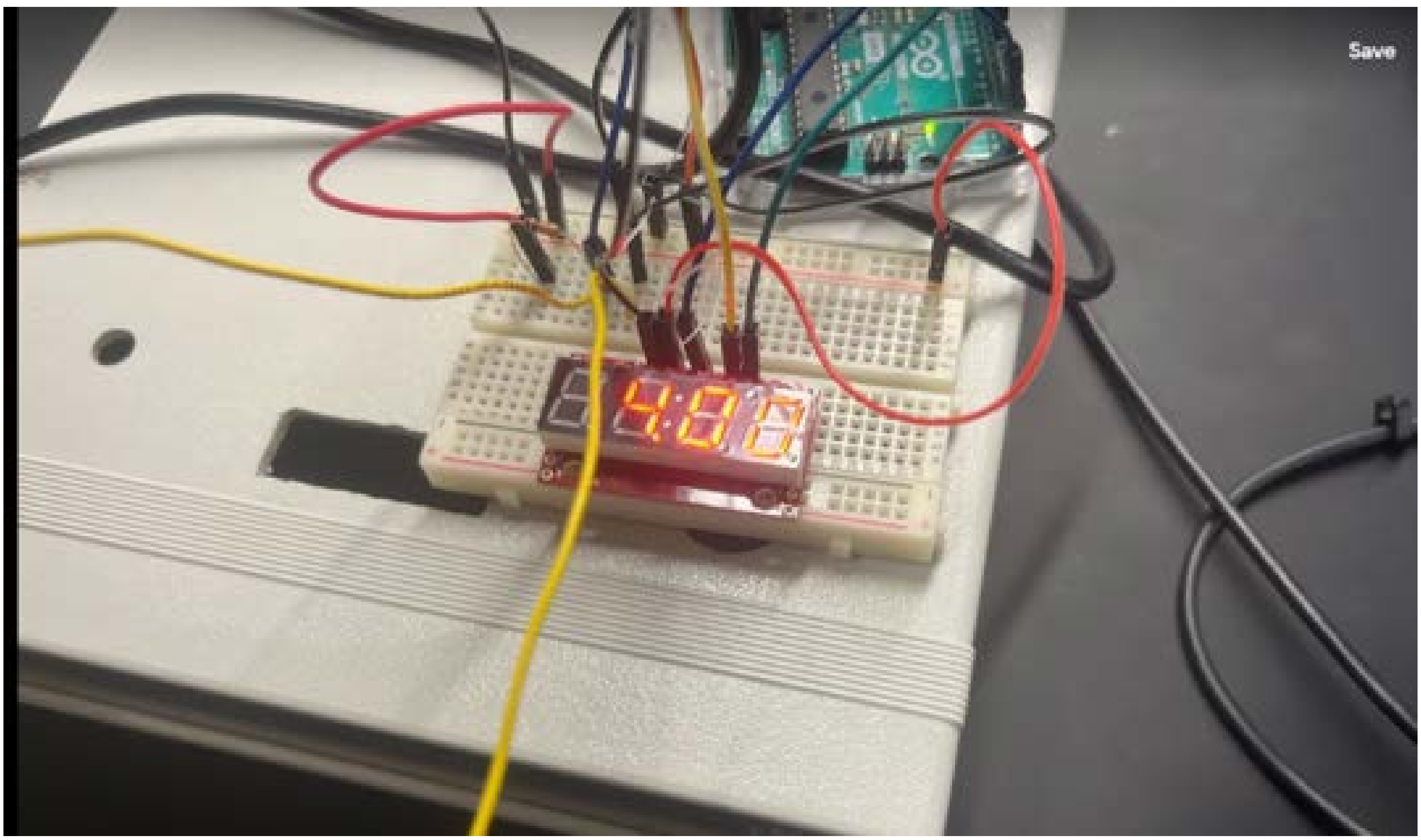
Goals: To code the display to show thermistor values.

Content:

Hardware Setup:







Code:

/* Serial 7-Segment Display Example Code
 SPI Mode Stopwatch
 by: Jim Lindblom
 SparkFun Electronics

```
  date: November 27, 2012
  license: This code is public domain.

  This example code shows how you could use the Arduino SPI
  library to interface with a Serial 7-Segment Display.

  There are example functions for setting the display's
  brightness, decimals and clearing the display.

  The SPI.transfer() function is used to send a byte of the
  SPI wires. Notice that each SPI transfer(s) is prefaced by
  writing the SS pin LOW and closed by writing it HIGH.

  Each of the custom functions handle the ssPin writes as well
  as the SPI.transfer()'s.

  There's a custom function used to send a sequence of bytes
  over SPI - s7sSendStringSPI, which can be used somewhat like
  the serial print statements.

  Circuit:
  Arduino -------------- Serial 7-Segment
    5V   --------------------  VCC
    GND  --------------------  GND
     8   --------------------  SS
    11   --------------------  SDI
    13   --------------------  SCK
*/
#include <SPI.h> // Include the Arduino SPI library

// Define the SS pin
//  This is the only pin we can move around to any available
//  digital pin.
const int ssPin = 8;

unsigned int counter = 0;  // This variable will count up to 65k
char tempString[10];  // Will be used with sprintf to create strings

//temp
int sensorPin = A0;    // select the input pin for the potentiometer
int ledPin = 13;      // select the pin for the LED
int sensorValue = 0;  // variable to store the value coming from the sensor
float volt_conversion = 5.0/1023.0;
float ADC_voltage = 0;
float K_temperature = 0;
float C_temp;
void setup()
{
  // -------- SPI initialization
  pinMode(ssPin, OUTPUT);  // Set the SS pin as an output
  digitalWrite(ssPin, HIGH);  // Set the SS pin HIGH
  SPI.begin();  // Begin SPI hardware
  SPI.setClockDivider(SPI_CLOCK_DIV64);  // Slow down SPI clock
  // --------

  // Clear the display, and then turn on all segments and decimals
  clearDisplaySPI();  // Clears display, resets cursor

  // Custom function to send four bytes via SPI
  //  The SPI.transfer function only allows sending of a single
  //  byte at a time.
  s7sSendStringSPI("DEGC");
  setDecimalsSPI(0b11111);  // Turn on all decimals, colon, apos

  // Flash brightness values at the beginning
  setBrightnessSPI(0);  // Lowest brightness
  delay(1500);
```

```
  setBrightnessSPI(255);  // High brightness
  delay(1500);

  // Clear the display before jumping into loop
  clearDisplaySPI();
}

void loop()
{

  // Magical sprintf creates a string for us to send to the s7s.
  //  The %4d option creates a 4-digit integer.
 // read the value from the sensor:
  sensorValue = analogRead(sensorPin);
  ADC_voltage = sensorValue * (volt_conversion);
  K_temperature = (ADC_voltage - 0.205) / 0.0153;
  C_temp = K_temperature - 91;
  counter = C_temp*100;
  sprintf(tempString, "%4d", counter);
  // This will output the tempString to the S7S
  s7sSendStringSPI(tempString);

  // Print the decimal at the proper spot
  if (counter < 10000)
    setDecimalsSPI(0b00000010);  // Sets digit 3 decimal on
  else
    setDecimalsSPI(0b00000100);

  counter++;  // Increment the counter
  delay(1000);  // This will make the display update at 100Hz.*/
}

// This custom function works somewhat like a serial.print.
//  You can send it an array of chars (string) and it'll print
//  the first 4 characters in the array.
void s7sSendStringSPI(String toSend)
{
  digitalWrite(ssPin, LOW);
  for (int i=0; i<4; i++)
  {
    SPI.transfer(toSend[i]);
  }
  digitalWrite(ssPin, HIGH);
}

// Send the clear display command (0x76)
//  This will clear the display and reset the cursor
void clearDisplaySPI()
{
  digitalWrite(ssPin, LOW);
  SPI.transfer(0x76);  // Clear display command
  digitalWrite(ssPin, HIGH);
}

// Set the displays brightness. Should receive byte with the value
//  to set the brightness to
//  dimmest------------->brightest
//     0--------127--------255
void setBrightnessSPI(byte value)
{
  digitalWrite(ssPin, LOW);
  SPI.transfer(0x7A);  // Set brightness command byte
  SPI.transfer(value);  // brightness data byte
  digitalWrite(ssPin, HIGH);
}
```

```
// Turn on any, none, or all of the decimals.
//  The six lowest bits in the decimals parameter sets a decimal
//  (or colon, or apostrophe) on or off. A 1 indicates on, 0 off.
//  [MSB] (X)(X)(Apos)(Colon)(Digit 4)(Digit 3)(Digit2)(Digit1)
void setDecimalsSPI(byte decimals)
{
  digitalWrite(ssPin, LOW);
  SPI.transfer(0x77);
  SPI.transfer(decimals);
  digitalWrite(ssPin, HIGH);
}
```

Conclusions/action items:

- Display was able to show the temperature values. Thermistor should be tested again for accuracy.

2/27/23 Fabrication of Display Box

Drew Hardwick - Feb 27, 2023, 1:55 PM CST

Title: Katie Day

Date: 2/27/2023

Content by: Katie Day

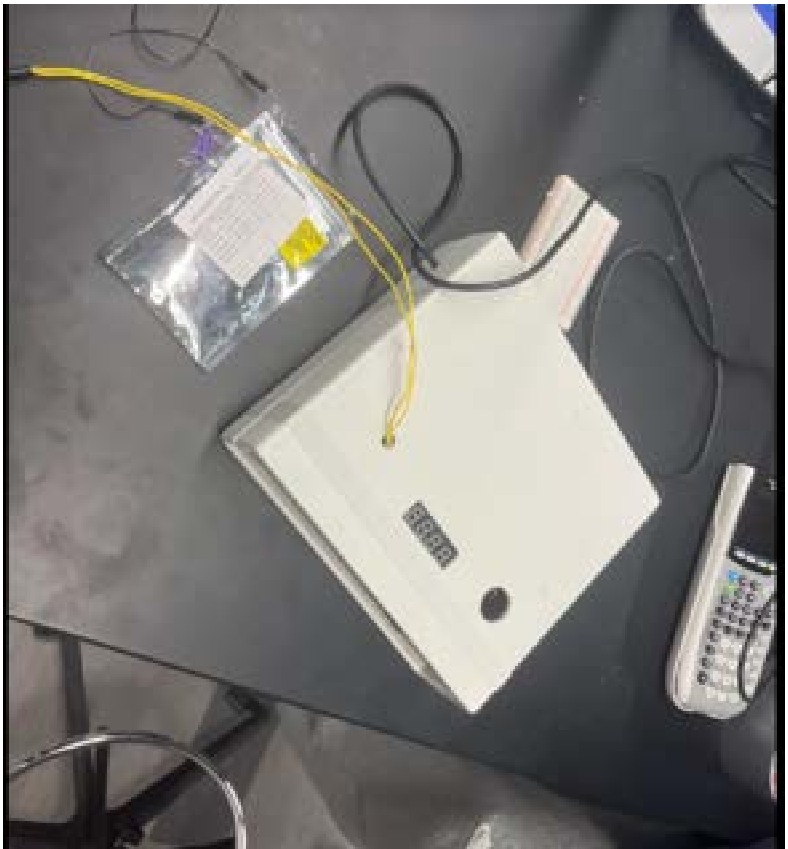
Present: Drew Hardwick

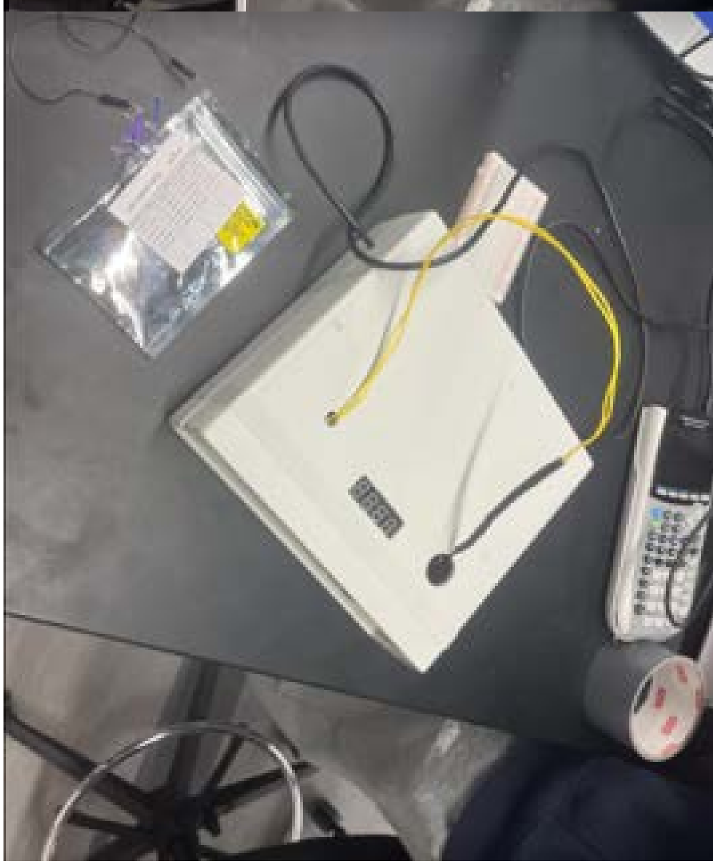
Goals: To put together all of our Arduino materials inside the box received from Dr. P.

Content:

Display for thermistor fits snuggly in box as shown below.

- wired were condensed and circuit was made as simple as possible



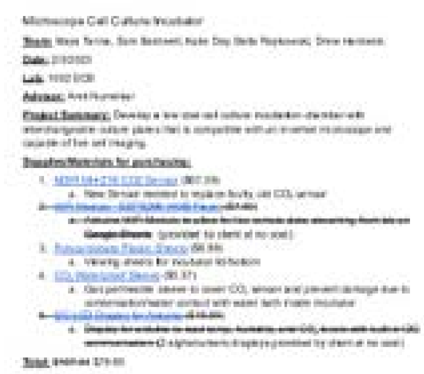


Conclusions/action items:

Looks much more professional. Saves time setting up materials. Need to test CO_2 sensor before putting it into the storage container, and once CO_2 regulation finalized, add entire circuit to box so only sensors and CO_2 input tube are visible - all wired, breadboards, valves, arduinos, relays etc are all housed out of sight within box interior.

Materials Purchasing Order #1

Drew Hardwick - Feb 08, 2023, 10:48 PM CST



Microscope Cell Culture Incubator

Team: [illegible]

Date: [illegible]

Lab: [illegible]

Advisor: [illegible]

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. [illegible] ([illegible])
   a. New Sensor needed to replace faulty old CO_2 sensor
2. ~~[illegible]~~
   a. ~~[illegible]~~ (provided to client at no cost)
3. [illegible] ([illegible])
   a. Viewing sheets for incubator [illegible]
4. CO_2 [illegible] ([illegible])
   a. Gas permeable sleeve to cover CO_2 sensor and prevent damage due to condensation/water contact with water bath inside incubator
5. ~~[illegible]~~
   a. ~~[illegible]~~ (provided by client at no cost)

Total: [illegible]

Download

Materials_Purchasing_Request_-_Spring_2023.pdf (50.9 kB)

Final Materials Log

Drew Hardwick - May 01, 2023, 4:49 PM CDT

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Final_Materials_Log.pdf (40.8 kB)

2/2/23 Newly Fabricated Incubator Box

SAMUEL BARDWELL - Feb 02, 2023, 3:44 PM CST

Title: Newly Fabricated Incubator Box

Date: 2/2/23

Content by: Sam

Goals: To fabricate a new incubator box that is more appealing to the eye and better functioning.

Content:

- The same SOLIDWORKS drawings were used to laser cut the black acrylic.

See Spring 2022 Notebook for SOLIDWORKS drawings

- The 2D print was put together with cement glue and then the inner cracks of the box were lined with silicone caulk to seal any gaps water could leak through.

- The copper piping was taken from the old incubator box and resoldered into this box. The copper piping holes were sealed with silicone caulk as well.

- The threaded adaptors for the heated water pump have a new layer of plumbers tape to add another sealant step.

- The incubator box was tested to see if it was water sealed and the test was successful. No water was leaking with a water bed and with the heated water pump turned on.

Figure 1: Ariel view of the newly fabricated incubator box connected to the heated water pump and contains a bed of water. No leakage.

Figure 2: Top view of the new incubator box showing the caulking and copper piping.

Figure 3: Side view of hose adaptors showing the new plumbers tape and caulk to prevent water leakage.

Conclusions/action items:

This new incubator box turned out very well. No lids were specifically fabricated for this design yet (the old lids will fit if needed) because we are unsure what type of material and what kind of lid is to be fabricated. Need to set up a meeting with Dr P to discuss future designs for the lid and condensation prevention. A disinfecting protocol needs to be made for each incubator box use to prevent mold.

2/8/23 Metal Lid Fabrication

SAMUEL BARDWELL - Feb 08, 2023, 11:10 AM CST

Title: Metal Lid Fabrication

Date: 2/8/23

Content by: Sam

Goals: To fabricate a partially metal lid in order to prevent warping of the lid while the incubator is running.

Content:

- The metal part of the lid is made from ~1/64" aluminum sheet metal. It was cut to the desired size with a sheet metal cutter in the TeamLab. The inner square was cut out by first using a drill to make a hole and then using metal shears to cut out the rest of the metal.

- A black acrylic bottom sheet was cut out on the laser cutter. This acrylic is to help with insulation of the incubator box because the aluminum would be a conductor of heat.

- The aluminum was also used because it should not corrode

- The aluminum sheet was glued to the black acrylic with cement glue and given time to dry.

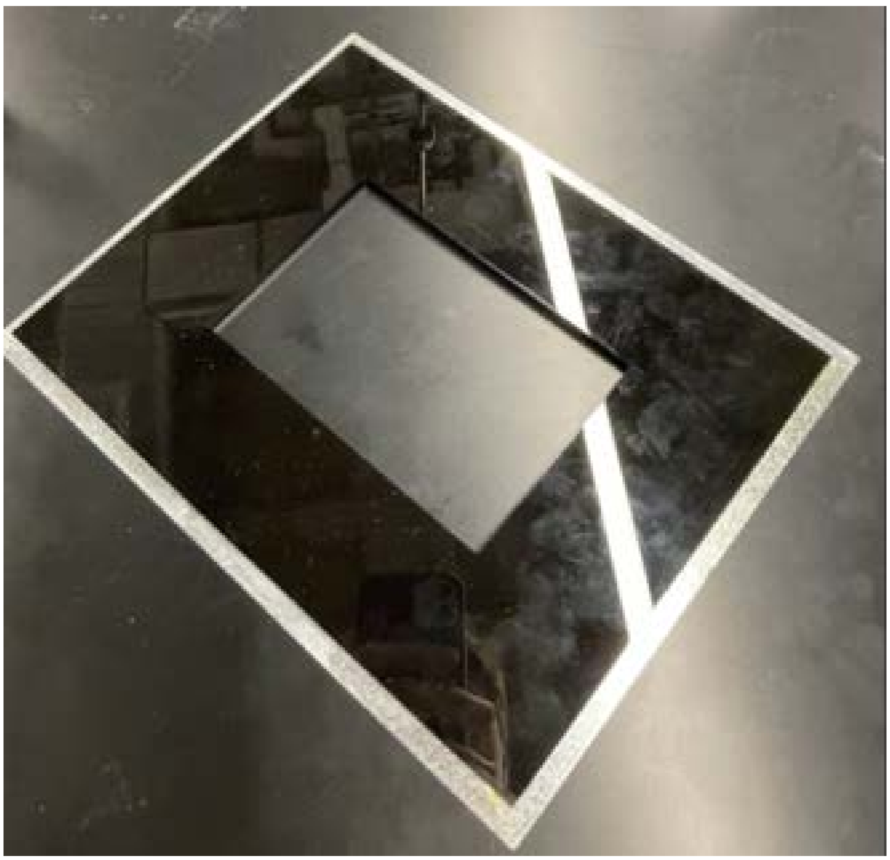

Figure 1: Bottom side of the metal lid

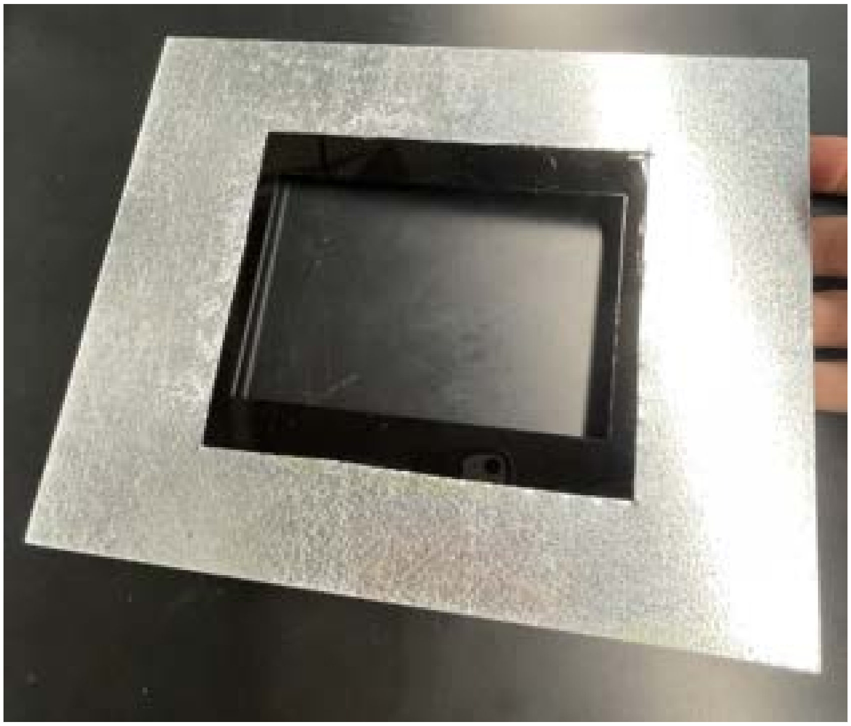

Figure 2: Top side of the metal lid.

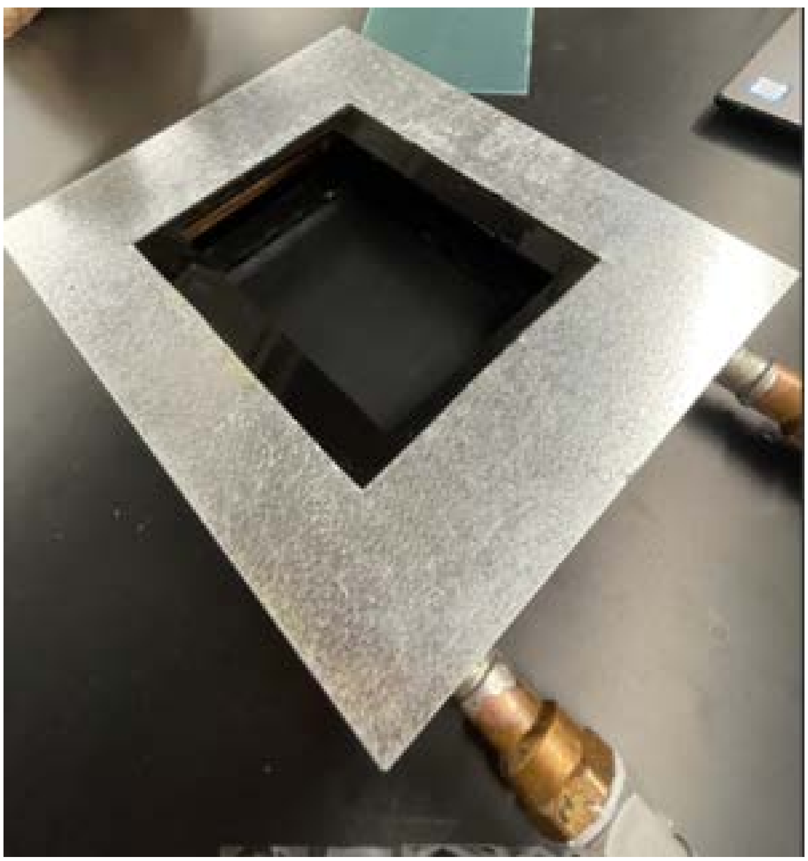

Figure 3: Metal lid placed on the new incubator box.

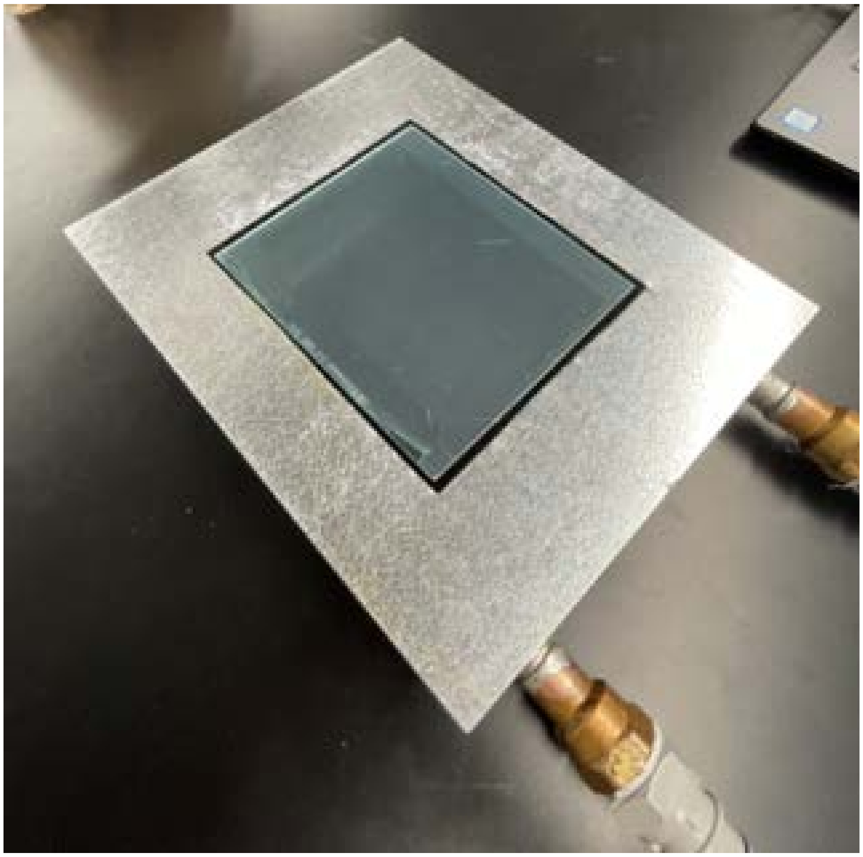

Figure 4: Metal lid on incubator box with a sheet of glass in the appropriate position.

Conclusions/action items:

The lid turned out looking pretty clean. A couple things I am worried about are if the reflective properties of the metal lid will cause any optical issues. This could be fixed by painting the metal to reduce its reflective properties. Another issue that may come into play is the metal being too thin. It is a little flimsy which may lead to it not doing what the original purpose of adding metal was, prevent warping and leaks. The cement glue used to glue the metal and acrylic together may not have been the appropriate glue to use. Can be changed to a two part epoxy from the TeamLab. Lastly, my next steps for the project are to figure out how to heat up the glass in order to prevent condensation build up. I ordered copper tape and am hoping to make a circuit similar to how rear window defrosters work in cars and I am worried that the aluminum sheet metal may cause shortage problems.

2/14/23 Thick Lid Fabrication

SAMUEL BARDWELL - Feb 14, 2023, 4:09 PM CST

Title: Thick Lid Fabrication

Date: 2/14/23

Content by: Sam

Goals: To fabricate a thicker lid so it will not warp when exposed to the incubator conditions.

Content:

- The thick lid was fabricated using the same SOLIDWORKS drawings and dimensions

- The bottom piece was fabricated using 1/8" Black Acrylic and cut on the laser cutter

Previously bought sheet of 1/8" black acrylic was used

- The top piece was fabricated using 1/4" Black Acrylic and cut on the laser cutter

A quarter sheet of 1/4" black acrylic was purchased for $10 at the UW Makerspace to cut this part of the lid

- Both pieces were glued together using the cement acrylic glue previously used.

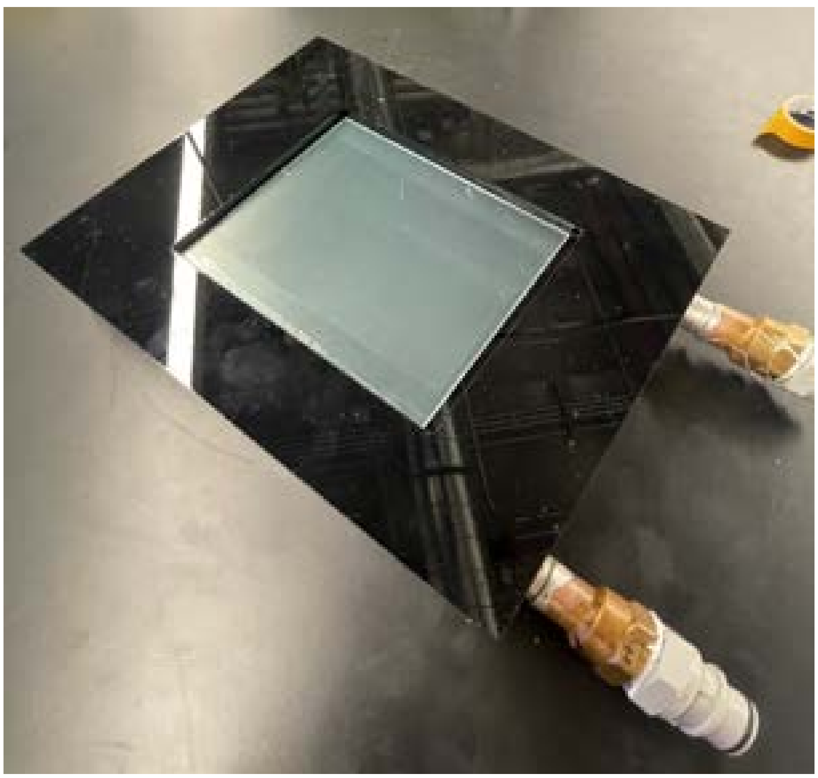

Figure 1: Top angle of thick lid fabrication showing its fit on the incubator and glass.

Figure 2: Top view of thick lid fabrication

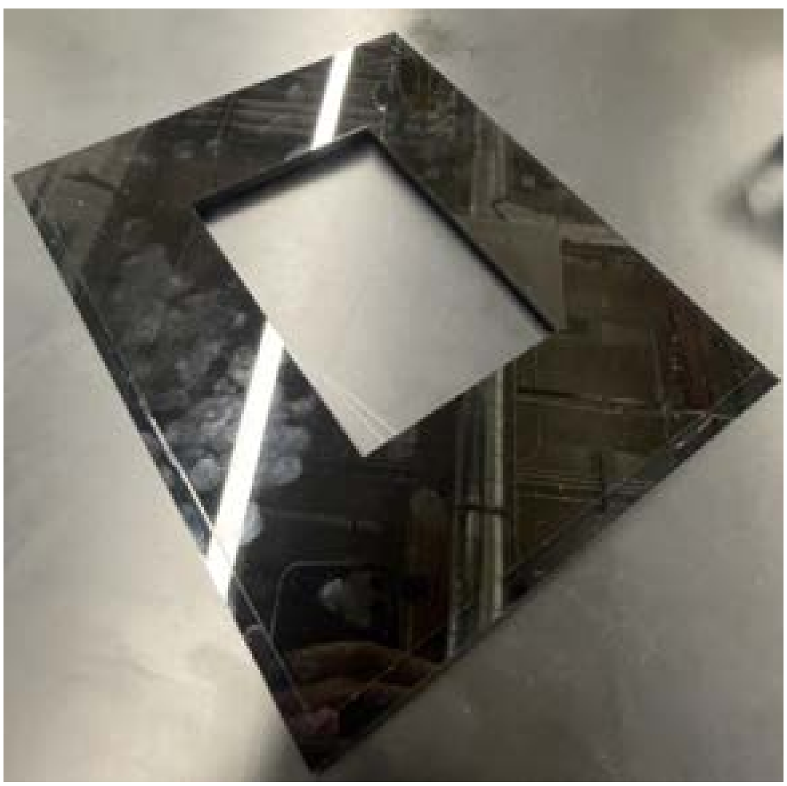

Figure 3: Bottom view of thick lid fabrication

Figure 4: Side view of thick lid fabrication showing the size and tight fit on the incubator box.

Conclusions/action items:

The thick lid turned out looking great. It functions the exact seem as the previously fabricated incubator lid in past semesters. This lid is slightly bigger on the top sheet to help prevent warping for when the lid is placed on the intense conditions of the incubator while turned on. This will be tested during live cell testing this semester to see if warping is reduced or discarded completely. Although the thicker lid may cause some height issues with the microscope, the idea that the glass is at the same height as the previous lid design makes me think there should be no new issues being presented.

02/06/23: Sanitation Protocol

Bella Raykowski - Feb 06, 2023, 4:43 PM CST

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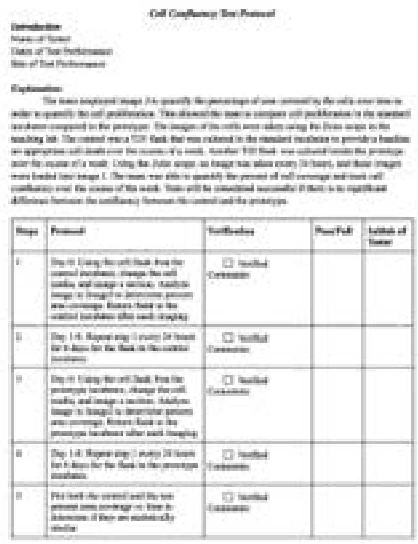
sanitation.pdf (278 kB)

02/06/23: Cell Confluency Protocol

Bella Raykowski - Feb 06, 2023, 4:58 PM CST



Cell Confluency Test Protocol

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

Explanation:
[illegible]

Steps	Protocol	Verification	Pass/Fail	Initials of Tester
1	[illegible]	☐ Verified Comments:		
2	[illegible]	☐ Verified Comments:		
3	[illegible]	☐ Verified Comments:		
4	[illegible]	☐ Verified Comments:		
5	[illegible]	☐ Verified Comments:		

[Download](#)

cell-confluency.pdf (328 kB)

05/01/23: ImageJ Analysis Protocol

Bella Raykowski - May 01, 2023, 4:36 PM CDT

ImageJ Percent Area Coverage Procedure

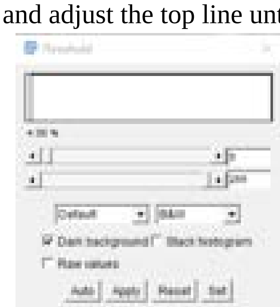
Introduction
Name of Tester:
Dates of Test Performance:
Site of Test Performance:

Explanation:

The team will be using ImageJ to analyze the images taken of the cells using the Zeiss microscope. ImageJ will calculate the percentage of surface area covered by the cells and from this, a trend line can be made that tracks the cell proliferation over the course of 5 days.

Procedure:

1. Take images of the cells, ideally in the same spot each time
2. Open ImageJ and open the file you just created (file type does not matter)
3. Image → Type → 8-bit; this will turn the image into an 8-bit greyscale
4. Process → Subtract Background; this will remove the background of the image making the cells more visible
    a. Adjust the rolling ball radius until the optimal contrast between the background and cells is achieved (somewhere between 60-150 pixels)
5. Process → Filters → Median; this will reduce noise and sharpen cell selection (a radius between 2 and 5 is usually acceptable)
6. Image → Adjust → Threshold; this will select only the cells
    a. Move the bottom line all the way to the right and adjust the top line until only the cells are white



7. Analyze → Set Measurements → Check Area Fraction; this will calculate the percentage area coverage of a selected image
8. Using the mouse to select the entire image, creating an ROI
9. Analyze → Tool → ROI Manager → Add → Click coordinates → Measure; this will provide you with an output box that has the percent area coverage calculated

05/01/23: Final Testing Protocols

MAYA TANNA - May 01, 2023, 8:24 PM CDT

Download

testing_protocols_final.pdf (162 kB)

2/15/23 + Edits Mini Fan Preliminary Testing

SAMUEL BARDWELL - Feb 23, 2023, 8:58 AM CST

Title: Mini Fan Preliminary Testing

Date: 2/15/23 + Edits

Content by: Sam & Bella & Maya

Goals: To determine if the mini fan condensation prevention route is possible.

Content:

- The mini fan was bought on amazon. (More details in Sam's Design Idea Folder)

- Dimensions of mini fan is 25x25x10 mm

- Needs a 5V 90mA power supply

- Has a USB cable end that can be plugged into any USB port

  The cable is very short and may pose an issue with setting up issues

- Can clearly see mini fan in the incubator because no exact spot has been decided on yet

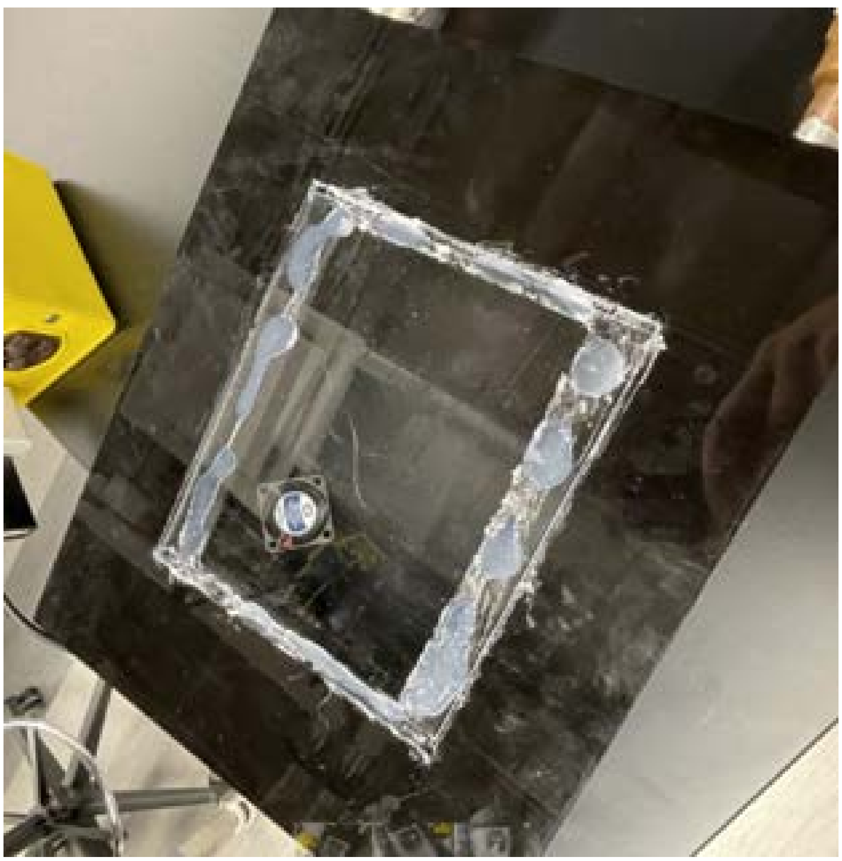


Figure 1: Mini fan placed inside of the incubator before incubator was turned on.

- No condensation

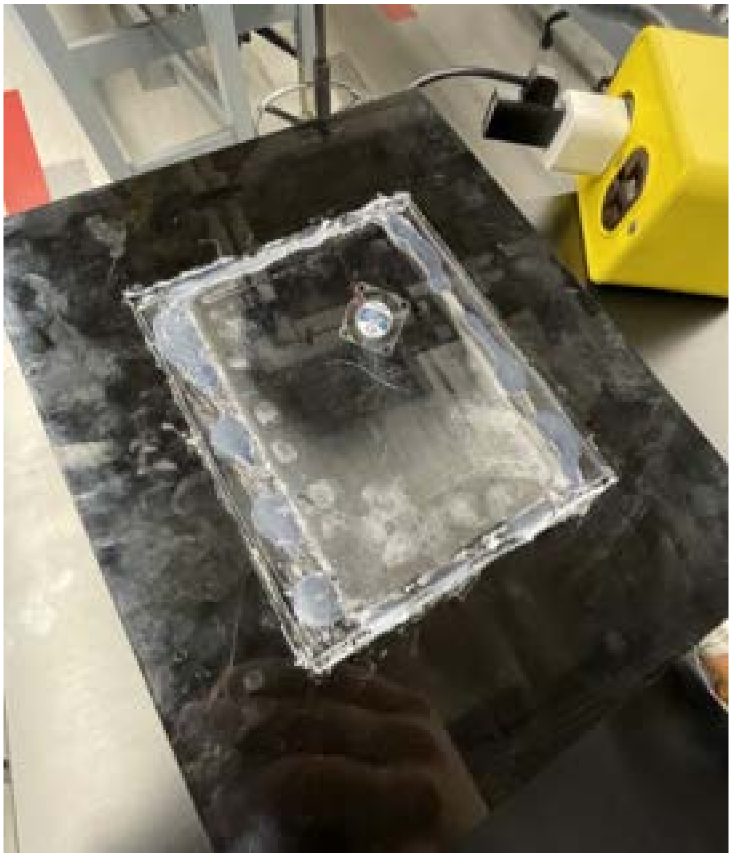


Figure 2: Mini fan in incubator conditions after ~10 minutes

- After 10 minutes the mini fan prevented the condensation from building up in its corner

- Slight condensation build up not in direct line with air fan is blowing

Figure 3: Mini fan in incubator conditions after ~30 minutes

- After 30 minutes the mini fan still did a good job of preventing condensation in its corner

- Clear condensation build up where mini fan is not blowing.

Edit 2/21/23: Diagonal Set Up

Figure 4: Photo showing the assembly of two mini fans pointed up at roughly 45 degrees on opposite corners

Figure 5: Photo showing diagonal set up at 20 minutes of incubation

Figure 6: Diagonal set up after 45 minutes

Figure 7: Diagonal set up after removing lid for one minute and then placing it back on for 15 minutes

Figure 8: Diagonal set up after 30 minutes after removing lid

2/22/23 Edit: Same side dual mini fan placement testing

Figure 9: Photo showing the same side dual mini fan set up where the fans are angled up at roughly 45 degrees

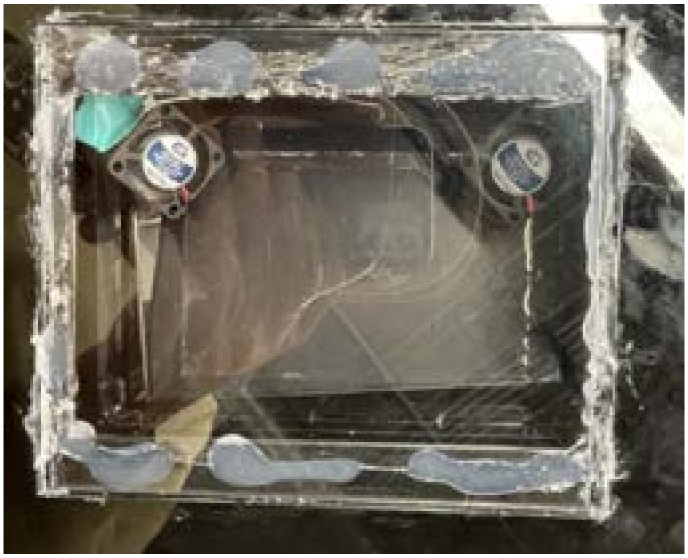


Figure 10: Photo showing same side set up with glass at time zero

Figure 11: Photo showing same size set up after 20 minutes of incubation

- Red arrow is highlighting the minimal condensation build up on the edge

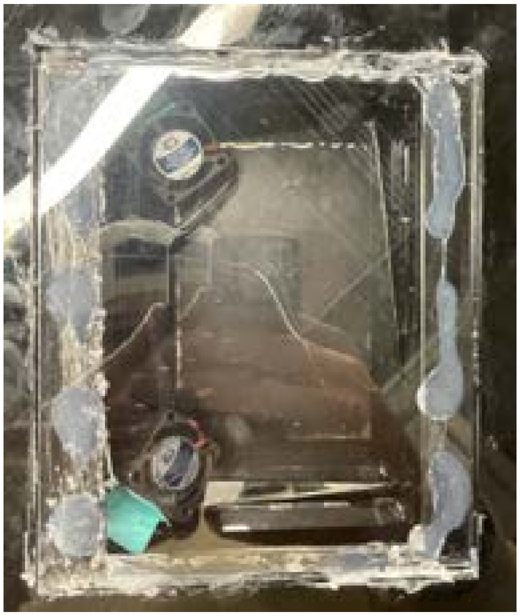


Figure 12: Photo showing same side setup after 45 minutes of incubation

Figure 13: Photo showing same side setup after removing lid for a minute and then waiting 15 minutes

Figure 14: Same side setup photo 30 minutes after removing lid

- No visual condensation buildup

Conclusions/action items:

The mini fan idea gives a lot of promising hope for condensation prevention. Another mini fan is being order to hopefully allow more condensation prevention with 2 fans. Some difficulties with this mini fan are placement options. I don't think there will be enough room in the well plate area if a full well plate is being used. A simple flask would leave enough room. I do not believe these fans are completely waterproof which could also pose a problem. More formal testing will be conducted next.

2/21/23 Edit: The diagonal set up showed that having two mini fans is much better than having one. The results were not completely perfect, so further experimentation on fan placement will be conducted. Analysis of fan condensation will be conducted by using the percentage of glass that has visible condensation at different times and after lid removal.

2/22/23 Edit: The same side mini fan arrangement worked very well. It did not allow any condensation to build up even after extended periods of time and even after lid removal. The one variable factor that might have helped provide these results was that the cords the mini fans are connected where fed under the incubator where there is no bottom glass plate. This would allow some colder outside are to have been blown toward the condensation, helping reduce the fog, but also interrupting the internal environment. I think this is something to not consider as a bad thing because if it is easier to maintain in internal environment versus finding a better condensation prevention, there are some benefits. Further testing on this hypothesis can be done.

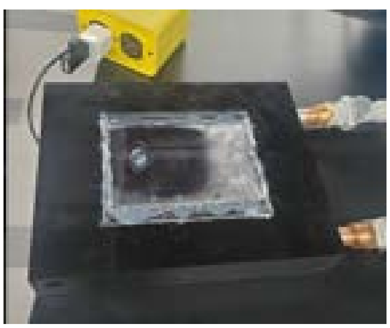
Bella Raykowski - Feb 19, 2023, 1:41 PM CST

Title: More Fan Test images

Content by: Bella

Present: Bella and Sam

Content:



Time: 5 min 30 min 15 min (fan moved to center)

- the fan did work at preventing condensation on the surface that it was blowing on

- will need at least 2 fans in order to cover the required surface area

- centering the fan did very little to prevent condensation

Conclusion: We will purchase another fan and see if that can prevent condensation in the required areas

2/20/23 Thermistor Accuracy Test

Katie Day - Feb 27, 2023, 2:49 PM CST

Title: Thermistor Accuracy Check

Date: 2/20/23

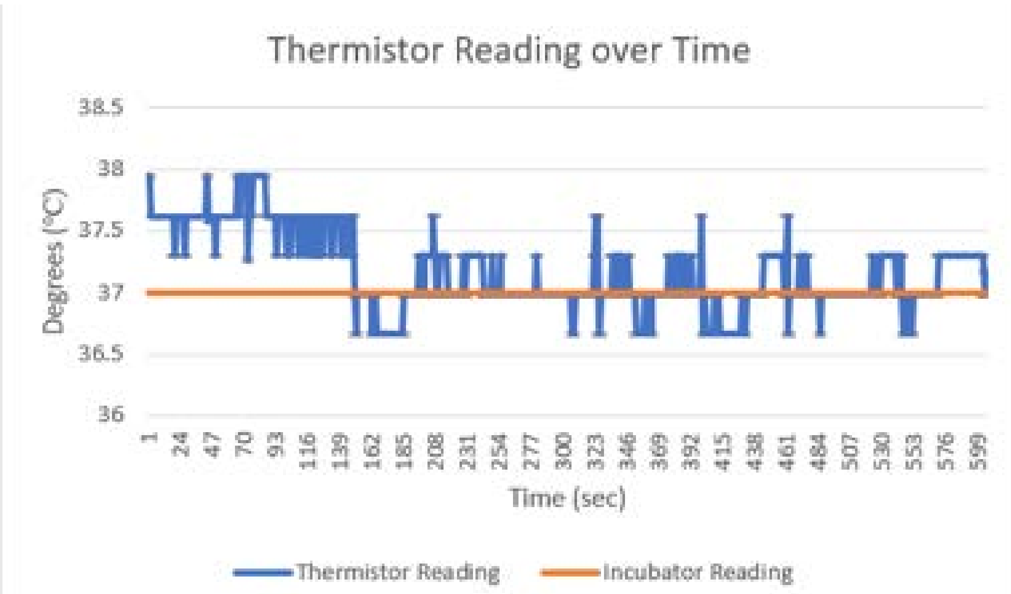
Content by: Katie Day

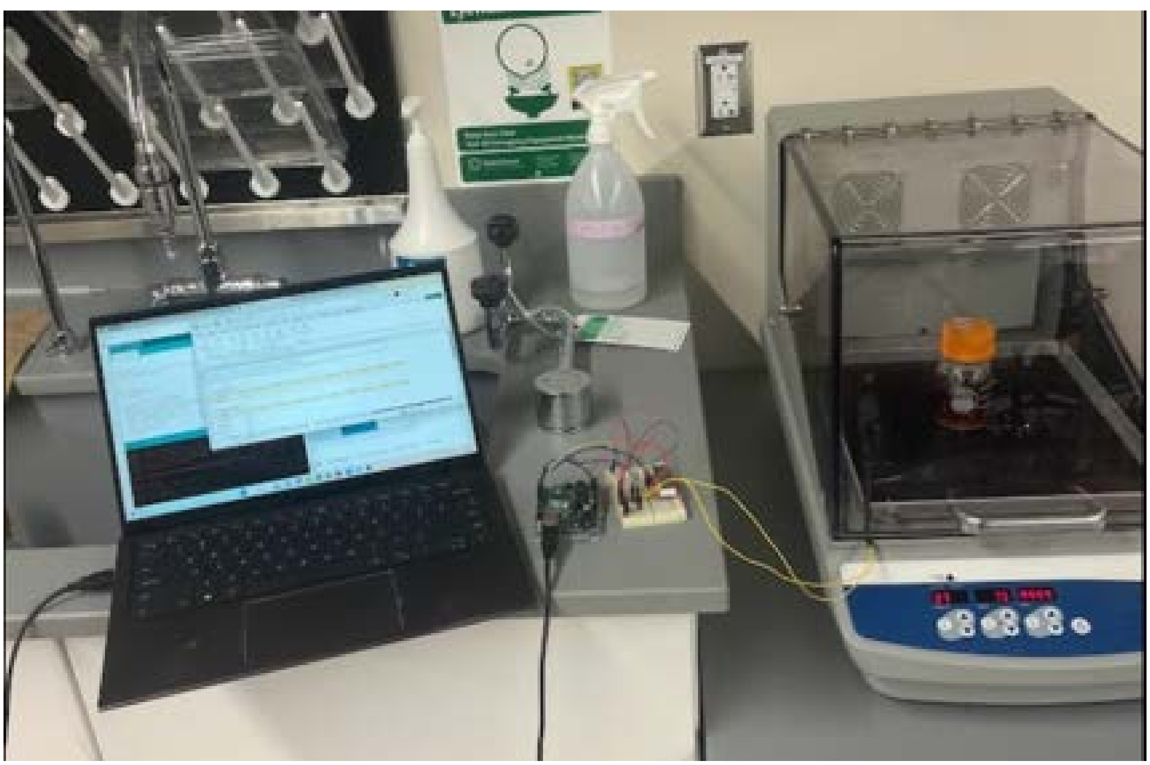
Present:

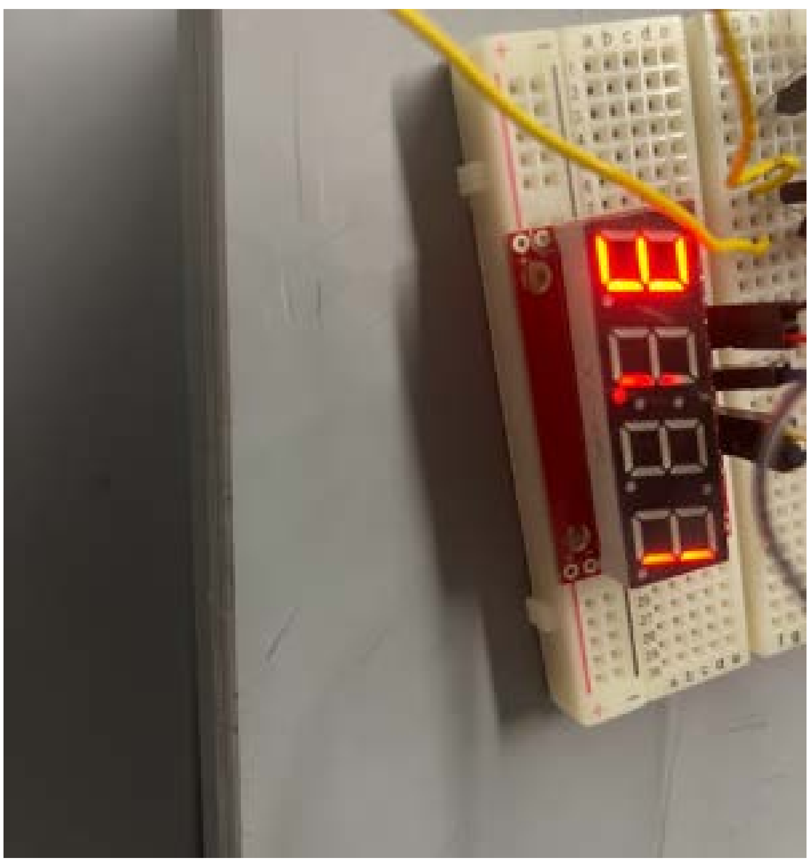
Goals: To make sure the thermistor is reading accurate values.

Content:

See attached file. p-value = 0.47







Conclusions/action items: None.

Katie Day - Feb 27, 2023, 2:49 PM CST

Download

Thermistor_Calibrated_Values.csv (6.57 kB)

2/28/23 + Edits: Dual Mini-Fan Full Fabrication Testing

SAMUEL BARDWELL - Mar 01, 2023, 7:13 PM CST

Title: Dual Mini-Fan Full Fabrication Testing + Edits

Date: 2/28/23

Content by: Sam

Goals: To conduct dual mini fan testing with a fully fabricated incubator.

Content:

- Same set up and protocols as 2/15/23 Mini Fan testing but this has a fully fabricated incubator.

Dual Mini Fan Same Side Testing

Figure 1: Inside of the box dual mini fan same side set up

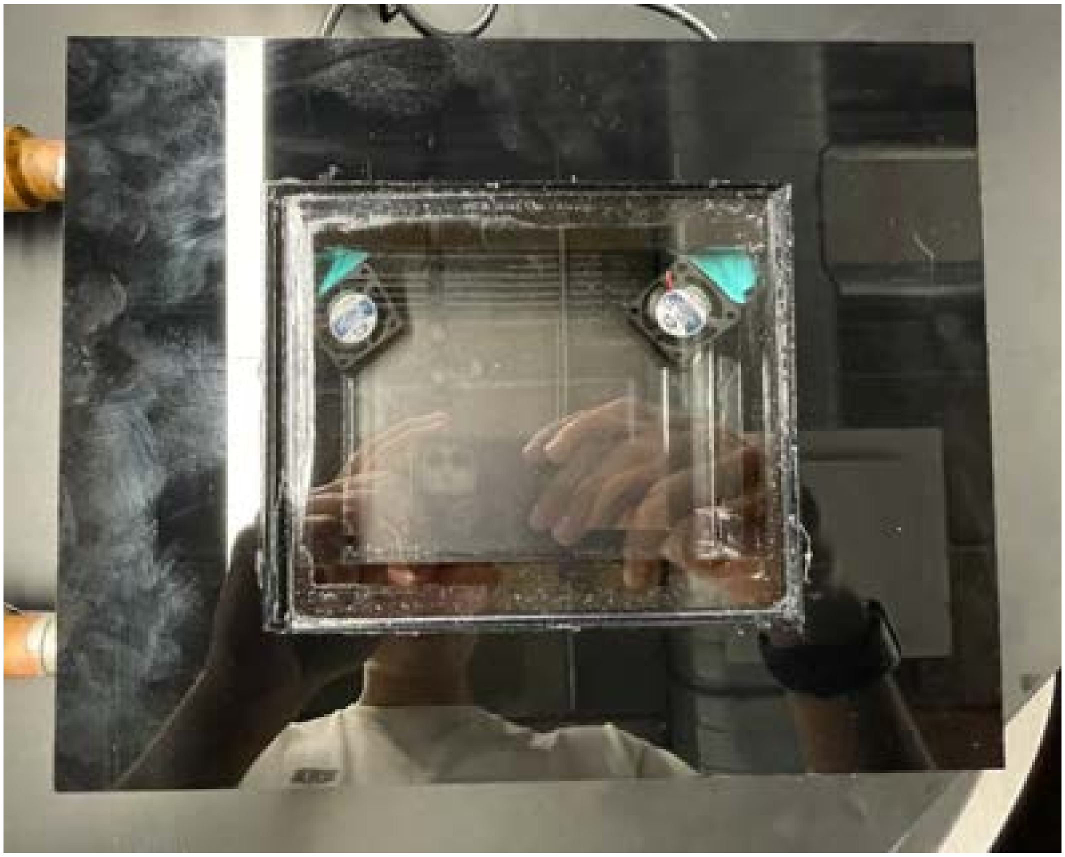


Figure 2: Time 0 of same side set up testing

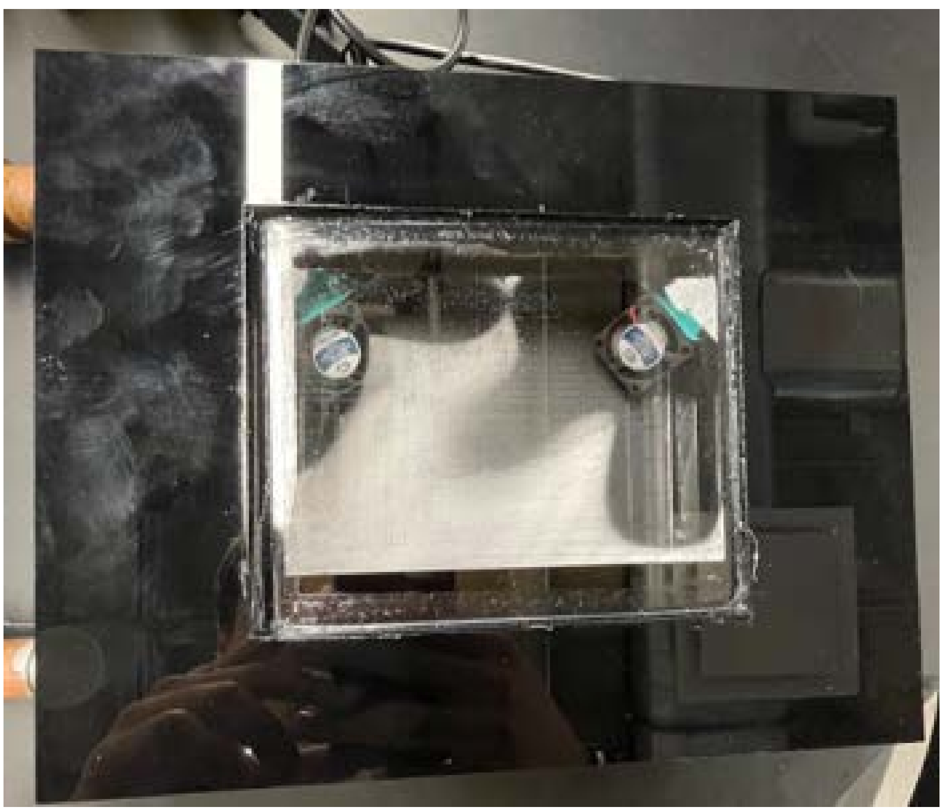


Figure 3: Time 20 (min) of same side dual mini fan set up

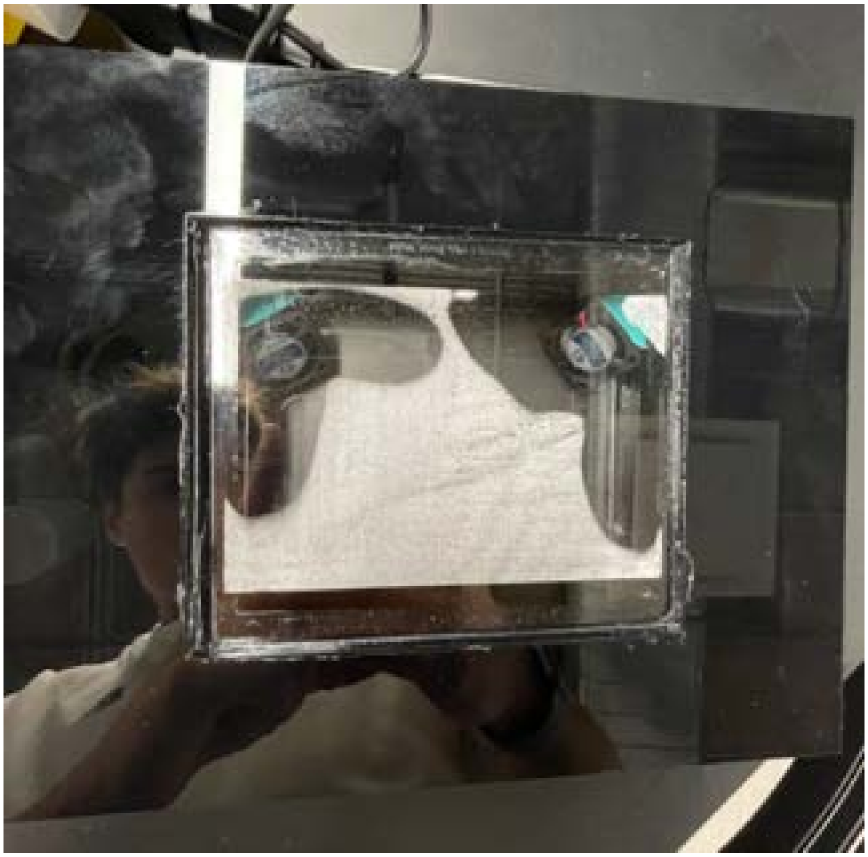


Figure 4: Time 45 (min) of dual mini fan same side set up

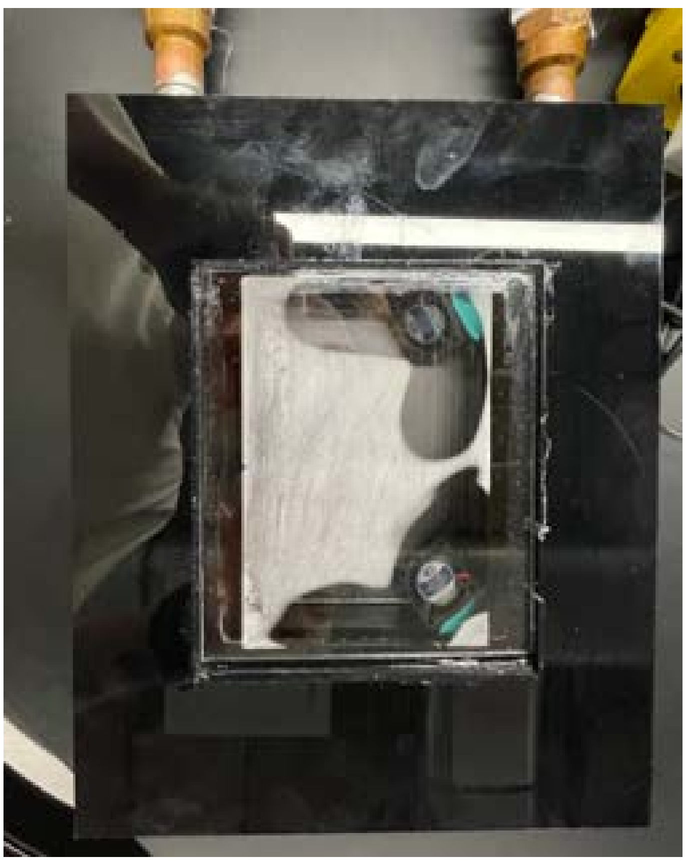


Figure 5: 15 minutes after lid opening and closing of same side dual mini fan set up testing

Figure 6: 30 minutes after lid opening and closing of dual mini fan same side set up.

Dual Mini Fan Side by Side Arrangement

- The mini fans were angled up to face the upper lid glass and place right next to eachother

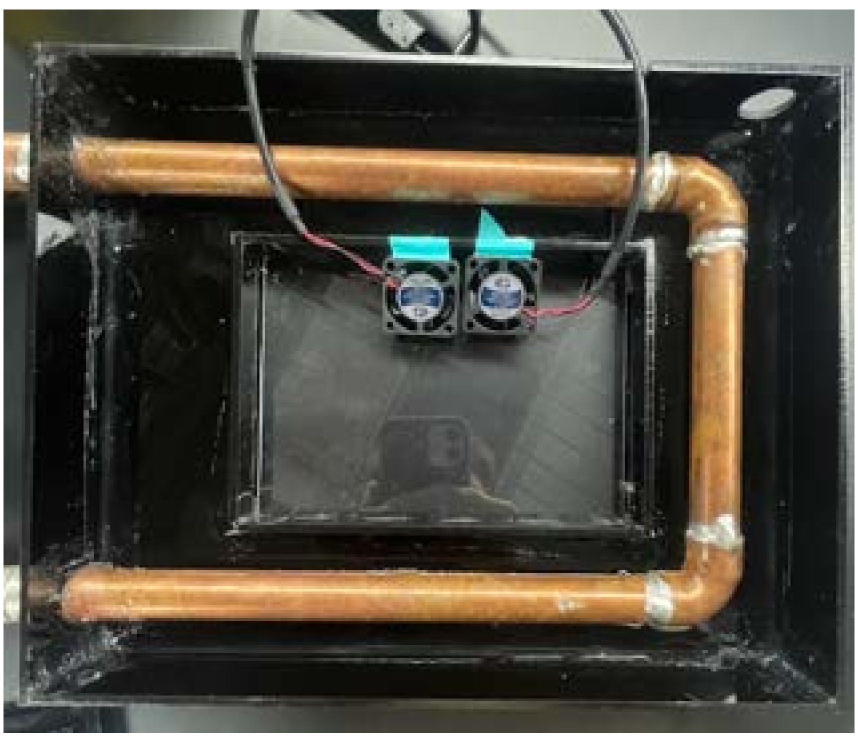


Figure 7: Dual Mini Fan Side by Side arrangement

Figure 8: Time zero of side by side arrangement

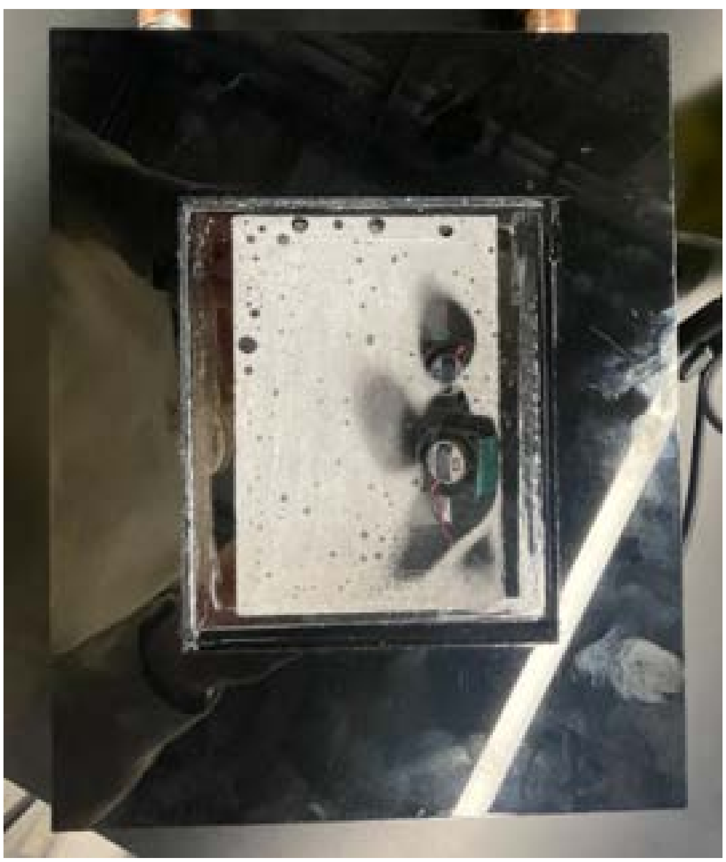


Figure 9: Time 20 of side by side arrangement

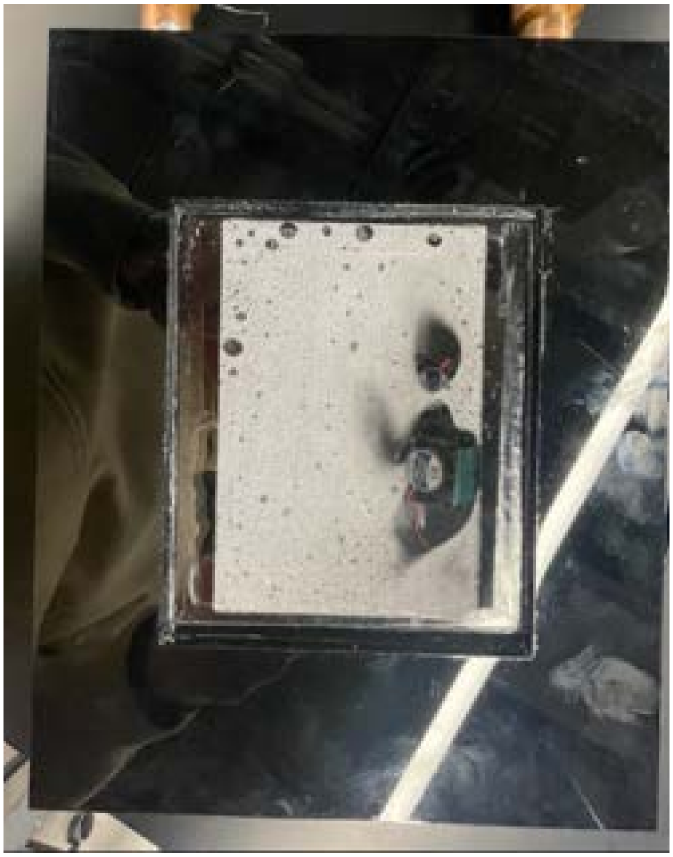


Figure 10: Time 45 of side by side arrangement

Figure 11: Time 15 post lid opening and closing for side by side arrangement

Figure 12: Time 30 post lid opening and closing for side by side arrangement

Conclusions/action items:

2/28/23: After retesting the dual mini fan same side set up, it is clear that exposure to the external environment played a crucial role in condensation removal. Condensation testing will have to be redone the rest of the week to truly find the best option after the box was completely fabricated. Applying the anti fog spray may be considered and tested as one of the trials to see if a mixture of the two ideas becomes the best performing.

3/1/23: The side by side arrangement did not work well at all. The entire glass part of the lid was covered in condensation. I am thinking of surrounding the rest of the glass with caulk because it does not appear that the external environment is getting into the incubator box to help with condensation at all. Since there is still a hole, the internal environment will seep out and condensate outside of the incubator box leaving wet spots that could possibly damage the microscope. This is why I want to caulk the rest of the glass. I think the next test I will do are with the anti-fog spray and the mini fans together. If neither of those work I might find some RainX and apply that to the glass but this might pose a risk to the viability of the cells.

2/28/23 Control Cell Confluency Test

Bella Raykowski - Feb 28, 2023, 5:59 PM CST

Title: Control Cell Confluency Test

Date: 02/28/2023

Content/testing by: Bella Raykowski

Goal: Document the results of the control cell test

Content:

- I passaged the Mice osteoblast cells we got from Dr. P into a new T25 flask at a concentration of ~200,000 cells

- I added fresh media on day 0 and did not change the media during the duration of the test

- The flask was imaged using the Zeiss microscope in the teaching lab ~24 hours (actual time of each image was recorded for accuracy)

- All images were analyzed in ImageJ which measured the percent area covered by the cells (this was done to track normal cell growth over the course of 5 days)

- I initially planned to run the test for 7-10 days however, the cells became very confluent at day 5 so I ended the test there and passaged them into a new flask

Day 0 (5 pm)

Day 1 (2:30 pm)

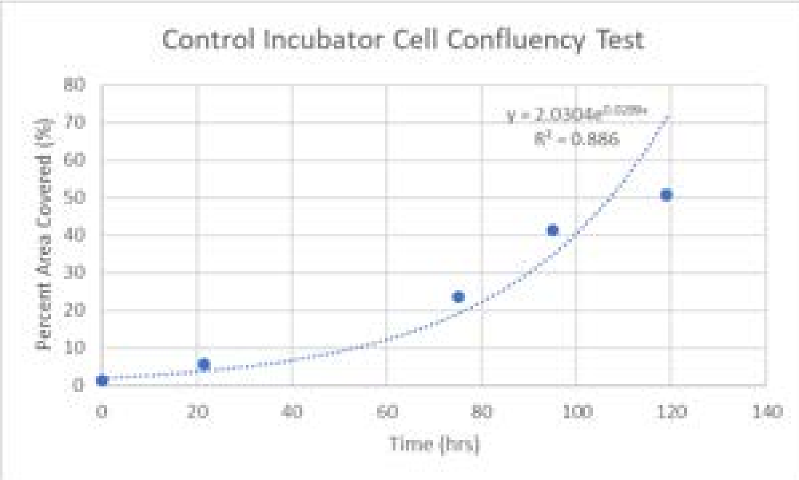
Day 3 (11 am)

Day 4 (4 pm)

Day 5 (4 pm)

Data collected on ImageJ

Day	Time (hr)	Percent Area Covered
0	0	1.34
1	21.5	5.578
3	75	23.732
4	95	41.406
5	119	50.781



- The graph shows how after day 4 the cells become confluent and run out of room to grow (they don't have the space to grow exponentially) therefore I stopped the test

Conclusion: This is the baseline that we will compare the cell growth in the prototype incubator to in order to determine if our prototype maintains cell viability.

3/2/23 CO2 Initial Testing

Katie Day - Apr 27, 2023, 4:56 PM CDT

Title: CO2 Initial Testing

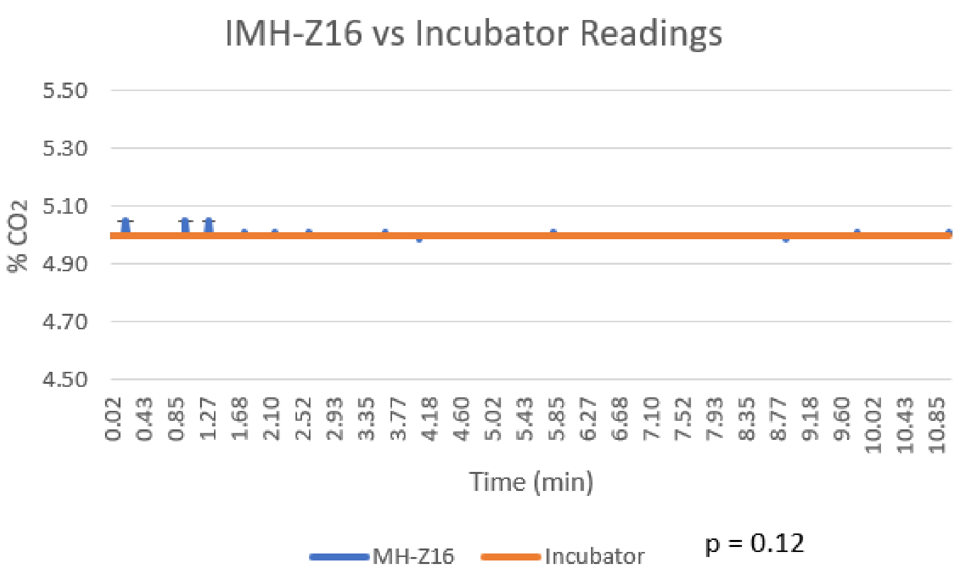
Date: 3/2/23

Content by: Katie

Present: Katie and Drew

Goals: To determine if our new CO2 sensor is able to read the correct values that the incubator is presenting.

Content:



We stuck the MH-Z16 in the standard incubator and let it run for approximately 11 minutes. The p value was 0.12 indicating that our results are not statistically significant.

See attached files for whole data.

Arduino Code:

```
//Reads concentration from NDIR sensor and translates to %CO2.

#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;
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);
    }

}
```

```
void loop() {
   if (mySensor.measure()) {
     // Serial.print("CO2 Concentration is ");
      Serial.println((mySensor.ppm*5.0)/10000);
     // Serial.println("ppm");
     // Serial.print("Percent CO2 is ");
    // Serial.print((mySensor.ppm/10000));
   //  Serial.println("%");
   } else {
      Serial.println("Sensor communication error.");
   }
  delay(1000);
   }
```

Conclusions/action items: Test the sensor with the feedback loop for the solenoid valve

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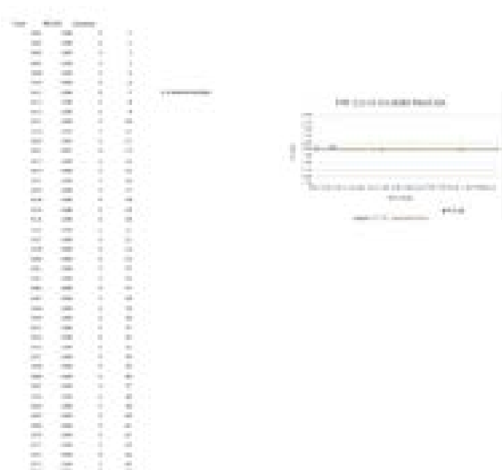
Katie Day - Mar 02, 2023, 4:51 PM CST



Download

CO2_Intial_Reading.xlsx (51.2 kB)

3/6/23 CO2 Feedback Loop Testing

Katie Day - Mar 06, 2023, 2:23 PM CST

Title: CO2 Feedback Loop

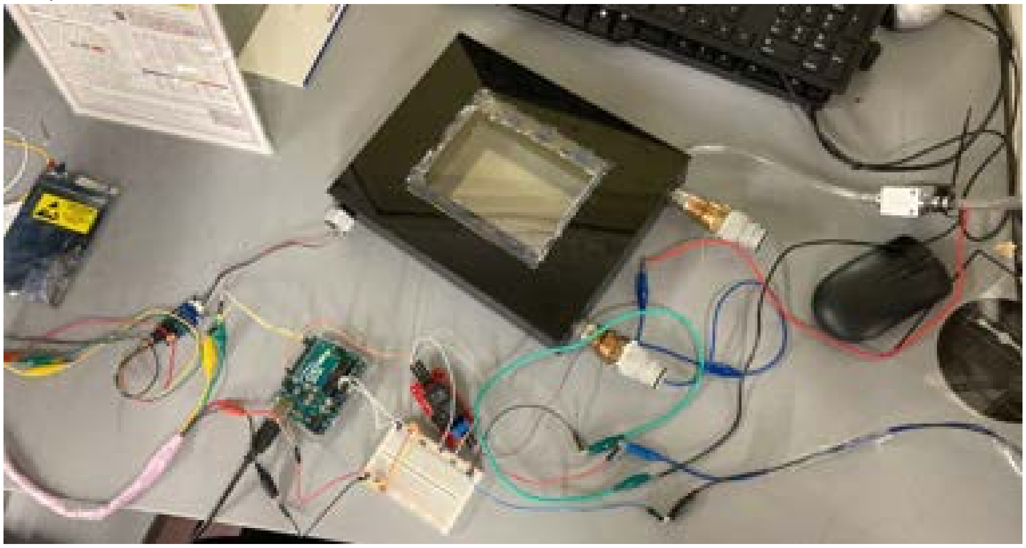
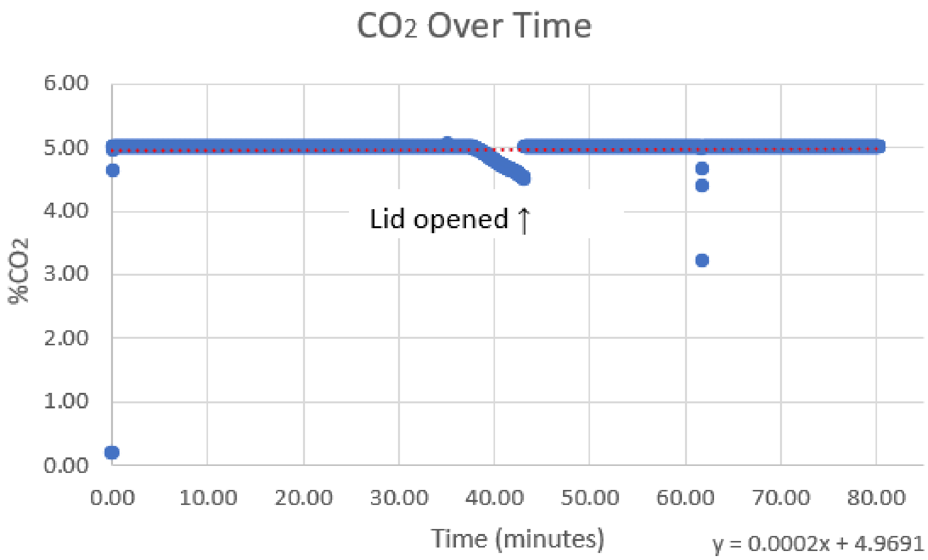
Date: 3/6/23

Content by: Katie and Drew

Present: Katie and Drew

Goals: To test the functionality of the feedback loop.

Content:

- The entire CO2 system was set up and tested on an empty box (no water bath or temp/humidity data collection) to test how the feedback loop regulates CO2 release
- Setup shown below:
- 
- The Lid was opened twice during data collection that lasted 1 hour, 20 min
  - 1st opening for extended period of time and marked on graph
  - 2nd opening not marked because very brief, but shown by 3 outlier data points around the ~61 min mark
- The testing proved very successful and the team is excited about initial results
- 

- See attached file for all data.
- Code:

```
#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);
int relayPin = 13;
float x;
void setup()
{
    Serial.begin(9600);
    pinMode(relayPin, OUTPUT);

    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);
    }
}

void loop() {
    if (mySensor.measure()) {
        Serial.println((mySensor.ppm*5.0)/10000);
    } else {
        Serial.println("Sensor communication error.");
    }
    x = (mySensor.ppm*5.0)/10000;
    Serial.println(x);
    if( x <= 4.5){
      digitalWrite(relayPin, HIGH);   //switch relay on
      delay(50);                      //short input of CO2
      digitalWrite(relayPin, LOW);
      delay(5000);
    }else{
      digitalWrite(relayPin, LOW);    //switch relay off
    }
 // digitalWrite(relayPin, HIGH);   //switch relay on
 // delay(1000);                    //wait 1 second
//  digitalWrite(relayPin, LOW);    //switch relay off
 // delay(1000);

    delay(1000);
}
```

Conclusions/action items:

- Feedback loop works very well
- Test system on entire incubator setup with water-bath, mini-fans and temp/humidity testing running to re-evaluate CO2 Feedback effectiveness

Katie Day - Mar 06, 2023, 11:53 AM CST

Download

CO2_Feedback_Testing.xlsx (205 kB)

3/8/23 Condensation Testing with Cells on the Microscope

SAMUEL BARDWELL - Mar 08, 2023, 4:41 PM CST

Title: Condensation Testing with Cells on the Microscope

Date: 3/8/23

Content by: Sam

Goals: To determine if the mini fans reduce condensation enough to keep clear images of the cells on the microscope, even if human visuals are impeded.

Content:

- Testing protocols used was the same as the 2/28 condensation testing

- One difference is the addition of the cell flask

- Mini fan placement is same side angled up toward the lid glass

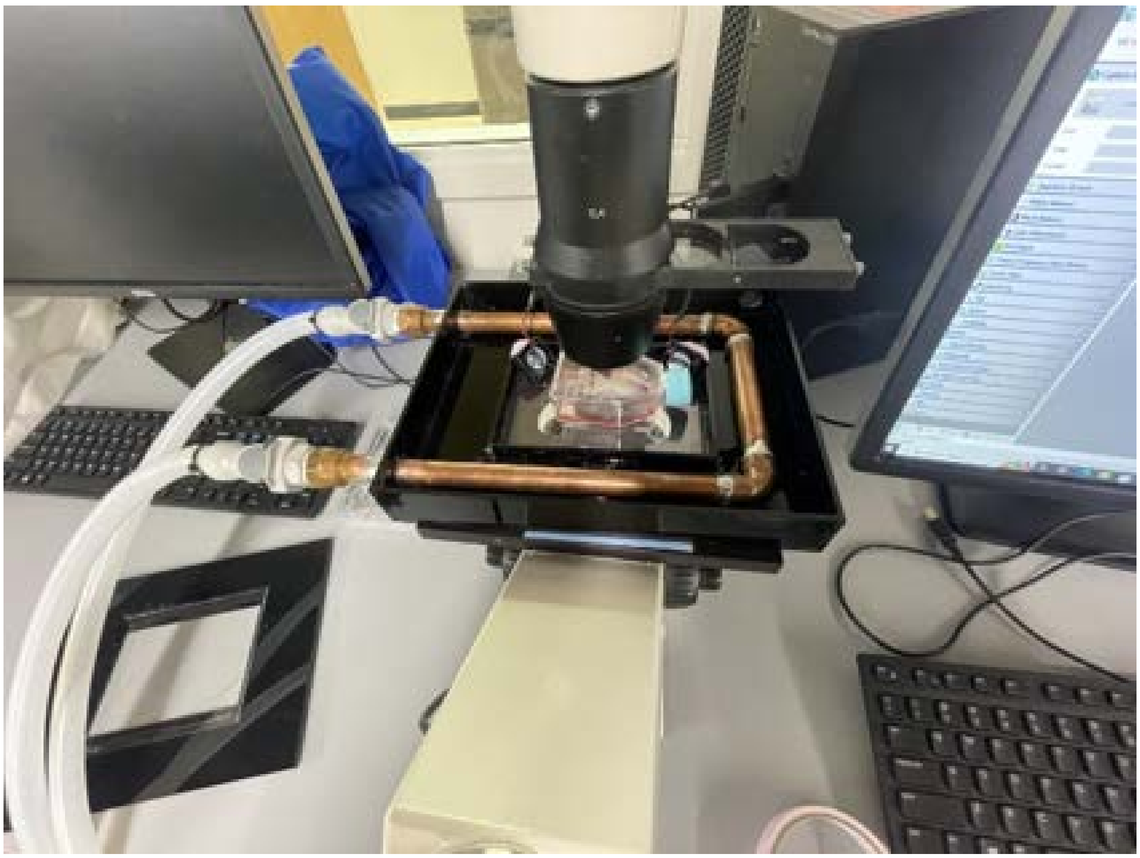


Figure 1: Incubator, mini fan, cell flask, and inverted microscope set up

Figure 2: Cell image at time 0 of incubator set up

Figure 3: Cell image at time 20 min

Figure 4: Cell image at time 45 min

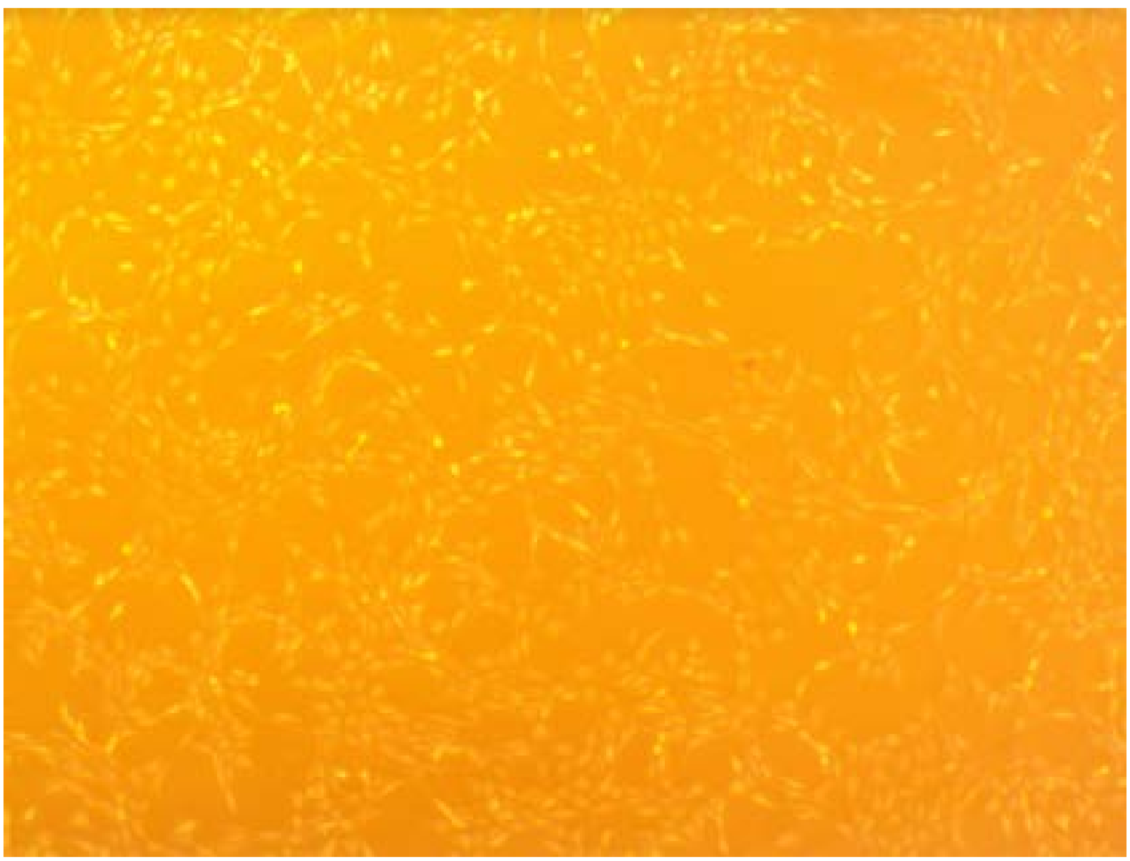


Figure 5: Cell image at time 15 minutes after the lid and flask was removed for a minute then replaced

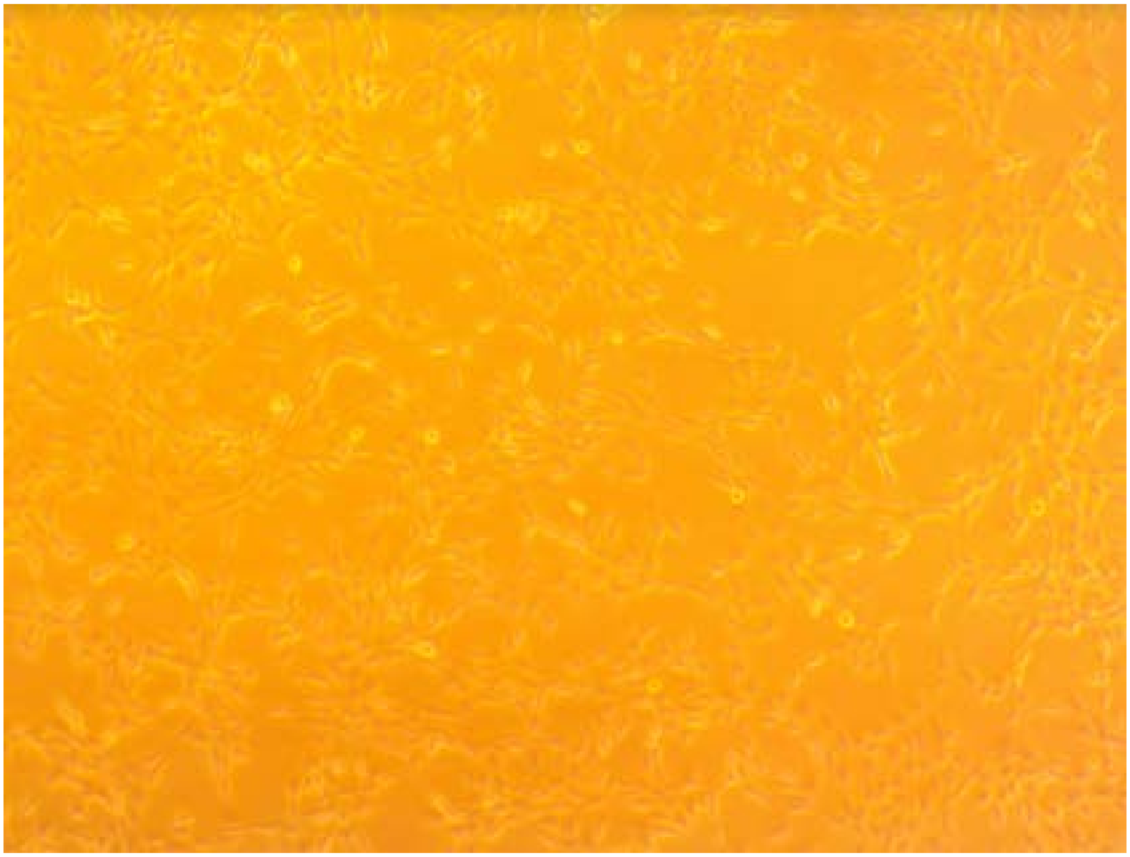


Figure 6: Cell image at time 30 minutes after the lid and flask was removed for a minute then replaced

Conclusions/action items:

Image analysis was done based on the clarity of the cell images using RBG square method. The bottom glass does not fog up because the flask does not allow it to as long as the bottom is wiped if the flask is moved. Still need to find a better fan placement or condensation prevention method. One idea is to place the fans on top of the flask and point them straight up but I don't think there will be enough room between the lid glass and the top of the flask to fit the fan.

3/9/23 CO2 with Temp and Hum Test

Katie Day - Mar 09, 2023, 4:29 PM CST

Title: CO2 Test with Temp and Humidity

Date: 3/9/23

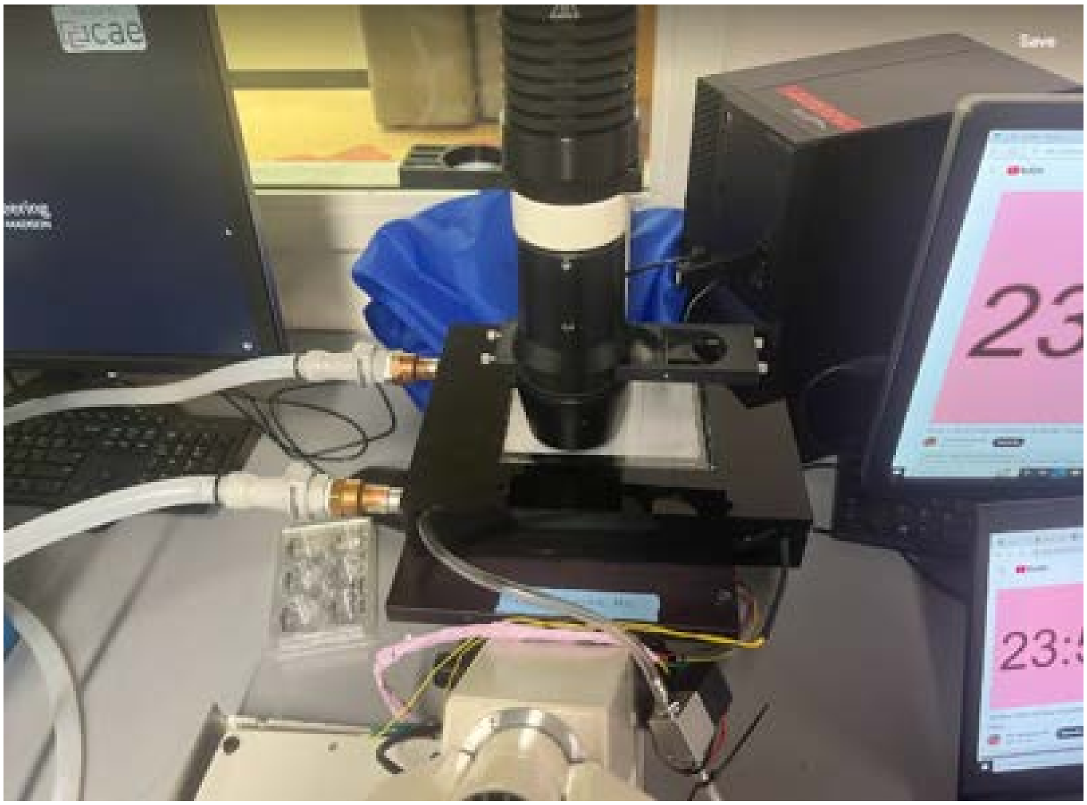
Content by: Katie Day

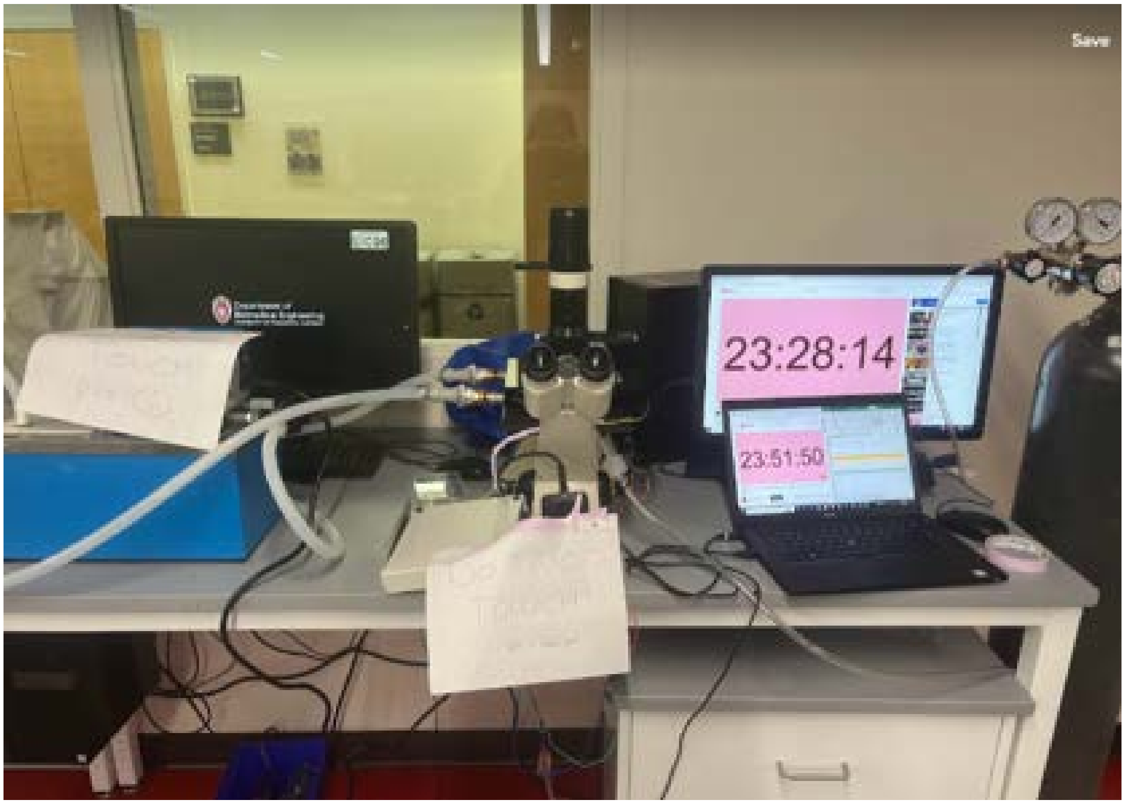
Present: Drew, Maya, Bella, and Katie

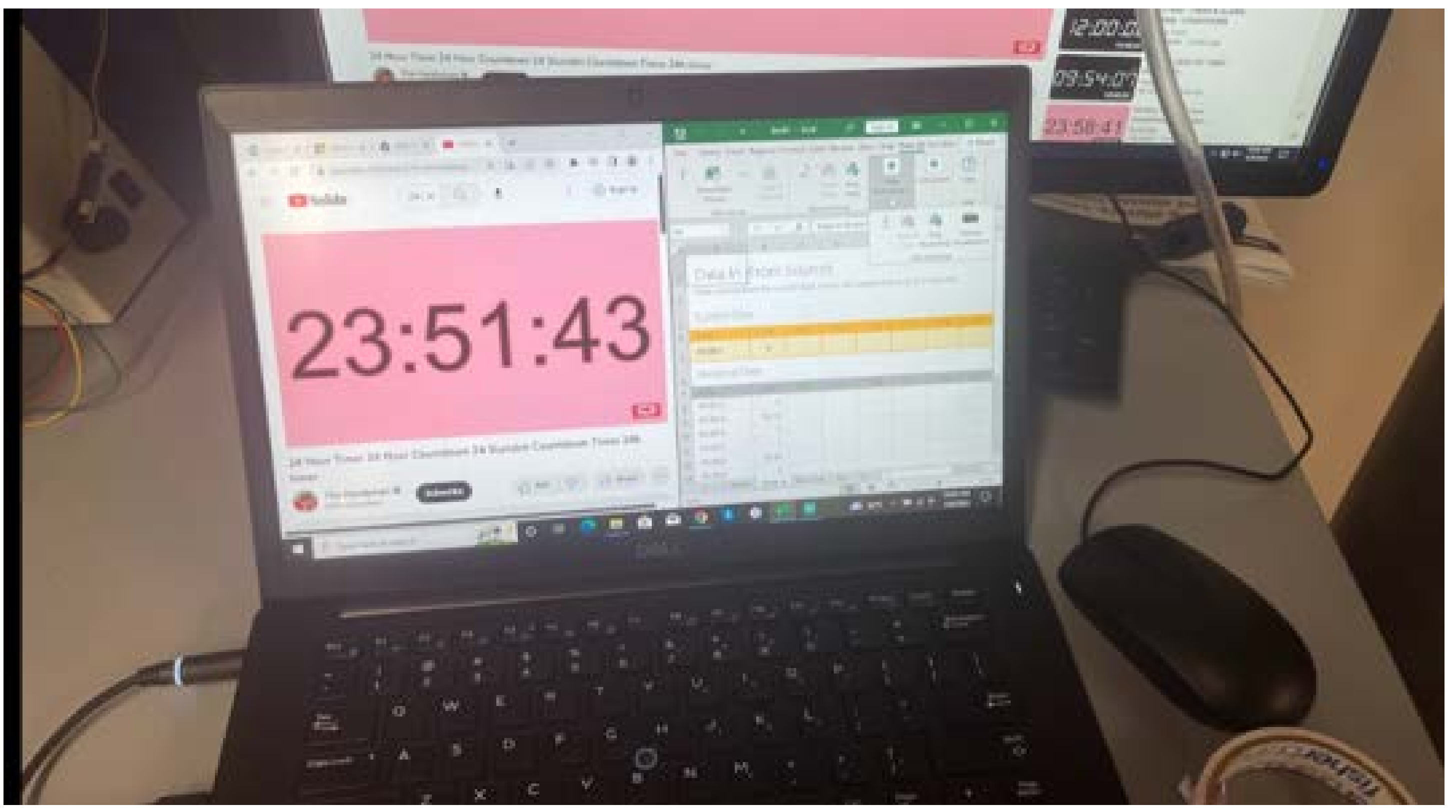
Goals: To determine if the feedback loop works when temperature, humidity, and mini-fans are added.

Content:

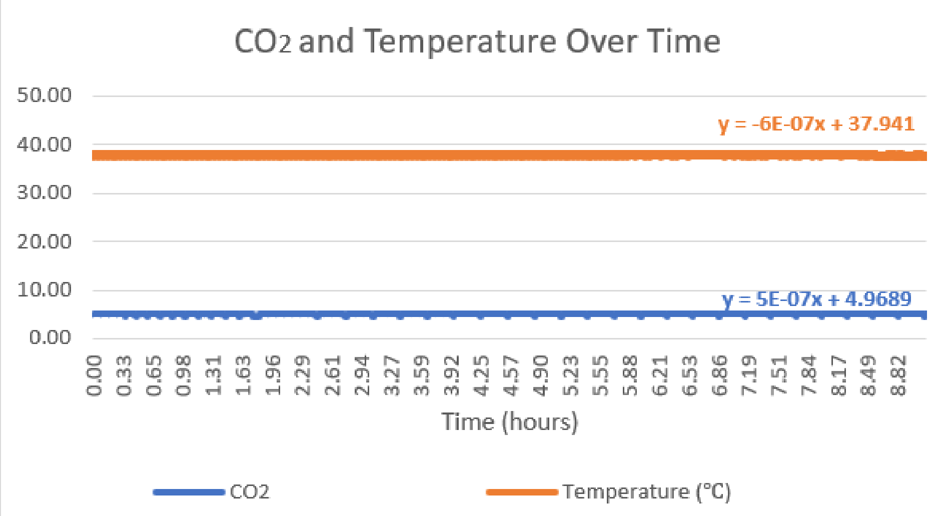
Set up the incubator for regular use. Tested the viability of the feedback system.

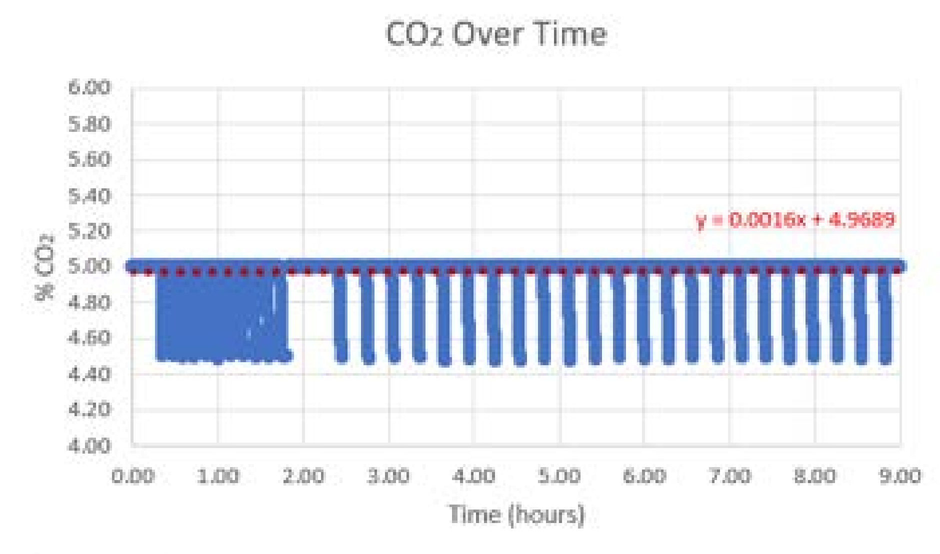






Results:





See attached file for code and raw data.

Conclusions/action items: Ready to Start Live Testing.

Katie Day - Mar 09, 2023, 9:53 AM CST

```
#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);

int relayPin = 13;

float x;

//temp

int sensorPin = A0;    // select the input pin for the potentiometer

int sensorValue = 0;  // variable to store the value coming from the sensor

float volt_conversion = 5.0/1023.0;

float ADC_voltage = 0;

float K_temperature = 0;

float C_temp;

void setup()

{

  Serial.begin(9600);

  pinMode(relayPin, OUTPUT);


  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);

  }

}


void loop() {
```

```
  //concentration

   if (mySensor.measure()) {

     Serial.println((mySensor.ppm*5.0)/10000);

   } else {

     Serial.println("Sensor communication error.");

   }

   x = (mySensor.ppm*5.0)/10000;

    if( x <= 4.5){

     digitalWrite(relayPin, HIGH);   //switch relay on

    delay(50);                  //short input of CO2

    digitalWrite(relayPin, LOW);

    delay(5000);

   }else{

    digitalWrite(relayPin, LOW);    //switch relay off

   }

   //temp

   // read the value from the sensor:

   sensorValue = analogRead(sensorPin);

   ADC_voltage = sensorValue * (volt_conversion);

   K_temperature = (ADC_voltage - 0.205) / 0.0153;

   C_temp = K_temperature - 91;

   //Printing

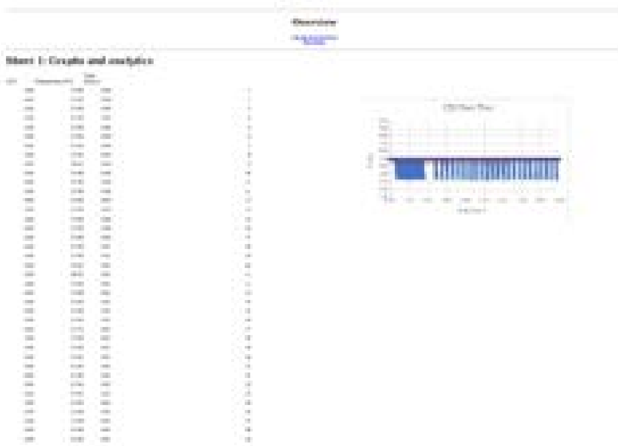
   Serial.println(C_temp);

   Serial.println(x);

   delay(50000);

 }
```

Katie Day - Mar 09, 2023, 4:30 PM CST



Download

CO2_Hum_Temp_Test.xlsx (2.71 MB)

3/28/23 Condensation Experimenting with Hand Sanitizer

SAMUEL BARDWELL - Apr 17, 2023, 1:12 PM CDT

Title: Condensation Experimenting with Hand Sanitizer

Date: 3/28/23

Content by: Sam

Goals: To experiment anti-condensation with hand sanitizer and a smaller water bath.

Content:

- Same testing protocols were used as the other anti-condensation experiments

- Humidity was recorded to see if values were still significant enough, even with a smaller water bath

- Glass was coated with a 1:1 ratio of anti-bacterial hand-sanitizer and water. The solution was applied evenly to the glass with a cotton ball and then air dried before the experiment began.

Figure 1: Time 0

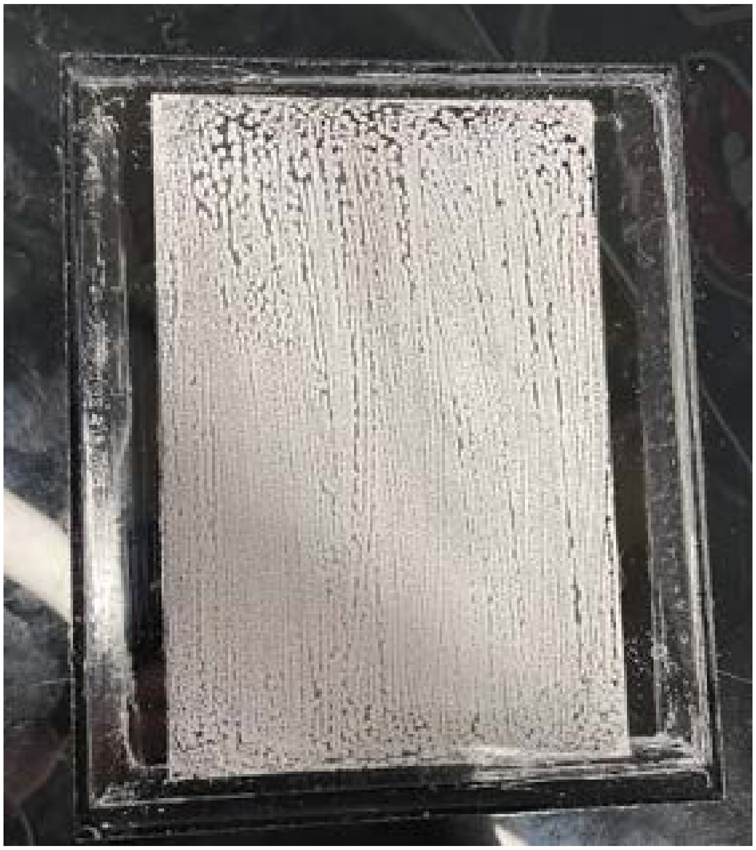


Figure 2: Time 20

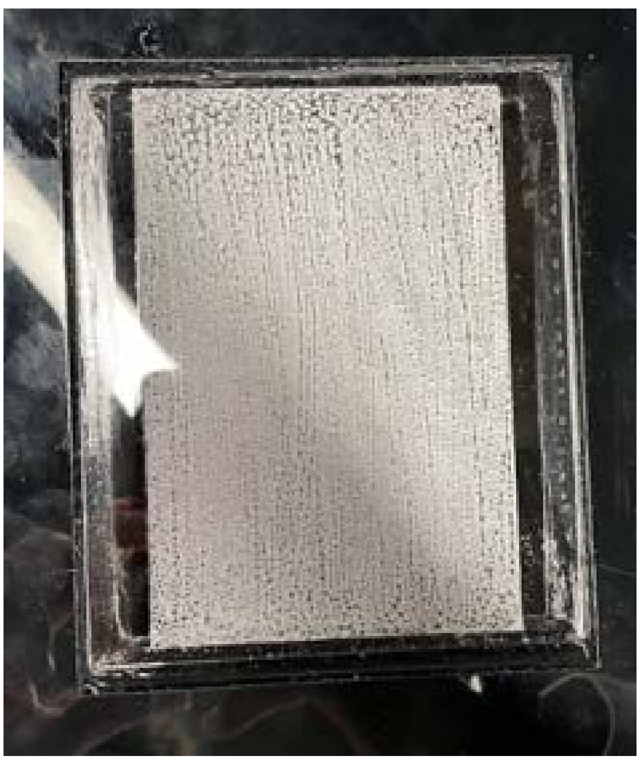


Figure 3: Time 45

Figure 4: Time 15 after lid removal

Figure 5: Time 30 after lid removal

Conclusions/action items:

The anti-bacterial hand sanitizer idea did not work well enough to be implemented into the project. There was some streaks that did not have condensation built up on the glass, but this would still alter optical data. The humidity with the smaller water bath was still able to get to significant levels of >95%. The condensation was even worse after removing the lid and wiping off the condensation.

Katie Day - Mar 28, 2023, 4:11 PM CDT

Download

Hum_Data.xlsx (40.6 kB)

4/5/23 Anti-Condensation PDMS Testing

Drew Hardwick - Apr 06, 2023, 2:30 PM CDT

Title: Anti-Condensation PDMS Testing

Date: 4/5/23

Content by: Drew and Sam

Present: Drew and Sam

Goals: Test PDMS hydrophobicity supplied by Dr. Puccinelli

Content:

- We set up a preliminary qualitative test in the lab to see if the hydrophobic PDMS strip that Dr. Puccinelli supplied us would be sufficient to prevent condensation buildup on the glass within the incubator
- We cannot test in the actual incubator since it is being utilized for live cell testing, so we set up a make shit testing aparatus
    - We heated water in a beaker on a hot plate with a stir bar and then placed an old prototype lid on top of it with the PDMS stuck to the bottom to create a sealed, humid and hot environment for condensation buildup
- Our experiment design can be seen in the Figures below for time 0min.
- We ran the test for ~30 min,

Figure 1: Testing Setup

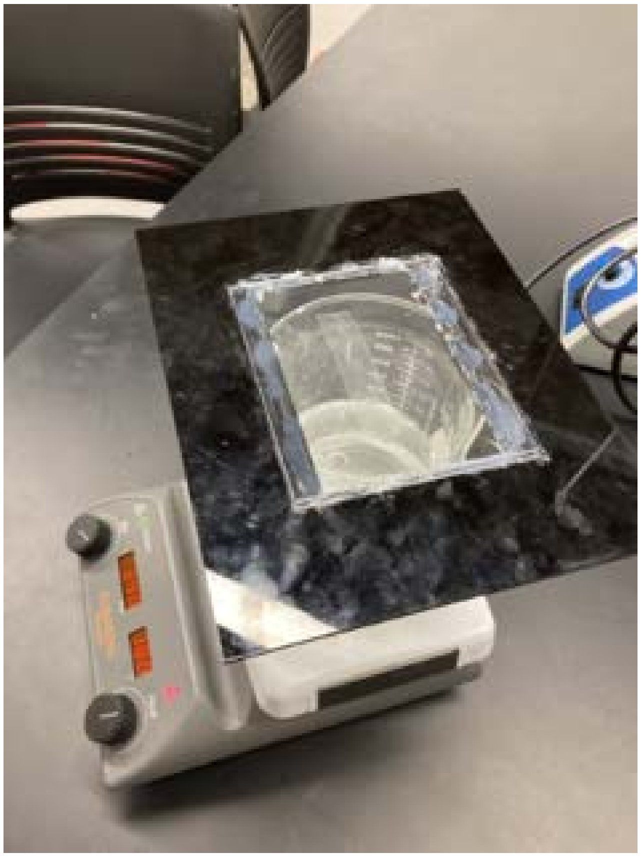


Figure 2: PDMS Setup

- After 30 min, there was no visible difference in the PDMS sliver than the rest of the glass
- We will return later this week and test the PDMS with the mini fan system. It is hypothesized that potentially the water is accumulating in clumps on the PDMS, but with a little circulation, we could potentially blow the water off of the PDMS, since the droplets will have high contact angles on such a hydrophobic surface.

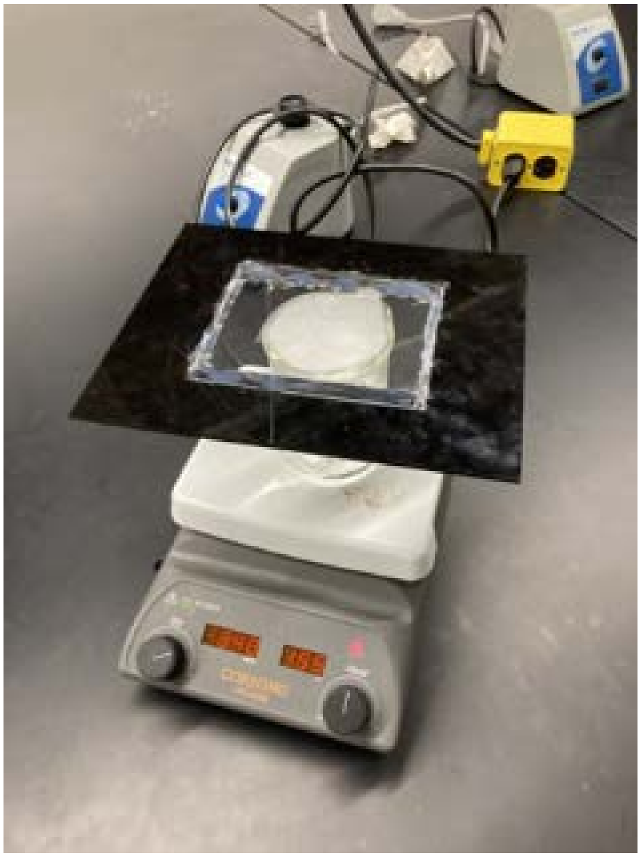


Figure 3: Setup after 30 min

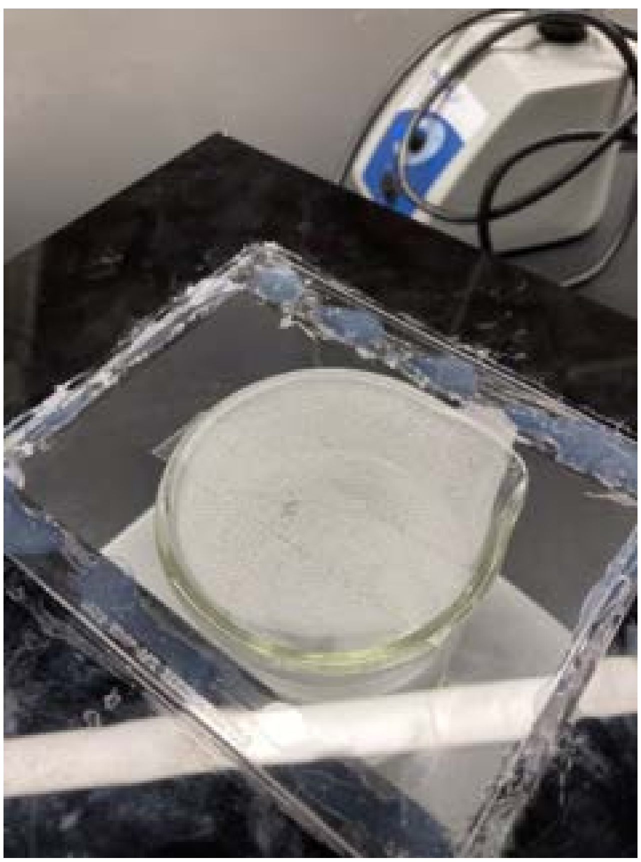


Figure 4: PDMS Strip after 30 min

- Result was not any different with addition of 1 mini fan. Still buildup on PDMS and Glass, both blown off by fan at similar rates

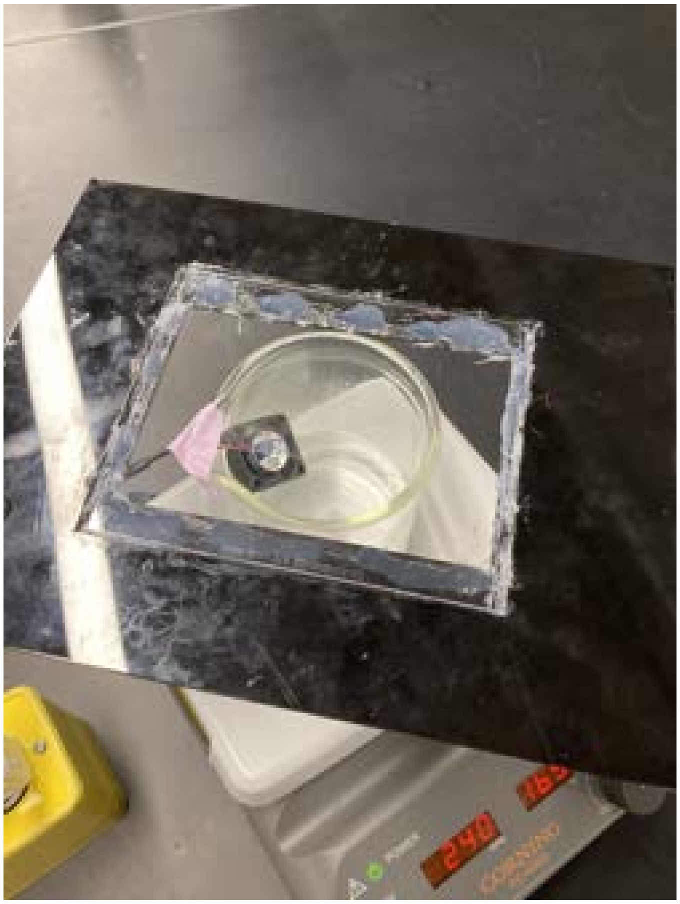


Figure 5: Setup with Fan addition time 0min

Figure 6: Fan setup at time 30 min

Conclusions/action items:

- This setup did not work on its own
- Try again with added minifans! UPDATE: also did not work :(

4/6/23 Cell Proliferation Test 1

Katie Day - Apr 07, 2023, 9:45 AM CDT

Title: Cell Proliferation Test 1

Date: 4/6/23

Content by: Bella Raykowski and Katie Day

Goal: document the results of the cell proliferation test 1

Content:

- made 2 T25 flasks each with 20k cells; place 1 in the control incubator and 1 in the prototype incubator

- imaged the cells roughly every 24 hours for 3 days

- control images:

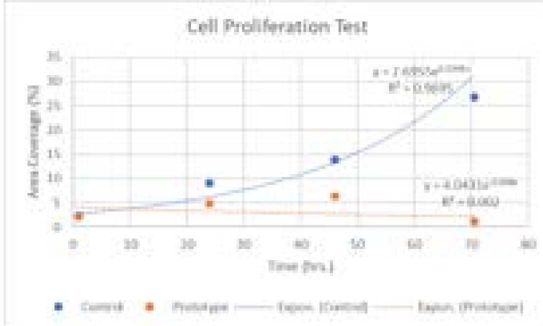



- prototype images:




- results:

Time	Control	Prototype
1	2.14	2.281
24	9.017	4.836
46	13.954	6.312
70.5	26.837	1.092



Conclusion: The prototype failed to keep the cells alive. We found that the CO2 solenoid shorted out in between day 1 and 2, the CO2 input was unplugged around day 3 and the temperature was low due to the water tank being placed below the incubator (it didn't pump strong enough to overcome gravity). Will make corrections and test again in a few days.

Katie Day - Apr 07, 2023, 9:47 AM CDT

Download

whole_data.xlsx (2.32 MB)

4/12/2023 Troubleshooting Testing for Temp and CO2

Katie Day - Apr 27, 2023, 4:57 PM CDT

Title: Katie Day

Date: 4/12/2023

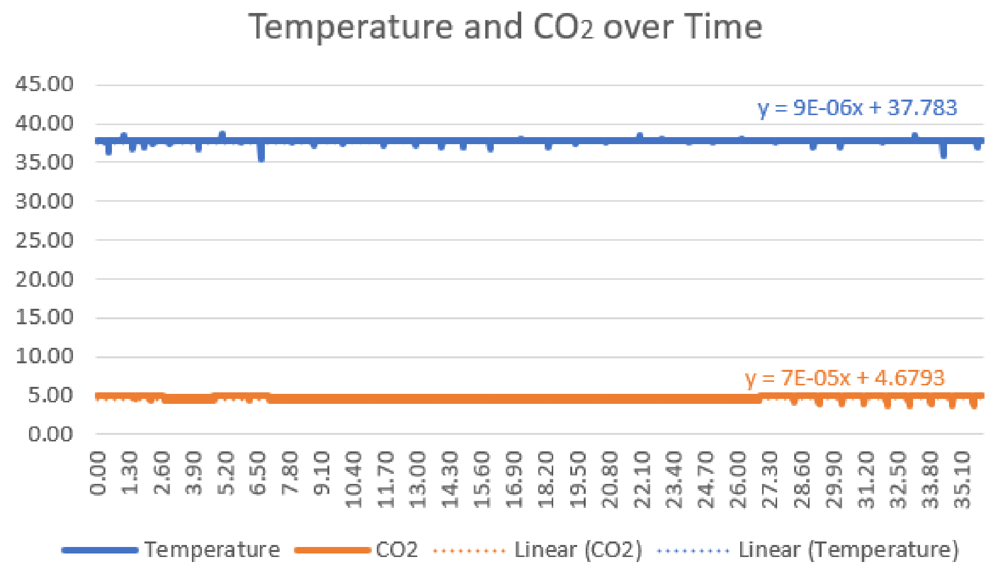
Content by:

Present:

Goals: To test troubleshooting methods to see if temperature and humidity can be maintained.

Content:

The heated water pump was set on the table this time. Code was reconfigured to connect the outputted value from the sensor to the solenoid valve to avoid Sensor Communication Errors. A gas permeable water cover was also placed on the sensor.



See file for raw data.

Arduino Code:

```
#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);
int relayPin = 13;
float x;
//temp
int ThermistorPin = 0;
int Vo;
float R1 = 10000;
float logR2, R2, T;
float c1 = 1.009249522e-03, c2 = 2.378405444e-04, c3 = 2.019202697e-07;
float Tc;
void setup()
{
  Serial.begin(9600);
  pinMode(relayPin, OUTPUT);
```

```
    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);
    }
}

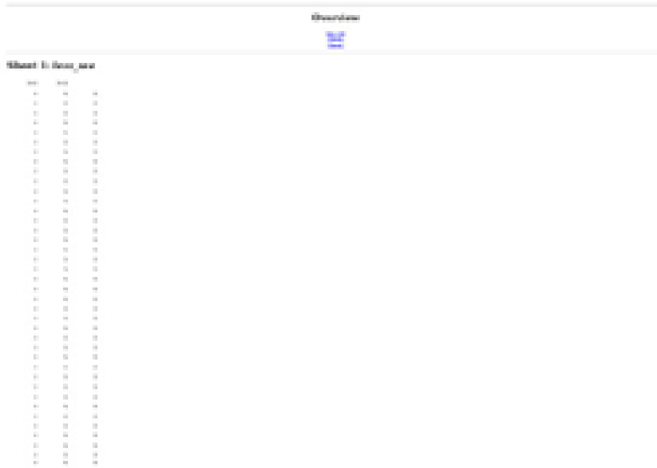
void loop() {
  //concentration
    if (mySensor.measure()) {
        Serial.println();
    } else {
        Serial.println("Sensor communication error.");
    }
    x = (mySensor.ppm*5.0)/10000;
      if( x <= 4.5){
        digitalWrite(relayPin, HIGH);   //switch relay on
      delay(50);                    //short input of CO2
      digitalWrite(relayPin, LOW);
      delay(5000);
    }else{
      digitalWrite(relayPin, LOW);    //switch relay off
    }
    //temp
    // read the value from the sensor:
   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 - 273.15;

    //Printing
   Serial.println(Tc);
    Serial.println(x);
    delay(1000);
}
```

Conclusions/action items:

Make a space for the CO2 sensor with cover on incubator. Start live cell testing round 2.

Katie Day - Apr 12, 2023, 5:10 PM CDT



Download

Initial_Trial_2.xlsx (444 kB)

4/17/23 Cell Proliferation Test 2

Katie Day - Apr 27, 2023, 5:00 PM CDT

Title: Cell Proliferation Test 2

Date: 4/17/23

Content by: Bella Raykowski

Goal: document the results of the cell proliferation test 2

Content:

- made 2 T25 flasks each with 20k cells; place 1 in the control incubator and 1 in the prototype incubator

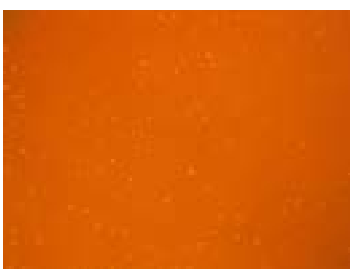
- imaged the cells roughly every 24 hours for 4 days

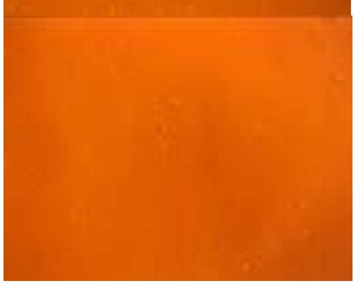
- control images:




Day 0 Day 1 Day 2 Day 4

- prototype images:

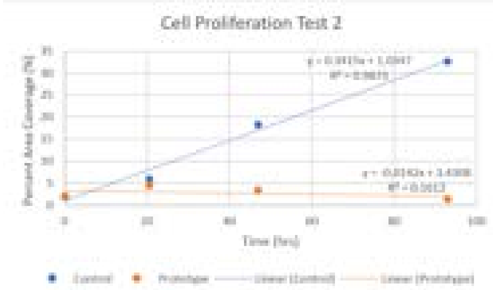


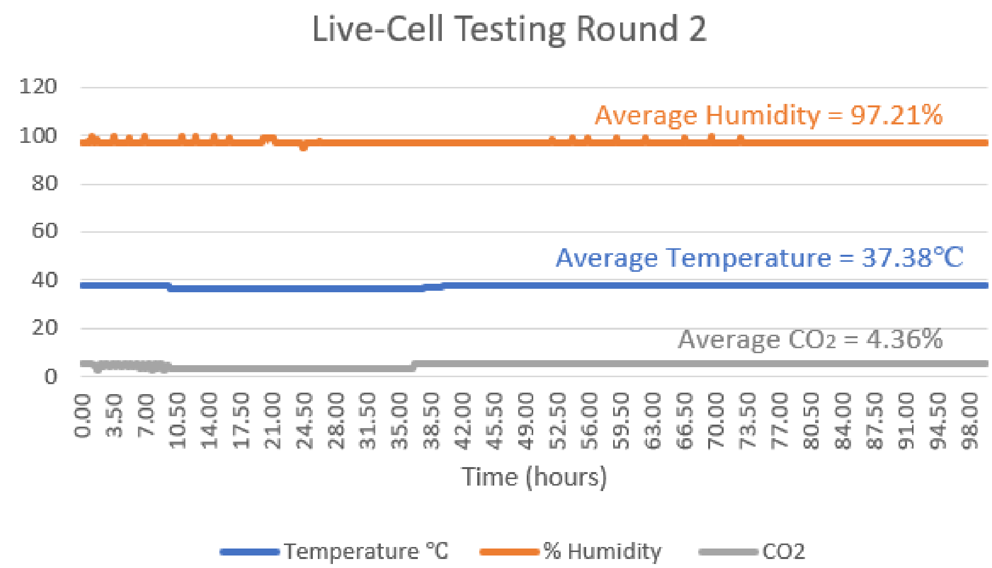



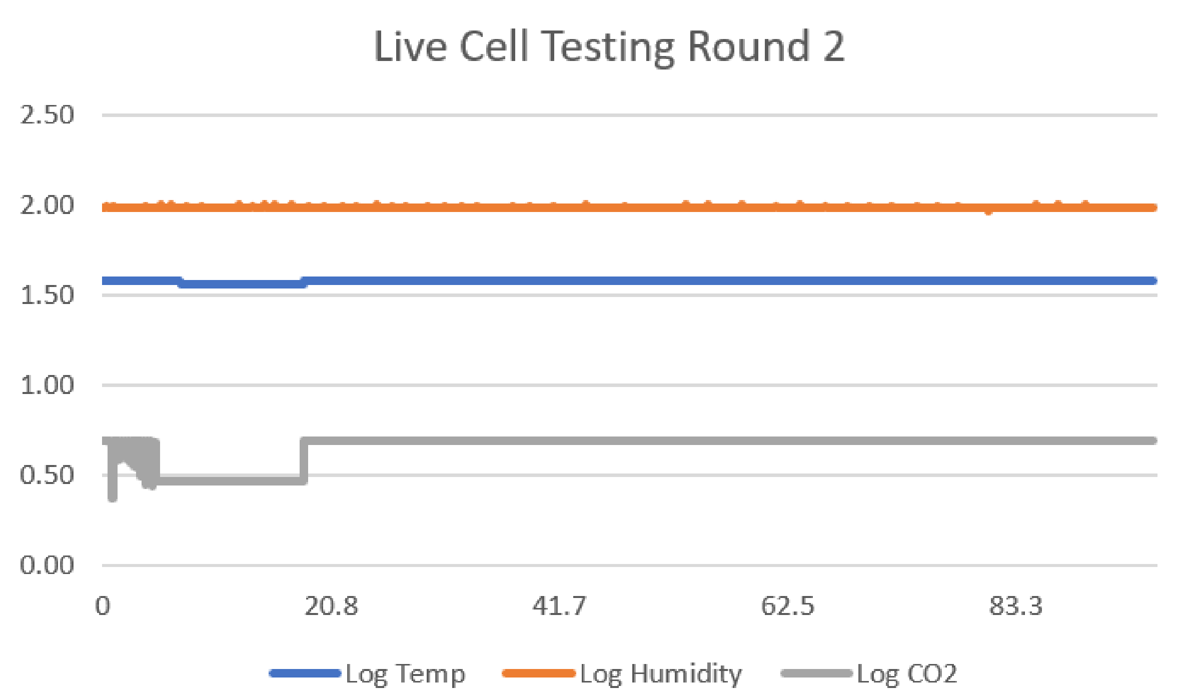
Day 0 Day 1 Day 2 Day 4

- Results:

Time	Control	Prototype
0	2.094	1.971
20.5	5.894	4.568
47	18.321	3.46
93	32.645	1.438







Arduino Code:

```
#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);

int relayPin = 13;

float x;

//temp

int ThermistorPin = 0;

int Vo;

float R1 = 10000;

float logR2, R2, T;

float c1 = 1.009249522e-03, c2 = 2.378405444e-04, c3 = 2.019202697e-07;

float Tc;

float e_s;

float e_d;

float Td = 36.1;

void setup()

{

  Serial.begin(9600);

  pinMode(relayPin, OUTPUT);


  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);

  }

}
```

```
void loop() {

 //concentration

  if (mySensor.measure()) {

      Serial.println();

  } else {

      Serial.println("Sensor communication error.");

       digitalWrite(relayPin, HIGH);   //switch relay on

       delay(50);                     //short input of CO2

       digitalWrite(relayPin, LOW);

       delay(5000);

  }

  x = (mySensor.ppm*5.0)/10000;

    if( x <= 4.5){

      digitalWrite(relayPin, HIGH);   //switch relay on

    delay(50);                     //short input of CO2

    digitalWrite(relayPin, LOW);

    delay(5000);

  }else{

    digitalWrite(relayPin, LOW);    //switch relay off

  }

  //temp

  // read the value from the sensor:

 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 - 273.15;

 //hum

 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 = ((e_d/e_s)*16)-4;



    //Printing

   Serial.println(Tc);

    Serial.println(x);

    Serial.println(hum);

    delay(600000);

}
```

Conclusion: The cells died, the device failed :(

Katie Day - Apr 17, 2023, 7:11 PM CDT

Download

Round_2_testing.xlsx (137 kB)

4/21/23 Cell pH Test

Drew Hardwick - May 02, 2023, 8:50 AM CDT

Title: Cell pH test

Content by: Bella Raykowski, Katie Day, Drew Hardwick

Goal: Document how we tested the pH of the cells in culture

Content:

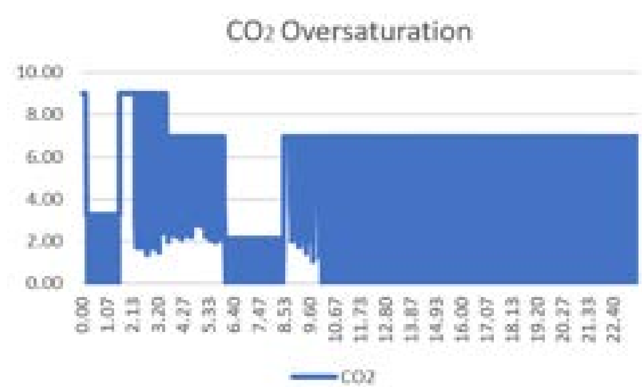
- After talking with Dr. P, we discovered that the cells were dying because the media was too basic (hot pink in color)

- CO2 is what manages the pH of the media therefore a basic culture means that there wasn't enough CO2

- An acidic culture would be more yellow in culture

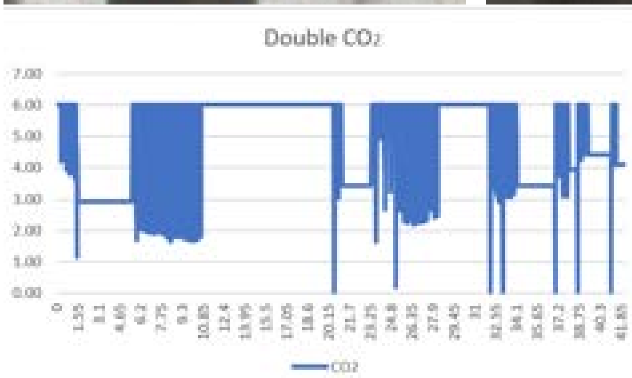
- A neutral culture would be a faded pale pinkish color (this was the color of the control incubator flask)

- We first tripled the amount of CO2 entering our device (from the original amount) and left a flask for 24 hours



- the yellow color and low pH indicate that it became very acidic (too much CO2)

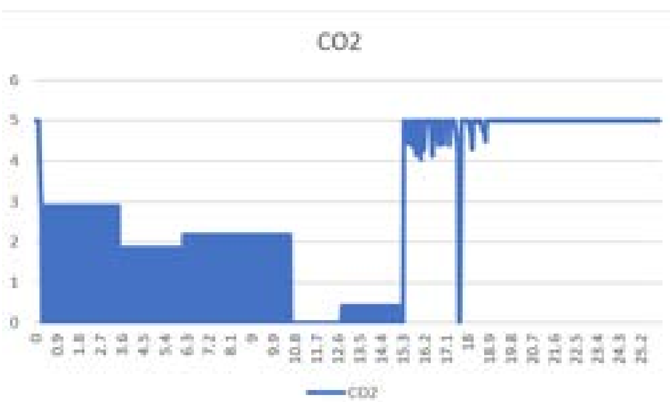
- we then doubled the amount of CO2 (from the original amount) and left a new flask for 24 hours



- it is still slightly yellow but the pH has increased so we are moving in the right direction (still too much CO2)

- we then did the original amount of CO2 with an increase of 1/2 the CO2 when there was a sensor communication error and left a new flask for 24 hours

- it is now a purple color (I will take the pH after this meeting and update it here)



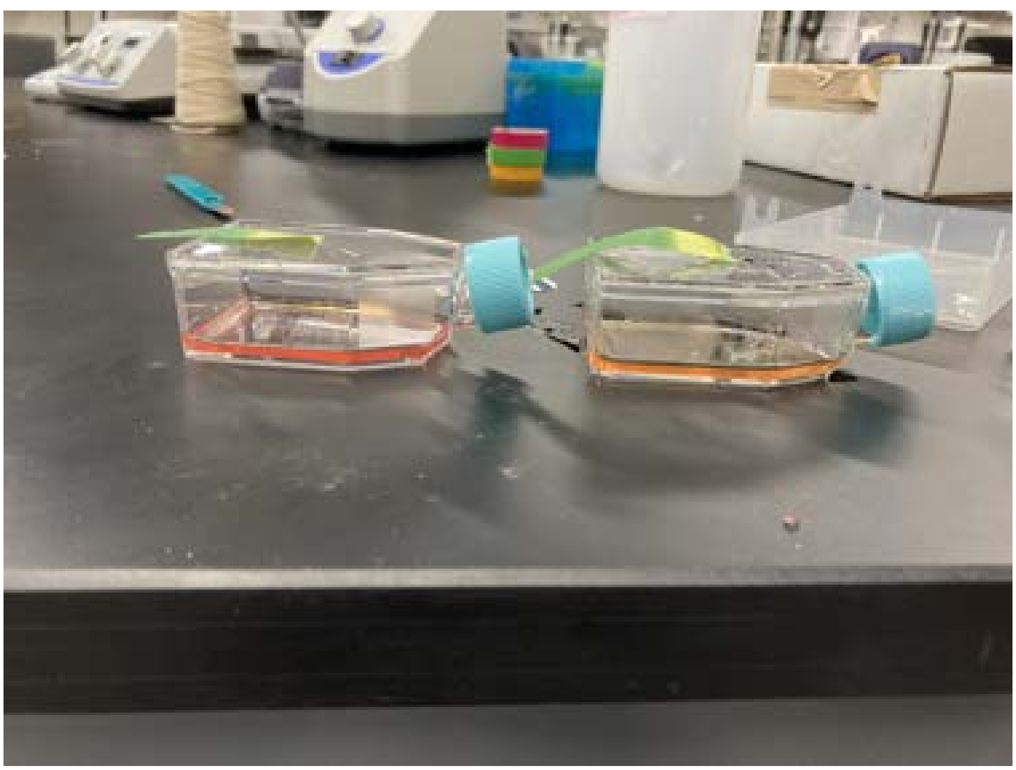
insert pH pic

-next day after increasing CO2 to 1.5x the original amount

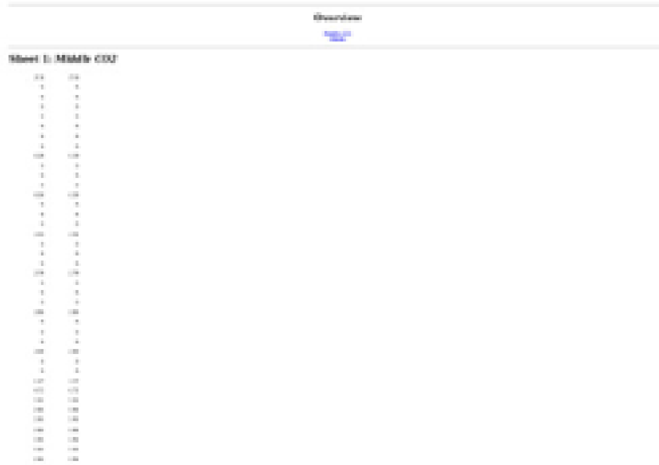
pH closer to 7.

- The final day testing pH images are shown below after increasing the CO_2 input to 1.75x the original amount. The results yielded a pH closest to the control flask. The control flask is depicted on the left, with a pH of roughly 7 as expected, and the testing flask is depicted on the right with a pH between 6 and 7.

The colors of the flask can be better visualized in the below image. As a reminder, the left flask is control, with a color of pinkish red for neutral pH, and the right flask is the experimental flask, with a organge-ish red color indicating a slightly acidic pH.



Katie Day - Apr 21, 2023, 11:39 AM CDT



Download

Middle_CO2.xlsx (101 kB)

Katie Day - Apr 21, 2023, 11:39 AM CDT

Download

Overdoing_CO2_test.xlsx (127 kB)

Katie Day - Apr 27, 2023, 5:01 PM CDT

Arduino Code for 3x

```
#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);

int relayPin = 13;

float x;

//temp

int ThermistorPin = 0;

int Vo;

float R1 = 10000;

float logR2, R2, T;

float c1 = 1.009249522e-03, c2 = 2.378405444e-04, c3 = 2.019202697e-07;

float Tc;

float e_s;

float e_d;

float Td = 36.1;

void setup()

{

  Serial.begin(9600);

  pinMode(relayPin, OUTPUT);


  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);
    }
}


void loop() {
  //concentration
    if (mySensor.measure()) {
        Serial.println();
    } else {
        Serial.println("Sensor communication error.");
         digitalWrite(relayPin, HIGH);   //switch relay on
         delay(150);                    //short input of CO2
         digitalWrite(relayPin, LOW);
         delay(5000);
    }
    x = (mySensor.ppm*5.0)/10000;
      if( x <= 4.5){
        digitalWrite(relayPin, HIGH);   //switch relay on
      delay(150);                    //short input of CO2
      digitalWrite(relayPin, LOW);
      delay(5000);
    }else{
      digitalWrite(relayPin, LOW);    //switch relay off
    }
    //temp
    // read the value from the sensor:
   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 - 273.15;

  //hum

  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 = ((e_d/e_s)*16)-4;


   //Printing

   Serial.println(Tc);

   Serial.println(x);

   Serial.println(hum);

   delay(600000);

}
```

Katie Day - Apr 27, 2023, 5:01 PM CDT

Arduino Code for 2x

```
#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);

int relayPin = 13;

float x;

//temp

int ThermistorPin = 0;

int Vo;

float R1 = 10000;

float logR2, R2, T;

float c1 = 1.009249522e-03, c2 = 2.378405444e-04, c3 = 2.019202697e-07;

float Tc;

float e_s;

float e_d;

float Td = 36.1;

void setup()

{

  Serial.begin(9600);

  pinMode(relayPin, OUTPUT);


  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);
    }
}

void loop() {
  //concentration
    if (mySensor.measure()) {
        Serial.println();
    } else {
        Serial.println("Sensor communication error.");
         digitalWrite(relayPin, HIGH);   //switch relay on
         delay(100);                    //short input of CO2
         digitalWrite(relayPin, LOW);
         delay(5000);
    }
    x = (mySensor.ppm*5.0)/10000;
      if( x <= 4.5){
        digitalWrite(relayPin, HIGH);   //switch relay on
      delay(100);                    //short input of CO2
      digitalWrite(relayPin, LOW);
      delay(5000);
    }else{
      digitalWrite(relayPin, LOW);    //switch relay off
    }
    //temp
    // read the value from the sensor:
   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 - 273.15;

//hum

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 = ((e_d/e_s)*16)-4;


  //Printing

 Serial.println(Tc);

  Serial.println(x);

  Serial.println(hum);

  delay(600000);

}
```

Katie Day - Apr 27, 2023, 5:02 PM CDT

Arduino Code for 1.5

```
#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);

int relayPin = 13;

float x;

//temp

int ThermistorPin = 0;

int Vo;

float R1 = 10000;

float logR2, R2, T;

float c1 = 1.009249522e-03, c2 = 2.378405444e-04, c3 = 2.019202697e-07;

float Tc;

float e_s;

float e_d;

float Td = 36.1;

void setup()

{

  Serial.begin(9600);

  pinMode(relayPin, OUTPUT);


  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);
    }
}

void loop() {
  //concentration
    if (mySensor.measure()) {
        Serial.println();
    } else {
        Serial.println("Sensor communication error.");
         digitalWrite(relayPin, HIGH);   //switch relay on
         delay(75);                   //short input of CO2
         digitalWrite(relayPin, LOW);
         delay(5000);
    }
    x = (mySensor.ppm*5.0)/10000;
      if( x <= 4.5){
        digitalWrite(relayPin, HIGH);   //switch relay on
      delay(75);                   //short input of CO2
      digitalWrite(relayPin, LOW);
      delay(5000);
    }else{
      digitalWrite(relayPin, LOW);    //switch relay off
    }
    //temp
    // read the value from the sensor:
   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 - 273.15;

  //hum

  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 = ((e_d/e_s)*16)-4;


    //Printing

   Serial.println(Tc);

    Serial.println(x);

    Serial.println(hum);

    delay(600000);

}
```

Katie Day - Apr 27, 2023, 5:02 PM CDT

Arduino Code for 1.75

```
#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);

int relayPin = 13;

float x;

//temp

int ThermistorPin = 0;

int Vo;

float R1 = 10000;

float logR2, R2, T;

float c1 = 1.009249522e-03, c2 = 2.378405444e-04, c3 = 2.019202697e-07;

float Tc;

float e_s;

float e_d;

float Td = 36.1;

void setup()

{

  Serial.begin(9600);

  pinMode(relayPin, OUTPUT);


  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);
    }
}

void loop() {
  //concentration
    if (mySensor.measure()) {
        Serial.println();
    } else {
        Serial.println("Sensor communication error.");
         digitalWrite(relayPin, HIGH);   //switch relay on
         delay(88);                    //short input of CO2
         digitalWrite(relayPin, LOW);
         delay(5000);
    }
    x = (mySensor.ppm*5.0)/10000;
      if( x <= 4.5){
        digitalWrite(relayPin, HIGH);   //switch relay on
      delay(88);                    //short input of CO2
      digitalWrite(relayPin, LOW);
      delay(5000);
    }else{
      digitalWrite(relayPin, LOW);    //switch relay off
    }
    //temp
    // read the value from the sensor:
   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 - 273.15;

  //hum

  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 = ((e_d/e_s)*16)-4;


    //Printing

   Serial.println(Tc);

    Serial.println(x);

    Serial.println(hum);

    delay(600000);

}
```

2/1/2023 Updated PDS

Katie Day - Apr 27, 2023, 4:48 PM CDT

Title: Updated PDS

Date: 2/1/23

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

Present:

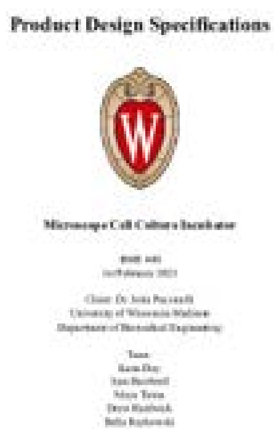
Goals: To update our PDS to better reflect where we are in the design process.

Content:

See attached file.

Conclusions/action items: N/A

Katie Day - Apr 27, 2023, 4:51 PM CDT



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Product_Design_Specifications_Spring_2023.pdf (229 kB)

2/6/2023 Design Matrices

Title: Design Matrices

Date: 2/6/2023

Content by: Katie, Drew, Maya, Sam, and Bella

Present:

Goals: To determine which method for measure CO2 and anti-fog/anti-condensation is best.

Content:

			MH-Z16		BME 680	
Rank	Criteria	Weight	Score (5 max)	Weighted Score	Score (5 max)	Weighted Score
1	Performance	30	3	18	5	
2	Water Resistance	20	5	20	0	
3	Ease of use	20	5	20	1	
4	Cost	15	1	3	5	
5	Life in Service	10	3	6	3	
6	Safety	5	5	5	4	
	Sum	100	Sum	72	Sum	59

Table 1: Design Matrix for CO_2 Sensor

			ITO Coating		Copper Grid Tape	
Rank	Criteria	Weight	Score (5 max)	Weighted Score	Score (5 max)	Weighted Score
1	Ease of Fabrication	25	3	15	4	
2	Performance	25	5	25	5	
3	Cost	20	1	4	4	
4	Safety	15	5	15	4	
5	Life in Service	15	5	15	3	
	Sum	100	Sum	74	Sum	82

Table 2: Design Matrix for Anti-Fog/Condensation

Conclusions/action items: The team will proceed with the MH-Z16 sensor as in previous semesters and the Copper Grid Tape.

2/15/23 Preliminary Presentation

Katie Day - Feb 27, 2023, 2:52 PM CST

Title: Preliminary Presentation

Date: 2/15/23

Content by: Katie, Bella, Drew, Sam, and Maya

Present:

Goals: To present our preliminary findings and current goals for the semester.

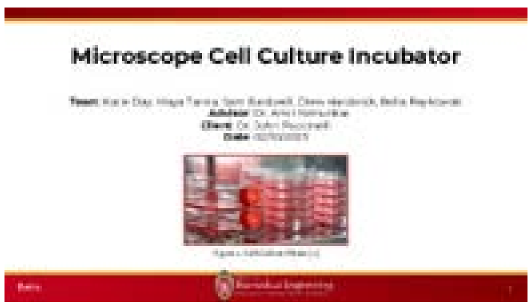
Content:

See attached file.

Conclusions/action items:

Begin materials purchasing and initial validation testing.

Katie Day - Feb 27, 2023, 2:52 PM CST



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Prelim_Presentation_Slides_Spring_2023.pdf (1.77 MB) Preliminary Presentation Spring 2023

4/28/23 Final Poster

MAYA TANNA - May 01, 2023, 8:29 PM CDT

Title: Final Poster

Date: 4/28

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

Present:

Goals: To present our work for the semester in poster form

Content:

See attached file.

Conclusions/action items: N/A

Katie Day - May 01, 2023, 2:56 PM CDT

Download

Final_Poster_Cell_Incubator_Spring_2023_2_.pdf (1.42 MB) Final Poster

5/1/23 Final Report

MAYA TANNA - May 01, 2023, 8:30 PM CDT

Title: Final Poster

Date: 5/1

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

Present:

Goals: To present our work for the semester in report form

Content:

See attached file.

Conclusions/action items: N/A

MAYA TANNA - May 01, 2023, 8:30 PM CDT


Microscope Incubator for Cell Culture: A Low Cost Alternative

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

Abstract

[Download](#)

Final_Report_1_.pdf (13 MB)

Final Anti-condensation Conclusions

SAMUEL BARDWELL - Apr 20, 2023, 8:40 AM CDT

Title: Final Anti-condensation Conclusions

Date: 5/3/23

Content by: Sam

Goals: To provide a final conclusion on anti-condensation efforts completed this semester.

Content:

Anti-condensation testing for the copper tape design was discontinued after calculations showed that 10-20 Amps of current were needed in addition to a 12 V power supply to obtain the needed temperatures to prevent condensation accumulation. The calculated voltage and amps were too high and posed safety issues.

When the two fans were located on opposite corners of the incubators, a maximum condensation area of around 18% was seen before lid removal, and then increasing to 51% after the internal environment disruption. The same-side dual mini fan setup had similar results. After 45 minutes of testing, the percent condensation was clearly too high and after the internal environment disruption, the percent coverage of fog was even worse. This was also deemed to be nonsignificant for optical clarity and was discontinued. If any method with the mini-fans work even better, I would still be hesitant to use them because the glass commonly fogged up in the middle first where the incubator light needs the most transparency to provide clear images, resulting in unclear images from the microscope. The mini-fans are also difficult to place inside of the incubator because there needs to be room for the flasks or well plates and the way the incubator box was designed, there is very little extra room.

The anti-bacterial condensation prevention idea was also discontinued after the results showed visibly minimal condensation prevention in as little as 20 minutes.

Lastly, the PDMS anti-condensation testing idea was also discontinued after visibly minimal condensation prevention after 30 minutes for both the PDMS with and without a fan.

Conclusions/action items:

In conclusion, no anti-condensation efforts were successful this semester. Ideas that were pursued and tested theoretically or experimentally include the mini-fans, copper tape (rear car window defroster), hydrophobic liners (Rain prevention stickers for cars), anti-bacterial hand sanitizer solution, a form of suction, PDMS liner, and ITO glass. Condensation prevention is difficult with this project due to the lack of space, need for sterility, need from transparency, and lack of funds. If I were to continue looking for anti-condensation methods, I would look at ways to heat the top lid glass outside of the incubator box without an electrical current. This could possible be completed with heated air or the implementation of a heated water pump extension. Another idea is to raise funding and obtain a more expensive liner to place on the glass to prevent condensation build up.

Final Fabrication

SAMUEL BARDWELL - May 01, 2023, 9:38 AM CDT

Title: Final Fabrication

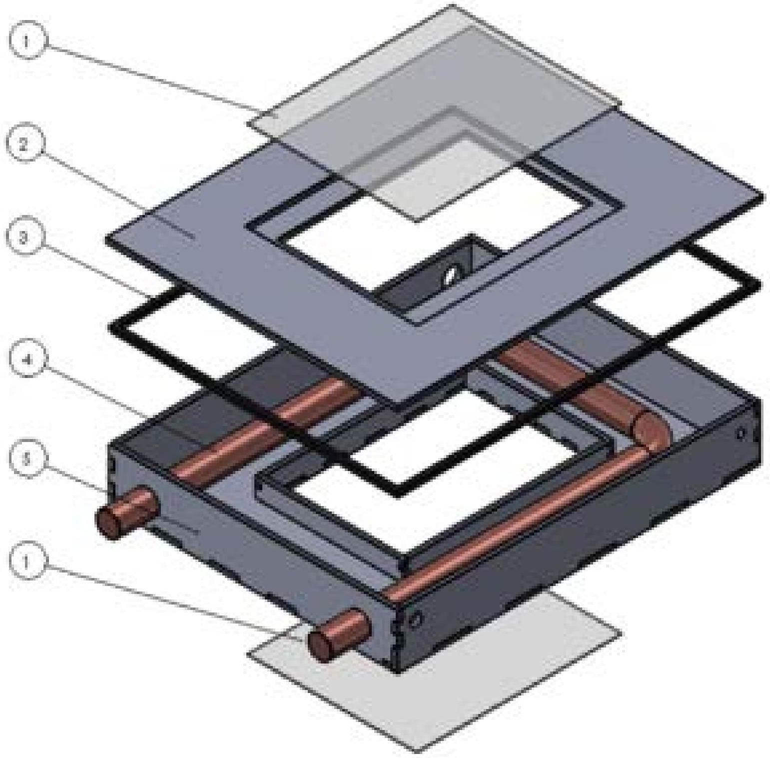
Date: 5/1/23

Content by: Sam

Goals: To provide the final fabrication design of the incubator.

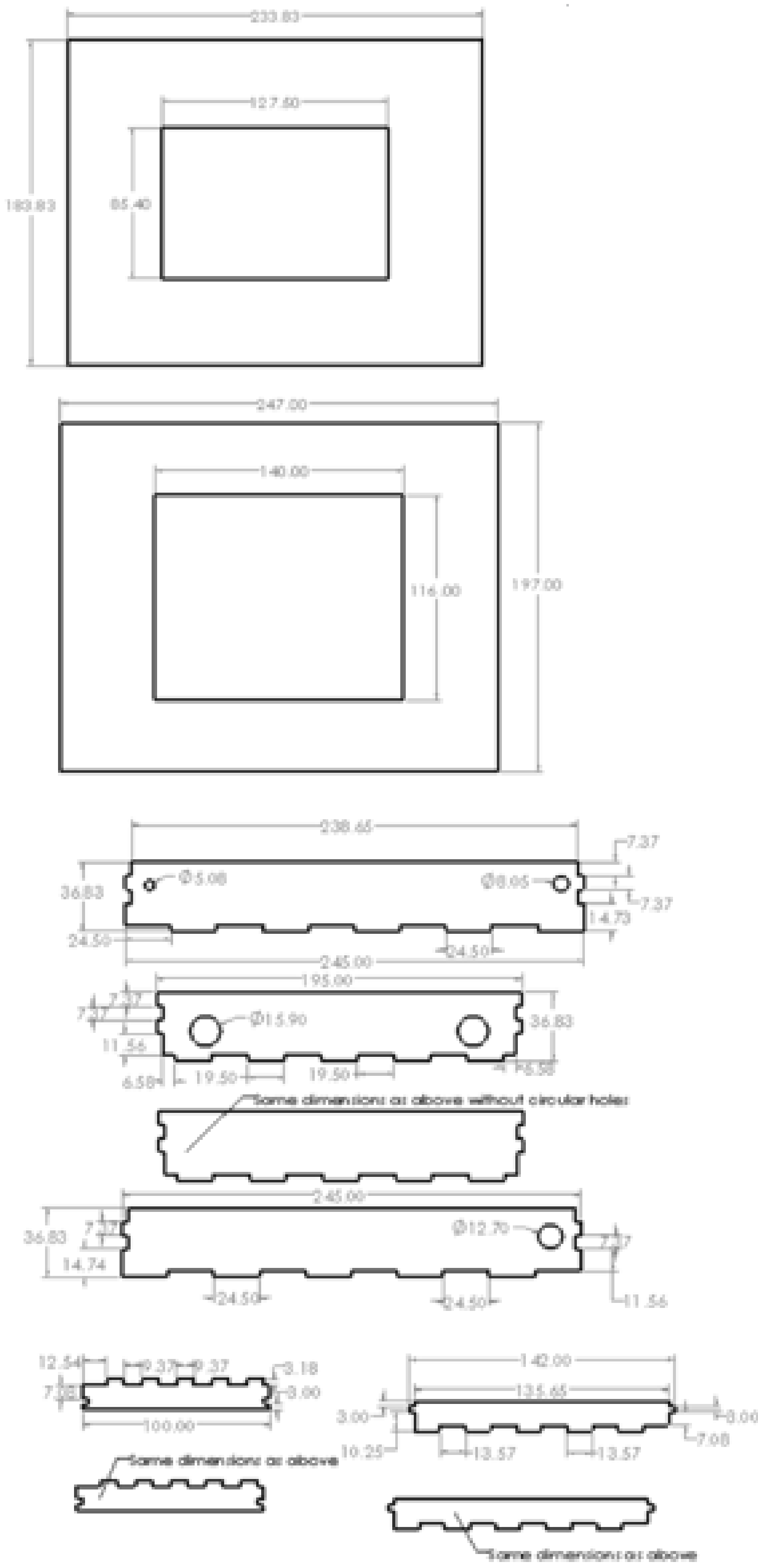
Content:

CAD Files and Drawings:



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


233.83
127.50
183.83
85.40
247.00
140.00
116.00
197.00
238.65
7.37
Ø5.08
Ø8.05
36.83
7.37
14.73
24.50
245.00
24.50
195.00
Ø15.90
36.83
11.56
6.58
19.50
19.50
6.58
Same dimensions as above without circular holes
245.00
Ø12.70
36.83
14.74
24.50
24.50
11.56
12.54
9.37
9.37
3.18
3.00
100.00
142.00
135.65
3.00
3.00
7.08
10.25
13.57
13.57
Same dimensions as above
Same dimensions as above

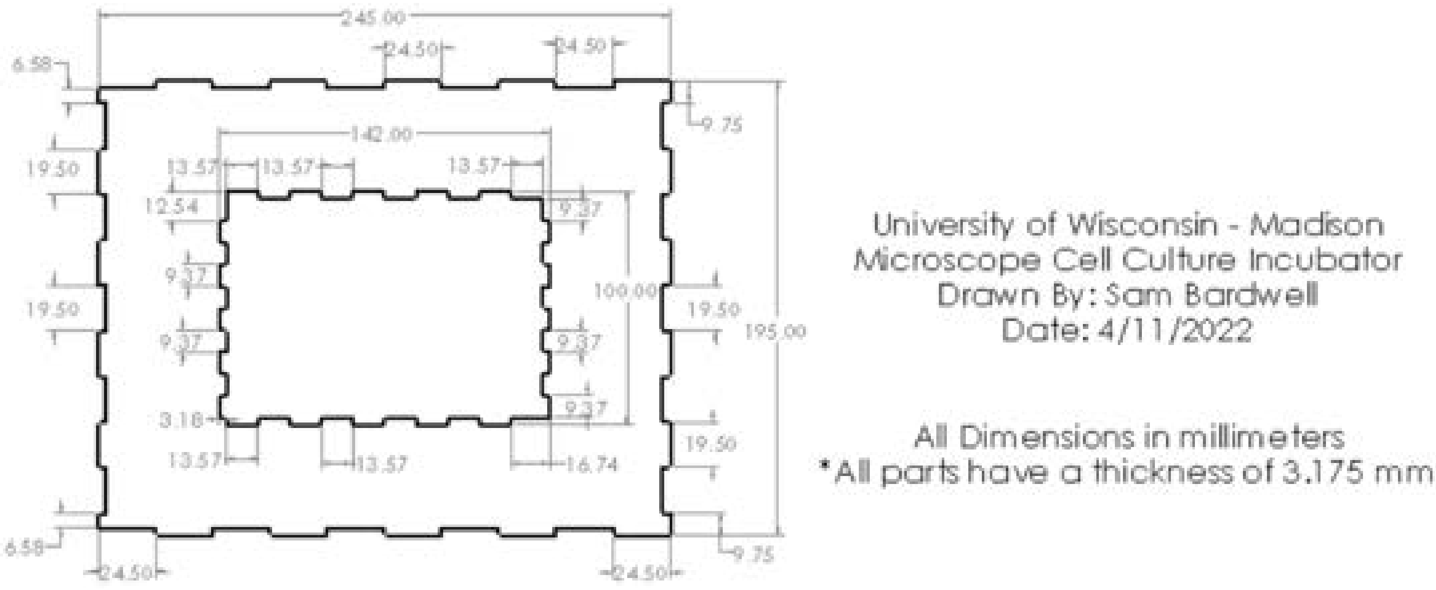


Figure 2: Laser Cut designs and dimensions

Box Fabrication:

Figure 3: Newly fabricated box with waterproof silicone caulk seals.

Figure 4: Thick lid incubator box fabrication

Conclusions/action items:

The final incubator box design worked well for its tasks, but could always be improved. The use of the metal lid may be beneficial in the future, because warping was still seen with the thicker acrylic lid. The incubator box CAD files could also be updated to fit the copper tubing more snug and to incorporate the sensors more efficiently. New and better materials can always be considered for the box and glass but the team worked with what was available.

SAMUEL BARDWELL - May 01, 2023, 9:38 AM CDT

Download

Incubator_Solidworks_Drawing.zip (1.36 MB)

Final Code

Katie Day - May 01, 2023, 2:53 PM CDT

Title: Final Code

Date: 5/1/2023

Content by: Katie Day

Present:

Goals: To present the final code that was used during testing.

Content:

```
#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);
int relayPin = 13;
float x;
//temp
int ThermistorPin = 0;
int Vo;
float R1 = 10000;
float logR2, R2, T;
float c1 = 1.009249522e-03, c2 = 2.378405444e-04, c3 = 2.019202697e-07;
float Tc;
float e_s;
float e_d;
float Td = 36.1;
void setup()
{
    Serial.begin(9600);
    pinMode(relayPin, OUTPUT);

    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);
    }
}

void loop() {
  //concentration
    if (mySensor.measure()) {
        Serial.println();
    } else {
        Serial.println("Sensor communication error.");
         digitalWrite(relayPin, HIGH);   //switch relay on
         delay(50);                      //short input of CO2
         digitalWrite(relayPin, LOW);
         delay(5000);
    }
    x = (mySensor.ppm*5.0)/10000;
      if( x <= 4.5){
        digitalWrite(relayPin, HIGH);   //switch relay on
      delay(50);                      //short input of CO2
      digitalWrite(relayPin, LOW);
      delay(5000);
```

```
    }else{
      digitalWrite(relayPin, LOW);    //switch relay off
    }
    //temp
    // read the value from the sensor:
   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 - 273.15;
  //hum
  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 = ((e_d/e_s)*16)-4;

    //Printing
   Serial.println(Tc);
    Serial.println(x);
    Serial.println(hum);
    delay(600000);
}
```

Conclusions/action items: N/A

Final Cell Viability

Bella Raykowski - May 01, 2023, 4:35 PM CDT

Title: Final Cell Viability Testing Results

Date: 5/1/23

Content by: Bella

Goal: Document the final results found after the semester of cell testing

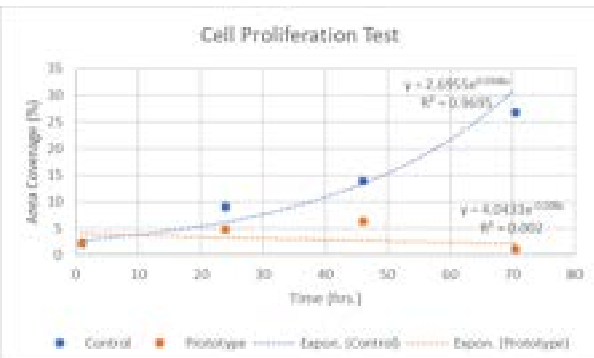
Content:

- all cells tests were run in T25 flasks, using mice osteoblast cells at a ~20k seeding density

- for each test 1 flask was housed in the prototype and an identical flask was housed in the standard device incubator

Test 1:

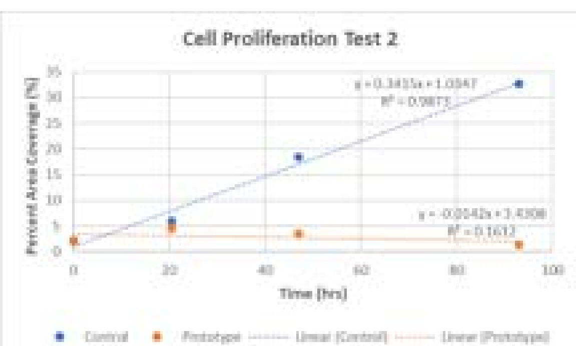
- Test was run for 3 days, with images being taken ~24 hours and analyzed using ImageJ



- cell viability failed due to a combination of human error/interference and a basic environment

Test 2:

- Test was run for 4 days, with images being taken ~24 hours and analyzed using ImageJ



- cell viability test failed due to a basic environment (pH = 10)

Test 3:

- Test was run for 3 with the prototype's flask being changed every 24 hours. The pH was measured for each flask every 24 hours.

CO_2 release time change from original amount (50ms)	pH	Average %CO_2
3x	5	10%
2x	6	6.5%
1.5x	8	3%
1.75x	7-9	Sensor Failure

- cell viability test failed due to the inability to maintain a neutral pH

Conclusion: Prototype was unable to maintain cell viability for more than 24 hours.

Final Conclusions/Discussions

Drew Hardwick - May 02, 2023, 8:58 AM CDT

Title: Final Conclusions/Discussion

Date: 5/2/23

Content by: Drew

Present: N/A

Goals: Draw Final Conclusions and discuss Semester Work

Content:

anti-fog testing:

- the results of every test showed that there is no one best solution to prevent the formation of condensation on the incubator lid glass
- Some possible sources of error between anti-condensation testing could be due to using a hot plate and beaker to test feasibility instead of using the actual incubator for each test
- Another error could be not including the flask while doing the anti-condensation testing, which could disrupt airflow of the mini-fans, changing results dramatically.

internal environment:

- temperature and humidity were easily achieved via a water bath and heated water pump. Both values were continuously in range after live cell round 2 testing.
- Unfortunately, NDIR CO2 sensor continuously got worse in terms of reading the value of CO2 after exposure to the incubator for a long period of time. It was initially able to withstand approximately 10 hours of exposure, but quickly the amount of condensation/humidity within the environment overpowered the sensor and it began to fail more frequently.
- The failure of the CO2 sensor led to a failure of the feedback loop to pump in the correct amount of CO2 needed to keep a neutral pH.
- The pH was consistently too acidic or too basic depending on the amount of time the feedback loop was instructed to pump out CO2.
- The NDIR sensor was not equipped to survive within these conditions and ultimately accelerated cell death.

cell viability:

- the device failed
- The pH was unable to be maintained at a neutral 7 which caused the cells to slowly die off either due to cell membrane damage or altered protein structures
- At most, the device could maintain cell viability for 24 hours, but any time after that the cells reacted negatively by stopping proliferation and condensing in on themselves.
- If the CO2 input would have been adequate to maintain a pH of 7, then the cells would have likely survived and proliferated making the device successful.

Sources of error:

- imaging a different area of the flask every day and some dead cells were included in images.
- numerous sensor communication error signals outputted during testing made it impossible to determine the true value of CO2 in the incubator.

Conclusions/action items:

The client envisioned a cell culture incubator for semesterly use in a teaching lab that would be lightweight and compact, compatible with an inverted microscope, able to maintain a stable internal environment, and cost-effective. The team proposed a design that meets all these criteria. The proposed final design included a copper tube that was wrapped around the inside of the incubator and connected to a heated water pump that regulated the internal incubator conditions. The lid to the incubator was placed on top which allowed for a tight seal of the internal environment and helped prevent leakage. The incubator box also contained holes for CO2 input, a CO2 sensor, and a thermistor temperature sensor that will in addition be coded to calculate the internal humidity. The CO2 input was monitored using a solenoid valve that received direction from a NDIR sensor in communication with an Arduino microcontroller. The team conducted testing to mitigate condensation buildup, measure cell viability, and determine if the internal homogenous environment could be maintained. While the prototype was able to maintain a homogenous internal environment for extended periods of time, unfortunately, condensation and cell viability issues persisted. Moving forward, the team would work to obtain either a new CO2 or pH sensor, continue live cell testing to evaluate cell viability, and experiment with anti-fog and anti-condensation methodologies.

3/22/23 Anti-Condensation Research

SAMUEL BARDWELL - Mar 22, 2023, 8:37 AM CDT

Title: Anti-Condensation Research

Date: 3/22/23

Content by: Sam

Goals: To conduct research on more possible anti-condensation methods.

Content:

Link: https://www.amazon.com/HLAA-Waterproof-Rainproof-Rearview-Protector/dp/B08PCWT2C3/ref=sr_1_12?crid=3CS40KZ9XWNG5&keywords=anti-fog%2Bfilm%2Badhesive%2Bmirror%2Bprotective%2Bfilm&qid=1679491176&sprefix=anti-fog%2Bfilm%2Badhesive%2Bmirror%2Bprotective%2Bfilm%2Caps%2C87&sr=8-12&th=1

Cite: "Car Rearview Mirror Waterproof Film - 6 Pieces Side Mirror Film Anti Fog Film for Car Rainproof Mirror Window Film Transparent Nano-Coated Protective Sticker for Cars Trucks Bus Side Windows." https://www.amazon.com/HLAA-Waterproof-Rainproof-Rearview-Protector/dp/B08PCWT2C3/ref=sr_1_12?crid=3CS40KZ9XWNG5&keywords=anti-fog%2Bfilm%2Badhesive%2Bmirror%2Bprotective%2Bfilm&qid=1679491176&sprefix=anti-fog%2Bfilm%2Badhesive%2Bmirror%2Bprotective%2Bfilm%2Caps%2C87&sr=8-12&th=1 (accessed Mar. 22, 2023).

Content:

- These are adhesive, clear, anti-fog films that can possibly be placed onto the inside glass of the incubator.

- They are only 0.2 mm in thickness which prevents any worries about spacing issues.

- There is easy an easy application process with a quick clean and stick set up.

- Package comes in different sizes and we are able to cut them to appropriate sizes if needed.

- One issue is that in the review section, people say it works well for heavy rain, but does not work well for fog which is what were trying to prevent.

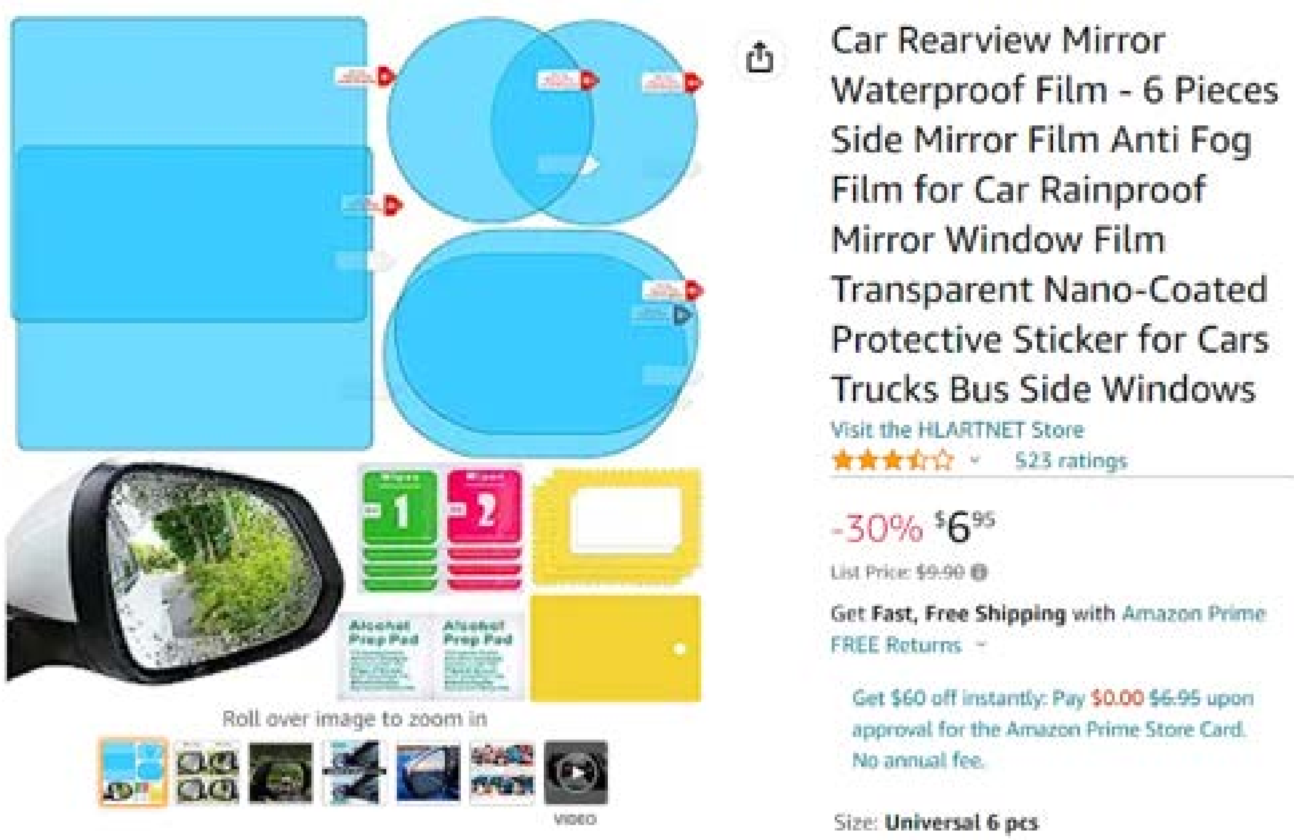


Figure 1: Image of the possible film product we can order and experiment with.

Conclusions/action items:

I don't have overly high hopes for this design because the reviews say it doesn't do the best in foggy conditions, only rain. Regardless, if we are able to order this set I will test it in the incubator and take photos of the amount of fog being accumulated.

3/27/23 Anti-Fog Research

SAMUEL BARDWELL - Apr 17, 2023, 1:27 PM CDT

Title: Anti-Fog Research

Date: 3/27/23

Content by: Sam

Goals: To research possible anti-fog methods.

Content:

Cite: A. Gärtner *et al.*, "Combined antifogging and antireflective double nanostructured coatings for LiDAR applications," *Appl. Opt., AO*, vol. 62, no. 7, pp. B112–B116, Mar. 2023, doi: 10.1364/AO.476974.

- This publication reviews anti-fogging methods for LiDAR applications

- After skimming through the publication, I found out they use a water absorbable coating in order to prevent fogging of their lenses

- More specifically, these researches used a product by Exxene called HCF-100 which is a permanent anti-fog treatment

Exxene Website: https://exxene.com/anti-fog

- I then visited the Exxene website to find any possible products that we could use for our project.

- They have a lot of possibilities, but no pricing which leads me to assume these are expensive materials.

<u>Exxene Anti-Fog Products</u>

HCF-100 Scratch Resistant

The HCF-100 performs well in a wide range of temperatures and moisture levels, excelling at low-temperature frost and ice reduction. It provides a scratch-resistant and formable anti-fog functionality on plastic and glass. The diacetone alcohol solution contains a polyurethane with a minimum cure temperature of 110 degrees Celsius.

HTAF-936 General Use

The HTAF-936 is best suited for semi-sealed environments such as gauges, optics, instrument panels, and lighting. It is a surface-active urethane dispersion with a minimum cure temperature of 60 degrees Celsius.

EX-99R   Optical Anti-Fog

EX-99R is an advanced formulation especially developed for use on coated substrates including Anti-Reflective (AR) coated glass, optics, mirrors, and hardcoated ophthalmic lenses. It is an air-drying, alcohol solution of hydrophilic and amphiphilic surfactants.

I-99 General Use

The I-99 Anti-Fog Cleaner is a concentrated anti-fog liquid developed for general use on uncoated plastic and glass. The product is an air-drying, aqueous solution of nonionic, hydrophilic surfactant. I-99 is available in bulk liquid and pre-packaged into multi-use towelettes (Klean n' Klear Anti-Fog Towelettes).

- I-99 General use sounds the most applicable to our product.

- I don't know the cost and can't find it

Anti-Fog Goggle Study

Cite: Y. Hongjiang, H. Xiaoqiong, K. Yue, C. Ping, C. Jing, and Y. Yunhua, "Effectiveness of 2 Pretreatment Methods in Antifogging of Goggles in a COVID-19 Isolation Ward: A Randomized Controlled Trial," *Journal of Emergency Nursing*, vol. 48, no. 5, pp. 571–582, Sep. 2022, doi: 10.1016/j.jen.2022.06.004.

- This study done in China used accessible materials in order to prevent fogging within goggles work for over 4 hours

- This study determined that anti-bacteria hand sanitizer had significant impact on the anti-fogging of the goggles.

- Antibacterial hand sanitizer contains chlorhexidine gluconate [0.2% 6 0.02% (W/V)] as the main active ingredient.

- Goggles were coated with antibacterial hand sanitizer and distilled water, mixed at a 1:1 ratio

- For the hand sanitizer group, antibacterial hand sanitizer solution was diluted with 1 mL of distilled water at a ratio of 1:1 to coat the goggles.15 Dry cotton balls were used to apply an appropriate amount of antibacterial hand sanitizer, creating a thin layer. Application of the solutions with dry cotton balls ensured even coverage across the entire surface of goggles and that the line of sight was not affected by excess solution in the form of droplets. Following application, the goggles were also dried with a hairdryer and then considered ready to use.

Conclusions/action items:

I think the next method we should pursue in order to combat the anti-condensation problem is coating the glass in a material that prevent the formation of fog. Finding an affordable and obtainable product is going to be the difficult part. We still have to try the inner box light option as well for incubator testing. The anti-bacterial hand sanitizer would be an easy solution because it is easily accessible. The hand sanitizer would most likely have to be reapplied multiple times throughout testing.

2/6/23 Heated Glass for Condensation Problems Brainstorm

SAMUEL BARDWELL - Feb 06, 2023, 11:42 AM CST

Title: Heated Glass for Condensation Problems

Date: 2/6/23

Content by: Sam

Goals: To brainstorm cost-effective ways to heat the glass on the incubator to prevent condensation build up.

Content:

- Purchase a conductive film to place on top of the glass and hook up a current to heat the glass up.

https://www.adafruit.com/product/1309?gclid=Cj0KCQiA54KfBhCKARIsAJzSrdpssPThJIQmhnd9jr-eRkDyIpzYpEBQZXVMHY57JYVJ-WuZQVSGSDkaAsBXEALw_wcB

- Purchase conductive tape to hook up a current to heat up glass

https://www.adafruit.com/product/3483?gclid=Cj0KCQiA54KfBhCKARIsAJzSrdoijhz8gVJ1tu4IbT_pcxBtUkm1oBBjZO_mKNuSosoRNxNtbF3TXc0aAvMqEALw_wcB

https://www.amazon.com/Double-Sided-Conductive-Shielding-Soldering-Electrical/dp/B09WGYP2VR/ref=sr_1_4?crid=2DYYGBAIGU466&keywords=conductive+tape&qid=1675704872&sprefix=conductive+tap%2Caps%2C102&sr=8-4

https://www.browndoggadgets.com/blogs/news/conductive-tape-experiment-in-great-detail#:~:text=Again%2C%20copper%20foil%20is%20pretty,heat%20and%20electronics%20very%20well.&text=We%20then%20bumped%20it%20up,heated%20up%20to%20about%20105F

- ITO Glass purchase

Have to talk to the chemistry building

Conclusions/action items:

Copper tape looks promising to hook up a current and voltage to in order to heat up our glass top to prevent condensation. The use of simple wires with a tape coating might work as well. The difficult part would be figuring out the correct voltage and amperage that would be safe and produce the correct heat we need. ITO glass is also an option but could get expensive and more difficult to fabricate.

2/8/23 Condensation Prevention with Copper Tape

SAMUEL BARDWELL - Apr 17, 2023, 1:12 PM CDT

Title: Condensation Prevention with Copper Tape

Date: 2/8/23

Content by: Sam

Goals: To start experimenting with ways to heat up the glass to reduce condensation in the incubator.

Content:

- The copper tape was purchased on Amazon for ~$10

- The thinner the copper tape the better to reduce optical interruptions

https://www.amazon.com/Double-Sided-Conductive-Shielding-Electrical-x21-9yards/dp/B07R6HNDDX/ref=sr_1_3?crid=PAVE6N62VUL7&keywords=copper%2Btape%2B1%2F8th&qid=1675877297&sprefix=copper%2Btape%2B1%2F8th%2Caps%2C98&sr=8-3&th=1

Figure 1: Copper tape to put a current through and heat up the glass

- The idea is to take the copper tape and to align it as seen in Figure 2

- Figure 2 shows the typical design for a rear window defroster on most modern cars. A current can be passed through the copper or other sort of conductive material with the hope that it will produce some heat. If I can hook up a circuit onto the incubator glass that can produce a little bit of heat and help reduce condensation build up it will be a success.

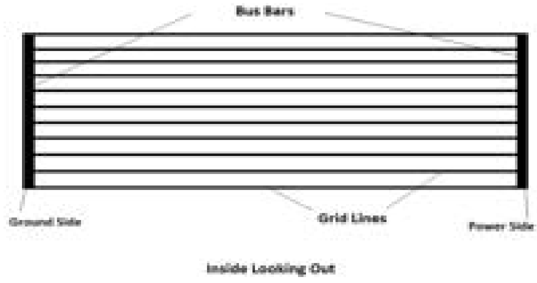


Figure 2: Proposed layout design for the copper tape

https://beranek.agrrmag.com/2018/08/rear-defroster-diagnosis/

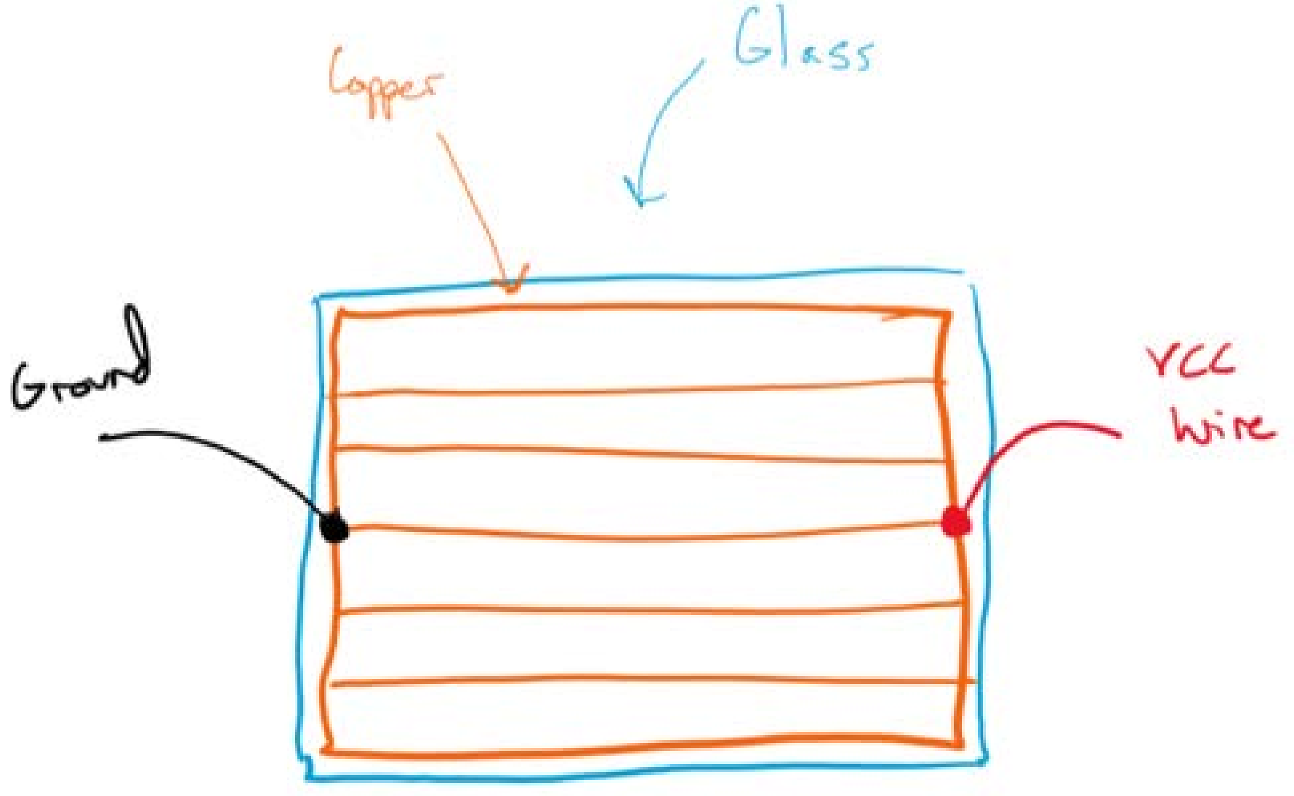


Figure 3: Drawing of intended plan for copper tape condensation prevention

Edit 2/10/23:

This method has good principals around it, but given the voltage and current supply available to the team, this method is not reasonable. A large amount of current (amps) is needed to make this copper tape method work. With the increase in current, comes a higher risk of safety and could blow out the circuit being used if it is not made properly. The next method that is going to be attempted is the use of a micro fan (25x25x10 mm).

Conclusions/action items:

I need to do multiple tests with different currents and voltages. I have the copper tape and need to figure out how to safely build this circuit as well. Eventually I can add more safety precautions. I am hoping to hook up a circuit on old incubator glass and then heating up some water with a hot plate to produce steam which will settle onto the glass and hopefully see the heated up copper rid of the steam.

2/15/23 Mini Fan Design

SAMUEL BARDWELL - Feb 15, 2023, 7:15 PM CST

Title: Mini Fan Design

Date: 2/15/23

Content by: Sam

Goals: To test a mini fan idea to prevent condensation.

Content:

Link: https://www.amazon.com/Coolerguys-25mm-25x25x10-USB-Fan/dp/B07NC4Z24T/ref=sr_1_4?crid=3T7TASJH4USER&keywords=mini+fan+25+mm+usb&qid=1676510065&sprefix=mini+fan+25+mm+usb%2Caps%2C142&sr=8-4

Conclusions/action items:

Intended mini fan to be used for condensation prevention testing.

3/7/23 Condensation Location Importance

SAMUEL BARDWELL - Mar 07, 2023, 4:35 PM CST

Title: Condensation Location Importance

Date: 3/7/23

Content by: Sam

Present: Sam and Bella

Goals: To determine what condensation and where is of importance and needs to be removed in order to have clear cell images.

Content:

- Bella and I turned on the incubator with the heated water pump and water bed. We also placed the cell flask in the middle of the incubator and put everything under the microscope to conduct some visual test.

- Once everything was set up and running, we took a thin piece of paper to cover up the light source from the incubator and then covered up the objective turrets, but still allowing light to pass through. We wanted to figure out what parts of the microscope needs the condensation removed more drastically.

Conclusions/action items:

We determined that both the top and bottom of the incubator are important. If the light source is covered up (imitating high condensation) the lighting will not be enough to illuminate the cells for imaging. We also determined that the bottom glass needs to be clear as well in order to have a clear focus on the cells. We also hypothesized that if the flask or well plate is resting on the bottom glass sheet, condensation would not be able to build up providing a clear image. If that is the case, we would only need to reduce the condensation build up on the top glass just enough to allow as much light through the glass as possible. This will be tested tomorrow (3/8) under the microscope with cells and the mini fans.

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:

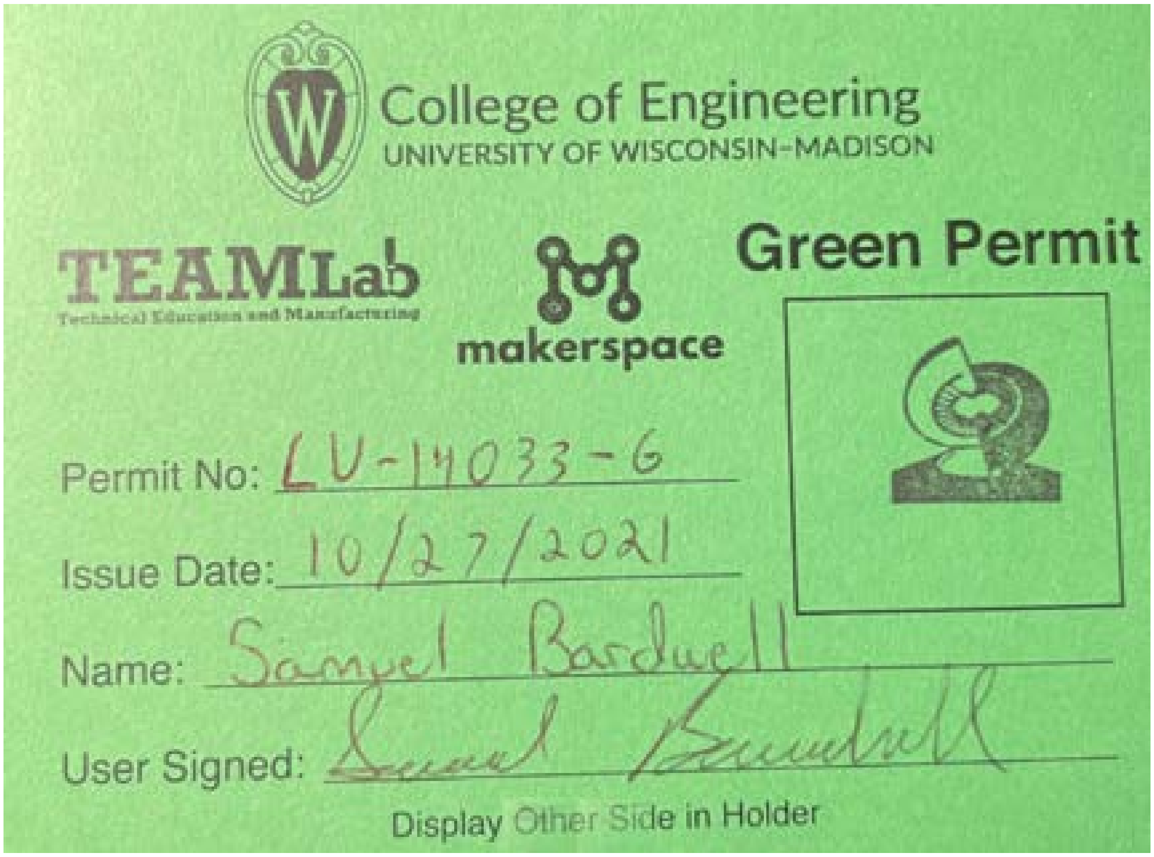


Figure 1: Front side of the green permit

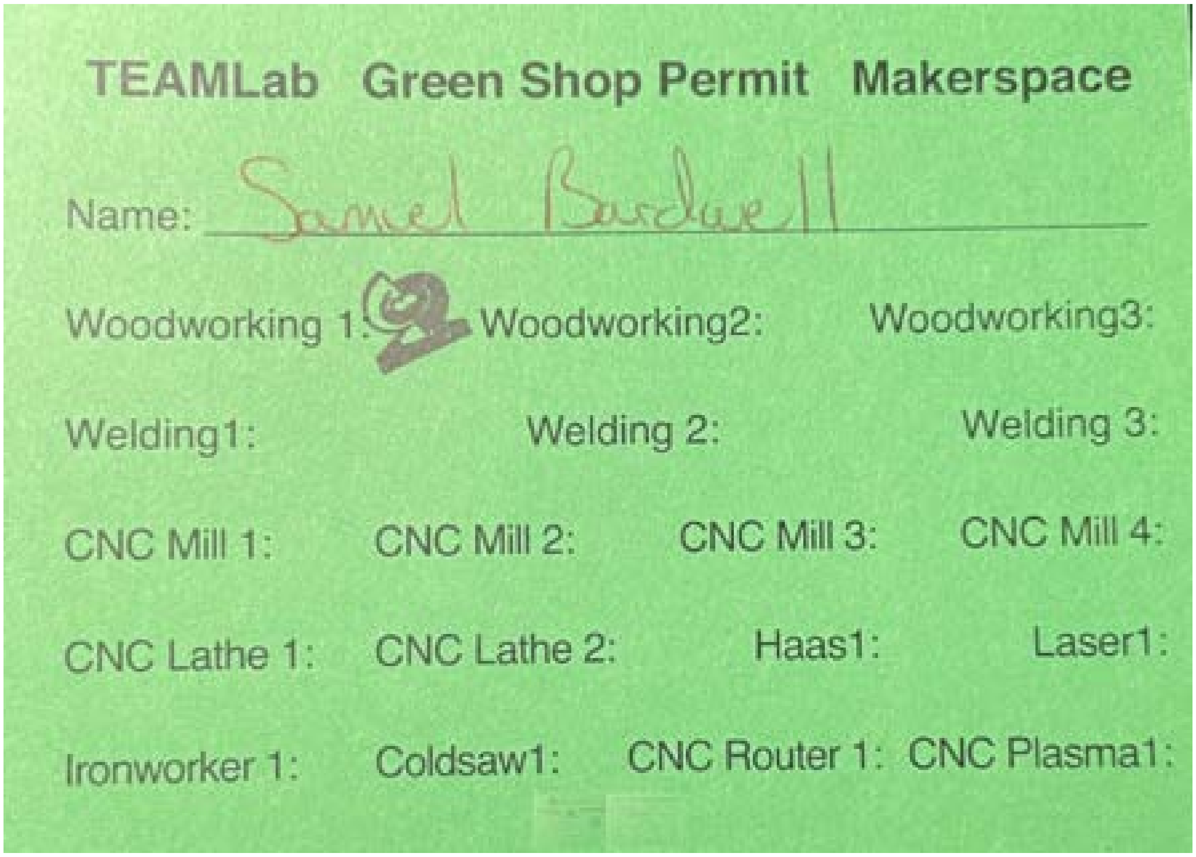


Figure 2: Back side of green permit

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.

2/2/23 Progress Report 1

SAMUEL BARDWELL - Feb 02, 2023, 3:34 PM CST

Title: Progress Report 1

Date: 2/2/23

Content by: Sam

Goals: Provide weekly updates on individual progress

Content:

- Began fabrication of the new incubator box: Laser cut new acrylic, waterproofed inside of box, and gutted copper tubing from old box and implemented it into the new one.

Figure 1: Ariel view of the newly fabricated incubator box connected to the heated water pump and contains a bed of water. No leakage.

Figure 2: Top view of the new incubator box showing the caulking and copper piping.

Figure 3: Side view of hose adaptors showing the new plumbers tape and caulk to prevent water leakage.

Conclusions/action items:

Have a client meeting with Dr. P to discuss lid designs for this semester. Begin fabrication of new lid design.

2/9/23 Progress Report 2

SAMUEL BARDWELL - Feb 08, 2023, 12:03 PM CST

Title: Progress Report 2

Date: 2/9/23

Content by: Sam

Goals: To provide weekly updates on my project contributions.

Content:

- Met with Dr. P to clarify design requirements, clarify materials that need to be purchased, and try to obtain cells.

*See 2/6/23 Client Meeting

- Fabricated a metal lid to hopefully reduce any warping caused by the humidity and temperature in the incubator.

*See Metal Lid Fabrication in the team activities folder

- Began brainstorming possible ways to reduce condensation on the incubator glass and began to test those ideas.

*See Condensation Prevention entries in Sam Bardwell's Design Idea folder

Conclusions/action items:

- Work on the preliminary report, prepare for the outreach project, and conduct some testing on original ideas to reduce condensation on the incubator glass.

2/16/23 Progress Report 3

SAMUEL BARDWELL - Feb 15, 2023, 7:45 PM CST

Title: Progress Report 3

Date: 2/16/23

Content by: Sam

Goals: To provide weekly updates on my individual progress.

Content:

- Fabricated a thicker lid for the incubator box to prevent warping.

  * See Thick Lid Fabrication in team activities fabrication folder

- Conducted a proof of concept test with the mini fan idea.

  * See Mini fan preliminary testing in team activities experimentation folder.

Conclusions/action items:

- Continue to do more formal experimental testing with the mini fan.

- Figure out the best place to have the fan located inside of the incubator.

- Determine if having 2 fans in the box is reasonable.

2/23/23 Progress Report 4

SAMUEL BARDWELL - Feb 23, 2023, 9:09 AM CST

Title: Progress Report 4

Date: 2/23/23

Content by: Sam

Goals: To provide weekly progress on my individual contributions

Content:

- Experimented with fan positioning for maximum condensation prevention

See Team Activities Testing and Results Experimentation folder for mini fan testing

Conclusions/action items:

- Continue to find optimal fan position for condensation prevention.

- Fabricate a way to secure mini fans into the incubator box.

- Put glass on the thick lid.

- Write the preliminary report.

3/2/23 Progress Report 5

SAMUEL BARDWELL - Mar 08, 2023, 11:01 AM CST

Title: Progress Report 5

Date: 3/2/23

Content by: Sam

Goals: To provide weekly updates on individual contributions.

Content:

- Completed preliminary deliverables.

See Team Activities Project Files folder for Preliminary Presentation and Report

- Conducted experiments on mini fan positioning for anti condensation.

See 2/28/23 Dual Mini-Fan Testing and edits

- Fabricated the glass on to the incubator box.

Conclusions/action items:

Continue to experiment with anti condensation methods.

3/9/23 Progress Report 6

SAMUEL BARDWELL - Mar 08, 2023, 3:17 PM CST

Title: Progress Report 6

Date: 3/9/23

Content by: Sam

Goals: To provide updates on weekly progress and contributions.

Content:

- Determined whether condensation is more impactful on the top or bottom glass.

See Sam's Folder > 3/7 Condensation Location

- Conducted mini-fan testing on the microscope to determine if the mini-fans help provide better optics while the incubator is running.

See Experimentation in Team Activities Testing > 3/8 Condensation Testing

- Helped with full incubator system testing.

Conclusions/action items:

- Help conduct live cell testing.

- Continue to improve condensation prevention.

3/23/23 Progress Report 7

SAMUEL BARDWELL - Mar 22, 2023, 4:26 PM CDT

Title: Progress Report 7

Date: 3/23/23

Content by: Sam

Goals: To provides updates on individual weekly progress.

Content:

- Set up the incubator for live cell testing.

Cells ended up dying so we were not able to conduct live cell testing this week.

- Continued to research condensation prevention methods.

See my Research Notes > Bio & Phys > 3/22/23 Anti-Condensation Testing

Conclusions/action items:

- Help perform live cell testing.

- Continue to research and brainstorm possible condensation prevention solutions.

3/30/23 Progress Report 8

SAMUEL BARDWELL - Mar 29, 2023, 9:01 AM CDT

Title: Progress Report 8

Date: 3/30/23

Content by: Sam

Goals: To provide a weekly update on my individual progress.

Content:

- Conducted condensation testing on the anti-bacterial hand sanitizer idea.

See Experimentation folder in Team Activities > 3/28/23 Condensation Experiment with Hand Sanitizer

Conclusions/action items:

- Help conduct live cell testing where needed.

- Begin to update final deliverables and prepare for the outreach project.

4/6/23 Progress Report 9

SAMUEL BARDWELL - Apr 05, 2023, 12:49 PM CDT

Title: Progress Report 9

Date: 4/6/23

Content by: Sam

Goals: To provide updates on individual weekly progress.

Content:

- Helped with live cell testing.

- Conducted more anti-condensation testing with a PDMS layer and PDMS layer with the mini fans.

See team activities experimentation folder > PDMS Anti-condensation testing

Conclusions/action items:

- Continue to help with live cell testing.

- Prepare for the outreach project.

- Work on final deliverables.

4/13/23 Progress Report 10

SAMUEL BARDWELL - Apr 12, 2023, 8:23 AM CDT

Title: Progress Report 10

Date: 4/13/23

Content by: Sam

Goals: To provide weekly updates on individual progress.

Content:

- Completed outreach project.

- Helped with live-cell testing.

- Worked on final deliverables.

Conclusions/action items:

- Continue updating final deliverables.

- Help with live-cell testing where needed.

4/20/23 Progress Report 11

SAMUEL BARDWELL - Apr 19, 2023, 10:56 AM CDT

Title: Progress Report 11

Date: 4/20/23

Content by: Sam

Goals: To provide weekly updates on my individual progress.

Content:

- Updated final deliverables

- Helped with live cell testing troubleshooting

Conclusions/action items:

- Complete final poster

- Work on the final report

- Help conclude live cell testing

4/25/23 Progress Report 12

SAMUEL BARDWELL - Apr 25, 2023, 4:34 PM CDT

Title: Progress Report 12

Date: 4/25/23

Content by: Sam

Goals: To provide weekly updates and progress on the project.

Content:

- Worked on final deliverables.

Conclusions/action items:

- Finish final deliverables.

12/10/22 Incubator Disinfectants and Cleaning

SAMUEL BARDWELL - Dec 10, 2022, 3:51 PM CST

Title: Incubator Disinfectants and Cleaning

Date: 12/10/22

Content by: Sam

Goals: To provide ways to reduce contamination within our incubator box.

Content:

Link: https://beta-static.fishersci.com/content/dam/fishersci/en_US/documents/programs/scientific/technical-documents/instruction-sheets/Thermo-Scientific-incubator-care-instruction.pdf

Cite: M. K. Bates and D. Wernerspach, “Proper Care and Maintenance for Your Cell Culture Incubator,” p. 6.

Content:

- There are many possible disinfectant agents we could use to clean our incubator.

- Some cleaners are considered VOCs (volatile organic chemicals) that can induce expression of heat shock and other stress proteins

We must be aware of what disinfectants we use when dealing with live cell incubation so we do not hurt our own cell growth.

- The best cleaner according to this article is quaternary ammonium disinfectant based on broadly effective against a range of microorganisms and harmless (non-corrosive) to incubator components.

- We should not use bleach.

- Sterile distilled water should also be considered for use in our water well.

Conclusions/action items:

After conducting our live cell testing this semester, we noticed some unwanted mold growth within our incubator. This was most likely due to poor attention to disinfecting our incubator before and during use. It was an unforeseen problem that only became apparent during our live cell testing but will be addressed next semester. This article was helpful with providing a possible solution that we could use to disinfect our incubator without damaging our incubator or cells with quaternary ammonium.

12/10/22 Clean Incubator Practices

SAMUEL BARDWELL - Dec 10, 2022, 4:12 PM CST

Title: Clean Incubator Practices

Date: 12/10/22

Content by: Sam

Goals: To learn the best practices for incubator maintenance and cleanliness.

Content:

Link: https://ibc.utah.edu/_resources/documents/fact-sheets-and-sops/best-practices-for-co2-incubator-maintenance-fact-sheet.pdf

Cite: “Best practices for CO2 incubator maintenance fact sheet - IBC,” *Best Practices for CO2 Incubator Maintenance*. [Online]. Available: https://ibc.utah.edu/_resources/documents/fact-sheets-and-sops/best-practices-for-co2-incubator-maintenance-fact-sheet.pdf. [Accessed: 10-Dec-2022].

Content:

- Reducing contamination: Clean the lab room. Many microorganisms are on dust particles and floating in the air
- Incubator disinfectants: Best is quaternary ammonium disinfectant
- Cleaning the Incubator: Have regular cleaning of the incubator. Clean the water every other week. Clean entire incubator at least once a month and allow air dry.
- Importance of Correct water: Agents can be added to pan water to prevent microbial growth.

Conclusions/action items:

This tips will be used to prevent mold growth next semester. I think the biggest ones we have to pay attention to is keeping the incubator wiped down with disinfectant before starting any live cell growth. The next biggest is possibly using an antimicrobial growth agent within our water to prevent any mold growth.

9/12/22 ibidi Stage Top Incubator

SAMUEL BARDWELL - Sep 13, 2022, 10:21 AM CDT

Title: ibidi Stage Top Incubator

Date: 9/12/22

Content by: Sam

Goals: To research any new possible designs that we were not aware of last semester.

Content:

Link: https://ibidi.com/stage-top-incubators/288-ibidi-stage-top-incubator-multiwell-plate-co2-silver-line.html

Cite: “ibidi Stage Top Incubator Multiwell Plate, CO2 – Silver Line | Live Cell Imaging,” *ibidi*. https://ibidi.com/stage-top-incubators/288-ibidi-stage-top-incubator-multiwell-plate-co2-silver-line.html (accessed Sep. 12, 2022).

- Small, precise functioning stage top incubator that is compatible with an inverted microscope

- Uses a heated glass to reduce condensation on the viewing glass

- Uses a gas mixer to keep Oxygen levels accurate

- Has patented humidity control

- Cost is $19,000 without shipping

Figure 1: ibidi Stage Top Incubator photo

Conclusions/action items:

This stage top incubator would be perfect for our task at hand except for the fact that it is $18k. We are trying to develop an incubator very similar to this for a fraction of the cost. I will be looking into and considering heating our outer glass panel in order to reduce the amount of condensation on our glass. I thought this was a unique solution to that problem we faced last semester.

9/12/22 Solenoid Valve Research

SAMUEL BARDWELL - Sep 13, 2022, 10:21 AM CDT

Title: Solenoid Valve Research

Date: 9/12/22

Content by: Sam

Goals: To understand how a solenoid valve works and see if it is a good implementation to our CO_2 input.

Content:

Link: https://sciencing.com/what-solenoid-4902174.html

Cite: "How Does a Solenoid Work?," *Sciencing*. https://sciencing.com/a-solenoid-work-4567178.html (accessed Sep. 12, 2022).

- Common applications are a power switch, valve, and sprinkler system. Our main use would be as a valve.

- Solenoid valves use electricity to create a magnetic field which will either open or close a piston depending on if the electricity is running or not.

- In valves, the solenoid requires constant electrical input to stay open.

- Can be AC or DC

- Can be pneumatic or hydraulic solenoids.

Figure 1: Example of a solenoid valve

Conclusions/action items:

Solenoids valves are going to be our main focus for CO_2 input regulation this semester. It is important to understand how they work so when it is time to implement it into the whole system, there is a smooth transition. The biggest worry with solenoids is the cost but we are willing to give up quality of the incubator for a cheaper cost. We will also be considering other type of CO_2 inputs in the future.

9/13/22 Ball Valve Research

SAMUEL BARDWELL - Sep 13, 2022, 10:19 AM CDT

Title: Ball Valve Research

Date: 9/13/22

Content by: Sam

Goals: To research possible CO2 input mechanisms.

Content:

Link: PVC Ball Valve - How They Work | Tameson.com

Cite: “PVC Ball Valve - How They Work | Tameson.com,” *Tameson*. https://tameson.com/pvc-ball-valve.html (accessed Sep. 13, 2022).

- Uses a simple PVC or brass outer tubing with a lever that can be twisted

- The lever that can be twisted is connected to a ball inside the tubing that has a through cut hole within it

- The the lever is turned perpendicular to the tubing the ball will rotate inside and the through cut in the ball will not align with the tubing, blocking any air or fluids from going through

- When the lever is parallel to the tubing, the through cut in the ball is aligned to the tubing, allow things to pass through.

Figure 1: Example of a double union PVC ball valve.

Conclusions/action items:

This is a cheap and very possible method to help us with CO2 regulation. These types of valves can be found on Grainger. We can brainstorm a way to connect a DC motor to the valve which will allow us to have automatic control of the valve. I will continue to look at different valve ideas and possibilities and also share this idea with the team.

9/18/22 Solenoid Air Valve

SAMUEL BARDWELL - Sep 18, 2022, 2:02 PM CD

Title: Solenoid Air Valve

Date: 9/18/22

Content by: Sam

Goals: To find an affordable solenoid valve.

Content:

Link: https://www.amazon.com/4inch-Normally-Closed-Electric-Solenoid/dp/B074Z5SDG3/ref=asc_df_B074Z5SDG3/?tag=hyprod-20&linkCode=df0&hvadid=198072472254&hvpos=&hvnetw=g&hvrand=6108957746982655889&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9018948&hvtargid=p 360267761983&psc=1

- Holds up to 100 psi (We on need ~14)

- 1/4" threads

- Electrically controlled.

- Valve stays closed when the coil is de-energized- and it opens when energized

Conclusions/action items:

This sounds like a very possible solenoid valve to use for our design. Need to figure out how to get reimbursed from Amazon. Will continue to explore other valve possibilities.

9/26/22 Rubber Stopper for Testing Lid

SAMUEL BARDWELL - Sep 26, 2022, 12:34 PM CDT

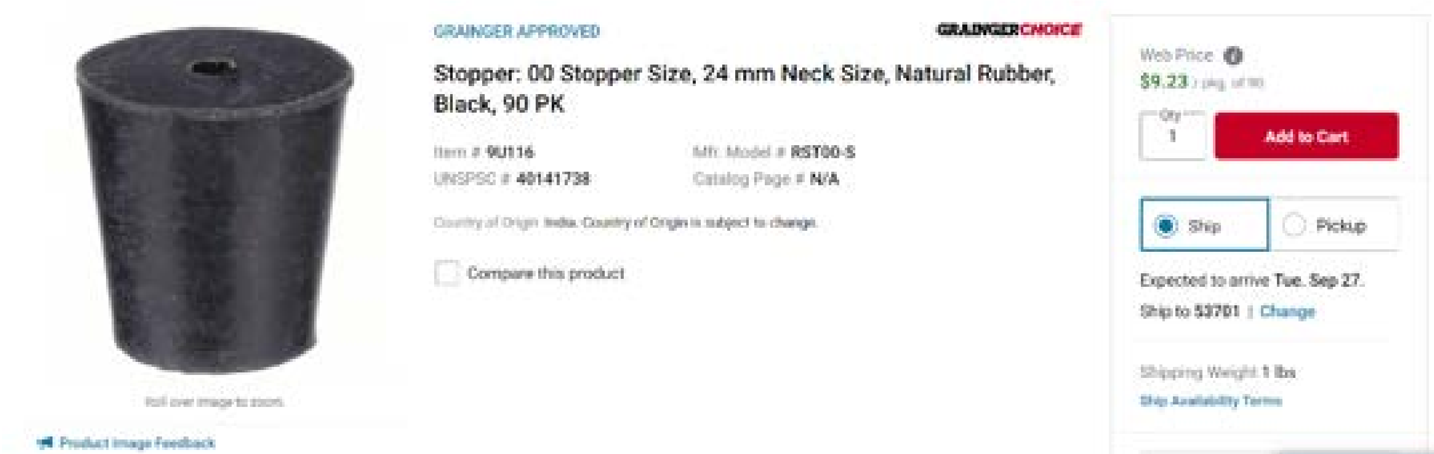
Title: Rubber Stopper for Testing Lid

Date: 9/26/22

Content by: Sam

Goals: To find rubber stoppers to use to plug the holes on the testing lid when inserting the sensors.

Content:



- 10mm - 15 mm 00 stopper size rubber stoppers from Grainger

- Fit the half inch hole design I made for the test lid

Link: https://www.grainger.com/product/GRAINGER-APPROVED-Stopper-00-Stopper-Size-9U116

Conclusions/action items:

Double check with the team to make sure we want those dimensions for the test lid and the put in an order request to get these rubber stoppers. Before we decide to order them, we should see if the Makerspace or TeamLab or Dr P has extras.

9/29/22 Solenoid Adaptors

SAMUEL BARDWELL - Sep 29, 2022, 11:03 AM CDT

Title: Solenoid Adaptors

Date: 9/29/22

Content by: Sam

Goals: To find adaptors for the solenoid.

Content:

Link: https://www.amazon.com/outstanding-Fitting-Connector-Barb-Fitting-Accessory/dp/B08LMMJG1S/ref=sr_1_3?keywords=g+1%2F4+to+1%2F4+barb&qid=1664467167&qu=eyJxc2MiOiIwLjg4IiwicXNhIjoiMC42NSIsInFzcCI6IjAuMDAifQ%3D%3D&sr=8-3

Conclusions/action items:

Order these adaptors for the solenoid to connect tubing.

10/31/22 Solenoid Flow Rate Math

SAMUEL BARDWELL - Nov 01, 2022, 3:26 PM CDT

Title: Solenoid Flow Rate Math

Date: 10/31/22

Content by: Sam

Goals: To mathematically determine the flow rate of the solenoid valve at 17 PSI.

Content:

Link: https://blog.exair.com/2018/11/08/how-to-calculate-scfm-volume-when-operating-at-any-pressure/#:~:text=As%20shown%20in%20the%20formula,consume%2014%20SCFM%20%40%2080%20PSIG.

Content:

The 1100 Super Air Nozzle Is Rated To Consume 14 SCFM @ 80 PSI, What Will The SCFM Be At 105 PSI?

$$New\ SCFM = SCFM\ @\ rated\ pressure \left(\frac{actual\ gauge\ pressure\ +\ 14.7\ psia}{rated\ pressure\ +\ 14.7\ psia}\right)$$

$$X = 14\ SCFM \left(\frac{105\ psig + 14.7\ psia}{80\ psig + 14.7\ psia}\right)$$

$$X = 14\ SCFM \left(\frac{119.7}{94.7}\right)$$

$$X = 14\ SCFM\ (1.264)$$

$$X = 17.69\ SCFM$$

- I used this equation found on the internet and plugged in the solenoids product description for for flow rate. 22 SCFM at 100 PSI (Air Flow)

Product Description

Feature:
Port Size : G1/4"
Model Number: 2V025-1/4-12VDC
Seal Material: NBR (Buna N)
Armature Tube Material: Brass
Body Material: Anodized Aluminum
Plunger & Spring Material: Stainless Steel
Response Time: Less than 20 ms
Port Size: G1/4" DN8
Operating Temperature: -10 to 80 °C
Coil Power: 6.5W
Coil Duty: 100% ED (Continuous Duty)
Coil Voltage: DC12V,
Service Media: Air, Gas, Liquid, Water
Valve Type: 2 Way Normally Closed (Valve opens with energized)
Flow Rate: 0.23Cv (Fluid Flow), 22 SCFM at 100 PSI (Air Flow)
Operating Pressure: 0.05 - 0.7Mpa(can be operated at 0 PSI (Vacuum))
Package included:
1 x 1/4inch DC 12V Electric Solenoid Air Valve

- Plugging 22 in for the SCFM @ the rated pressure and 100 PSI at the rated pressure and then 17 PSI in for the actual gauge pressure, I obtained a value of 6.08 SCFM

- 6.08 SCFM is the Standard Cubic Feet per Minute but needs to be converted to CFM. In order to do this I need the temperature, humidity, barometric pressure, SCFM, and inlet pressure. I looked up this information for the date we conducted the flow rate testing with the balloons.

Monday Oct, 24th

Temp: Room temp 68 *F

SCFM: 6.08 (based on math from above)

Inlet Pressure: 17 PSI (pressure coming out of tank)

Barometric pressure: 29.73 (based on weather data)

Relative Humidity: 61% (weather data)

- After plugging in the values to a SCFM to CFM calculator (linked below) the CFM of the gas coming out of the solenoid based on mathematical calculations is 5.25 CFM.

SCFM to CFM Link: https://www.coastpneumatics.com/scfm-conversion/

- After obtaining the new CFM value, an online calculator was used to convert CFM to mL/s

Link: https://www.kylesconverter.com/flow/cubic-feet-per-minute-to-milliliters-per-second

mL/s with the tank set to 17 PSI based on mathematical calculation is 2477.72 mL/s

Conclusions/action items:

This does not agree with our testing of 335 mL/s. Further research will be conducted and possibly retesting the flow rate with balloons can be conducted.

11/1/22 Solenoid Flow Rate Math PSI and D

SAMUEL BARDWELL - Dec 10, 2022, 7:30 PM CST

Title: Solenoid Flow Rate Math PSI and D

Date: 11/1/22

Content by: Sam

Goals: To mathematically calculate the flow rate of CO_2 coming through the solenoid valve.

Content:

- The output pressure from the CO_2 tank is set to 17 PSI using a regulator

- The diameter of the solenoid pipe is 2 mm

- Calculator to calculate flow rate from pressure and diameter of pipe.

Link: https://www.omnicalculator.com/conversion/psi-to-gpm

Pressure at exit: 14.76 PSI

Pressure Entering Solenoid: 17 PSI

Pressure inside tank: 750 PSI

Diameter of pipe: 2 mm

Flow Rate in mL/s: 17.46 mL/s @ 17 psi

21.0 mL/s @ 18 psi

316.39 mL/s @ 750 psi

Conclusions/action items:

If we are using the psi from the regulator, the flow rate appears to be very small, but if we use the psi from the tank, the flow rate nearly matches our calculated flow rate exactly. 316 mL/s compared to 335 mL/s.

12/11/22 Bernoulli's Equation

SAMUEL BARDWELL - Dec 12, 2022, 4:59 PM CST

Title: Bernoulli's Equation

Date: 12/11/22

Content by: Sam

Goals: To use Bernoulli's equation to solve for an expected flow rate outside of the solenoid valve.

Content:

Image preview

Conclusions/action items:

This outputted to a value fairly close to the flow rate we calculated using the balloon and water displacement measurements. We had a 5% error which is pretty good. Some possible sources of error are the tension in the latex of the balloon reducing the actual volume of gas outputted by the solenoid valve. There was also possible leakages when tying the balloon in a knot. We may want implement the expected flow rate into our solenoid code, but this would need to be tested to see if it is accurate.

11/11/22 Tong Lecture

SAMUEL BARDWELL - Nov 11, 2022, 12:33 PM CST

Title: Tong Lecture

Date: 11/11/22

Content by: Sam

Goals: To learn about entrepreneurship.

Content:

- 50%+ young adults are interested in starting their own business.

- Entrepreneurship is very sought out in the business school

- Engineers play a critical role in entrepreneurship. Foundation to the global economy.

- Use entrepreneurship thinking frequently to make it a habit.

- Entrepreneurship is a rare training topic for engineers. Need to equip engineers with tools and strategies.

- Strongly context dependent. Most research looks at individual level determinants.

- Three reasons why student entrepreneurship is important.

1. many students have strong interests.

2. Research done at universities can provide new opportunities that can lead to formations of new things.

3. The role of a university is seen as broader than just generating IP.

University Entrepreneurial Role

- Economic and social development

- Commercialization of research

- Managerial and attitudinal changes

- Industry enthusiasm

- TEO is a new office to foster the entrepreneurial environment.

- UW Madison is now a partner in the Great Lakes Hub

Conclusions/action items:

After this lecture I am more informed about what entrepreneurship is and how I can become one. I am aware that we are trying to make this topic more accessible to engineers at UW and I have to seek out help and resources if it is an interest to me.

9/15/22 Progress Report 1

SAMUEL BARDWELL - Sep 19, 2022, 6:46 PM CDT

Title: Progress Report 1

Date: 9/15/22

Content by: Sam

Goals: To record weekly progress and work.

Content:

- Researched different ways to regulate airflow in order to have options for CO_2 input this semester.

- The best options I have come up with so far is the use of a solenoid valve or a ball valve.

Conclusions/action items:

- Continue to find ways to regulate air flow for our CO_2 input mechanism.

- Begin looking at costs and ordering materials.

- Develop a design matrix for CO_2 input.

9/22/22 Progress Report 2

SAMUEL BARDWELL - Sep 21, 2022, 10:52 AM CDT

Title: Progress Report 2

Date: 9/22/22

Content by: Sam

Goals: To track weekly individual progress.

Content:

- Researched more possible CO_2 input valves that we could continue to move forward with and create a design matrix with.

- Brainstormed ideas to possibly heat up the incubator glass to reduce the amount of condensation.

- Updated and finalized the PDS.

- Attended and led the client meeting to update the client on the scope of the project this semester and to receive feedback.

Conclusions/action items:

- Order a solenoid valve from amazon to begin testing circuitry and CO_2 regulation.

-Continue to research ways to reduce condensation on the glass.

- Either order an anti-fog spray from amazon or develop a way to heat the glass on the box to reduce condensation formation.

- Develop a design matrix for CO_2 input

9/29/22 Progress Report 3

SAMUEL BARDWELL - Sep 28, 2022, 4:42 PM CDT

Title: Progress Report 3

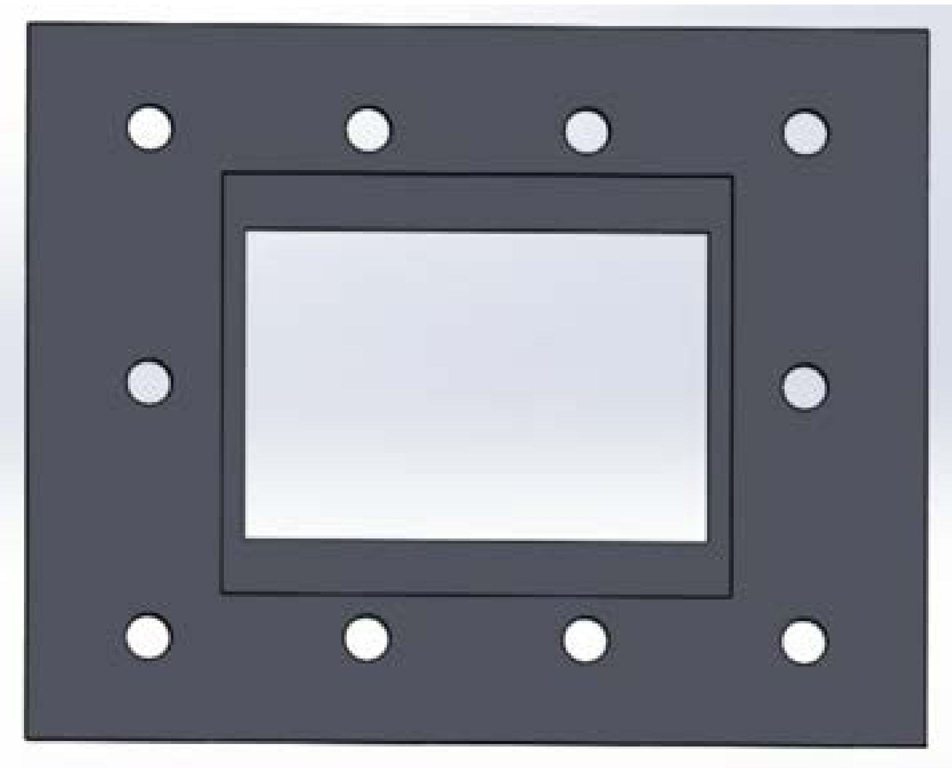
Date: 9/29/22

Content by: Sam

Goals: To give weekly updates on my progress.

Content:

- Developed CAD drawings in SOLIDWORKS for the homogeneity testing lid (Under Design Ideas).



- Helped create the design matrix to determine the best way to control CO_2 input.

- Found rubber stoppers on Grainger to use for the testing lid (Under Part Research).

Conclusions/action items:

- Possibly laser cut the testing lid so it is ready for homogeneity testing.

- Place an order to Dr P for the rubber stoppers unless he has any laying around.

- Begin working on the preliminary deliverables.

10/6/22 Progress Report 4

SAMUEL BARDWELL - Oct 05, 2022, 11:49 AM CDT

Title: Progress Report 4

Date: 10/6/22

Content by: Sam

Goals: To provide updates on my weekly progress.

Content:

- Mainly focused my time on completing the preliminary presentation and report.

- Contacted Dr. P, Makerspace, and TeamLab about rubber stoppers to use to plug holes on the homogeneity testing lid.

Conclusions/action items:

- Finalize the preliminary report.

- Help the team with the solenoid valve functioning.

- Begin fabrication on the homogeneity testing lid

10/13/22 Progress Report 5

SAMUEL BARDWELL - Oct 12, 2022, 11:05 AM CDT

Title: Progress Report 5

Date: 10/13/22

Content by: Sam

Goals: To keep a weekly report of my progress on the project.

Content:

- Helped finalize the preliminary report.

- Obtained rubber stopper for homogeneity testing

Conclusions/action items:

- Work with Katie to fabricate the homogeneity testing lid and conduct homogeneity testing.

- Help fabricate the CO_2 input for the incubator.

10/20/22 Progress Report 6

SAMUEL BARDWELL - Oct 19, 2022, 10:25 AM CDT

Title: Progress Report 6

Date: 10/20/22

Content by: Sam

Goals: To provide updates on my weekly project progress.

Content:

- Worked with Katie to laser cut and fabricate the homogeneity testing lid.

- Brainstormed ideas for the outreach project the team has to do.

- Completed peer evaluations and reflections

Conclusions/action items:

- Continue fabricating the homogeneity testing lid.

- Conduct homogeneity testing on the incubator.

- Begin writing the outreach project report.

10/27/22 Progress Report 7

SAMUEL BARDWELL - Oct 26, 2022, 6:51 PM CDT

Title: Progress Report 7

Date: 10/27/22

Content by: Sam

Goals: To update everyone with my weekly progress.

Content:

- Finished fabricating the homogeneity testing lid with Katie.

  See Testing Lid Fabrication in Team Fabrication folder

- Conducted flow rate testing on the solenoid and CO_2 tank.

  See flow rate testing in the team's testing and results folder

- Began to help Katie write equations to insert into the code to talk between the CO_2 sensor and solenoid valve

- Decided on outreach project ideas.

Conclusions/action items:

- Conduct temperature and humidity homogeneity testing.

- Troubleshoot the code between the CO_2 sensor and the solenoid valve.

- Prepare for show and tell.

11/3/22 Progress Report 8

SAMUEL BARDWELL - Nov 03, 2022, 9:50 AM CDT

Title: Progress Report 8

Date: 11/3/22

Content by: Sam

Goals: To keep weekly updates of my project progress.

Content:

- Researched mathematical equations to determine the flow rate based on PSI from the tank and diameter of the solenoid valve.

* See Sam Bardwell > Research > Part Research > Solenoid Flow Rate Math

- Conducted homogeneity testing for the temperature on the incubator with Katie

* See Team Activities > Experimentation > Temp Homogeneity Testing

Conclusions/action items:

- Conduct homogeneity testing for humidity next week.

- Research more mathematical equations in order to determine flow rate.

- Possibly redo flow rate testing with the balloons and solenoid valve.

11/10/22 Progress Report 9

SAMUEL BARDWELL - Nov 09, 2022, 10:35 AM CST

Title: Progress Report 9

Date: 11/10/22

Content by: Sam

Goals: To provide weekly updates on project progress.

Content:

- Conducted a second round of temperature homogeneity testing with more strict protocols and steps.

  See team activities experimentation entry

- Conducted a round of humidity homogeneity testing.

  See team activities experimentation entry

- Ordered a squeegee to begin fabrication on the windshield wiper idea to combat condensation issues

Conclusions/action items:

- Conduct CO_2 homogeneity testing.

- Continue possible fabrication on the windshield wiper idea.

- Contribute to outreach project report.

- Add more caulk to the leaking part of the incubator.

11/17/22 Progress Report 10

SAMUEL BARDWELL - Nov 21, 2022, 4:15 PM CST

Title: Progress Report 10

Date: 11/17/22

Content by: Sam

Goals: To provide updates on weekly progress

Content:

- Began fabrication on the wiper design with Drew in order to combat condensation

See wiper fabrication under team activities > fabrication > wiper fabrication

Conclusions/action items:

- Continue working on a possible solution for the fabrication of the wiper.

- Begin to think about preliminary presentations.

- Begin outreach project report.

11/24/22 Progress Report 11

SAMUEL BARDWELL - Nov 24, 2022, 9:06 AM CST

Title: Progress Report 11

Date: 11/24/22

Content by: Sam

Goals: To provide weekly updates on my progress.

Content:

- Fabricated more of the condensation wiper with Drew.

See Team Activities > Fabrication > Wiper Fabrication

- Did some anti-fog testing with the wiper.

See Team Activities > Fabrication > Wiper Fabrication

Conclusions/action items:

- Work on the outreach project report.
- Begin working on final deliverables.
- Help conduct live cell testing if the team is ready.

11/30/22 Progress Report 12

SAMUEL BARDWELL - Nov 30, 2022, 2:54 PM CST

Title: Progress Report 12

Date: 11/30/22

Content by: Sam

Goals: To provide weekly updates on my progress on the project.

Content:

- Began working on the outreach project report.

- Began working on the team's final poster to be ready before the final presentation

Conclusions/action items:

- Finalize poster presentation and practice.

- Begin working on the final report.

- Finish rough draft for outreach project.

- Help conduct live cell testing

12/8/22 Progress Report 13

SAMUEL BARDWELL - Dec 07, 2022, 5:04 PM CST

Title: Progress Report 13

Date: 12/8/22

Content by: Sam

Goals: To provide weekly updates of my progress.

Content:

- Conducted live cell testing.

- Worked on final deliverables

See project files in the team activities notebook.

Conclusions/action items:

Complete final deliverables.

9/18/22 Needle Valve Design Idea

SAMUEL BARDWELL - Sep 18, 2022, 2:14 PM CDT

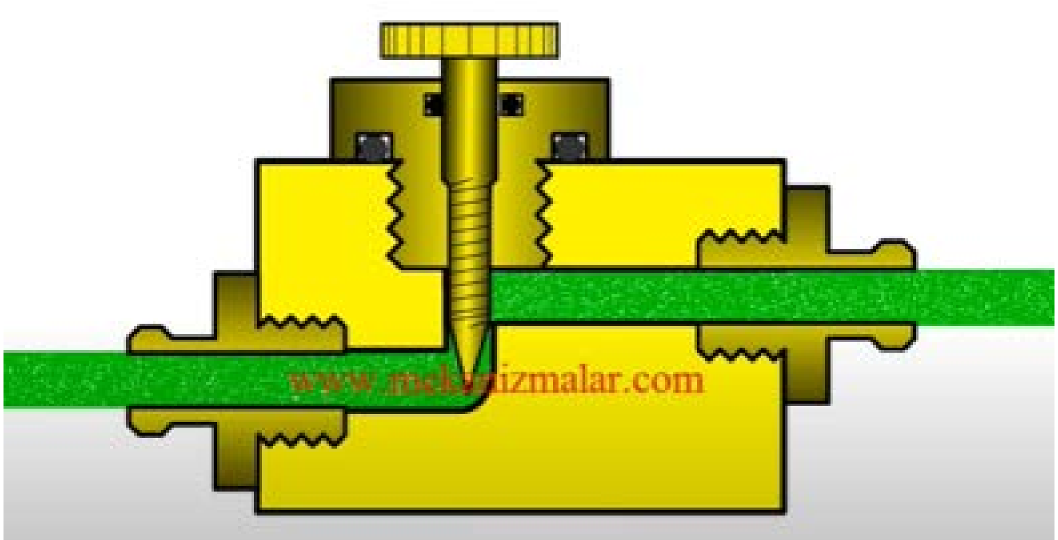
Title: Needle Valve Design Idea

Date: 9/18/22

Content by: Sam

Goals: To brainstorm a way to have CO2 input regulation.

Content:



- Uses a needle to block gas or fluid flow

Conclusions/action items:

Will brainstorm ideas on how to incorporate this into our CO2 input design. Can be machined out of materials found around the team lab or makerspace.

9/21/22 Pin Valve Design Ideas

SAMUEL BARDWELL - Sep 21, 2022, 11:12 AM CDT

Title: Pin Valve Design Ideas

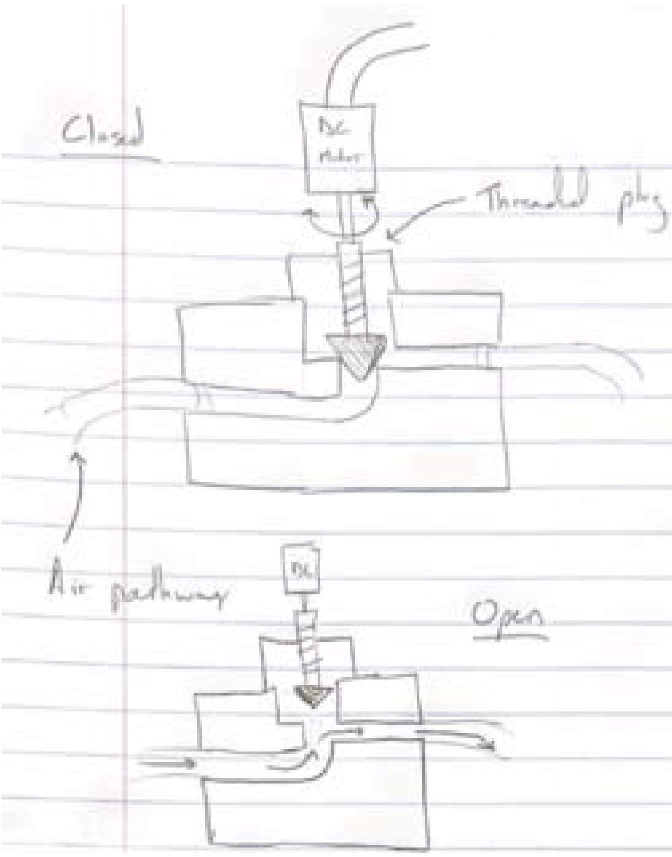
Date: 9/21/22

Content by: Sam

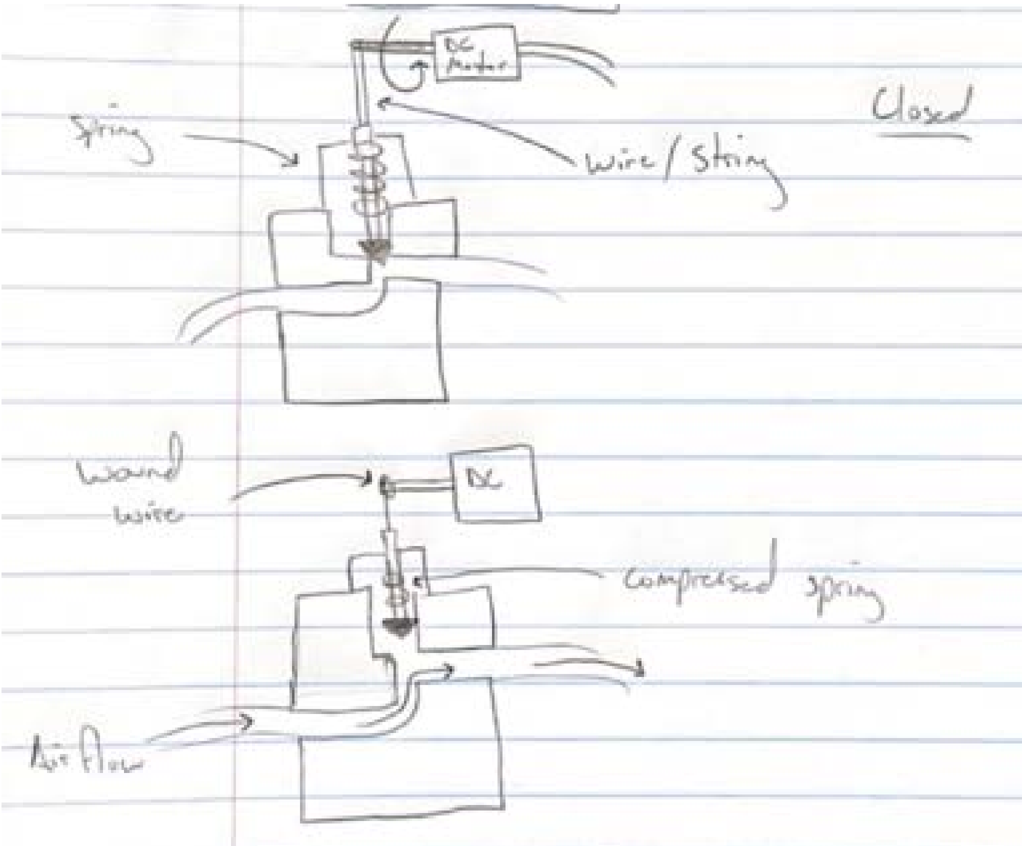
Goals: To develop a cheap way to regulate CO2 input.

Content:

Threaded DC Motor Pin Valve



String DC Motor Pin Valve



Conclusions/action items:

Will discuss these designs with the team and advisor and if approved, will go into SOLIDWORKS and start CAD drawing the designs to see if they are reasonable to pursue.

9/26/22 Testing Lid Design

SAMUEL BARDWELL - Oct 24, 2022, 6:25 PM CDT

Title: Testing Lid Design

Date: 9/26/22

Content by: Sam

Goals: To design a lid for testing on SOLIDWORKS

Content:

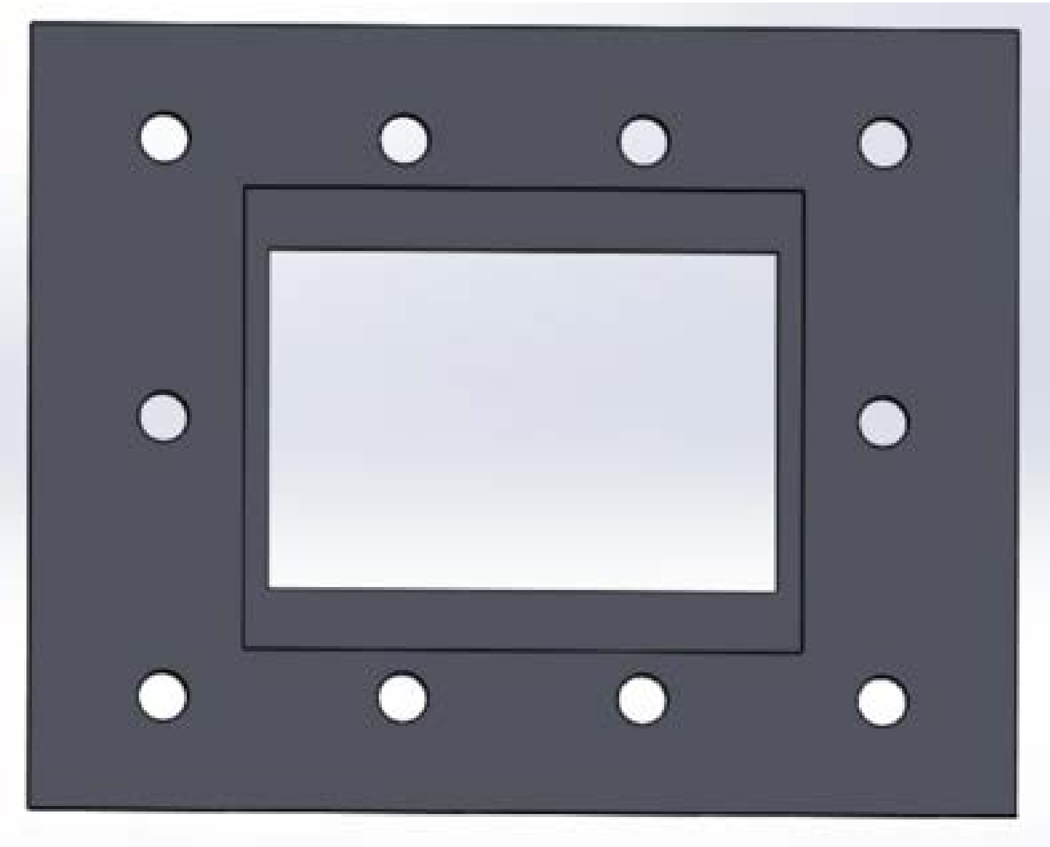


Figure 1: SOLIDWORKS Assembly for lid that can be used for testing internal homogeneity.

- Same dimensions as current lid

- Has 10 evenly spaced 1/2 inch holes surrounding the well plate glass where thermistor and CO2 sensors can be inserted to collect raw data on the temperature, humidity, and CO2 levels throughout the incubator.

Conclusions/action items:

Need to be able to laser cut from the Makerspace. Decide if there should even be a space for the glass or if we should laser cut holes in the middle where the well plate would be to collect homogeneity data from these points.

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:

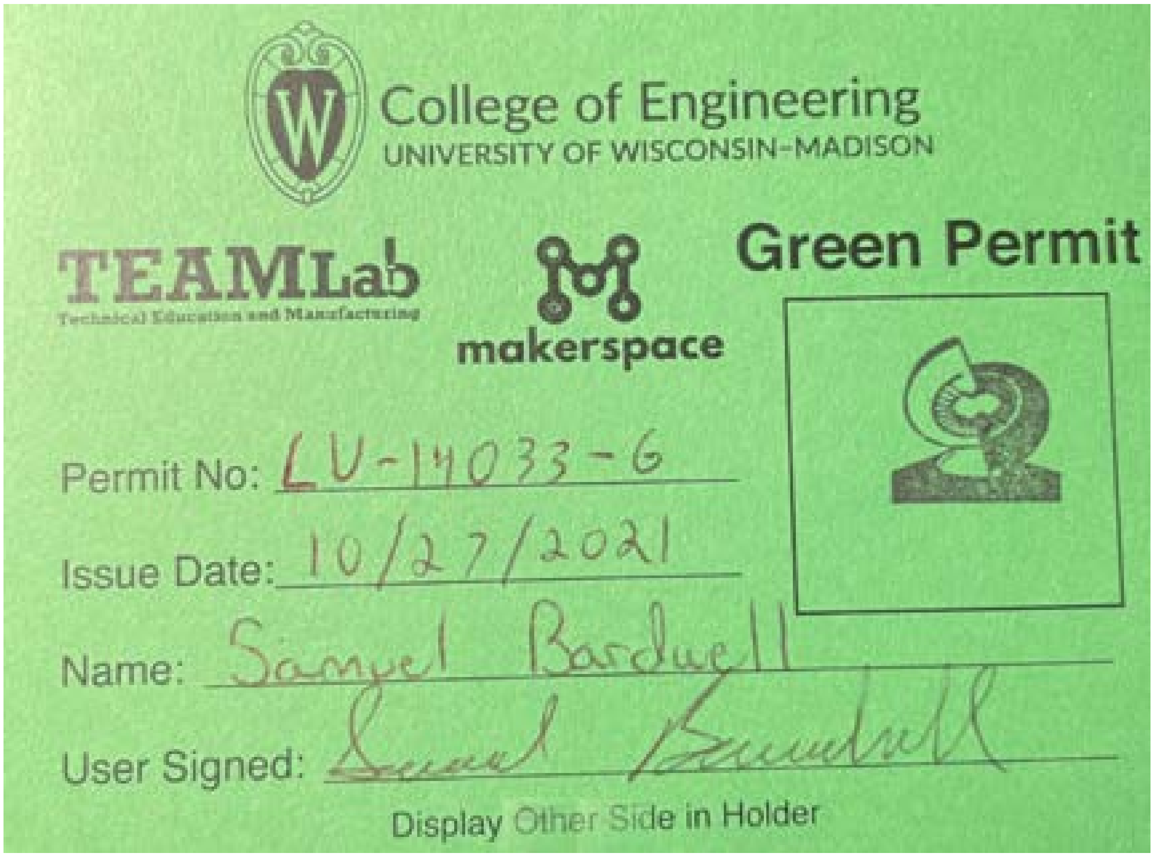


Figure 1: Front side of the green permit

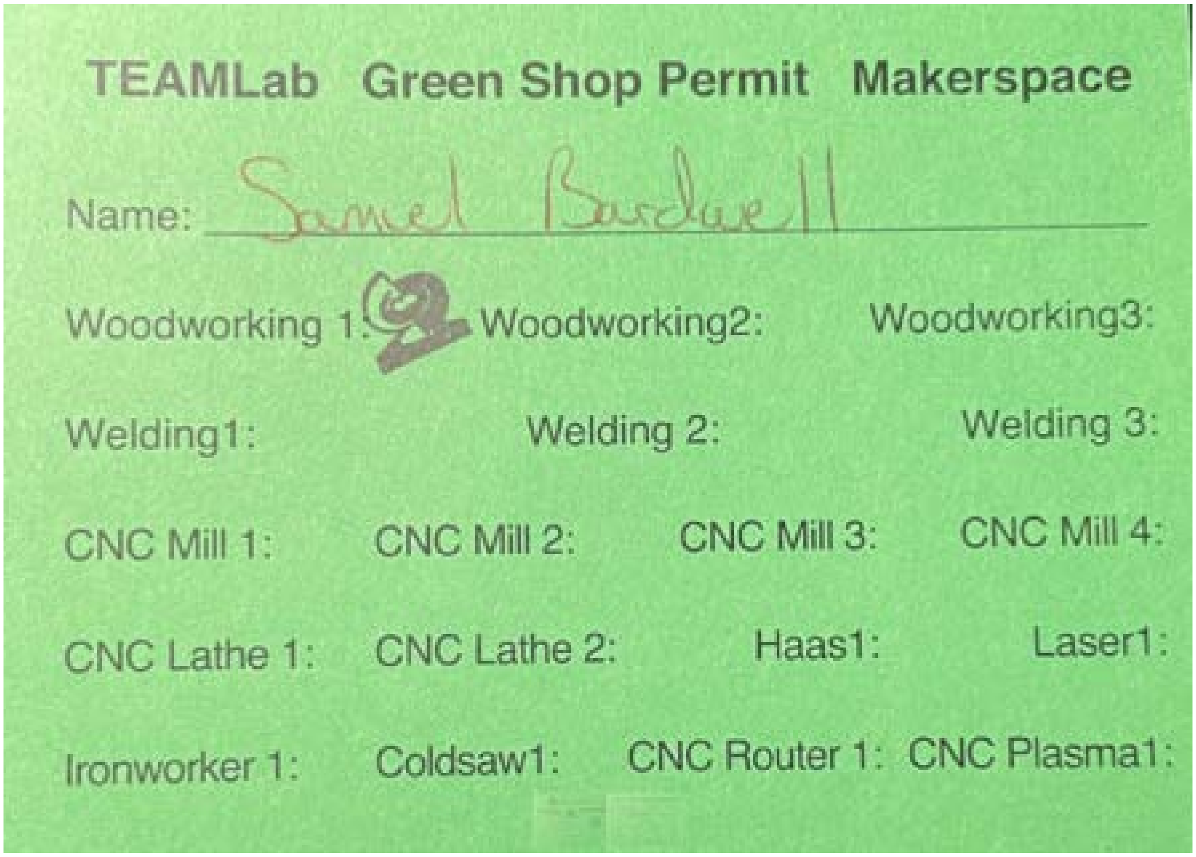


Figure 2: Back side of green permit

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.

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™ 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.

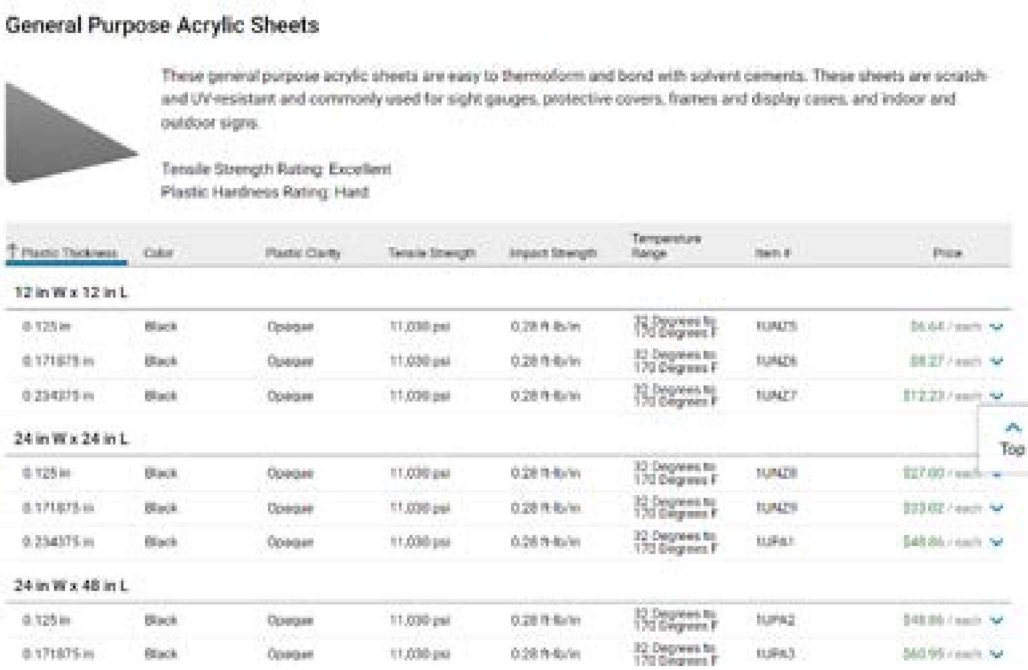
Content:

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

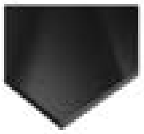
These general purpose acrylic sheets are easy to thermoform and bond with solvent cements. These sheets are scratch- and UV-resistant and commonly used for sight gauges, protective covers, frames and display cases, and indoor and outdoor signs.

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	1UAZ5	$6.64 / each
0.171875 in	Black	Opaque	11,030 psi	0.28 ft-lb/in	32 Degrees to 170 Degrees F	1UAZ6	$8.27 / each
0.234375 in	Black	Opaque	11,030 psi	0.28 ft-lb/in	32 Degrees to 170 Degrees F	1UAZ7	$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	1UAZ8	$27.00 / each
0.171875 in	Black	Opaque	11,030 psi	0.28 ft-lb/in	32 Degrees to 170 Degrees F	1UAZ9	$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 / eac
0.25 in	Black	Opaque	9,000 psi	0.3 ft-lb/in	40 Degrees to 190 Degrees F	60AZ61	$15.68 / eac
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	$26.53 / 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 out 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 Makersp 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=
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

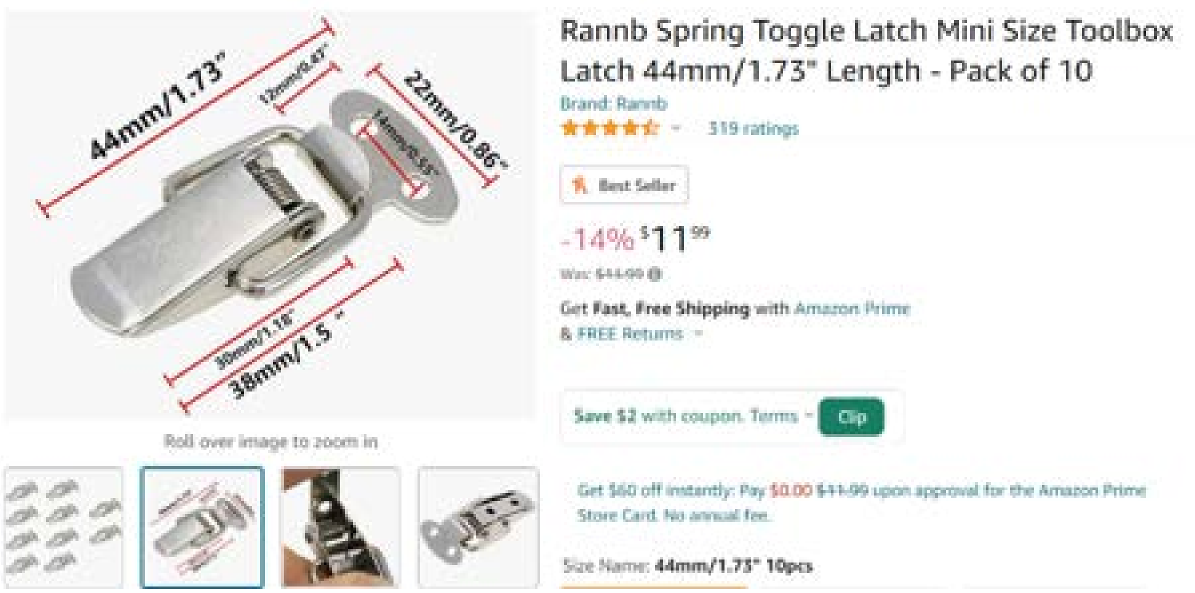
Date: 3/23/22

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:

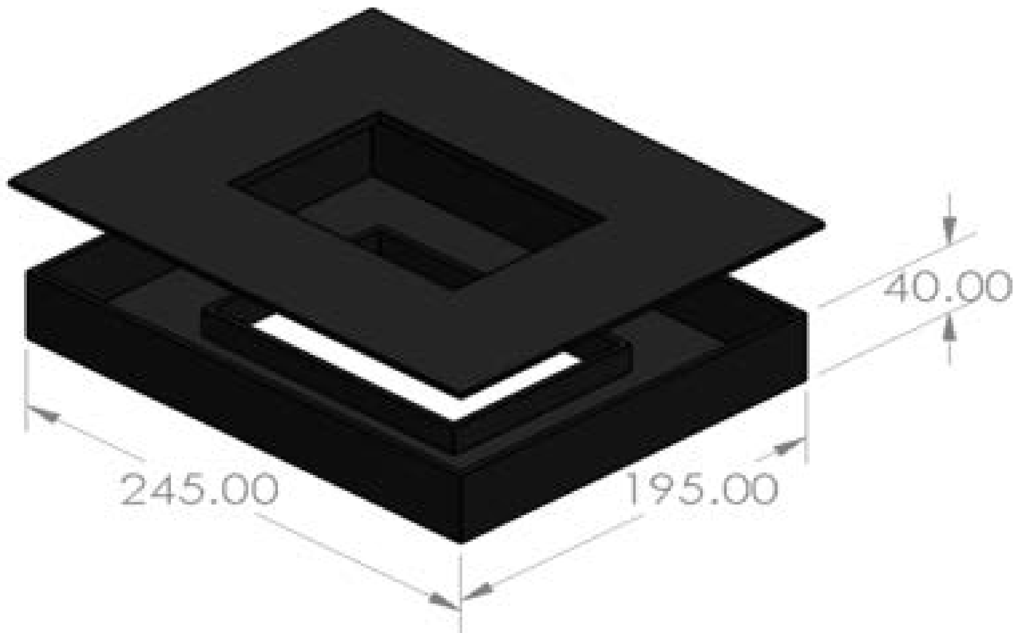


Figure 1: Hinge Top Acrylic Incubator drawing with dimensions in millimeters.

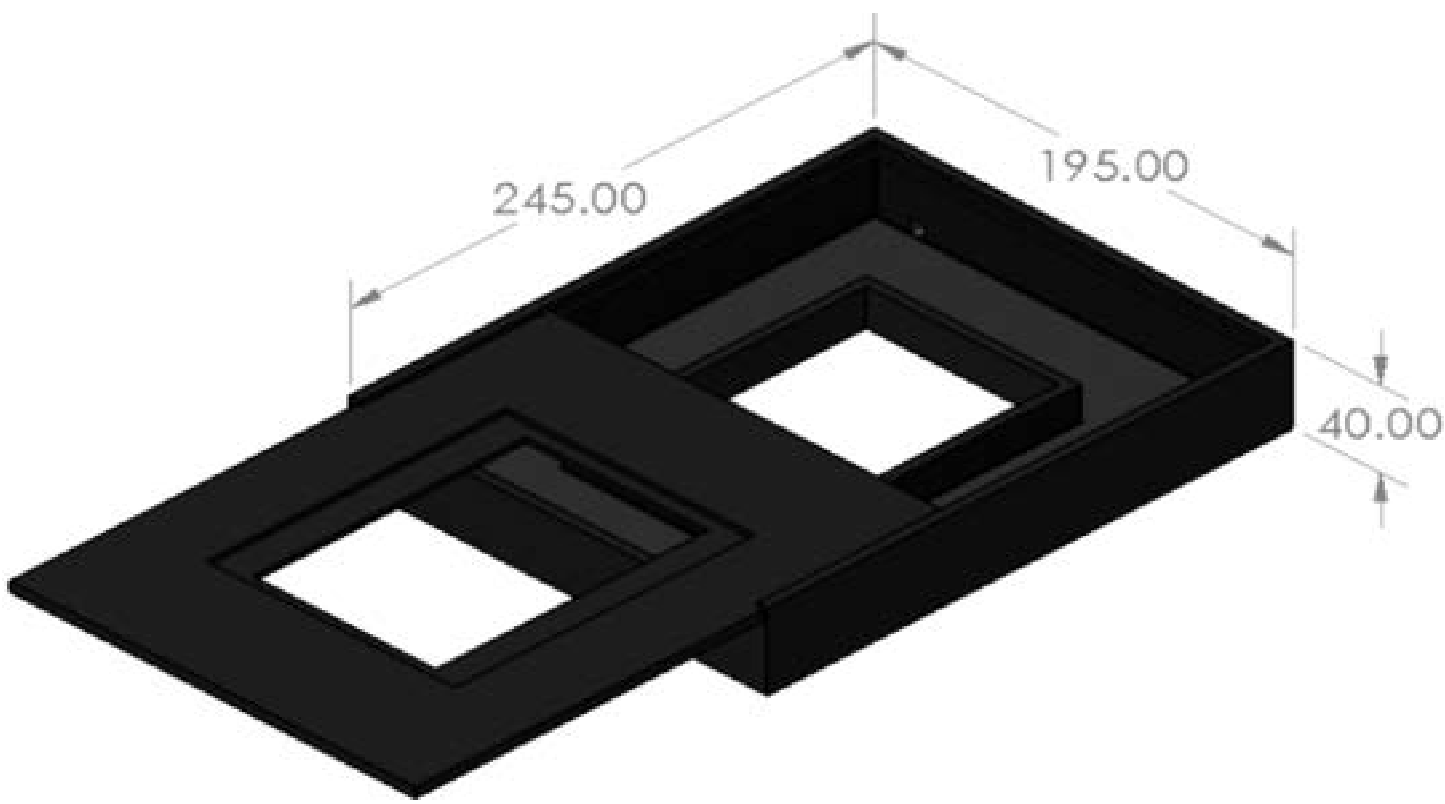


Figure 2: Slide Top Acrylic Incubator drawing with dimensions in millimeters.

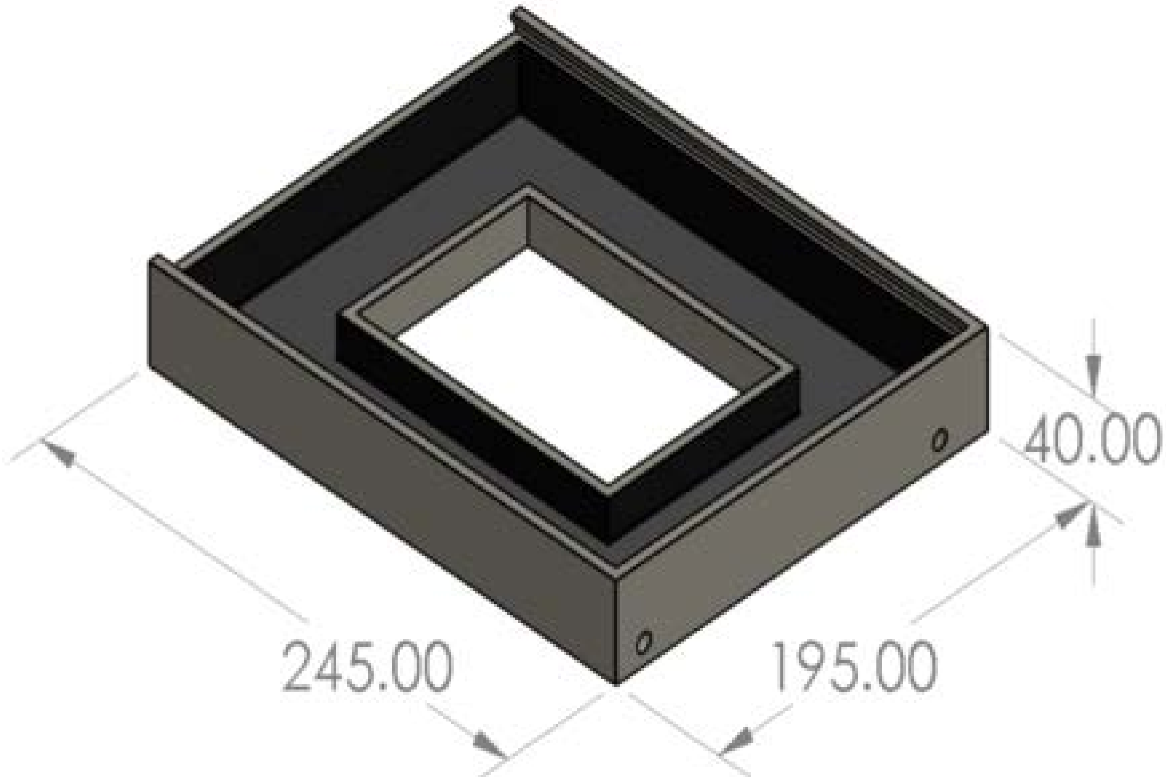


Figure 3: 3D Printed Box with insulation coating drawing with dimensions in millimeters.

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:

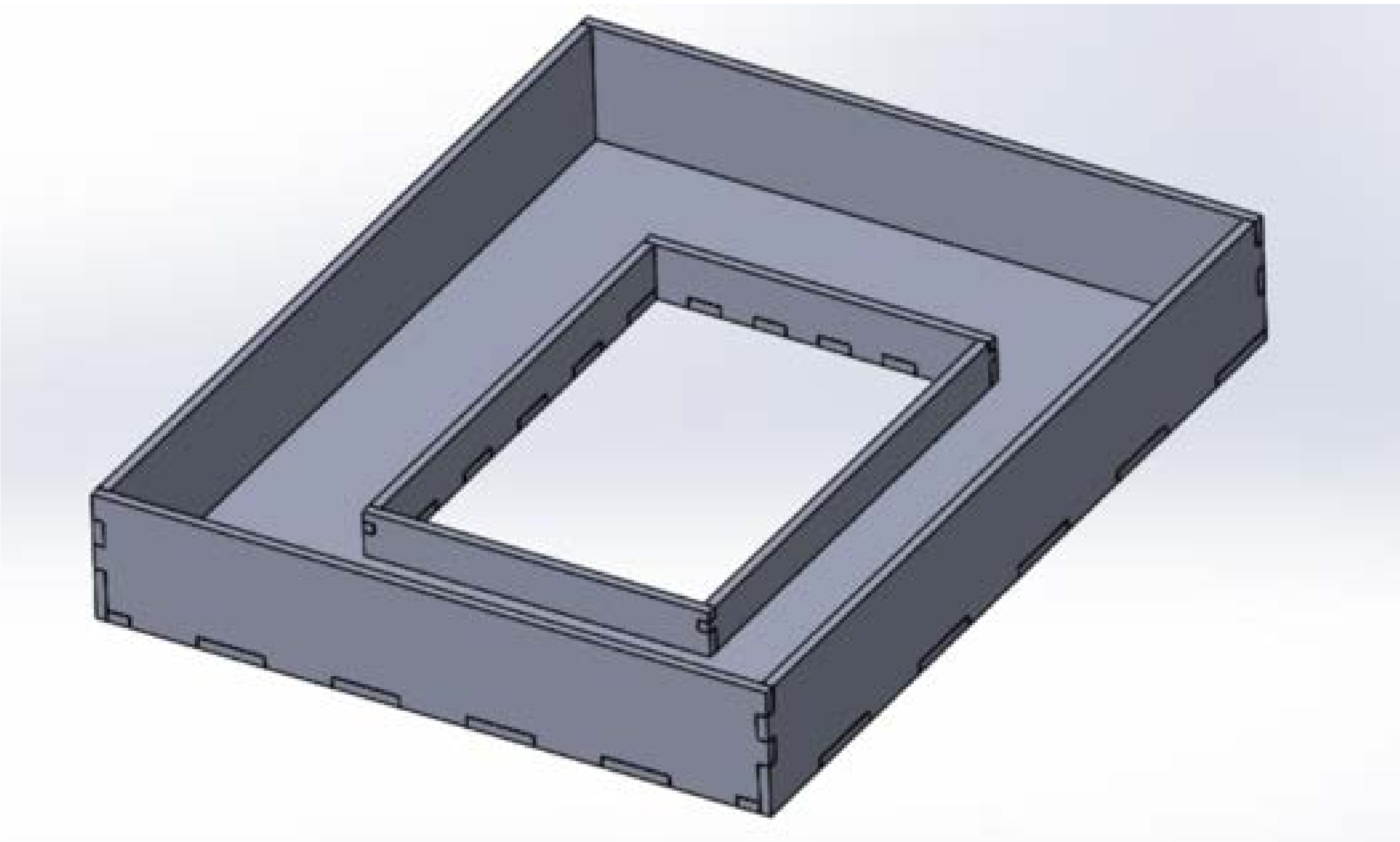


Figure 1: Acrylic hinge top SOLIDWORKS drawing with fingered edges.

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:

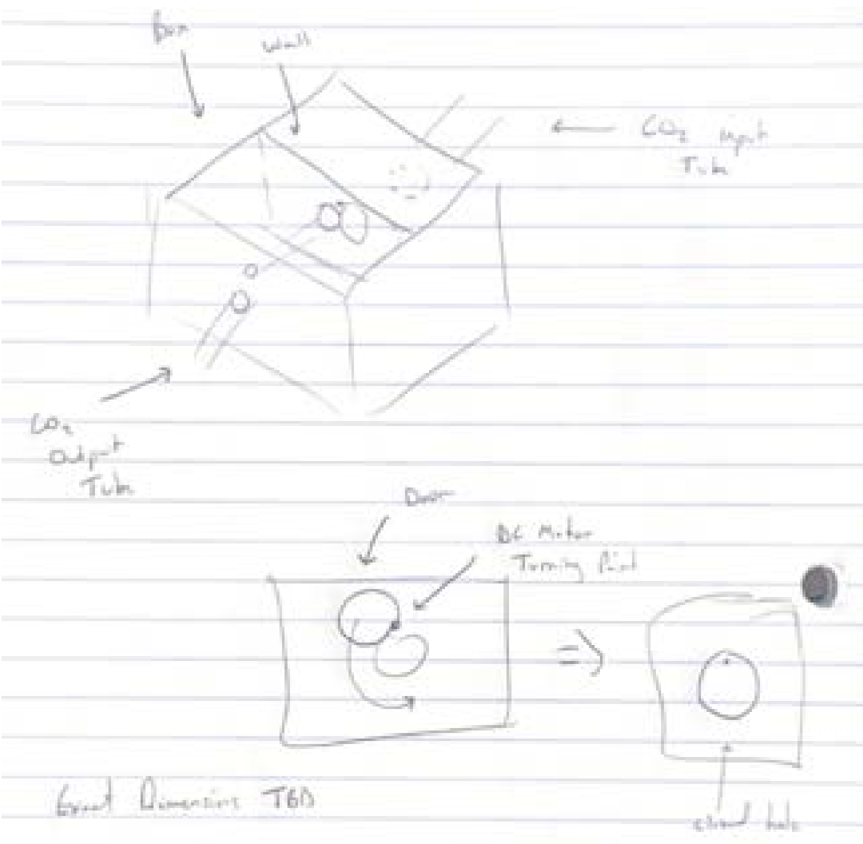


Figure 1: Hand written drawing of possible CO2 monitor for the CO2 input

- 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:

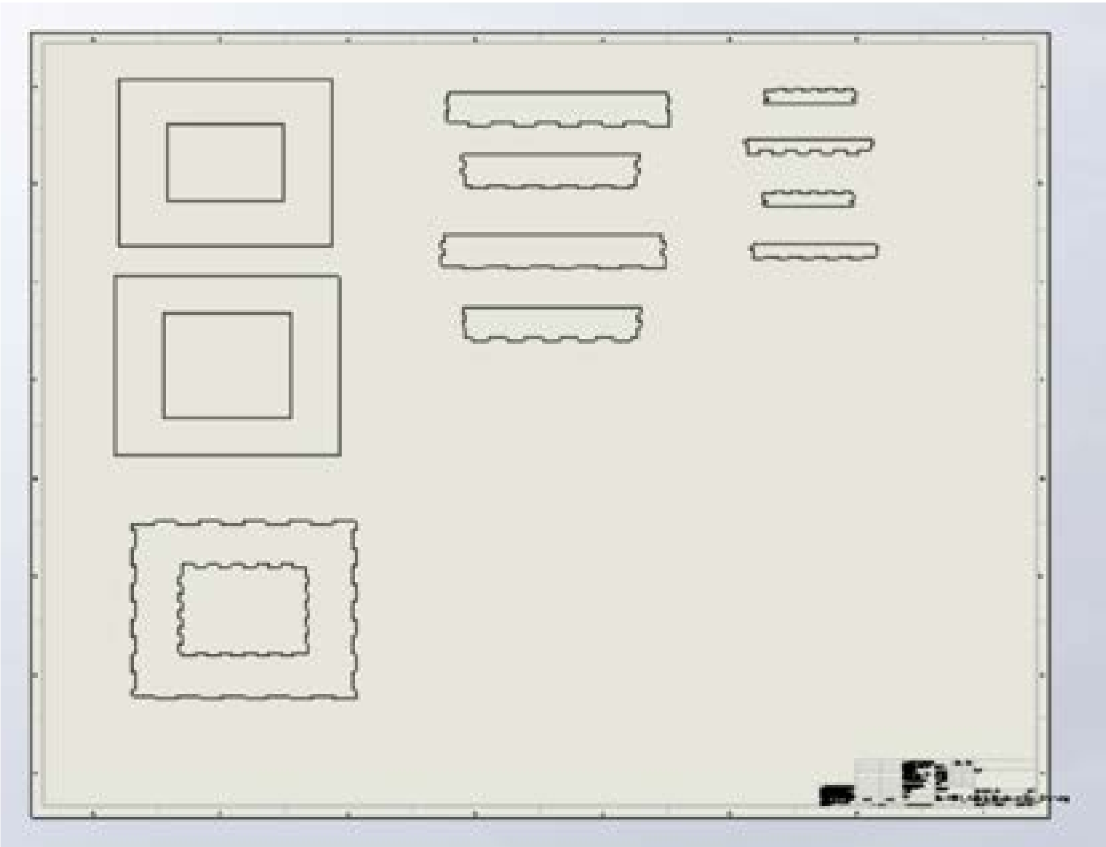


Figure 1: SOLIDWORKS drawing that was converted to ADOBE Illustrator files in order to be printed on the laser cutter

- 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:

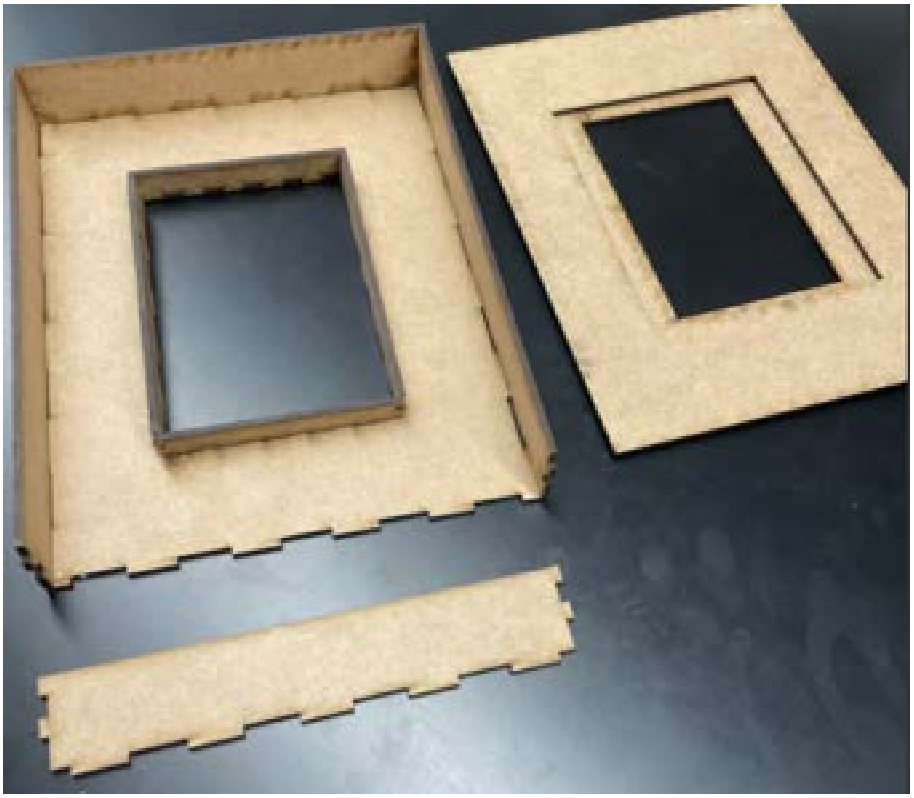


Figure 1: Photo of the laser cut HDF showing the parts being not completely assembled

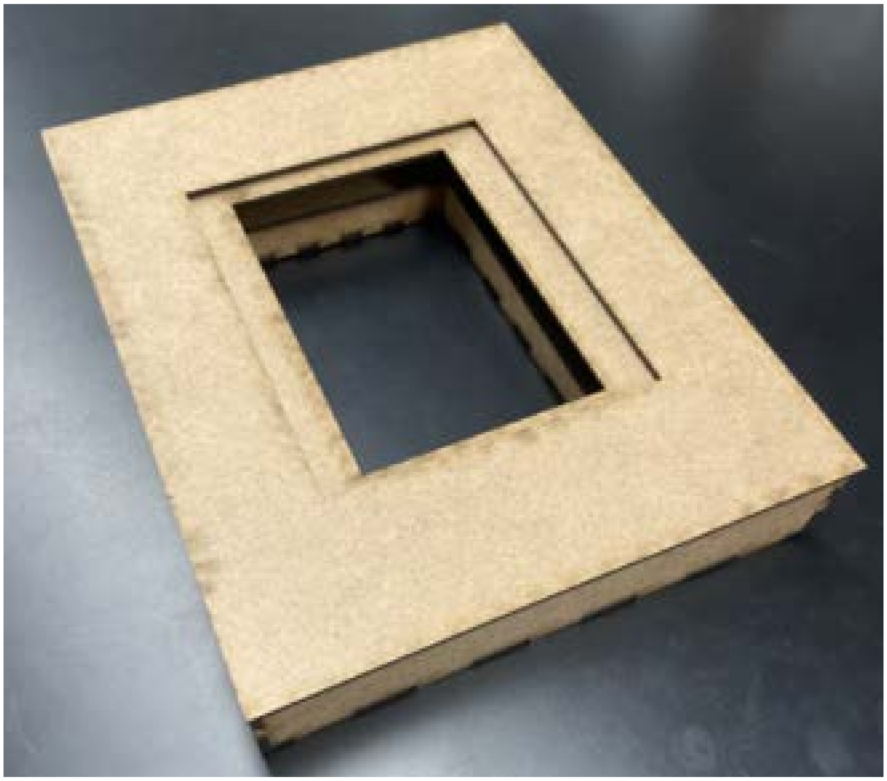


Figure 2: Photo of the laser cut HDF prototype with all the pieces assembled together.

- 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 CO_2/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:

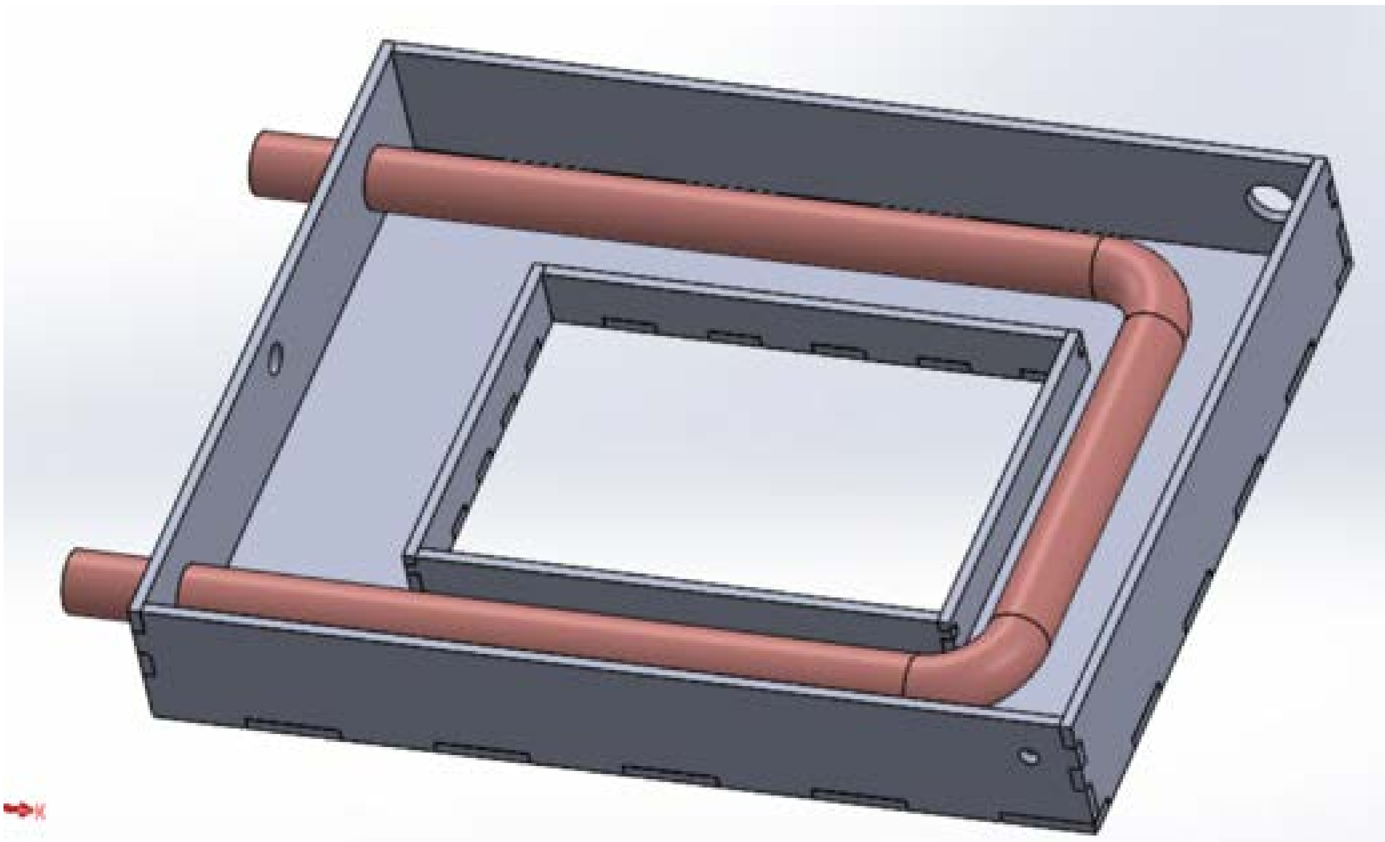


Figure 1: SOLIDWORKS drawing without the lid on the updated assembly.

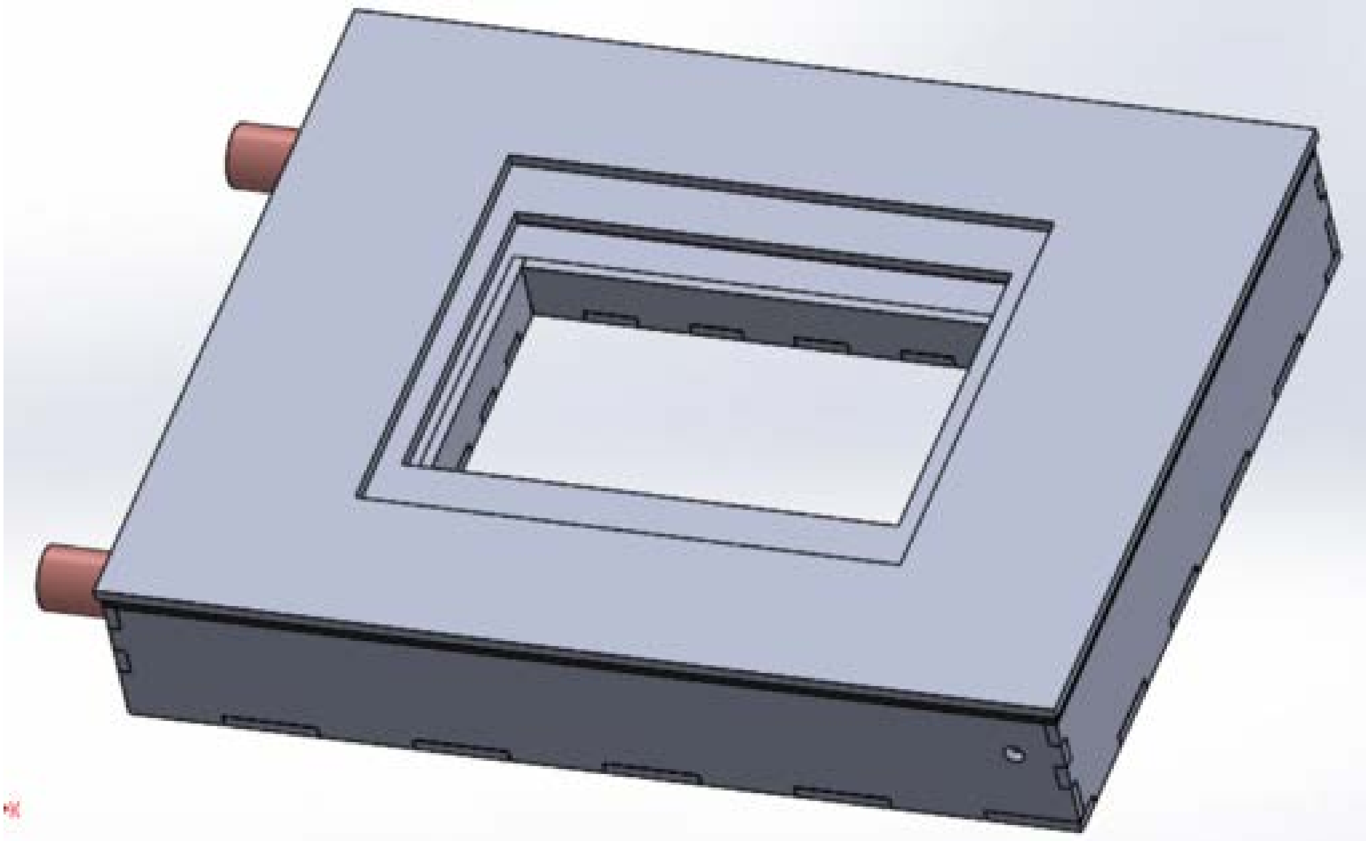


Figure 2: Updated SOLIDWORKS assembly with the lid on top.

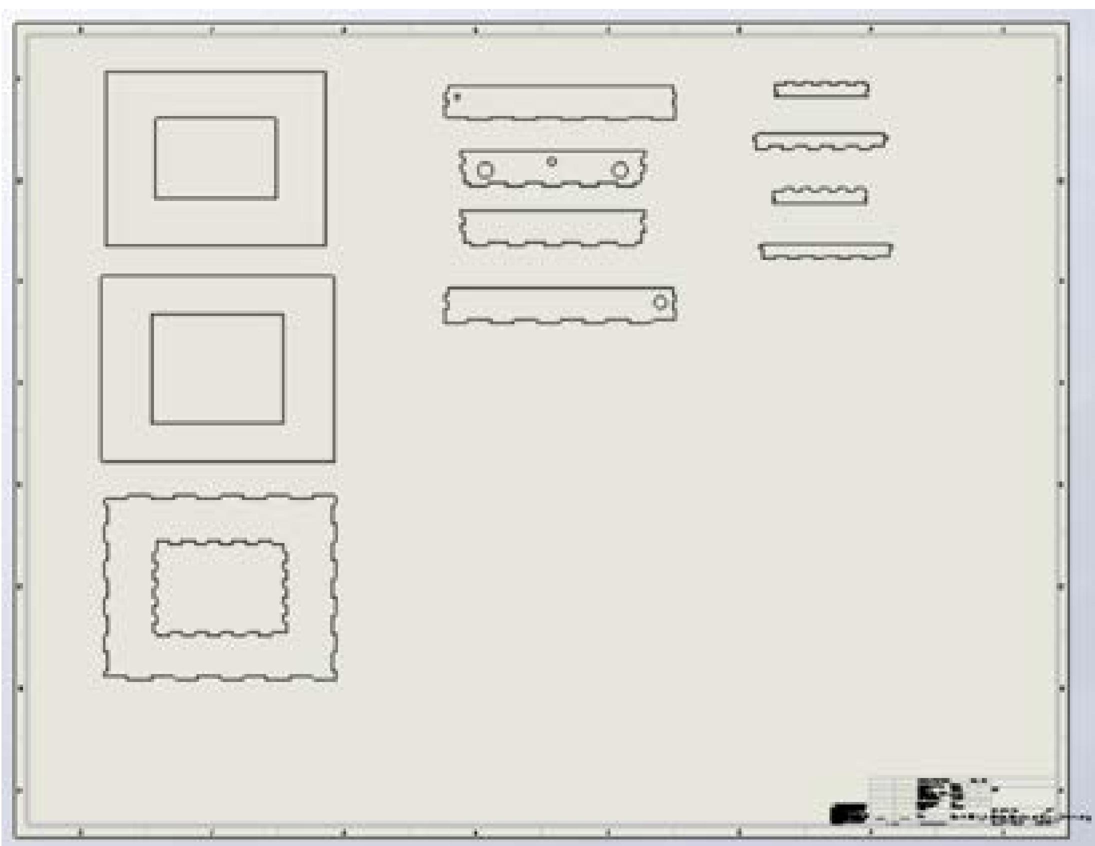


Figure 3: SOLIDWORKS drawing ready to be cut by the laser cutter with acrylic.

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:

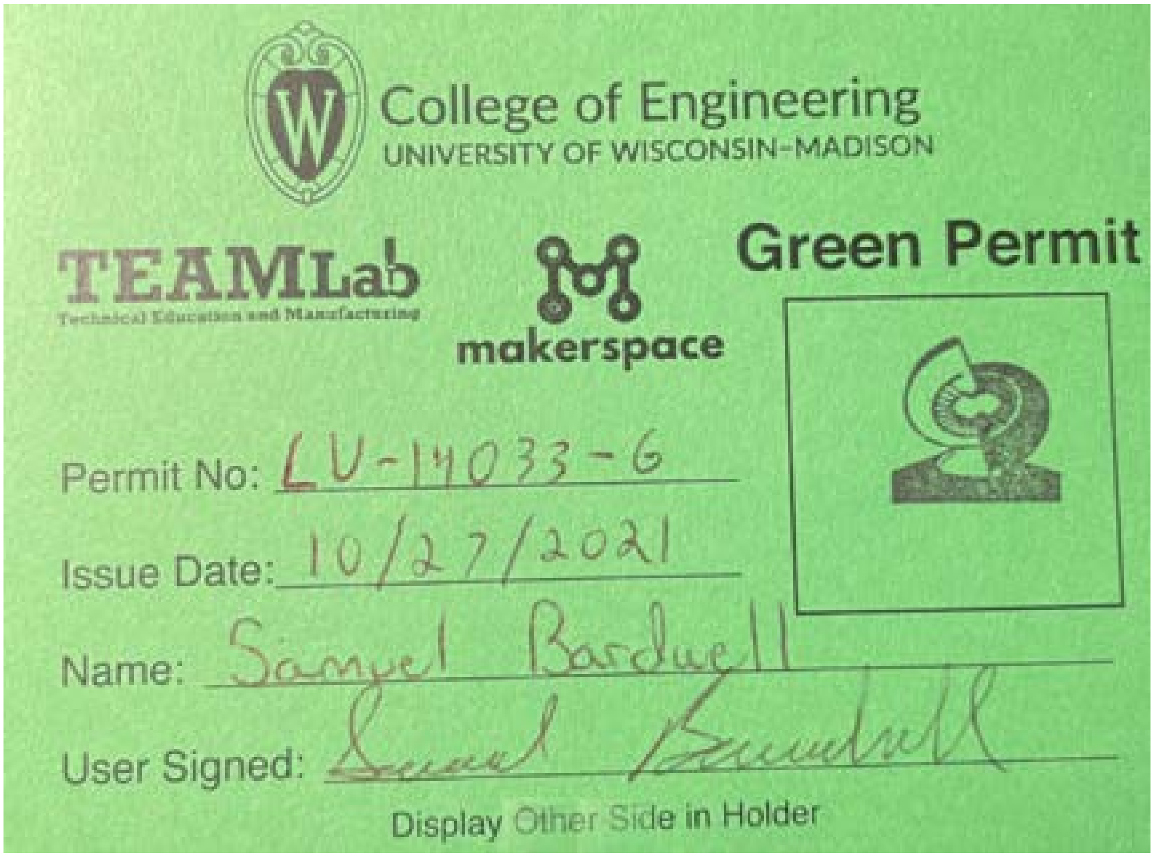


Figure 1: Front side of the green permit

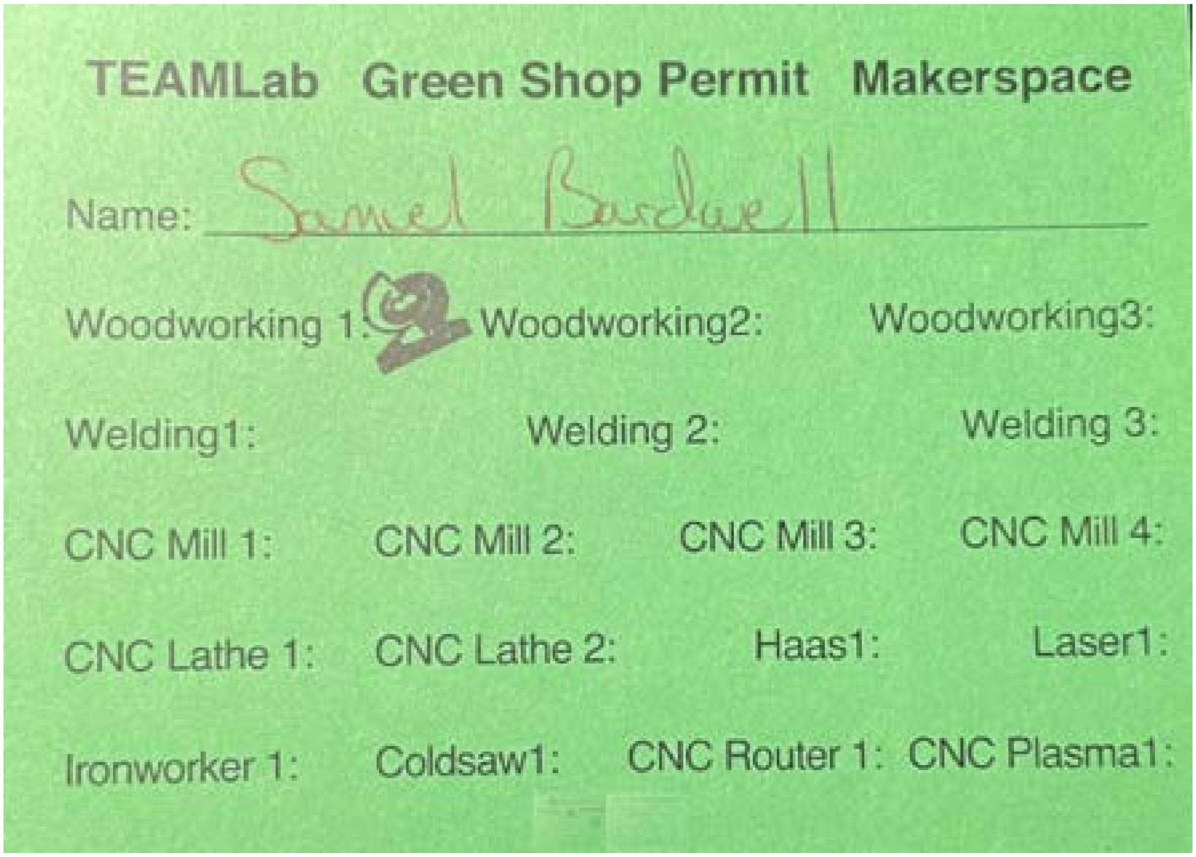


Figure 2: Back side of green permit

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:


TEAMLab Green Shop Permit Makerspace

Name: Samuel Bardwell

Woodworking 1: Woodworking2: Woodworking3:

Welding1: Welding 2: Welding 3:

CNC Mill 1: CNC Mill 2: CNC Mill 3: CNC Mill 4:

CNC Lathe 1: CNC Lathe 2: Haas1: Laser1:

Ironworker 1: Coldsaw1: CNC Router 1: CNC Plasma1:

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.

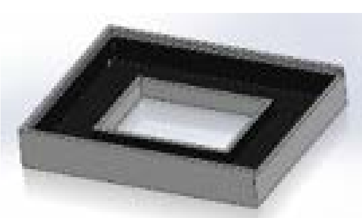
Content:

- 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

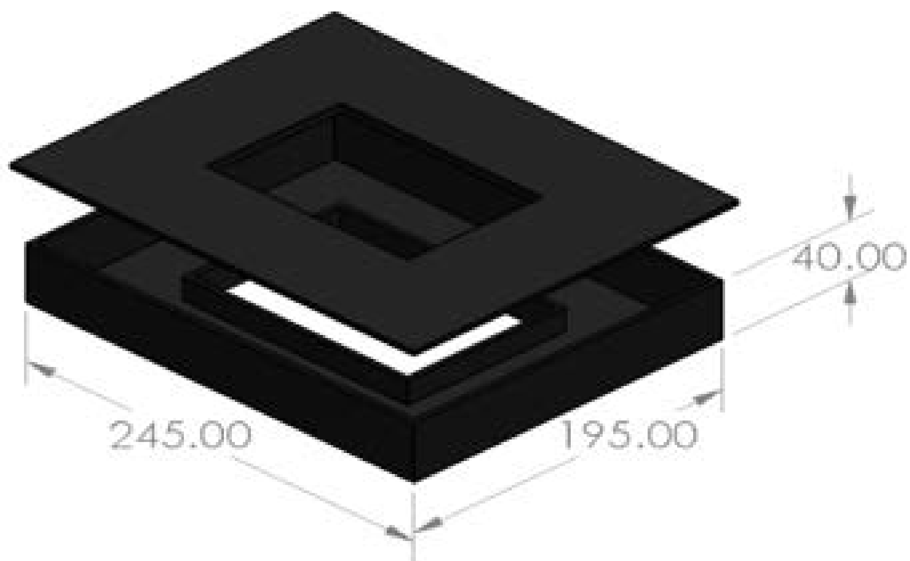
Date: 2/17/22

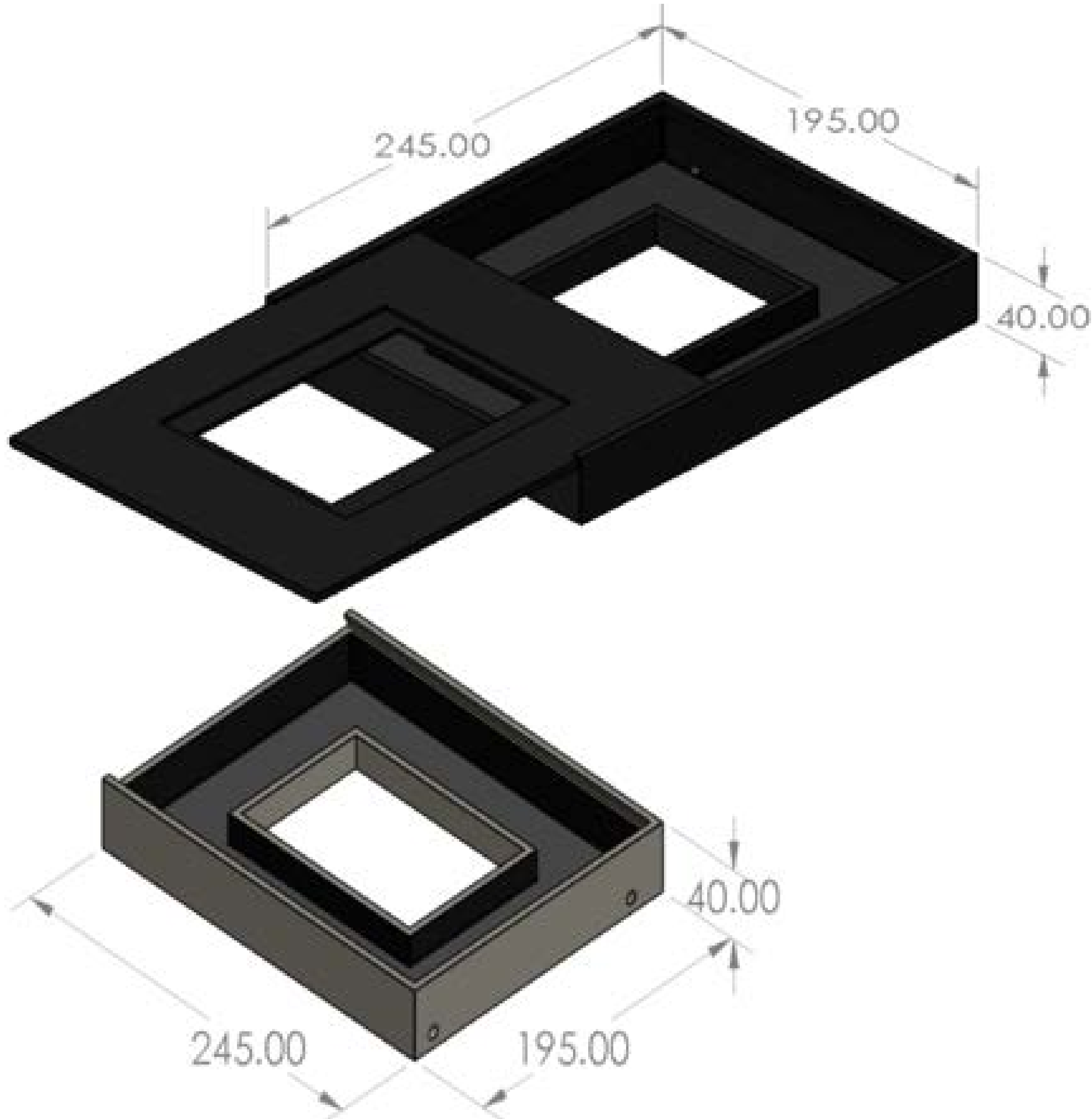
Content by: Sam

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

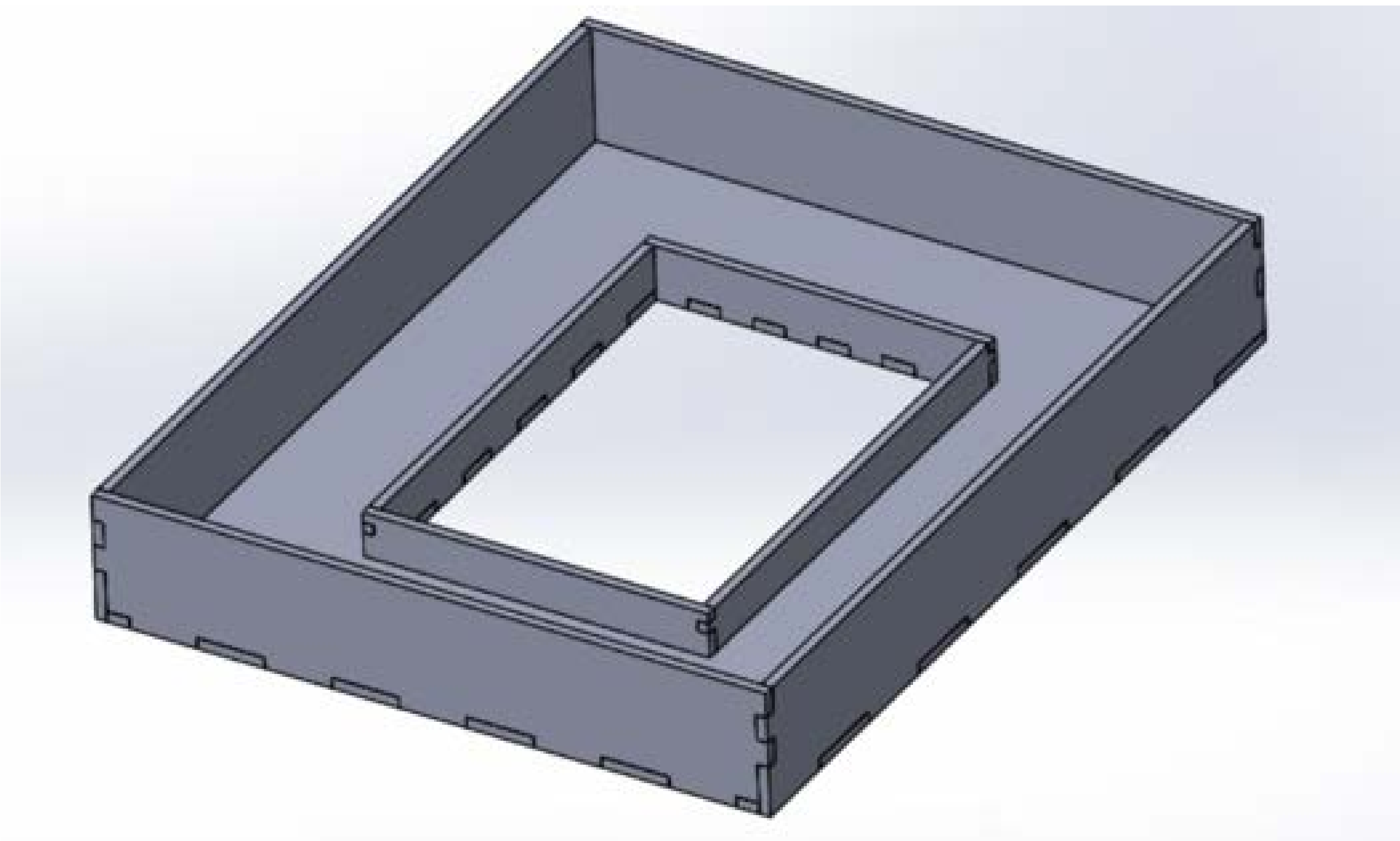
Goals: To show my weekly progress and contributions to the project.

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.

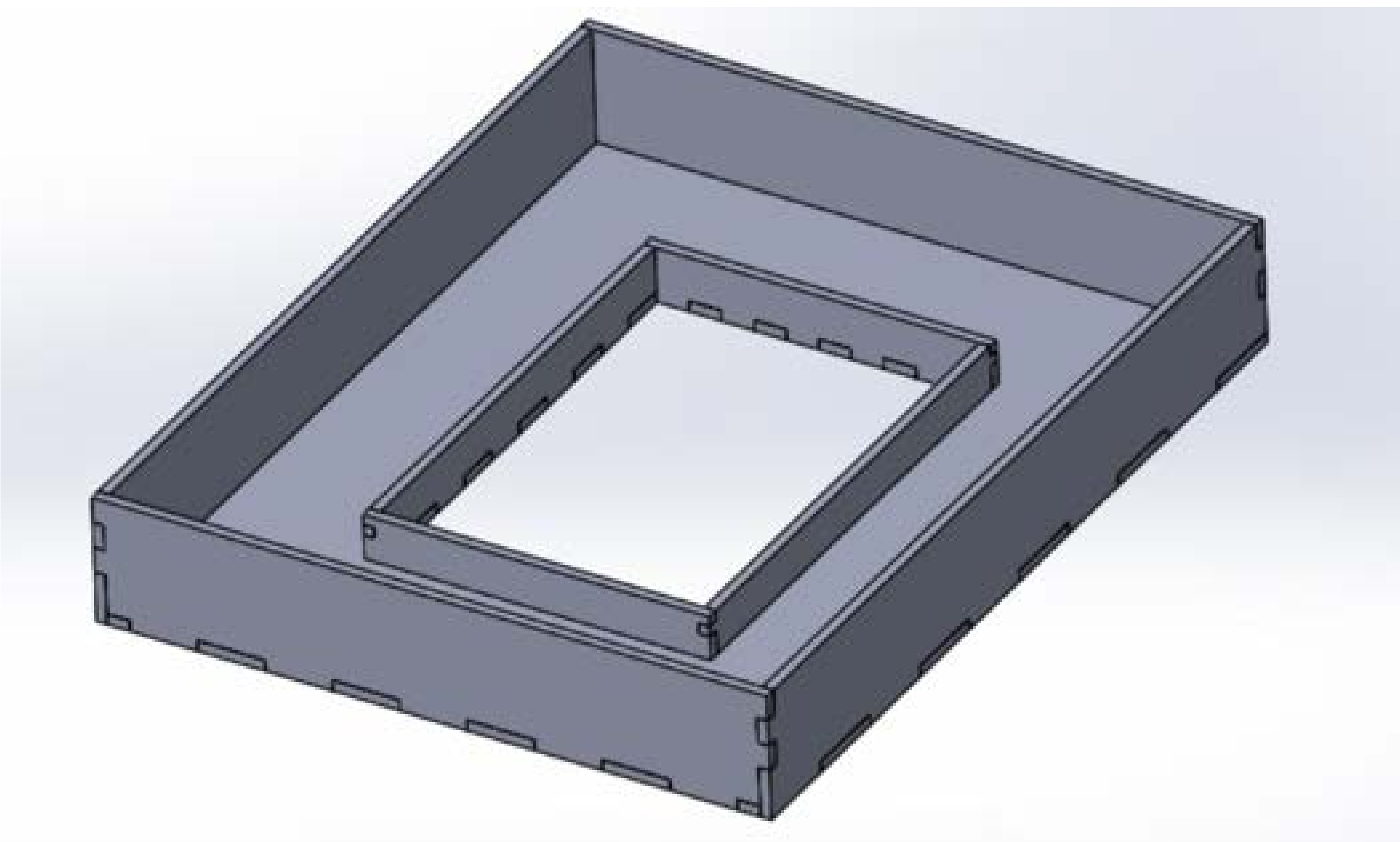
Content:

- 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, ¼" x ¼", 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 CO2 input regulation designs

* See 3/8/22 Handwritten Drawing of CO2 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 CO2 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.

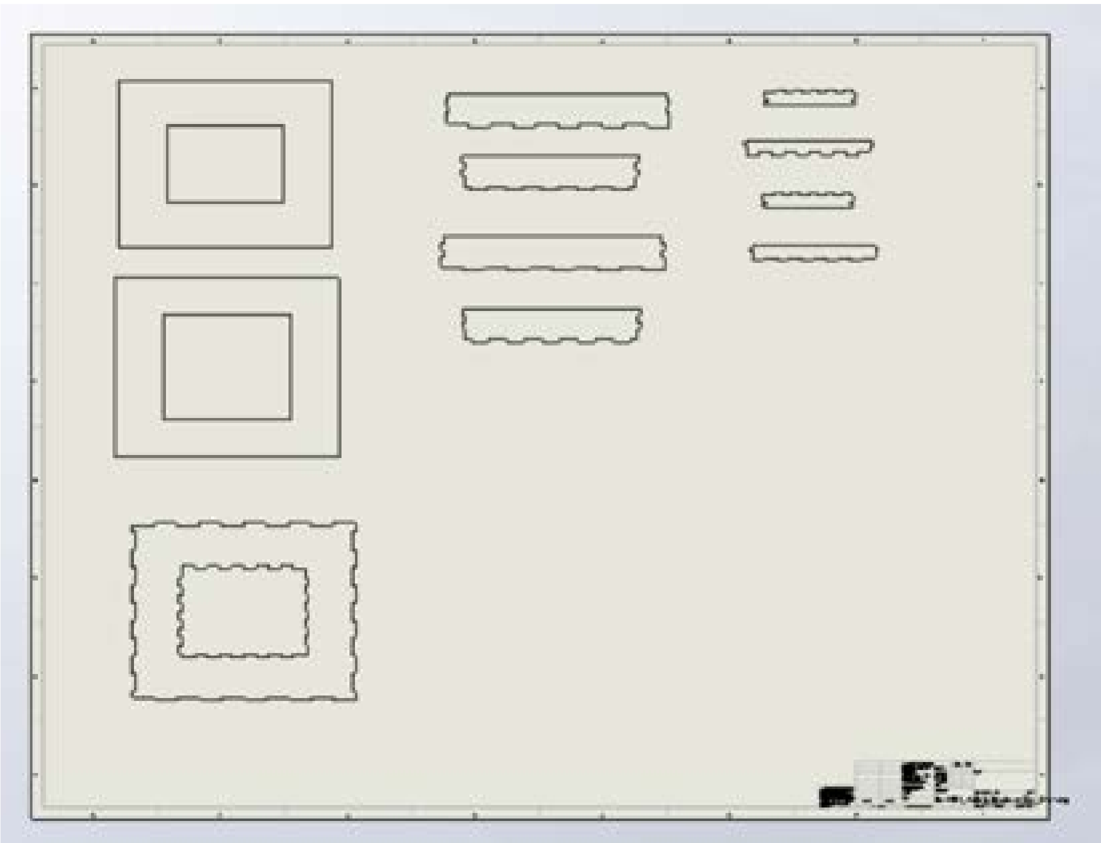


Figure 1: SOLIDWORKS drawing of the box used for the laser cutter.

- Laser cut the HDF wood and assembled the incubator prototype.

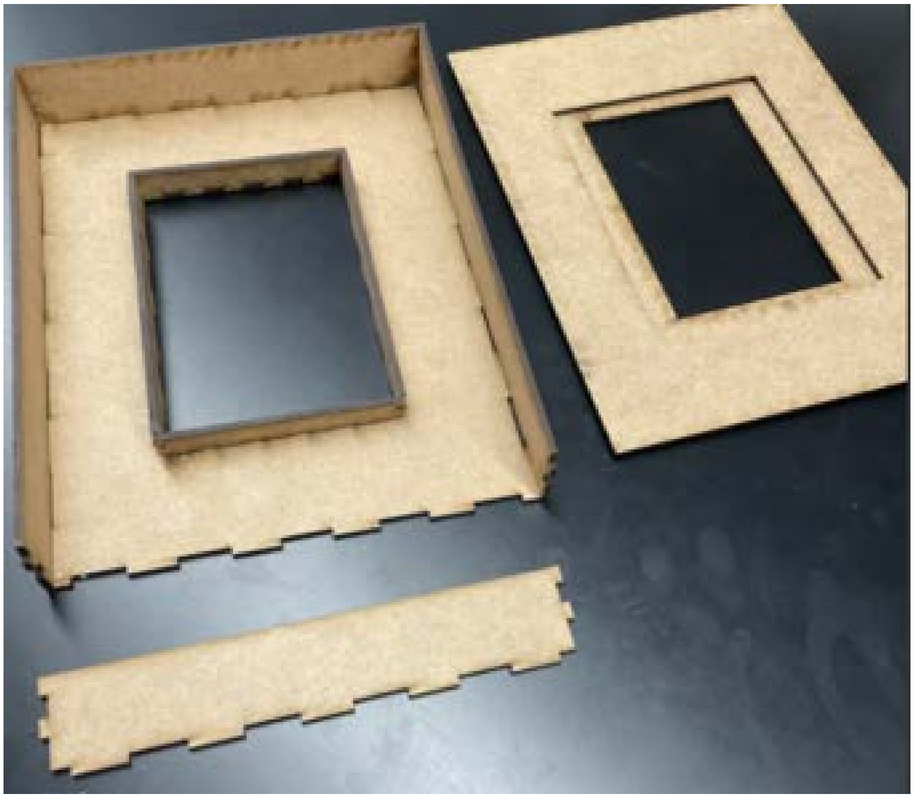


Figure 2: Disassembled laser cut box made from HDF wood in the Makerspace

- 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:

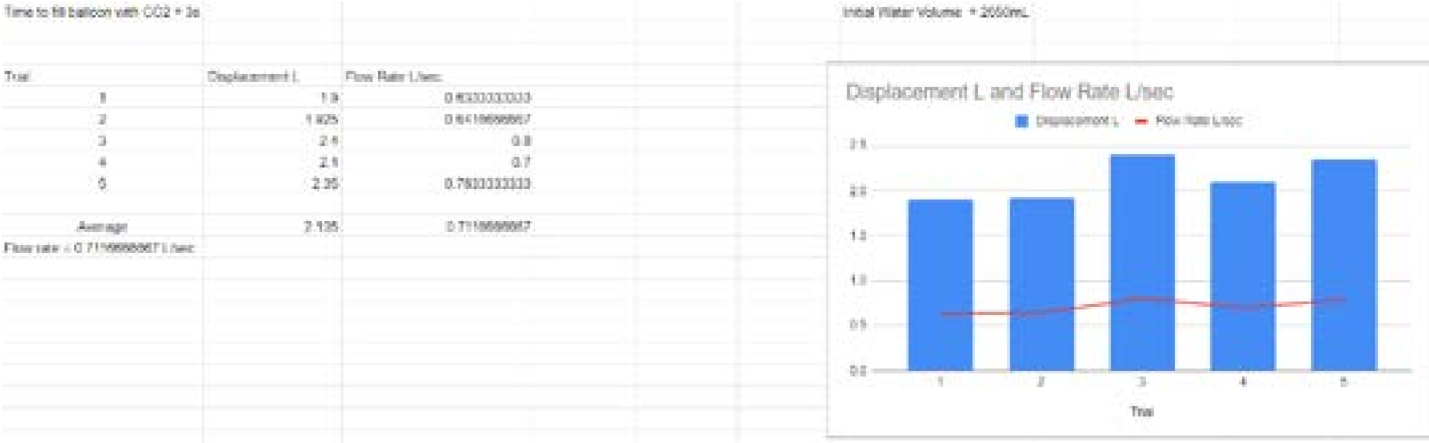
- Found barbed connectors and copper couplings for the tubing part of the incubator

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 = 2050mL

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

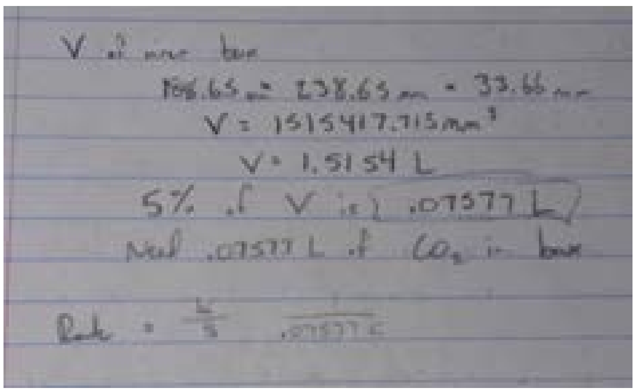


Figure 4: Photo of the mathematical calculations for the inner volume of the incubator box.

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

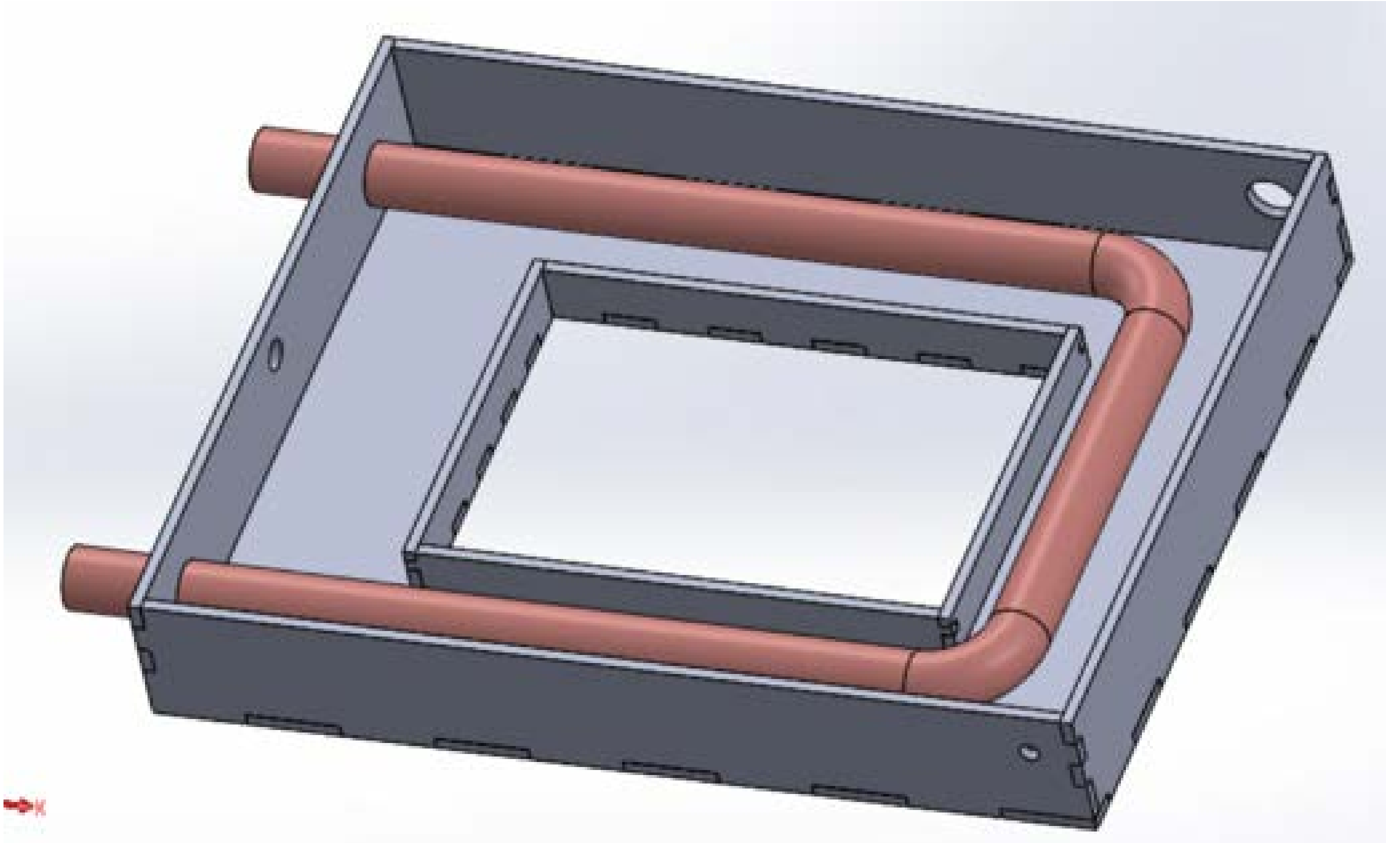


Figure 2: SOLIDWORKS drawing without the lid on the updated assembly.

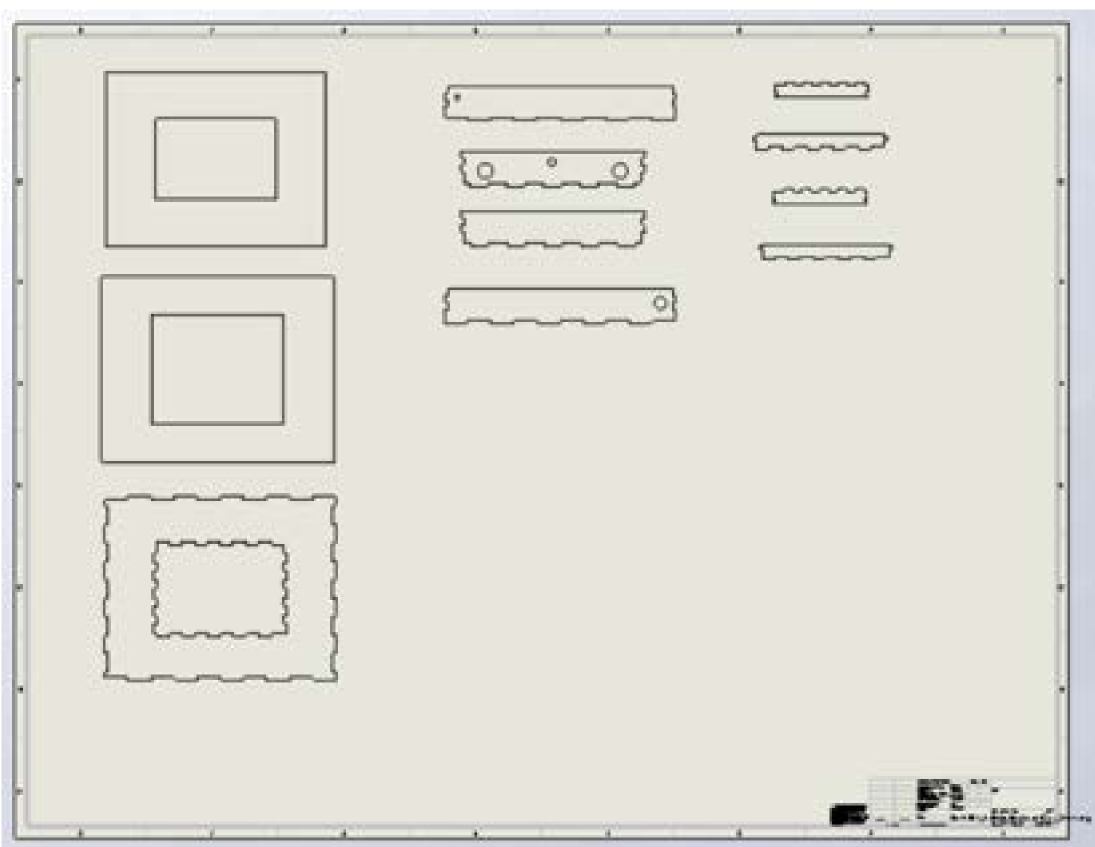


Figure 3: SOLIDWORKS drawing ready to be cut by the laser cutter with acrylic.

- 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

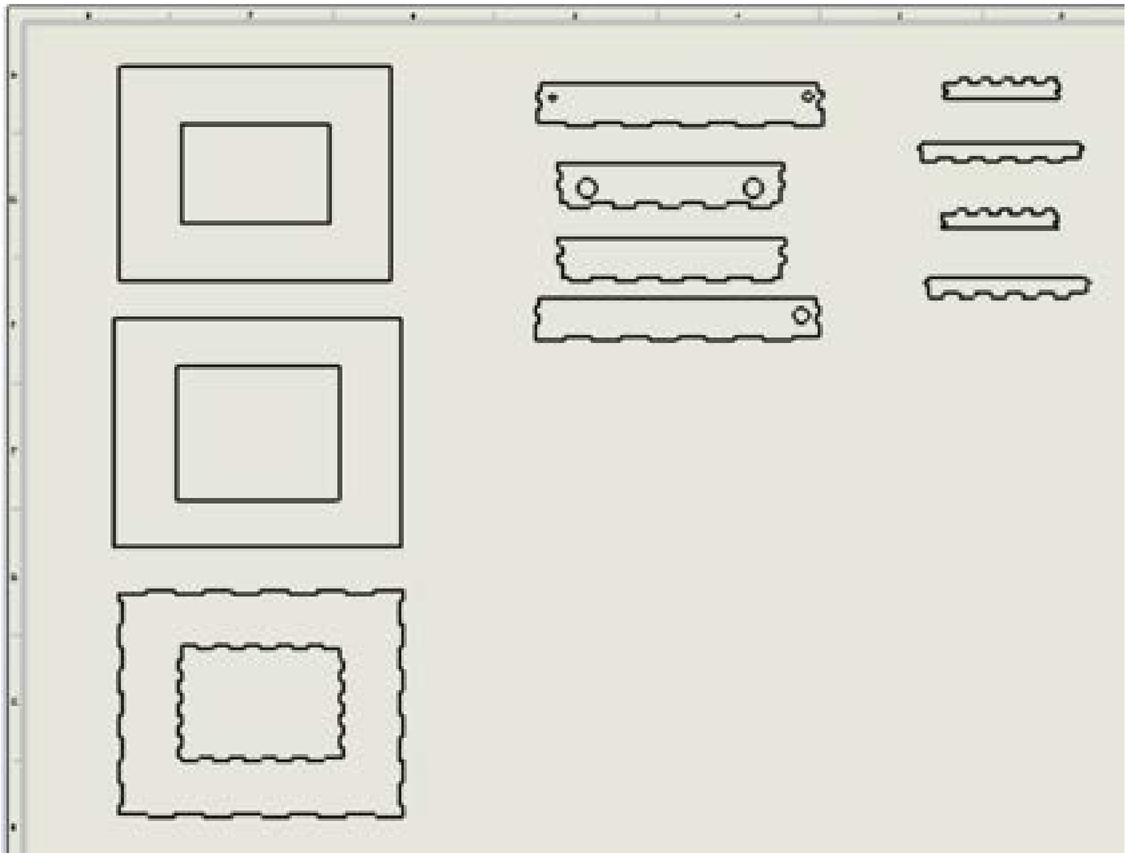


Figure 1: Final drawing before laser cutting the black acrylic.

- Laser cut black acrylic and assembled the box for the incubator.

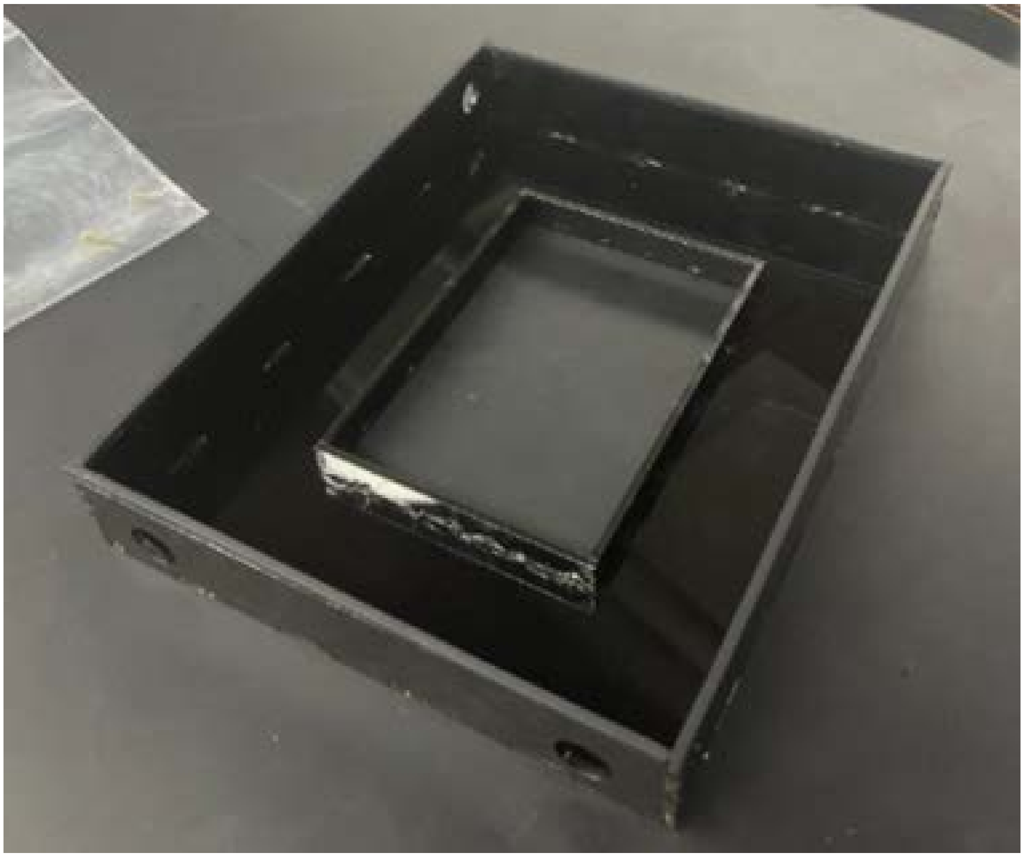


Figure 2: Assembled black acrylic box after being laser cut.

- 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.

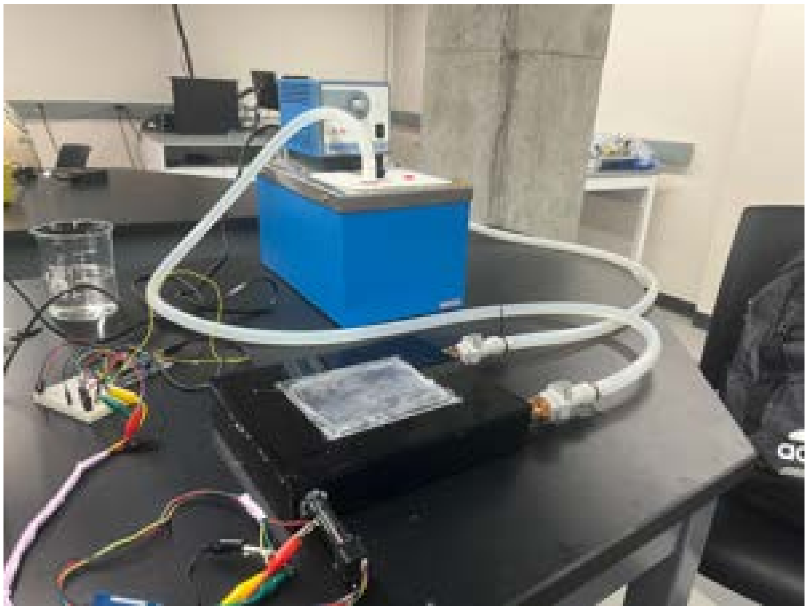


Figure 1: Whole Incubation Set-up

- Practiced the final presentation.

Conclusions/action items:

Complete all final deliverables and last day documents.

1/31/2023 Laplacian Energy Graphs

MAYA TANNA - Feb 03, 2023, 2:56 PM CST

Title: Laplacian Energy Graphs

Date: 1/31/2023

Content by: Maya

Goals: To document notes on understanding Laplacian energy graphs

Content:

-
- The Laplacian energy of a graph is defined as the sum of the absolute values of the differences of average degree and eigenvalues of the Laplacian matrix of the graph
- The Laplacian matrix is a discrete analog of the Laplacian operator in multivariable calculus and serves a similar purpose by measuring to what extent a graph differs at one vertex from its values at nearby vertices.
    - Measures how different a graph is at each part of the image - more of a comparison

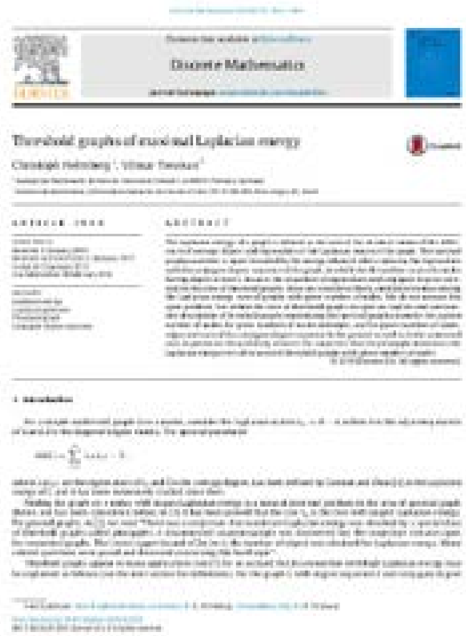
Conclusions/action items: Use this for deliverables and showing our data from testing in a more meaningful way that makes sense mathematically.

Reference:

[1] C. Helmberg and V. Trevisan, “Threshold graphs of maximal Laplacian energy,” *Discrete Mathematics*, vol. 338, no. 7, pp. 1075–1084, Jul. 2015, doi: 10.1016/j.disc.2015.01.025.

[2] E. W. Weisstein, “Laplacian Matrix.” https://mathworld.wolfram.com/ (accessed Jan. 31, 2023).

MAYA TANNA - Jan 31, 2023, 1:12 PM CST



Discrete Mathematics

Threshold graphs of maximal Laplacian energy

Download

1-s2.0-S0012365X1500045X-main.pdf (641 kB)

2/4/2023 Sensaphone Combination Sensor

MAYA TANNA - Feb 04, 2023, 10:56 AM CST

Title: Sensaphone Combination Sensor

Date: 2/4/2023

Content by: Maya

Goals: To document research about the Sensaphone Combination Sensor

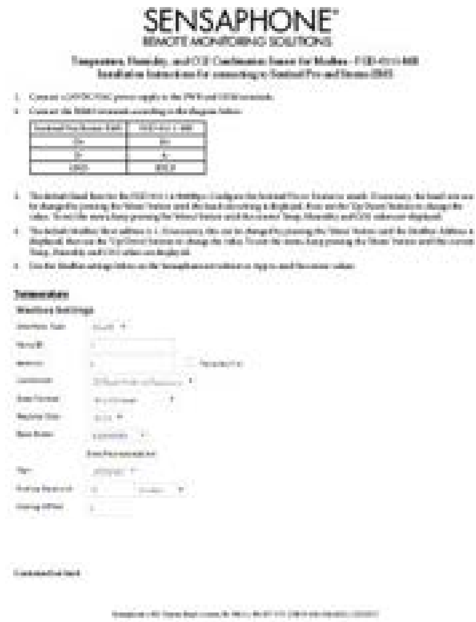
Content:

- A highly accurate and reliable dual-channel, non-dispersive infrared (NDIR) sensor to monitor CO2
- A precision thermistor to monitor temperature
- A thermoset polymer based capacitance sensor to measure humidity levels
- LCD for configuration and monitoring
- Field replaceable sensors
- Choose between Modbus or 4-20mA compatible sensor
- Multiple Modbus sensors can be ran in parallel

Link: https://www.sensaphone.com/products/temperature-humidity-and-co2-combination-sensor

Conclusions/action items: Determine how feasible this would be to add to our box system, the price, and where the data would go. Not sure how to connect this sensor to the system.

MAYA TANNA - Feb 04, 2023, 10:49 AM CST



Download

LIT-0217_MB_TempHumCO2.pdf (673 kB)

MAYA TANNA - Feb 06, 2023, 9:36 AM CST

Download

31071_UW_-_Madison_Bio_Eng.pdf (208 kB)

2/4/2023 Grove - SCD30 Sensor

MAYA TANNA - Feb 04, 2023, 10:56 AM CST

Title: Grove - SCD30 Sensor

Date: 2/4/2023

Content by: Maya

Goals: To document research about the SCD30 Sensor

Content:

The Grove - SCD30 is a 3-in-1 Arduino sensor that can measure CO2, temperature, and humidity. Based on Sensirion SCD30, it is a Non-Dispersive Infrared(NDIR) carbon dioxide sensor with high precision and wide measurement accuracy which can reach ±(30 ppm + 3%) between 400ppm to 10'000ppm. It would be a perfect choice if you are not looking for a simple Arduino temperature sensor or a CO2 sensor, but a multifunctional sensor for your Arduino weather station or other environmental projects.

Price: $60

Link: https://www.seeedstudio.com/Grove-CO2-Temperature-Humidity-Sensor-SCD30-p-2911.html#:~:text=Description-,The%20Grove%20%2D%20SCD30%20is%20a%203%2Din%2D1%20Arduino,between%20400ppm%20to%2010'000ppm.

Conclusions/action items: Determine how this will connect to our setup and discuss feasibility with team.

2/11/2023 Image Analysis Protocol/Data Analysis for Last Semester Images

MAYA TANNA - Feb 24, 2023, 12:13 PM CST

Title: Image Analysis Protocol/Data Analysis for Last Semester Images

Date: 2/11/2023

Content by: Maya

Goals: To document results from finalized image analysis protocol

Content:

See attachments below.

Conclusions/action items: Present this analysis to team during next advisor meeting and use this as the primary method of image analysis for testing that is conducted this semester.

MAYA TANNA - Feb 11, 2023, 2:48 PM CST

Download

Image_Analysis_Protocol.pdf (45.1 kB)

MAYA TANNA - Feb 11, 2023, 2:49 PM CST

Download

ImageJ_Data_Analysis.xlsx (9.78 kB)

2/21/2023 Fan Testing Protocol/Preliminary Images

MAYA TANNA - Feb 21, 2023, 4:23 PM CST

Title: Fan Testing Protocol/Preliminary Images

Date: 2/21/2023

Content by: Maya

Goals: To document results from fan testing protocol/preliminary images

Content:

See attachments below.

Conclusions/action items: Present this analysis to team during next advisor meeting and use this as the primary method of anti fog analysis for testing that is conducted this semester.

MAYA TANNA - Feb 21, 2023, 4:38 PM CST

Download

Fan_Testing_Protocol_1_.pdf (39.2 kB)

MAYA TANNA - Feb 24, 2023, 12:12 PM CST

Download

drive-download-20230224T180157Z-001.zip (11.4 MB)

MAYA TANNA - Feb 24, 2023, 12:12 PM CST

Download

drive-download-20230224T170451Z-001.zip (346 kB)

2/24/2023 Fan Testing Data Analysis

MAYA TANNA - Feb 27, 2023, 3:22 PM CST

Title: Fan Testing Data Analysis

Date: 2/24/2023

Content by: Maya

Goals: To document results from fan testing data analysis

Content:

See attachment below.

Conclusions/action items: Present this analysis to team during next advisor meeting and use this as the primary method of image analysis for additional fan testing that is conducted this semester. Overall, anti fog results look good though and there shouldn't be a need for further fan testing.

MAYA TANNA - Feb 27, 2023, 3:23 PM CST

[Download](#)

Fan_Testing_Data_Analysis_1_.xlsx (9.84 kB)

3/2/2023 Fan Data Full Fabrication

MAYA TANNA - Mar 02, 2023, 7:48 PM CST

Title: Fan Data Full Fabrication

Date: 3/2/2023

Content by: Maya

Goals: To document results from fan testing data analysis

Content:

See attachment below.

Conclusions/action items: Present this analysis to team during next advisor meeting. Overall, results look bad and we need to find a way to mitigate this because 80% fog is not ideal.

MAYA TANNA - Mar 02, 2023, 7:49 PM CST

Download

Fan_Data_Full_Fabrication.xlsx (9.97 kB)

3/9/2023 Cell Fan Testing Data

MAYA TANNA - Mar 09, 2023, 12:07 PM CST

Title: Cell Fan Testing Data

Date: 3/9/2023

Content by: Maya

Goals: To document results from cell fan testing done this week

Content:

See attachment below.

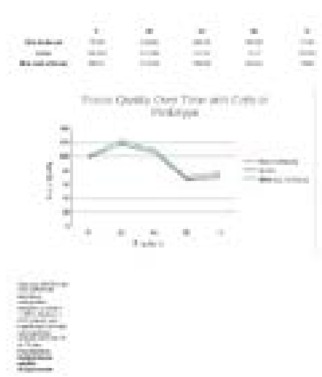
Conclusions/action items: Present this analysis to team during next advisor meeting. Overall, results look bad and we need to find a way to mitigate this because the optical focus quality was compromised.

MAYA TANNA - Mar 09, 2023, 12:07 PM CST

Download

drive-download-20230309T172417Z-001.zip (8.56 MB)

MAYA TANNA - Mar 09, 2023, 12:08 PM CST



Download

3_8_Incubator_Cell_Fan_Testing_Data.xlsx (7.95 kB)

3/29/2023 Condensation Testing with Antibacterial Solution Data Analysis

MAYA TANNA - Mar 29, 2023, 8:54 PM CDT

Title: Condensation Testing with Antibacterial Solution Data Analysis

Date: 3/29/2023

Content by: Maya

Goals: To document results from condensation testing done this week

Content:

See attachment below.

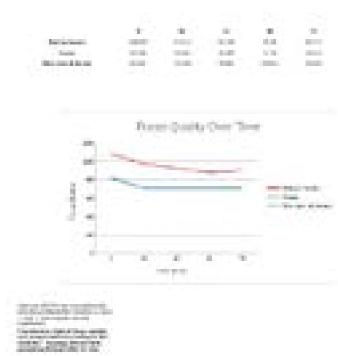
Conclusions/action items: Present this analysis to team during next advisor meeting. Overall, results look pretty decent according to the statistics but visually imaging via the microscopic doesn't look promising. Need to continue condensation prevention efforts.

MAYA TANNA - Mar 29, 2023, 8:54 PM CDT

Download

drive-download-20230330T011918Z-001.zip (22.4 MB)

MAYA TANNA - Mar 29, 2023, 8:55 PM CDT



Download

3_28_Condensation_Data.xlsx (7.89 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 CO2 Function

Date: 02/06/2022

Content by: Maya

Present: Maya

Goals: To document information on how to ensure that CO2 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 CO2 levels at 5% to maintain the cell medium at a physiological pH
  - Even though CO2 sensors aim to maintain the desired CO2 level, the calibration may shift over time from the set point
  - Easiest and most accurate method to measure CO2 is a gas analyzer - Fyrite instrument (can also measure O2 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 CO2 so we're really going to have to look into that since a CO2 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

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

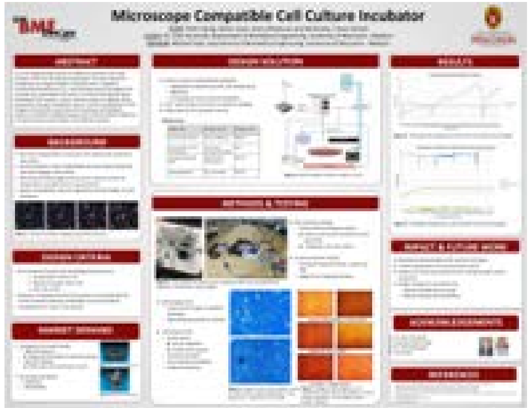
Conclusion: Since the spring 2017 team got CO2 working, I want to look more into what they did as well as use actual connectors with threading in the box in order to ensure heat is conserved as much as possible. In the future, I need to read the 2017 final report and look at the CO2 tank in person to determine possible connection ideas.

MAYA TANNA - Feb 12, 2022, 6:18 PM CST

Download

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)

11/07/2022 Anti-Fog Coating Mechanisms and Application

MAYA TANNA - Nov 07, 2022, 6:00 PM CST

Title: Anti-Fog Coating Mechanisms and Application

Date: 11/07/2022

Content by: Maya

Present: Maya

Goals: To document findings regarding anti-fog coating mechanisms and application

Content:

- Industrial anti-fog coatings are optical thin film coatings usually made from hydrophilic coatings that maximize surface energy
    - Ex) polymers and hydrogels and they prevent fogging at very low or high temps
    - Typically sustainable and environmentally friendly
- Anti-fog agents are either hydrophilic agents or surfactant-based
- Permanent anti-fog solutions consist of layering and covalently binding polymers to surfaces to achieve increase stability and durability of the system

Conclusions/action items: Use this information when trying to solve the anti fog/condensation issue.

Citation: S. Canet, “Anti-Fog Coating: The Mechanism and Applications,” *Advanced Nanotechnologies S.L.*, May 09, 2019. https://www.advancednanotechnologies.com/anti-fog-coating-the-mechanism-and-application/ (accessed Nov. 07, 2022).

11/07/2022 Incubator Sterilization Using H2O2

MAYA TANNA - Nov 07, 2022, 6:01 PM CST

Title: Incubator Sterilization Using H2O2

Date: 11/07/2022

Content by: Maya

Present: Maya

Goals: To document findings regarding incubator sterilization to make sure we are maintaining a clean environment for cells to thrive

Content:

See attachment below.

Conclusions/action items: This information on sterilization will be beneficial as we approach the final steps of this project in the spring.

MAYA TANNA - Nov 07, 2022, 6:01 PM CST


STERILIZATION OF REACH-IN INCUBATORS USING H_2O_2

Abstract

Introduction

Download

ReachInH2O2WhitePaperRevA.pdf (479 kB)

09/11/2022 PrintrLab Incubator

MAYA TANNA - Sep 11, 2022, 10:33 AM CDT

Title: PrintrLab Incubator

Date: 09/11/2022

Content by: Maya

Present: Maya

Goals: To document findings from a recently published article about a new low-cost cell culture incubator in the field to better inform current project decisions

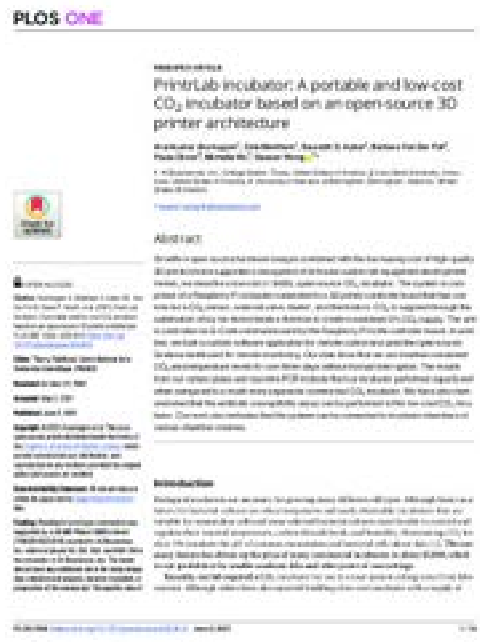
Content:

- Cost: less than $400
- Open-source CO2 incubator
- Purpose: to regulate temperature and keep bacterial cultures healthy during incubation
- Components
  - Raspberry Pi computer connected to a 3D printer controller board that has controls for a CO2 sensor, solenoid valve, heater, and thermistors
  - CO2 is supplied via the sublimation of dry ice (readily available and flexible to accommodate different incubator volumes needed) stored inside a thermos to maintain a 5% CO2 supply
  - The entire system is controlled by G-Code commands sent by the Raspberry Pi to the controller board and the team built a software app to control and monitor the system remotely
  - Internal system - system has a leak-proof food storage container that holds a CO2 sensor, 3D-printer heater-bed heater, and a thermistor from a 3D printer to keep the internal environment at optimal levels
  - External system - electronics, solenoid valve, home-made pressure-relief valve, power, and a thermos for dry ice storage
  -
- Results
  - Can maintain consistent internal environment for 3+ days without manual interruption
  - Testing shows that results are comparable with more expensive/commercial incubators in the field

Conclusions/action items: Potentially, we can use this device's CO2 mechanism for our incubator or at least take some inspiration/similar concepts from it when incorporating CO2 into our system.

Citation: A. Arumugam *et al.*, “PrintrLab incubator: A portable and low-cost CO2 incubator based on an open-source 3D printer architecture,” *PLOS ONE*, vol. 16, no. 6, p. e0251812, Jun. 2021, doi: 10.1371/journal.pone.0251812.

MAYA TANNA - Sep 11, 2022, 10:30 AM CDT


PLOS ONE

PrintrLab incubator: A portable and low-cost CO_2 incubator based on an open-source 3D printer architecture

Abstract

Introduction

Download

journal.pone.0251812.pdf (3.88 MB)

MAYA TANNA - Dec 12, 2022, 5:07 PM CST

In response to comment:

This project compares with our project because we used a solenoid valve for our CO2 system, as I explained in the conclusion section of the entry above and at the time of this entry, I thought this might be useful for our project if we wanted to use a Raspberry Pi.

09/18/2022 Anti Fog Options

MAYA TANNA - Sep 18, 2022, 7:51 PM CDT

Title: Anti Fog Options

Date: 09/18/2022

Content by: Maya

Present: Maya

Goals: To research anti fogging materials to prevent the issue that we had last semester with having a cloudy coating on the top glass and also look for practical purchasing options.

Content:

- Option 1: FogShield XP Pre-Moistened Towelette Station: 25 Wipe Count, Individually Wrapped, Pre-Moistened
    - Cost: $10.28 (for 25 wipes)
    - https://www.grainger.com/product/BAUSCH-LOMB-FogShield-XP-Pre-Moistened-1AHE8
- Option 2: Lens Cleaning Solution: Anti-Fog/Anti-Static, Non-Silicone, 16 fl oz Bottle Size
    - Cost: $6.32 (for 16 fl oz)
    - https://www.grainger.com/product/BAUSCH-LOMB-Lens-Cleaning-Solution-Anti-5BB83
- Option 3: Lens Cleaning Solution: Anti-Fog/Anti-Static, Silicone, 16 fl oz Bottle Size
    - Cost: $6.58 (for 16 fl oz)
    - https://www.grainger.com/product/BAUSCH-LOMB-Lens-Cleaning-Solution-Anti-4T932?opr=APPD&analytics=altItems_5BB83

Conclusions/action items: All of these are very reasonably priced options. I think that Option 3 is the best, because it has silicone which is the active ingredient in anti-fogging. Grainger had very limited options, so these were the top contenders.

10/22/2022 ImageJ Quantification Methods

MAYA TANNA - Oct 22, 2022, 10:27 AM CDT

Title: ImageJ Quantification Methods

Date: 10/22/2022

Content by: Maya

Present: Maya

Goals: To document findings from research on ImageJ quantification methods

Content:

1. Option 1: Do Process >> Image Calculator (subtract the 2 images)
    1. Problem: another image is generated, do we need to see quantitative results or just compare differences in generated images?
2. Option 2: Do Plugins >> Classification >> Microscope Image Focus Quality
    1. Need to install "classification"
    2. Need to convert images to 16-bit integer data only
    3. Instructions: https://imagej.net/imagej-wiki-static/Microscope_Focus_Quality
3. Option 3: If you just want a number that describes how "different" the 2 images are, sum the square of the difference between pixel values for all pixels.
    1. Gives you a quantitative way to compare the differences between different image pairs.
    2. If you want to find places in the image where 1 and 2 are different, plot the absolute value of the difference between the 2 images.

Conclusions/action items: Use these results when conducting testing (specfically optical and anti fog) later on.

11/02/2022 ImageJ Intensity Quantification Methods

MAYA TANNA - Nov 02, 2022, 5:19 PM CDT

Title: ImageJ Intensity Quantification Methods

Date: 11/02/2022

Content by: Maya

Present: Maya

Goals: To document findings from research on ImageJ intensity quantification methods

Content:

See attached document.

Conclusions/action items: Use these tools if needed for optical and anti fog data analysis.

MAYA TANNA - Nov 02, 2022, 5:20 PM CDT

Basic Intensity Quantification with ImageJ

Quantify Gray Levels Across an Entire Image or Single Object/Region

Download

Quantification.pdf (534 kB)

11/04/2022 Show and Tell Notes/Ideas

MAYA TANNA - Nov 07, 2022, 3:33 PM CST

Title: Show and Tell Notes/Ideas

Date: 11/4/2022

Content by: Maya

Present: Maya

Goals: To document optical testing results.

Content:

- Pitch: looking for ideas regarding image analysis and anti fog improvement
- Ideas
    - Use MATLAB - convert to RGB values, put a certain threshold on focused vs. not focused, write a code in MATLAB
        - Ask Alexander McGee
    - Check code from ECE 203 - there's MATLAB code provided
    - Try to regulate where the condensation is going (a drip point and a swirl)
        - May need to buy it and may be expensive
    - Change the slope of the glass so it could lean one way and condensation could follow a specific path
    - Do more research on image recognition
    - Apply a blur filter to the original image and see what matches
    - Put a squeegee (motor with a wiper) every 30 seconds
    - can you use MATLAB to analyze the images?
        - MATLAB can find all the areas that are out of focus
        - MATLAB as an app has premade programs that we don't even have to code and we can just run it.
    - Screenshot of the image and put it back into image J
    - There's an image processing class and we can reach out to the professor
        - He uses mathatic
        - Setharts
- Next steps: Bella will make the glass hydrophobic in her research lab

Conclusions/action items: Use this feedback from Show and Tell to work on completing data analysis.

Key ideas:

1. Use MATLAB or python libraries to analyze the images
2. Use a windshield wiper or rainX to get ride of condensation.

11/07/2022 Image Analysis in MATLAB

MAYA TANNA - Nov 07, 2022, 6:16 PM CST

Title: Image Analysis in MATLAB

Date: 11/07/2022

Content by: Maya

Present: Maya

Goals: To document findings regarding doing image analysis in MATLAB and experiment with this later in the week

Content:

- Reading image data into the workspace: https://www.mathworks.com/help/images/read-image-data-into-the-workspace.html
- Getting image data: https://www.mathworks.com/help/images/ref/getimage.html
- Image information tool: https://www.mathworks.com/help/images/ref/imageinfo.html
- In vs. out of focus: https://www.mathworks.com/matlabcentral/answers/164384-difference-between-focus-and-out-of-focus-images

Conclusions/action items: Try to troubleshoot data later using these resources.

11/11/2022 Tong Lecture Notes

MAYA TANNA - Nov 11, 2022, 12:03 PM CST

MAYA TANNA - Nov 11, 2022, 12:22 PM CST

Title: Tong Lecture Notes

Date: 11/11/2022

Content by: Maya

Present: Maya

Goals: To document notes from the Tong Lecture

Content:

- How to Evolve an Entrepreneurial Mindset for Students and Faculty
- Entrepreneurs are everywhere
- Entrepreneurship is generally found in B-schools
- Entrepreneurially interested engineering students can go to a university eship center or take additional courses in the B-school for a minor or certificate.
- Can we not develop both engineering and entrepreneurship interests side by side?
- Can we go farther to include co-curricular, translational research activities, events, and programs?
- Entrepreneurship is the backbone of the global economy
- Engineers play a critical role by addressing problems and creating solutions
- The same characteristics are required for entrepreneurial mindset
- Strongly context dependent

Conclusions/action items: Use these notes to inspire my future career.

12/1/2022 ImageJ Problem-Solving

MAYA TANNA - Dec 01, 2022, 10:20 PM CST

Title: ImageJ Problem-Solving

Date: 12/1/2022

Content by: Maya

Present: Maya

Goals: To document findings on ImageJ analysis

Content:

1. Take a screenshot of image after microscope image focus quality plugin and split channels and measure so that you get a number with arbitrary units associated with the amount of red, green, and blue within the image
    1. Can graph these values over time
2. Do microscope image focus quality plugin normally --> measuring step TBD

Conclusions/action items: Action items are stated as goals in the content above.

09/18/2022 Homogeneity Test Protocol

MAYA TANNA - Sep 18, 2022, 11:05 AM CDT

Title: Homogeneity Test Protocol

Date: 09/18/2022

Content by: Maya

Present: Maya

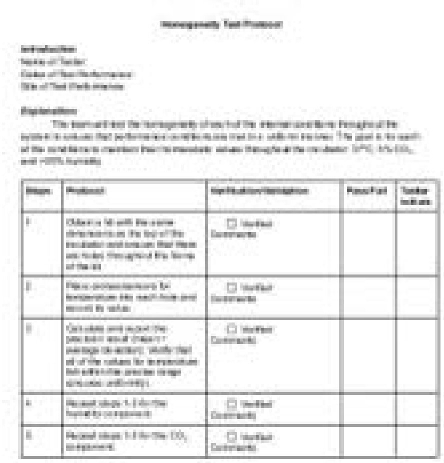
Goals: To document an additional test protocol that has been added to the collection in order to check homogeneity and a uniform distribution of each of the internal environment components of the system

Content:

See attached document.

Conclusions/action items: Review this protocol with the team and add it to the test protocol template document, as well as execute during incubator testing.

MAYA TANNA - Sep 18, 2022, 11:05 AM CDT



Download

Homogeneity_Test_Protocol.pdf (58.2 kB)

09/24/2022 Anti Fog Application Test Protocol

MAYA TANNA - Sep 24, 2022, 12:18 PM CDT

Title: Anti Fog Application Test Protocol

Date: 09/24/2022

Content by: Maya

Present: Maya

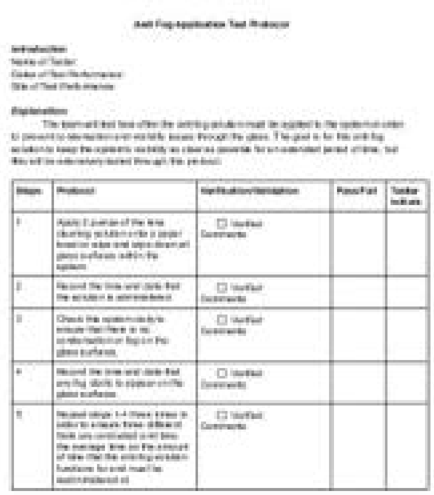
Goals: To document the creation of a newly written test protocol that will evaluate the time that the anti fog solution must be reapplied to the system to ensure clear visibility

Content:

See attached document.

Conclusions/action items: Use this protocol to determine the time period that the anti fog solution lasts, and when moving into characterization and verification/validation testing.

MAYA TANNA - Sep 24, 2022, 12:19 PM CDT



Download

Anti_Fog_Application_Test_Protocol.pdf (54.5 kB)

09/24/2022 Testing Protocols (Template) Updated 1

MAYA TANNA - Sep 24, 2022, 12:20 PM CDT

Title: Testing Protocols (Template) Updated 1

Date: 09/24/2022

Content by: Maya

Present: Maya

Goals: To document updated testing protocols that better reflect current project plans

Content:

See attached document.

Conclusions/action items: Use these protocols when moving into characterization and verification/validation testing.

MAYA TANNA - Sep 24, 2022, 12:20 PM CDT

Download

Testing_Protocols_Template_2_.pdf (102 kB)

09/20/2022 Testing Protocols (Template) Updated

MAYA TANNA - Sep 20, 2022, 4:17 PM CDT

Title: Testing Protocols (Template) Updated

Date: 09/20/2022

Content by: Maya

Present: Maya

Goals: To document updated testing protocols that better reflect current project plans

Content:

See attached document.

Conclusions/action items: Use these protocols when moving into characterization and verification/validation testing.

MAYA TANNA - Sep 20, 2022, 4:17 PM CDT

Download

Testing_Protocols_Template_1_.pdf (98.9 kB)

09/11/2022 Testing Protocols (Template)

MAYA TANNA - Sep 11, 2022, 10:45 AM CDT

Title: Testing Protocols (Template)

Date: 09/11/2022

Content by: Maya

Present: Maya

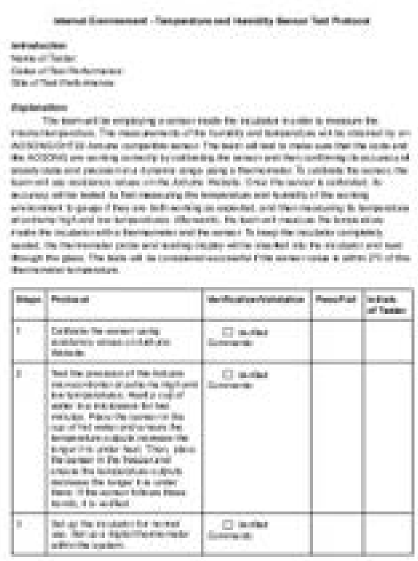
Goals: To document updated testing protocols that better reflect current project plans

Content:

See attached document.

Conclusions/action items: Use these protocols when moving into characterization and verification/validation testing.

MAYA TANNA - Sep 11, 2022, 10:46 AM CDT



Download

Testing_Protocols_Template_.pdf (95.7 kB)

10/03/2022 Anti Fog Test Results

MAYA TANNA - Oct 03, 2022, 7:08 PM CDT

Title: Anti Fog Test Results

Date: 10/03/2022

Content by: Maya

Present: Maya

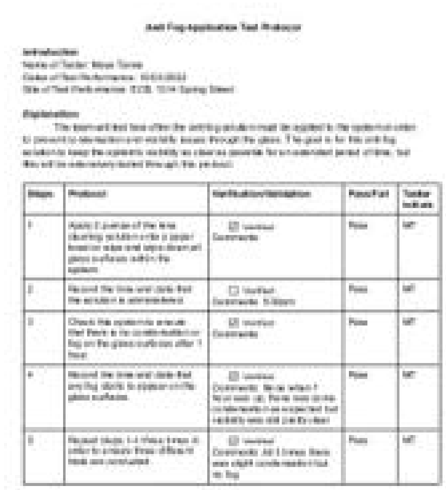
Goals: To document test results from the anti fog application testing

Content:

See attached document.

Conclusions/action items: Use these results to wipe the glass and reapply anti fog solution after using the incubator for more than an hour.

MAYA TANNA - Oct 03, 2022, 7:09 PM CDT



Download

Anti_Fog_Testing.pdf (56.4 kB)

MAYA TANNA - Dec 12, 2022, 4:56 PM CST

In response to comment:

Anti-fog testing did not pass the tests due to condensation, which potentially would have compromised microscope functionality while imaging - more tests were done as a result of this experiments and this experiment directly informed future work that Bella and I completed with the project

10/20/2022 Anti Fog Pilot Imaging

MAYA TANNA - Oct 21, 2022, 3:14 PM CDT

Title: Anti Fog Pilot Imaging

Date: 10/20/2022

Content by: Maya

Present: Maya

Goals: To document images taken from the inverted microscope to analyze the effectiveness of the anti fog solution

Content:

Control Group: cells without the incubator

Experimental: 10 min

Experimental: 20 min

Experimental: 30 min

Experimental: 40 min

- Results showed substantial fog around the 30 min timepoint but then went away at the 40 min timepoint (more timepoints need to be run)
- Control showed be cells in the incubator at 0 min timepoint for an accurate study
- May need to try increasing the number of coats of anti fog solution on the glass

Conclusions/action items: Run optical testing next week and redo this anti fog testing for 3 different trials and then take an average of the results.

MAYA TANNA - Oct 20, 2022, 4:26 PM CDT

Download

drive-download-20221020T212548Z-001.zip (75.7 MB)

10/25/2022 Optical Testing Results

MAYA TANNA - Nov 02, 2022, 5:57 PM CDT

Title: Optical Testing Results

Date: 10/25/2022

Content by: Maya

Present: Maya

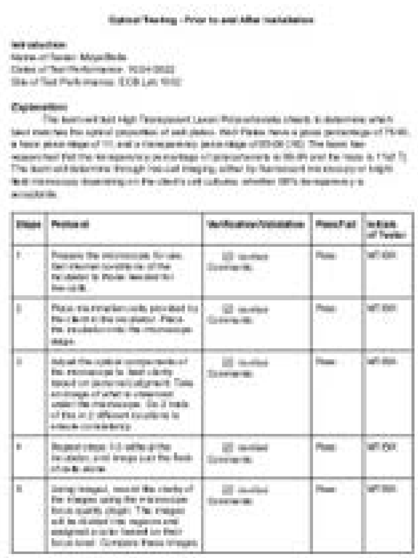
Goals: To document optical testing results.

Content:

See attachment below.

Conclusions/action items: Use these results for future technical reports. Figure out a better way to quantify results (so far we have subtracted control from experimental images).

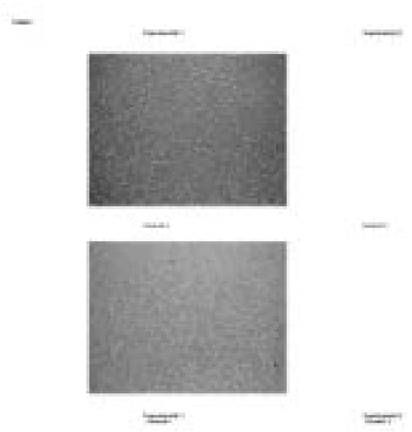
MAYA TANNA - Nov 02, 2022, 5:53 PM CDT



Download

Optical_Testing.pdf (61.5 kB)

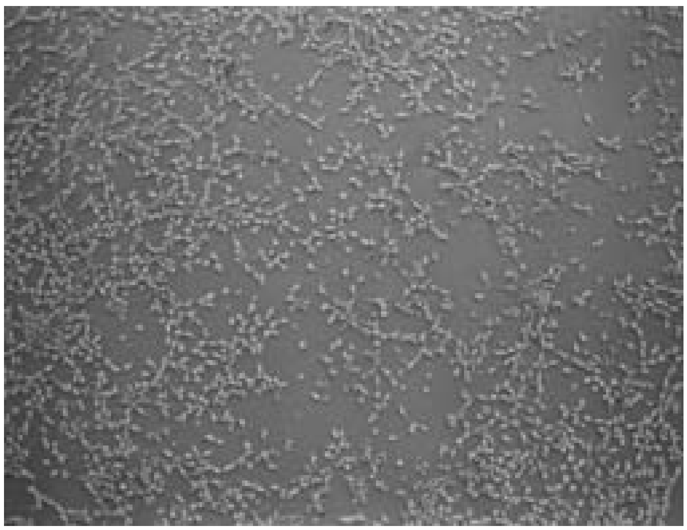
MAYA TANNA - Nov 02, 2022, 5:55 PM CDT



Download

Optical_Anti_Fog_Testing_Results.xlsx (5.29 MB)

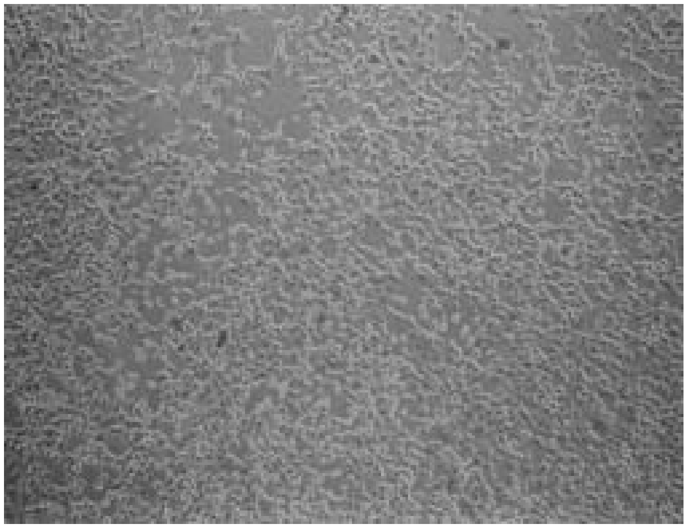
MAYA TANNA - Nov 02, 2022, 5:56 PM CDT



Download

optic_testing_prototype_1_16_bit.jpg (1.65 MB)

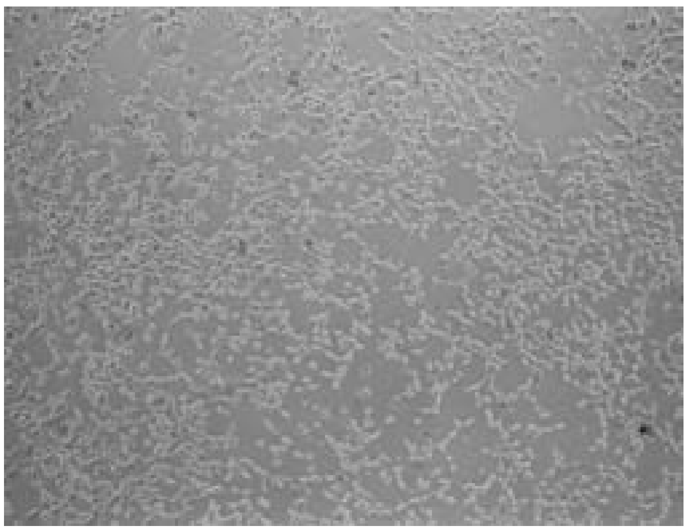
MAYA TANNA - Nov 02, 2022, 5:56 PM CDT



Download

optic_testing_prototype_2_16_bit.jpg (1.68 MB)

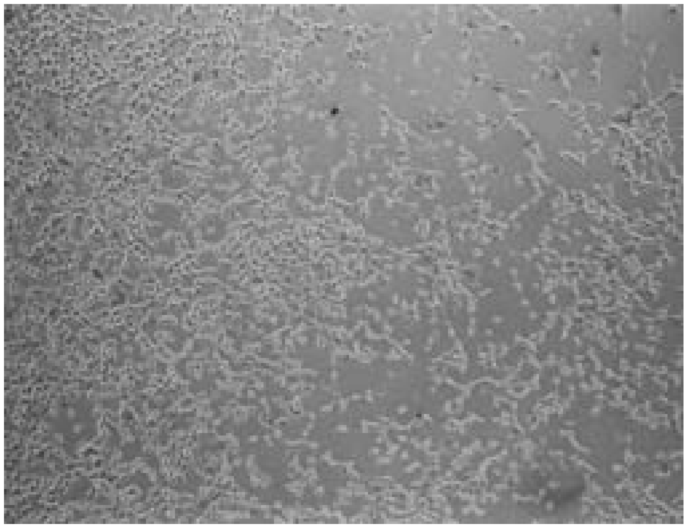
MAYA TANNA - Nov 02, 2022, 5:56 PM CDT



Download

optical_testing_control_1_16_bit.jpg (1.48 MB)

MAYA TANNA - Nov 02, 2022, 5:56 PM CDT



Download

optical_testing_control_2_16_bit.jpg (1.67 MB)

10/28/2022 Anti Fog Testing Trial 1

MAYA TANNA - Nov 07, 2022, 3:58 PM CST

Title: Anti Fog Testing Trial 1

Date: 10/28/2022

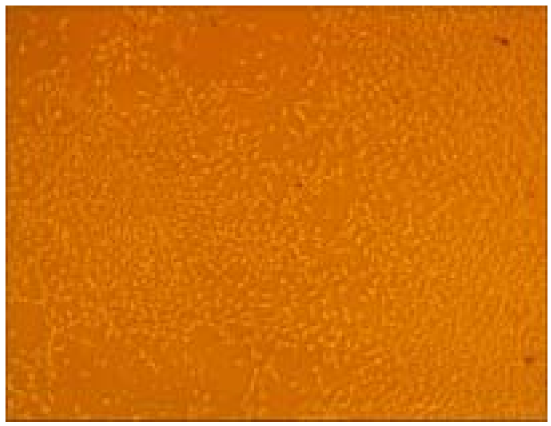
Content by: Maya

Present: Maya

Goals: To document anti fog testing results.

Content:

Control 1 Control 2 0 min



10 min 20 min 30 min

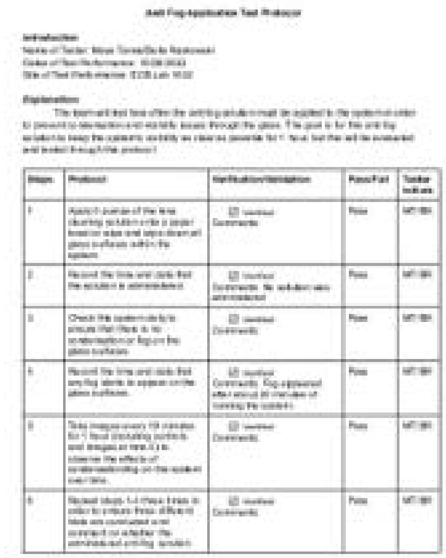


40 min 50 min 60 min



Conclusions/action items: Use these results for future technical reports. Figure out a better way to quantify results.

MAYA TANNA - Nov 07, 2022, 3:46 PM CST



Download

Anti_Fog_Application_Test_Protocol_Trial_1.pdf (58.5 kB)

11/01/2022 Anti Fog Testing Trial 2

MAYA TANNA - Nov 07, 2022, 5:31 PM CST

Title: Anti Fog Testing Trial 2

Date: 11/01/2022

Content by: Maya

Present: Maya

Goals: To document anti fog testing results.

Content:

Control 1 Control 2 0 min

10 min 20 min 30 min

40 min 50 min 60 min

Conclusions/action items: Use these results for future technical reports. Figure out a better way to quantify results.

MAYA TANNA - Nov 07, 2022, 5:25 PM CST

Download

Anti_Fog_Application_Test_Protocol_Trial_2.pdf (57.9 kB)

11/02/2022 Anti Fog Testing Trial 3

MAYA TANNA - Nov 07, 2022, 5:41 PM CST

Title: Anti Fog Testing Trial 3

Date: 11/02/2022

Content by: Maya

Present: Maya

Goals: To document anti fog testing results.

Content:

Control 1 Control 2 0 min

10 min 20 min 30 min

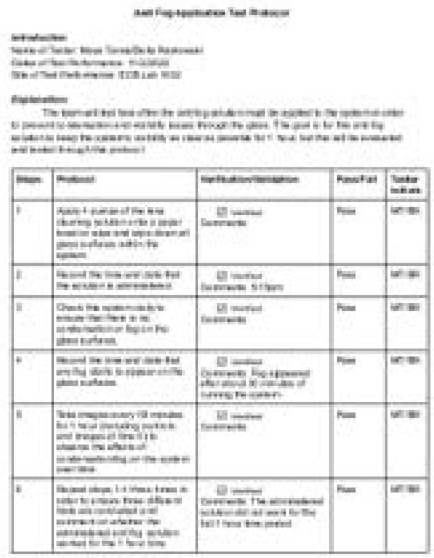


40 min 50 min 60 min



Conclusions/action items: Use these results for future technical reports. Figure out a better way to quantify results.

MAYA TANNA - Nov 07, 2022, 5:35 PM CST


Anti Fog Application Test Protocol

Introduction

[illegible]

Explanation

[illegible]

Steps	Protocol	Verification/Validation	Pass/Fail	Tester Initials
1	[illegible]	☑ Verified Comments:	Pass	[illegible]
2	[illegible]	☑ Verified Comments: [illegible]	Pass	[illegible]
3	[illegible]	☑ Verified Comments:	Pass	[illegible]
4	[illegible]	☑ Verified Comments: [illegible]	Pass	[illegible]
5	[illegible]	☑ Verified Comments:	Pass	[illegible]
6	[illegible]	☑ Verified Comments: [illegible]	Pass	[illegible]

Download

Anti_Fog_Application_Test_Protocol_Trial_3.pdf (57.9 kB)

09/11/2022 Biosafety and Chemical Safety Training

MAYA TANNA - Sep 11, 2022, 10:07 AM CDT

Title: Biosafety and Chemical Safety Training

Date: 09/11/2022

Content by: Maya Tanna

Present: Maya Tanna

Goals: To document biosafety and chemical safety training

Content:

See attachment below as proof of training

Conclusions/action items: Do more training and get a Green Pass Certification from the TEAM Lab.

MAYA TANNA - Sep 12, 2021, 11:29 PM CDT

Download

biosafety_training.pdf (608 kB)

MAYA TANNA - Sep 12, 2021, 11:29 PM CDT


University of Wisconsin-Madison

Download

Chemical_Safety_Training.jpg (287 kB)

09/15/2022 Maya's Progress Report 1

MAYA TANNA - Sep 11, 2022, 10:43 AM CDT

Title: Maya's Progress Report 1

Date: 09/15/2022

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
- Helped brainstorm questions for client meeting with Dr. Puccinelli
- Researched a recently designed incubator on the market and looked into their design for adding CO2 to the system
- Updated testing protocols to reflect current information
- Uploaded team progress report to the website

Goals

- Make any necessary edits to the PDS based on client feedback
- Update the website and help wherever else it is needed
- Start cell viability testing with Bella to determine their viability before being placed in our incubator (use an incubator available in a lab)

Conclusions/action items: Action items are stated as goals in the content above.

09/22/2022 Maya's Progress Report 2

MAYA TANNA - Sep 21, 2022, 5:48 PM CDT

Title: Maya's Progress Report 2

Date: 09/22/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Created new homogeneity test protocol
- Attended client meeting with team and helped take meeting notes
- Researched anti-fogging options for the glass screens on Grainger
- Updated testing protocols to reflect current information
- Emailed Dr. Puccinelli to obtain cells
- Helped finalize the PDS based on client feedback
- Coordinated purchasing with Drew for the anti-fog solution
- Uploaded team progress report to the website

Goals

- Update the website and help wherever else it is needed
- Obtain cells from Dr. Puccinelli to start conducting testing
- Write a testing protocol to determine how often anti-fog spray should be applied to the glass
- Start helping team with design matrices
- Start cell viability testing with Bella to determine their viability before being placed in our incubator (use an incubator available in a lab)

Conclusions/action items: Action items are stated as goals in the content above.

09/29/2022 Maya's Progress Report 3

MAYA TANNA - Sep 27, 2022, 9:04 PM CDT

Title: Maya's Progress Report 3

Date: 09/29/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Created new anti fog application test protocol
- Updated testing protocols to reflect current information
- Finalized purchasing with Drew re: anti fog solution
- Helped team with design matrices
- Uploaded team progress report to the website

Goals

- Update the website and help wherever else it is needed
- Continue with live-cell testing as the control so we can test cells on our incubator when the time comes
- Start preliminary presentation

Conclusions/action items: Action items are stated as goals in the content above.

10/06/2022 Maya's Progress Report 4

MAYA TANNA - Oct 03, 2022, 5:35 PM CDT

Title: Maya's Progress Report 4

Date: 10/06/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Conducted anti fog testing
- Helped with preliminary presentation and report
- Uploaded team progress report to the website

Goals

- Update the website and help wherever else it is needed
- Continue with live-cell testing as the control so we can test cells on our incubator when the time comes
- Perform any other testing as needed

Conclusions/action items: Action items are stated as goals in the content above.

10/13/2022 Maya's Progress Report 5

MAYA TANNA - Oct 09, 2022, 2:36 PM CDT

Title: Maya's Progress Report 5

Date: 10/13/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Helped with preliminary presentation and report
- Uploaded team progress report to the website

Goals

- Update the website and help wherever else it is needed
- Continue with live-cell testing as the control so we can test cells on our incubator when the time comes
- Perform any other testing as needed

Conclusions/action items: Action items are stated as goals in the content above.

10/20/2022 Maya's Progress Report 6

MAYA TANNA - Oct 22, 2022, 9:44 AM CDT

Title: Maya's Progress Report 6

Date: 10/20/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Updated PDS and preliminary report to reflect cell viability requirements
- Completed peer evaluation reflection
- Brainstormed ideas for outreach activity
- Conducted anti fog testing on the system
- Uploaded team progress report to the website

Goals

- Finish data analysis from anti fog imaging testing
- Finalize outreach plan
- Complete other testing wherever possible
- Upload the website when necessary

Conclusions/action items: Action items are stated as goals in the content above.

10/27/2022 Maya's Progress Report 7

MAYA TANNA - Oct 22, 2022, 10:31 AM CDT

Title: Maya's Progress Report 7

Date: 10/22/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Finalized outreach plan with the team
- Conducted optical testing on the system
- Started anti fog testing on the system
- Uploaded team progress report to the website

Goals

- Finish data analysis from anti fog imaging testing
- Start making outreach arrangements
- Complete other testing wherever possible
- Upload the website when necessary

Conclusions/action items: Action items are stated as goals in the content above.

11/03/2022 Maya's Progress Report 8

MAYA TANNA - Nov 07, 2022, 5:42 PM CST

Title: Maya's Progress Report 8

Date: 11/03/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Prepared show and tell pitch
- Analyzed data from optical testing
- Conducted 3 trials of testing for anti fog to evaluate how much of the solution would maintain adequate focus quality
- Researched ImageJ intensity quantification methods
- Uploaded team progress report to the website

Goals

- Finish data analysis from anti fog imaging testing
- Start making outreach arrangements
- Complete other testing wherever possible
- Upload the website when necessary

Conclusions/action items: Action items are stated as goals in the content above.

11/10/2022 Maya's Progress Report 9

MAYA TANNA - Nov 09, 2022, 3:05 PM CST

Title: Maya's Progress Report 9

Date: 11/10/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Documented peer feedback and ideas from Show and Tell
- Researched anti fog coating mechanisms and application methods
- Researched incubator sterilization using hydrogen peroxide
- Researched image analysis in MATLAB and found some resources that may help with our anti fog images
- Uploaded team progress report to the website

Goals

- Finish data analysis from anti fog imaging testing
- Start making outreach arrangements
- Complete other testing wherever possible
- Update the website when necessary

Conclusions/action items: Action items are stated as goals in the content above.

11/17/2022 Maya's Progress Report 10

MAYA TANNA - Nov 16, 2022, 5:18 PM CST

Title: Maya's Progress Report 10

Date: 11/17/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Attended Tong Lecture and took notes
- Tried to troubleshoot MATLAB and anti fog data analysis - did not work
- Emailed Jeremy Rogers from BME 325 for help
- Uploaded team progress report to the website

Goals

- Continue troubleshooting data analysis from anti fog imaging testing
- Start making outreach arrangements
- Complete other testing wherever possible
- Update the website when necessary

Conclusions/action items: Action items are stated as goals in the content above.

11/24/2022 Maya's Progress Report 11

MAYA TANNA - Dec 01, 2022, 9:50 PM CST

Title: Maya's Progress Report 11

Date: 11/24/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Met with Dr. Nimunkar to troubleshoot anti-fog image analysis in MATLAB
- Tried a Laplacian filter and tested different code options as well
- Uploaded team progress report to website

Goals

- Figure out which functions work best on MATLAB
- Do testing wherever possible (maybe recovery or whole system testing)
- Start final deliverables

Conclusions/action items: Action items are stated as goals in the content above.

12/01/2022 Maya's Progress Report 12

MAYA TANNA - Dec 01, 2022, 9:52 PM CST

Title: Maya's Progress Report 11

Date: 12/1/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Continued troubleshooting anti-fog data analysis strategies on MATLAB
- Helped team with outreach project report
- Started focusing efforts towards final deliverables
- Uploaded necessary files to the website

Goals

- Set up a meeting with Dr. Nimunkar to review anti-fog data analysis strategies on MATLAB, and select the most effective and appropriate one
- Continue working on final deliverables
- Finalize outreach proposal
- Help team with live-cell testing

Conclusions/action items: Action items are stated as goals in the content above.

12/08/2022 Maya's Progress Report 13

MAYA TANNA - Dec 05, 2022, 10:16 PM CST

Title: Maya's Progress Report 13

Date: 12/8/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Met with Dr. Hai regarding anti-fog data analysis troubleshooting on ImageJ and resolved issues, will complete data analysis and compare with Bella's data from MATLAB
- Helped with final poster and final report
- Helped team with live-cell testing
- Uploaded necessary files to the website

Goals

- Finalize deliverables for the semester

Conclusions/action items: Action items are stated as goals in the content above.

12/15/2022 Maya's Progress Report 14

MAYA TANNA - Dec 09, 2022, 6:46 PM CST

Title: Maya's Progress Report 14

Date: 12/15/2022

Content by: Maya

Present: Maya

Goals: To document accomplishments of the past week and goals for the next week

Content:

Accomplishments

- Completed final deliverables
- Uploaded necessary files to the website

Goals

- Study for finals

Conclusions/action items: Action items are stated as goals in the content above.

2/2/2023 Progress Report 1

MAYA TANNA - Feb 08, 2023, 6:04 PM CST

Title: Progress Report 1

Date: 2/2/2023

Content by: Maya

Goals: Provide weekly updates on individual progress.

Content:

This Week

- Helped Sam with box fabrication and melting off copper tubing.
- Researched elementary schools in the Madison area for outreach projects.
- Researched the units of Laplacian for optical testing to better represent our findings and indicate that on deliverables mathematically.

Upcoming

- Obtain cells from Dr. Puccinelli and start creating baseline cell culture data.
- Continue helping with fabrication if needed.
- Hopefully meet with Dr. Puccinelli to determine if the wiper blade design is needed for the project.

Conclusions/action items:

Attend client meeting to clarify project requirements and evaluate the need for the wiper blade design. Start cell culture baseline data experiments.

2/9/2023 Progress Report 2

MAYA TANNA - Feb 08, 2023, 6:07 PM CST

Title: Progress Report 2

Date: 2/9/2023

Content by: Maya

Goals: Provide weekly updates on individual progress.

Content:

This Week

- Created an email draft to send to elementary schools in the area for outreach project
- Sent emails 5 to elementary schools in the area
- Brainstormed questions for meeting with client
- Researched combination sensors for the incubator
- Helped with design matrices and preliminary deliverables

Upcoming Goals

- Hopefully get cells
- Finish preliminary deliverables
- Help with testing, cell culture baseline, or fabrication (wherever possible and needed most)

Conclusions/action items:

Stated in upcoming goals.

2/16/2023 Progress Report 3

MAYA TANNA - Feb 21, 2023, 4:17 PM CST

Title: Progress Report 3

Date: 2/16/2023

Content by: Maya

Goals: Provide weekly updates on individual progress.

Content:

This Week

- Completed data analysis on last semester images using ImageJ
- Created image analysis protocol.

Upcoming Goals

- Obtain cells.
- Help with establishing cell culture baseline and perform optical testing.
- Help with preliminary deliverables.

Conclusions/action items:

Stated in upcoming goals.

2/23/2023 Progress Report 4

MAYA TANNA - Feb 21, 2023, 4:52 PM CST

Title: Progress Report 4

Date: 2/23/2023

Content by: Maya

Goals: Provide weekly updates on individual progress.

Content:

This Week

- Worked on fan orientation design ideas with Sam.
- Wrote a fan testing protocol for data analysis.
- Completed data analysis on both fan tests.

Upcoming Goals

- Complete preliminary deliverables.
- Hopefully obtain glass to do optical testing.
- Help wherever needed.

Conclusions/action items:

Stated in upcoming goals.

3/2/2023 Progress Report 5

MAYA TANNA - Mar 02, 2023, 7:50 PM CST

Title: Progress Report 5

Date: 3/2/2023

Content by: Maya

Goals: Provide weekly updates on individual progress.

Content:

This Week

- Completed preliminary deliverables.
- Continued anti-fog/condensation testing with the mini fans and completed data analysis for the next set of tests.

Upcoming Goals

- Help wherever needed - likely with anti-fog/condensation.
- Help with whole box testing if needed.

Conclusions/action items:

Stated in upcoming goals.

3/9/2023 Progress Report 6

MAYA TANNA - Mar 09, 2023, 12:10 PM CST

Title: Progress Report 6

Date: 3/9/2023

Content by: Maya

Goals: Provide weekly updates on individual progress.

Content:

This Week

- Helped with initial incubator testing with CO2 sensor and monitored the system every few hours.
- Helped with data analysis of additional fan testing.

Upcoming Goals

- Conduct live-cell testing with the full incubator and help with data analysis of various components.
- Continue working on condensation prevention efforts.
- Take care of cells after break.

Conclusions/action items:

Stated in upcoming goals.

3/23/2023 Progress Report 7

MAYA TANNA - Mar 22, 2023, 5:19 PM CDT

Title: Progress Report 7

Date: 3/22/2023

Content by: Maya

Goals: Provide weekly updates on individual progress.

Content:

This Week

- Passaged cells and worked on troubleshooting issues with cell culture.

Upcoming Goals

- Obtain cells and start live-cell testing.
- Help with condensation prevention in the box.
- Do data analysis on any testing that is completed.

Conclusions/action items:

Stated in upcoming goals.

3/30/2023 Progress Report 8

MAYA TANNA - Mar 29, 2023, 8:57 PM CDT

Title: Progress Report 8

Date: 3/30/2023

Content by: Maya

Goals: Provide weekly updates on individual progress.

Content:

This Week

- Helped with condensation testing on the anti-bacterial hand sanitizer idea.
- Completed data analysis for condensation testing using optical imaging protocol.
- Tried to obtain additional living cells from Parker/Dr. Puccinelli.
- Confirmed outreach activity with elementary school.

Upcoming Goals

- Help with live cell testing.
- Start working on final deliverables and gathering materials for the outreach project.

Conclusions/action items:

Stated in upcoming goals.

4/6/2023 Progress Report 9

MAYA TANNA - Apr 05, 2023, 3:20 PM CDT

Title: Progress Report 9

Date: 4/6/2023

Content by: Maya

Goals: Provide weekly updates on individual progress.

Content:

This Week

- Helped set up live cell testing.
- Worked on executive summary.
- Worked on the final report a lot.

Upcoming Goals

- Help wherever needed.
- Continue working on final report.
- Complete outreach activity.

Conclusions/action items:

Stated in upcoming goals.

4/13/2023 Progress Report 10

MAYA TANNA - Apr 11, 2023, 3:04 PM CDT

Title: Progress Report 10

Date: 4/13/2023

Content by: Maya

Goals: Provide weekly updates on individual progress.

Content:

This Week

- Completed outreach activities.
- Worked on the final report.

Upcoming Goals

- Finalize outreach report.
- Continue working on final deliverables.
- Help wherever needed.

Conclusions/action items:

Stated in upcoming goals.

4/20/2023 Progress Report 11

MAYA TANNA - Apr 19, 2023, 4:18 PM CDT

Title: Progress Report 11

Date: 4/20/2023

Content by: Maya

Goals: Provide weekly updates on individual progress.

Content:

This Week

- Worked on final deliverables.
- Helped with live cell testing troubleshooting.
- Finalized executive summary.
- Submitted outreach deliverables.

Upcoming Goals

- Complete final deliverables.
- Help conclude live cell testing.

Conclusions/action items:

Stated in upcoming goals.

4/27/2023 Progress Report 12

MAYA TANNA - May 01, 2023, 8:27 PM CDT

Title: Progress Report 12

Date: 4/27/2023

Content by: Maya

Goals: Provide weekly updates on individual progress.

Content:

This Week

- Worked on final report and poster.

Upcoming Goals

- Complete final deliverables.

Conclusions/action items:

Stated in upcoming goals.

1/27/2023 I2C Coding

Katie Day - Feb 26, 2023, 5:47 PM CST

Title: I2C Coding

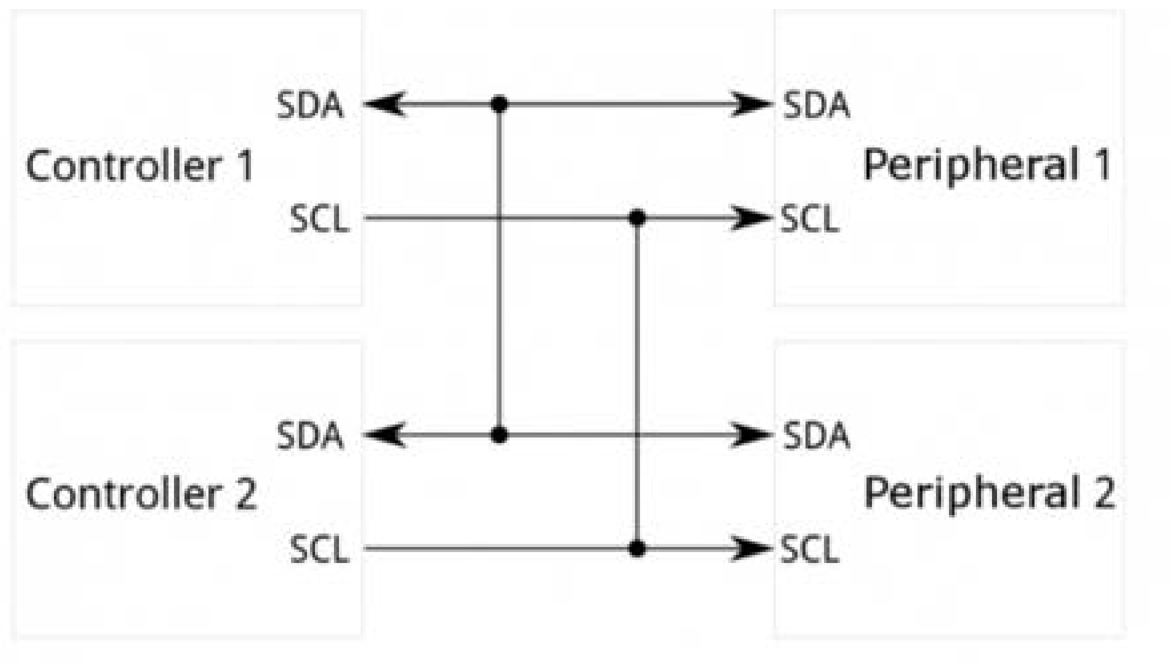
Date: 1/27/2023

Content by: Katie Day

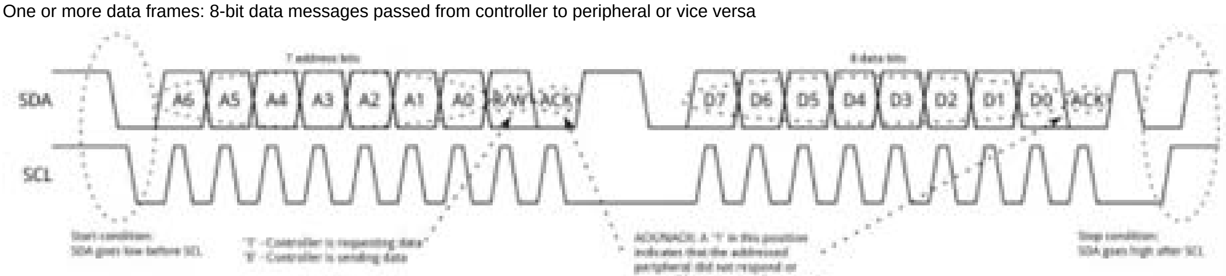
Present:

Goals: To gain an understanding of I2C coding.

Content:



Sparkfun Tutorial: I2C requires two wires that can support up to 1008 peripheral devices.

- History
  - Developed by Philips for their chips
  - Modes:
    - 400 kHz with 10-bit address space
    - fast-mode plus, at 1MHz
    - high-speed mode, at 3.4 MHz
    - ultra-fast mode, at 5MHz
  - Signals
    - SDA and SCL
      - SDA = serial data the data signal
      - SCL= clock signal generated by the current bus controller
        - Ask about clock stretching
  - Start with a 4.7 kOhm resistor
- Messages:
  - Address frame: controller indicates the peripheral to which the message is being set
  - One or more data frames: 8-bit data messages passed from controller to peripheral or vice versa
  - 

- Link for more info: https://learn.sparkfun.com/tutorials/i2c/all#:~:text=The%20Inter%2DIntegrated%20Circuit%20(I,communications%20within%20a%20single%20device.
- Citation:

S. SFUPTOWNMAER, “I2C,” *I2C - SparkFun Learn*, 2019. [Online]. Available: https://learn.sparkfun.com/tutorials/i2c/all#:~:text=The%20Inter%2DIntegrated%20Circuit%20(I,communications%20within%20a%20single%20device. [Accessed: 26-Feb-2023].

MH-Z16 NDIR CO2 Sensor I2C interface for autocalibration tutorial

Citation:

MH-Z16 NDIR CO2 Sensor with I2C/UART Interface Adaptor for Arduino. YouTube, 2016.

Understanding the I2C

- Open drain for Bidirectional communication
- Communicate via the Slave and Master
    - The general procedure for a master to access a slave device is the following:
        - Suppose a master wants to send data to a slave:
            - Master-transmitter sends a START condition and addresses the slave-receiver
            - Master-transmitter sends data to slave-receiver • Master-transmitter terminates the transfer with a STOP condition 2
        - If a master wants to receive/read data from a slave:
            - Master-receiver sends a START condition and addresses the slave-transmitter
            - Master-receiver sends the requested register to read to slave-transmitter
            - Master-receiver receives data from the slave-transmitter
            - Master-receiver terminates the transfer with a STOP condition
- Start and Stop conditions
    - Start = high-to-low transition on the SDA line while SCL is high = START condition
    - Stop = a low-to-high transition on the SDA line while the SCL is high = STOP
- Data is sent and received to or from the slave devices
- See PDF for more info
- J. Valdez and J. Becker, “Understanding the I2C bus - texas instruments,” *Texas Instruments*, 2015. [Online]. Available: https://www.ti.com/lit/an/slva704/slva704.pdf. [Accessed: 26-Feb-2023].

Conclusions/action items:

CO2 Sensor Research

Katie Day - Feb 04, 2023, 3:1

Title: CO2 Sensor Research

Date: 2/4/2023

Content by: Katie Day

Present:

Goals: To research alternative methods to measure CO2.

Content:

- **Measuring CO2 with an Arduino: Creating a Low-Cost, Pocket-Sized Device with Flexible Applications That Yields Benefits for Students and Schools**
  - Based on Arduinos
  - Tested in chemical reactions, plats, respiration, and gas diffusion
  - Used an ATmega328, unnamed sensor, SD card to store data, RGB Lef to switch CO2 sensor on and off

Figure 1

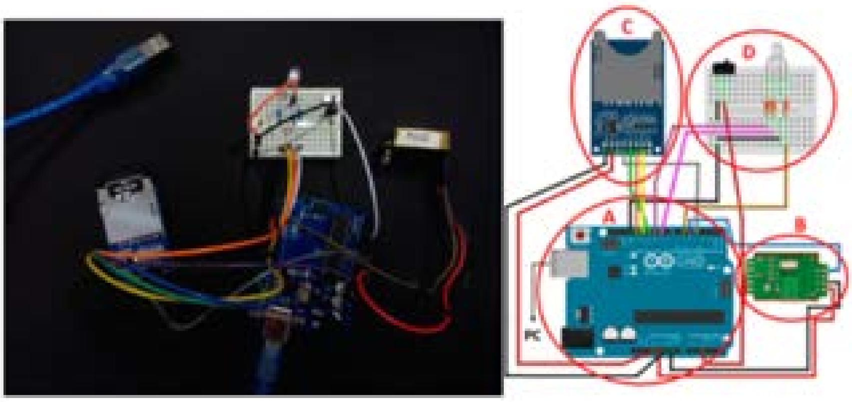


Figure 1. Photo of the proposed device (left) and diagram of the proposed CO_2 device (right). (A–D) Four principal elements: (A) Arduino board, (B) CO_2 sensor, (C) SD-card module, and (D) control panel.

  -
  - No notes on waterproof ability
  - *J. Chem. Educ.* 2019, 96, 2, 377–381
    Publication Date:December 13, 2018
    https://doi.org/10.1021/acs.jchemed.8b00473
- **Potentiometric pCO2 sensor using polyaniline-coated pH-sensitive electrodes**
  - Polyaniline electrodes make a pCO2 probe and reference electrode
  - waterproof
  - Gives readings in pressure not ppm
  - Would require us to create electrodes and code outselves
  - G. Cui, J. S. Lee, S. J. Kim, H. Nam, G. S. Cha, and H. D. Kim, “Potentiometric PCO 2 sensor using polyaniline-coated ph-sensitive electrodes,” *Analyst*, 1998. [Online]. Available: https://pubs.rsc.org/en/content/articlehtml/1998/an/a802872i?casa_token=SyDbuyl8G8IAAAAA%3AantjZ8_v3JdA10-p9aUIuACeExOM6mG6tRs-9FUE91BmCKvWZL0AUHW3utcwS72sypYlu-UdPNwAPA. [Accessed: 04-Feb-2023].
- A Miniaturized Carbon Dioxide Gas Sensor Based on Sensing of pH-Sensitive Hydrogel Swelling with a Pressure Sensor
  - pH-sensing hydrogrel is measured with small pressure sensor and quantifies the partial pressure of CO2

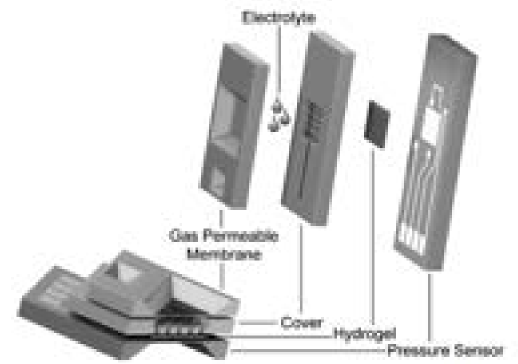


Fig. 1. *Cross-section and exploded view of the hydrogel-based CO_2 sensor.*

-

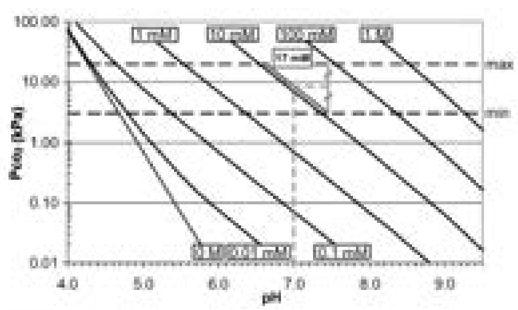


Fig. 2. *P_{CO_2} vs. pH for various bicarbonate concentrations. The limits of the medically relevant range are indicated.*

-
- S. Herber, J. Bomer, W. Olthuis, P. Bergveld, and A. van Berg, “A miniaturized carbon dioxide gas sensor based on sensing of ph-sensitive hydrogel swelling with a pressure sensor,” *Biomedical Microdevices*, vol. 7, no. 3, pp. 197–204, 2005.

Conclusions/action items: Maybe look into measuring the pH of the system instead.

9/11/22 Solenoid Vale Principles

Katie Day - Dec 10, 2022, 2:48 PM CST

Title: Solenoid Valve Principles

Date: 9/11/2022

Content by: Katie Day

Present:

Goals: To understand the technical principles behind solenoid valves so that I may code for them better.

Content:

Technical Principles of Valves

- Used for controlling fluid flow automatically
- control units that when electrically energized or de-energized either open or close fluid flow --> works as an electromagnet to pull a plunger against a spring.
- Cycle periods
  - Solenoid valves can cycle for 2,5,10, or 30 minutes.
- Flow rate is determined by the design and type of flow.
- Coding
  - Always consists of a capital letter for Omega Valves

- O. Engineering, “Technical principles of valves,” *https://www.omega.com/en-us/*, 09-Apr-2020. [Online]. Available: https://www.omega.com/en-us/resources/valves-technical-principles. [Accessed: 11-Sep-2022].

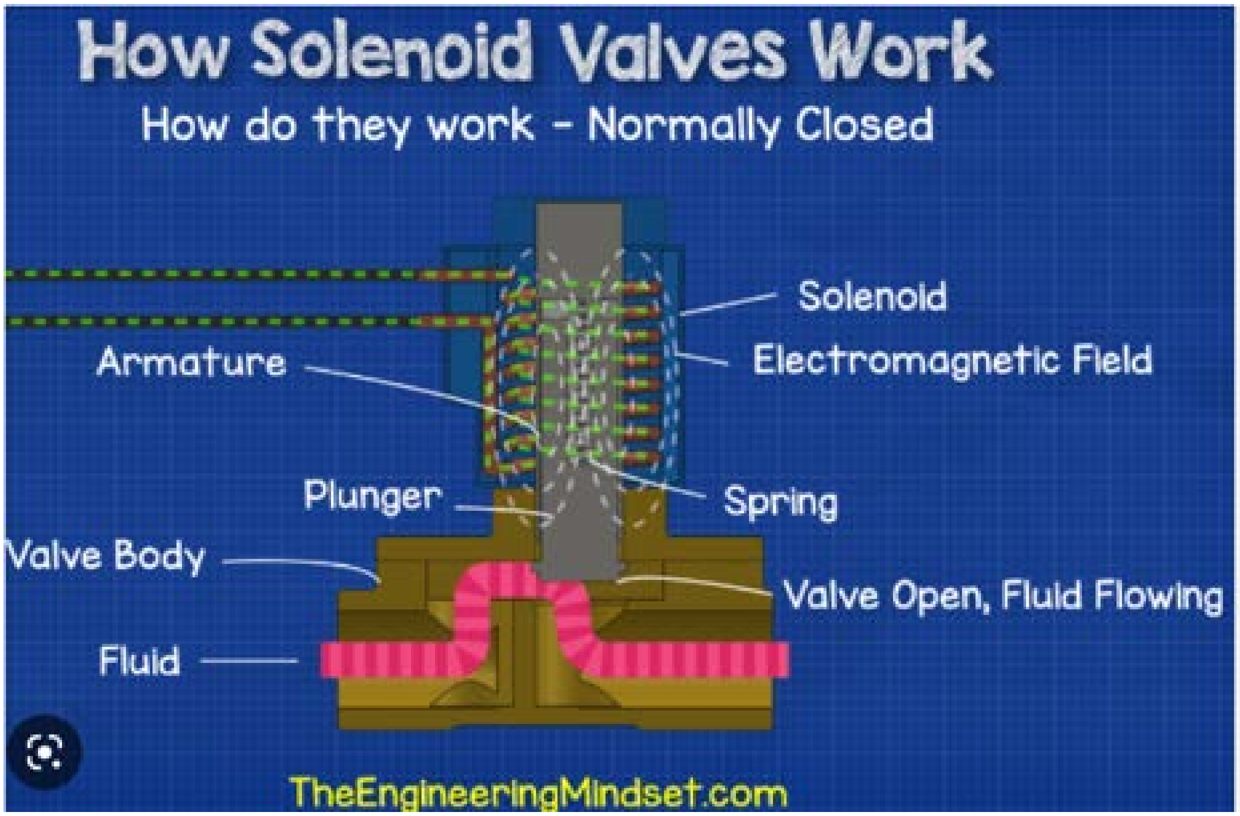
What is a solenoid vale and how does it work?

- Pilot operated: use system line pressure to open and close the valve body
- Direct operated: directly open or close main valve
  - used in systems with low flow capacities and low pressure
- Consists of a coil, plunger, and sleeve
- Standards: NAMUR Solenoid Valve

- Burkert Fluid Control Systems, “How a solenoid valve works: Definition of a solenoid valve,” *How a Solenoid Valve Works | Definition of a Solenoid Valve*, 2022. [Online]. Available: https://www.burkert-usa.com/en/Company-Career/What-s-New/Press/Media/Technical-Reports/Technical-Reports-additional-topics/What-is-a-solenoid-valve-and-how-does-it-work#:~:text=Solenoid%20valves%20consist%20of%20a,raises%20the%20plunger%2C%20enabling%20flow. [Accessed: 11-Sep-2022].

How Solenoid Valves work

- Magnetic tool app tests if the valve is working properly
- Convert electric to mechanical energy
- Normally closed type
  - Armature, solenoid, valve body
  - Armature contains plunger and spring which sits in a down position to close it
  - When electrocurrent does it the current causes the plunger to move upwards
  - Strongest
- Normally open
  - Spring pushes the plunger down unless powered on
- Direction of current determines whether there is a pushing or pulling motion

- 

- TheEngineeringMidset, *How Solenoid Valves Work - Basics actuator control valve working principle*. YouTube, 2019.

Conclusions/action items:

Discover if a normally open or normally closed solenoid valve would be best.

9/11/ 22 Coding

Katie Day - Sep 11, 2022, 5:13 PM CDT

Title: Coding Research for Solenoid valves

Date: 9/11/2022

Content by: Katie Day

Present:

Goals: To understand the Arduino tutorial for coding a solenoid valve.

Content:

Refer to the following articles and videos.

1. **https://bc-robotics.com/tutorials/controlling-a-solenoid-valve-with-arduino/**
    1. C. BCR, “Controlling a solenoid valve with Arduino,” *BC Robotics*, 02-Dec-2021. [Online]. Available: https://bc-robotics.com/tutorials/controlling-a-solenoid-valve-with-arduino. [Accessed: 11-Sep-2022].
2. https://www.youtube.com/watch?v=ioSYlxHlYdI&ab_channel=Tinker%26Build
    1. Build & Tinker, *Arduino Solenoid Valve Circuit: How to control water flow with an Arduino*. YouTube, 2017.

Conclusions/action items:

Figure out which solenoid valve would be best for our project and find a 12V DC power supply.

9/13/22 Waterproofing applications

Katie Day - Sep 21, 2022, 4:56 PM CDT

Title: Waterproofing applications

Date: 9/13/2022

Content by: Katie Day

Present:

Goals: To determine different methods to reduce condensation on the glass in order to approve optics.

Content:

- Lens Cleaning Solution - Grainger
  - Anti-fog
  - Anti-static
  - Non-silicone formula
  - 16 fl oz
  - hazardous
    - Physical and chemical properties
      - Physical form: liquid
      - Color: clear
      - BP: 100 C
      - pH: 7
      - Relative density: 1
      - Water solubility: soluble
      - Vapor pressure: 30 torr at 25C
      - Flash point: 40.6 C in a closed unit
- Fog Gone - Optix 55
  - anti fog
  - Used for polycarbonate lensesn
  - polarized coting
  - hypoallergic
  - "all natural" --> no properties sheet
- Fog Defender System - Zeiss
  - Anti fog
  - Lasts 72 hours
  - Comes with microfiber cloth
  - leaves thin film on the lens
  - less than 3% of alcohol
  - Safe to use on polycarbonate
  - Ingredients: water, proprietary detergents and preservatives
  - sheerness has a 4.3/5

Conclusions/action items:

9/20/22 How to Make Electrically Conductive Glass

Katie Day - Sep 20, 2022, 4:28 PM CDT

Title: How to Make Electrically Conductive Glass

Date: 9/20/22

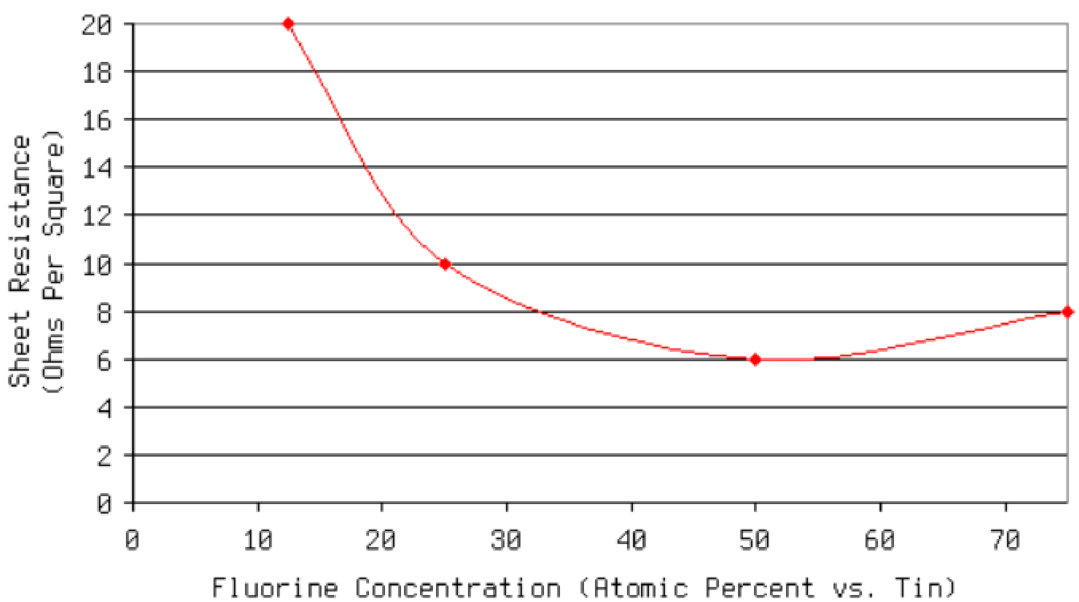
Content by: Katie Day

Present:

Goals: To figure out how to make electrically conductive glass.

Content:

- Simplifier
    - Need:
        - Solution
            - 30 mL Distilled Water
            - 3384mg Stannous Chloride
            - 214mg Ammonium Bifluoride
            - HCL added dropwise until the solution becomes clear
        - Heat source
        - Air spray cannister
    - Heat glass to roughly 350-400*C
    - Use 10mL of above solution to spray uniformly onto the heated glass
    - After the solution is evaporated there is a thin, strong, transparent layer of fluorine-doped tin oxide
    - NOTE: DO THIS OUTSIDE (we do not set fire to the lab again :0)



- Tin Oxide conductive Glass
    - Stannous Chloride
    - Isoproply alcohol
    - Crest toothpaste
    - Instructions
        - abrase the glass with the toothpaste
        - Clean the glass with soapy water
        - Wash off with alcohol
        - Stack two pieces of glass with glass spacers between it
        - Put a small pile of stanneous chloride on one end of the glass
        - put in kiln and heat to 400*C
    - Disadvantages: has a thin rainbow film around it.

Conclusions/action items:

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.

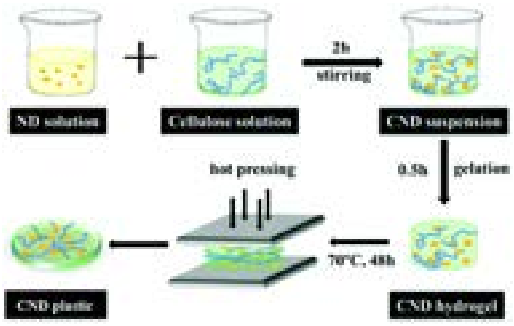
Content:

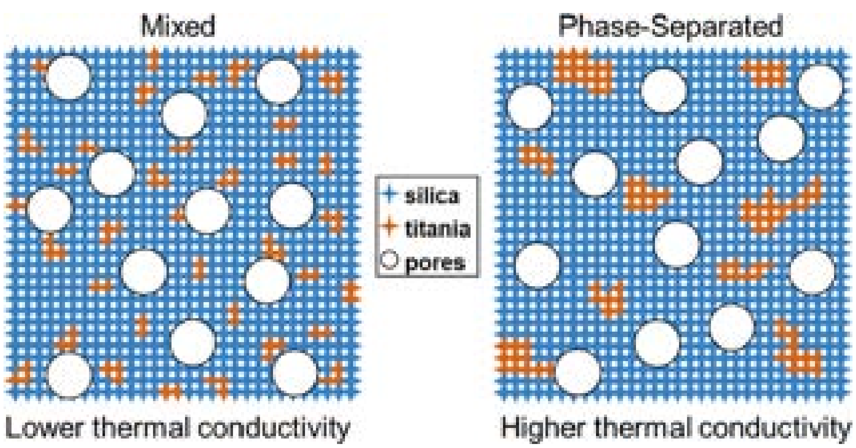
- Mechanical Properties of Zirconia Re-inforced Lithium Silicate Glass-Ceramic
    - Zirconia: enhanced mechanical properties of all-ceramic restorations
    - Lithium dislicate ceramic restoation
        - fabricated with a heat-pressed or CAD/CAM fabrication processes
        - enhanced translucency 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
  - image
    - 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	λa (mW m^-1	λr (mW m^-1	λa/λr	T	RH

	m^-3)	K^-1)	K^-1)		(K)	(%)
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
- image
  - 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.

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 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)

9/12/2021 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 CO_2 atmosphere
  - Temps: 4-50*C
    - controlled by a water bath circulating cabinet or by electric coils that give off heat
  - CO_2: 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
    - CO_2 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 O_2, CO_2, 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.

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

Download

heat_transfer.pdf (535 kB)

CO2 Sensors

Katie Day - Feb 04, 2023, 3:06 PM

Title: CO2 Sensor Options

Date: 2/4/2023

Content by: Katie Day

Present:

Goals: To find alternative CO2 sensors that may be used.

Content:

Sensor	Waterproof	Arduino Compatible	Cost	Link	Notes
MH-Z16	☑	☑	$67.95	Link	Anti-water interface we can also a waterproof sleeve on it that wo with sensor CO2 in water
BME 680	☐	☑	$18.95	Link	Requires some calibration and reads gas in kOhms
MG_Z14A	☑	☑	$37.17	Link	Compatible with Arudino used in refrigerators resitant to water droplets (I say we put it on the li
PH Sensor for Arduino, PH0-14 Value Detect Sensor Module + PH Electrode Probe BNC, PH Sensor UNO, PH Sensor Arduino Kit, PH Sensor Raspberry Pi Kit, by HQ&LP	☑	☑	$37.99	Link	Why don't we just measure the p of the solution and have that cor CO2

Conclusions/action items: Meet with the entire group to create a design matrix to determine which of the following sensors is the best one to order.

4/5/2022 Humidity Testing

Katie Day - Apr 27, 2023, 5:11 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.

Humidity formula and Arduino code provided below. Humidity formula takes the temperature and uses it to calculate the relative humidity. [1]

```
//temp
  // read the value from the sensor:
 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 - 273.15;
//hum
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 = ((e_d/e_s)*16)-4;
```

[1] “Relative Humidity Calculator.” https://www.omnicalculator.com/physics/relative-humidity (accessed Apr. 27, 2023).

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)

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

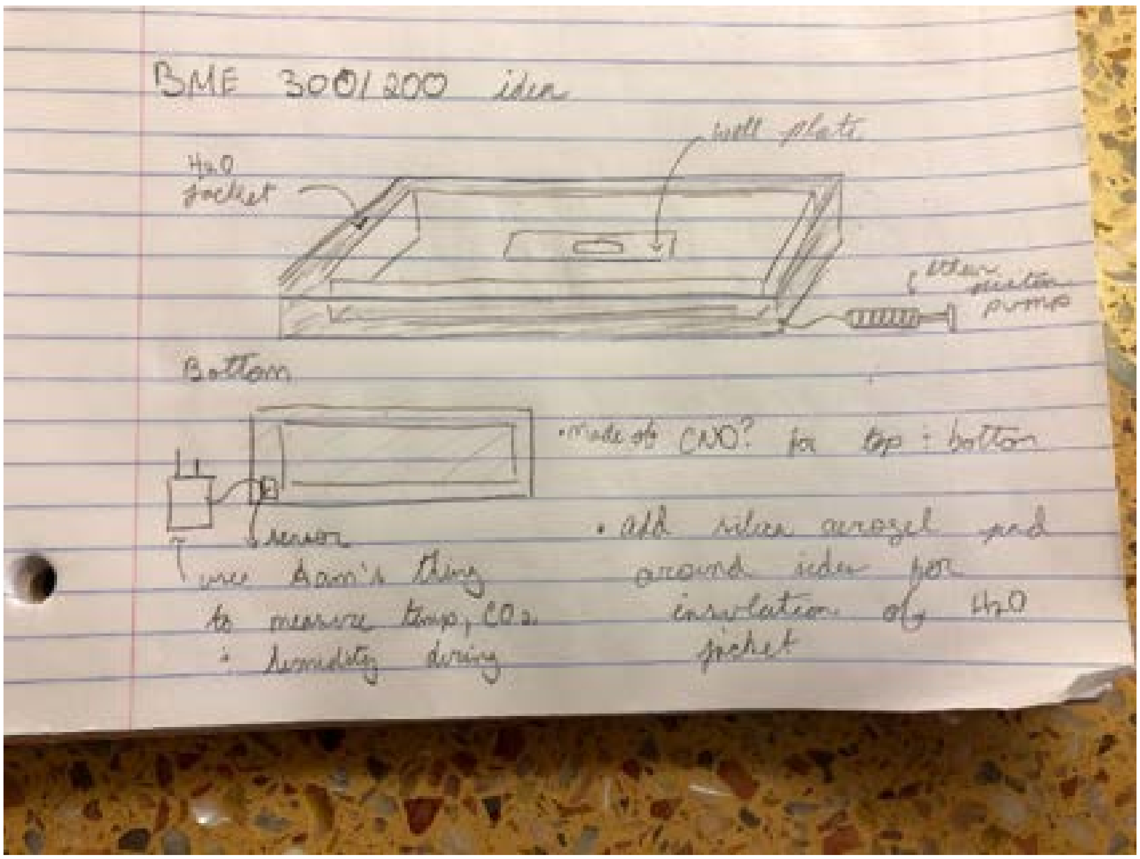
Date: 9/23/2021

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

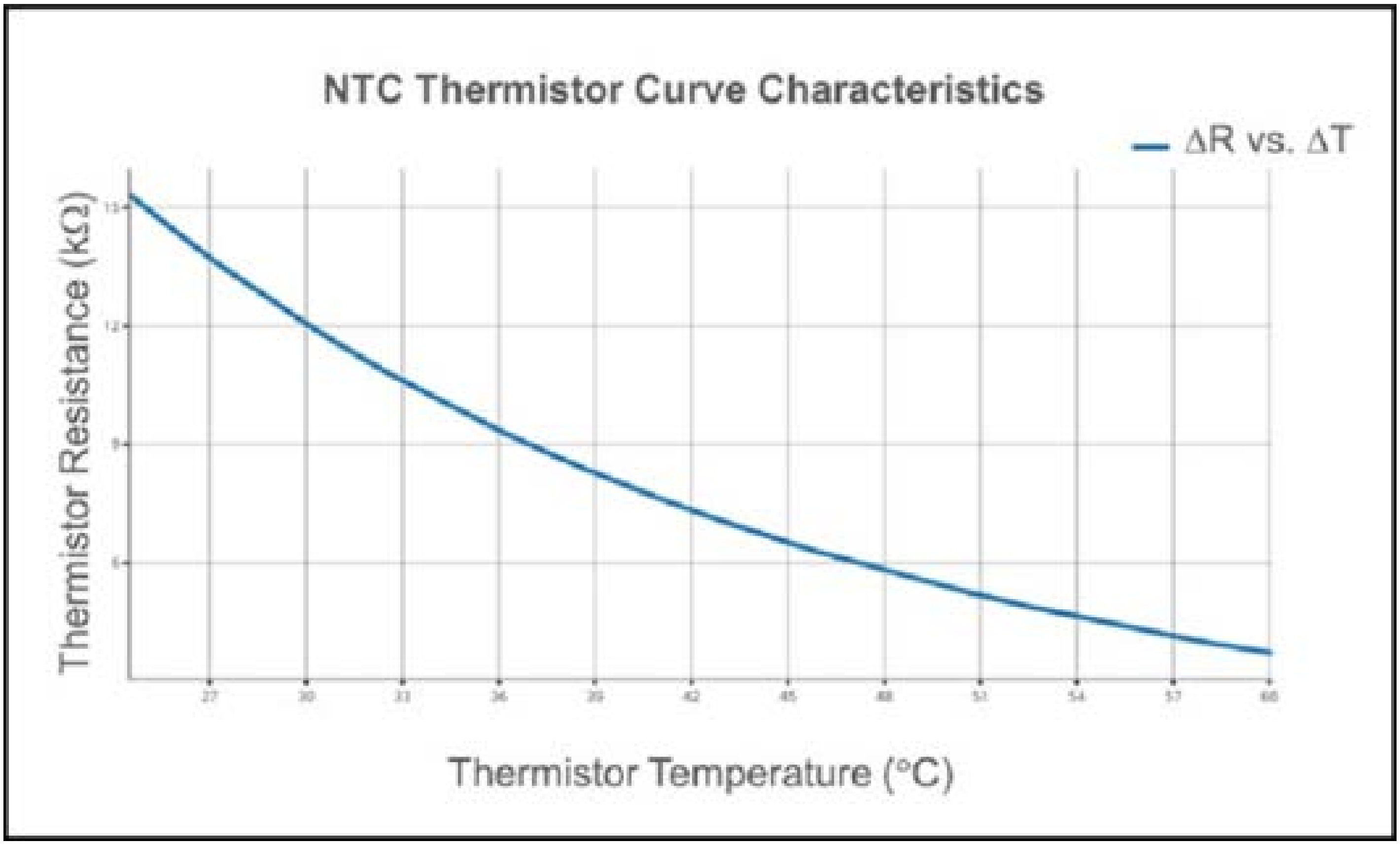
Content by: Katie Day and Olivia Jaekle

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.



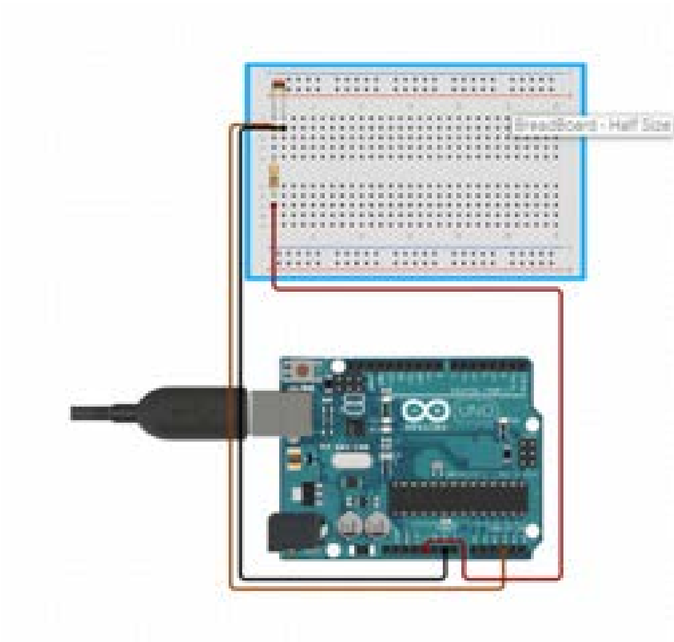
Conclusions/action items: Thermistor is working properly and outputs correct temperatures. Use in testing protocol next week with completed incubator prototype.

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.

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Download

DHT_U.cpp (6.44 kB) Download and put into libraries folder in Arduino.

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DHT_U.h (3.08 kB) Download and put into libraries folder in Arduino.

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DHT.cpp (12 kB) Download and put into libraries folder in Arduino.

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DHT.h (3.22 kB) Download and put into libraries folder in Arduino.

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[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:

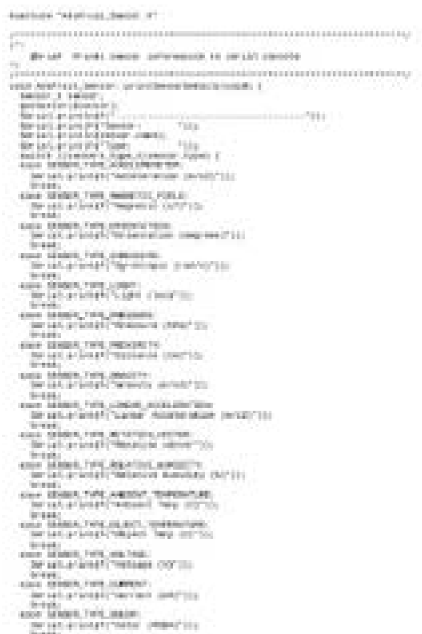
Goals:

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



Download

Adafruit_Sensor.cpp (2.34 kB) Download and add to libraries folder in Arduino.

Katie Day - Nov 14, 2021, 8:45 PM CST

Download

Adafruit_Sensor.h (7.78 kB) Download and add to libraries folder in Arduino.

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library.properties (380 B) Download and add to libraries folder in Arduino.

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LICENSE.txt (11.4 kB) Download and add to libraries folder in Arduino.

Katie Day - Nov 14, 2021, 8:45 PM CST

Download

README.md (10.4 kB) Download and add to libraries folder in Arduino.

Katie Day - Nov 14, 2021, 8:45 PM CST

Download

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.

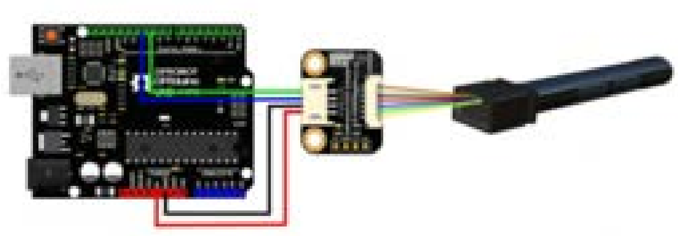
Conclusions/action items: Test the CO2 sensor using the testing protocols created by Maya and Caroline. Figure out a way to convert ppm to percentage.

Katie Day - Dec 03, 2021, 12:25 PM CST

Download

ReadConcentration.ino (888 B)

Katie Day - Dec 03, 2021, 12:25 PM CST



Download

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

Download

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

Download

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

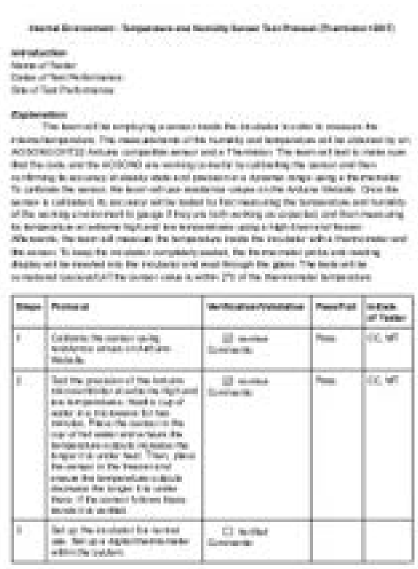
Goals: To create testing protocols and verify that the elements of our design are working as expected, accurately, and precisely.

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



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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.

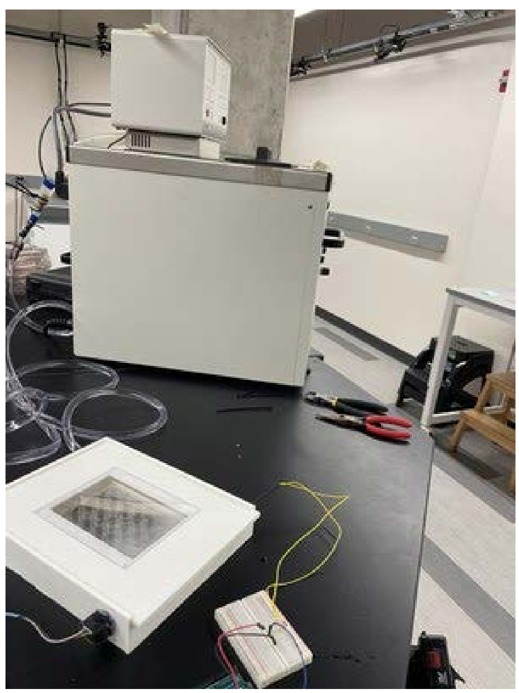
Content:

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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IMG_5896.jpg (780 kB)

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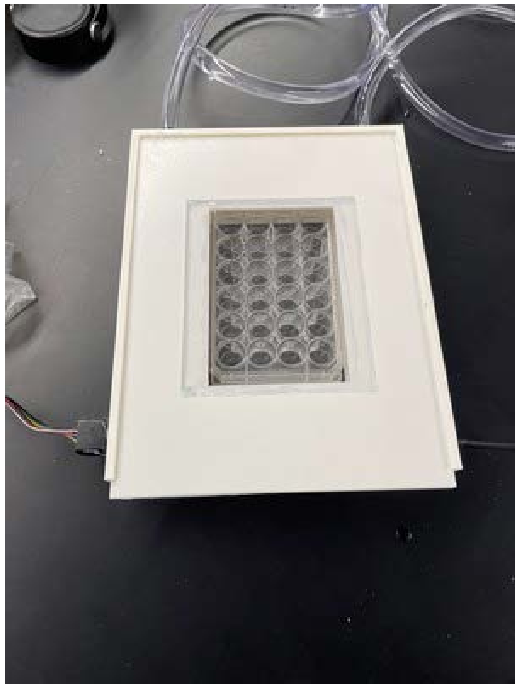

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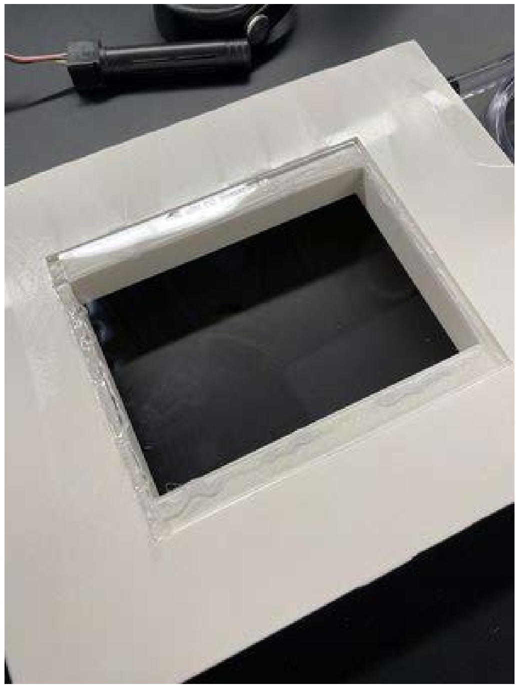

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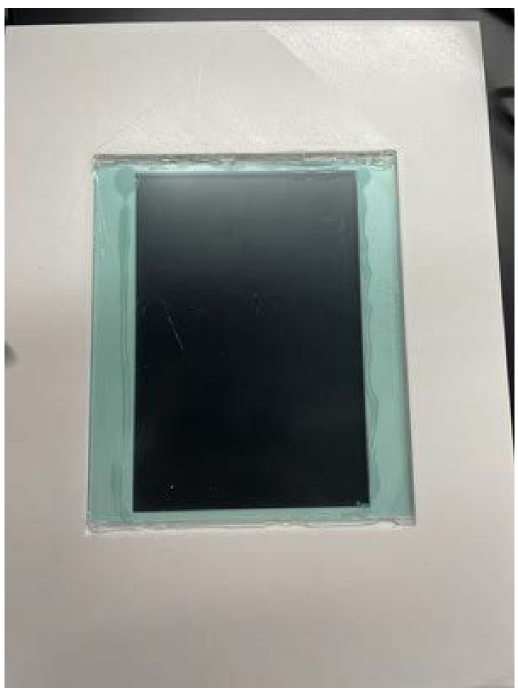

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IMG_5890.jpg (404 kB)

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IMG_5889.jpg (1.27 MB)

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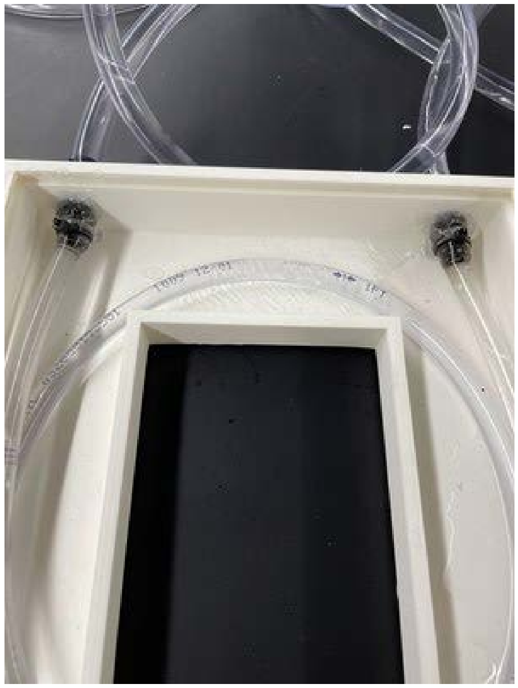

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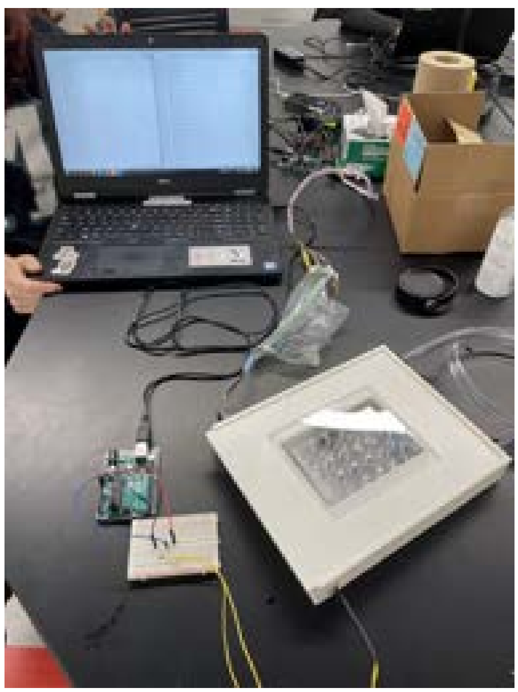
Katie Day - Dec 07, 2021, 7:52 PM CST



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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:

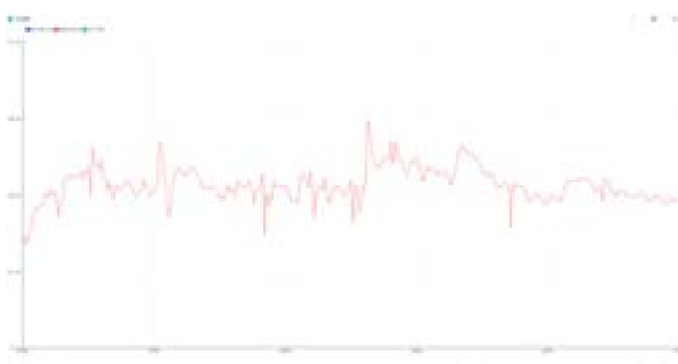
1. Polyethelene tubing acted more as an insulator than a conductor and would not heat up the water bath to the desired temperature. Need to use a metal tube.
2. PLA box was leaking slightly. It is unclear where or how it is leaking as it has been sealed via hot glue and zipties.
3. Glass did fog up after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



Download

Incubator_Temp_Over_Time.PNG (68.7 kB)

Katie Day - Dec 07, 2021, 8:01 PM CST

Download

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)

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

Download

IMG_0451.heic (3.25 MB)

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

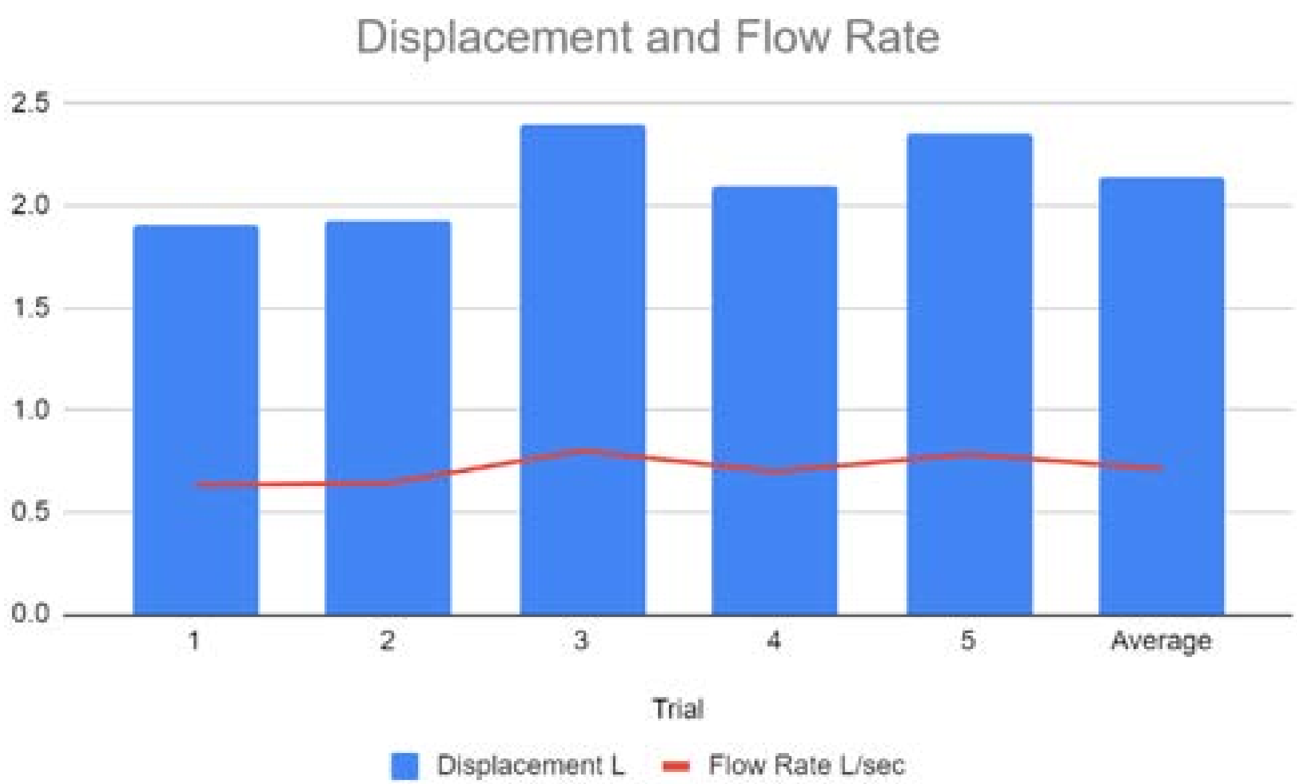
Content by: Katie Day

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

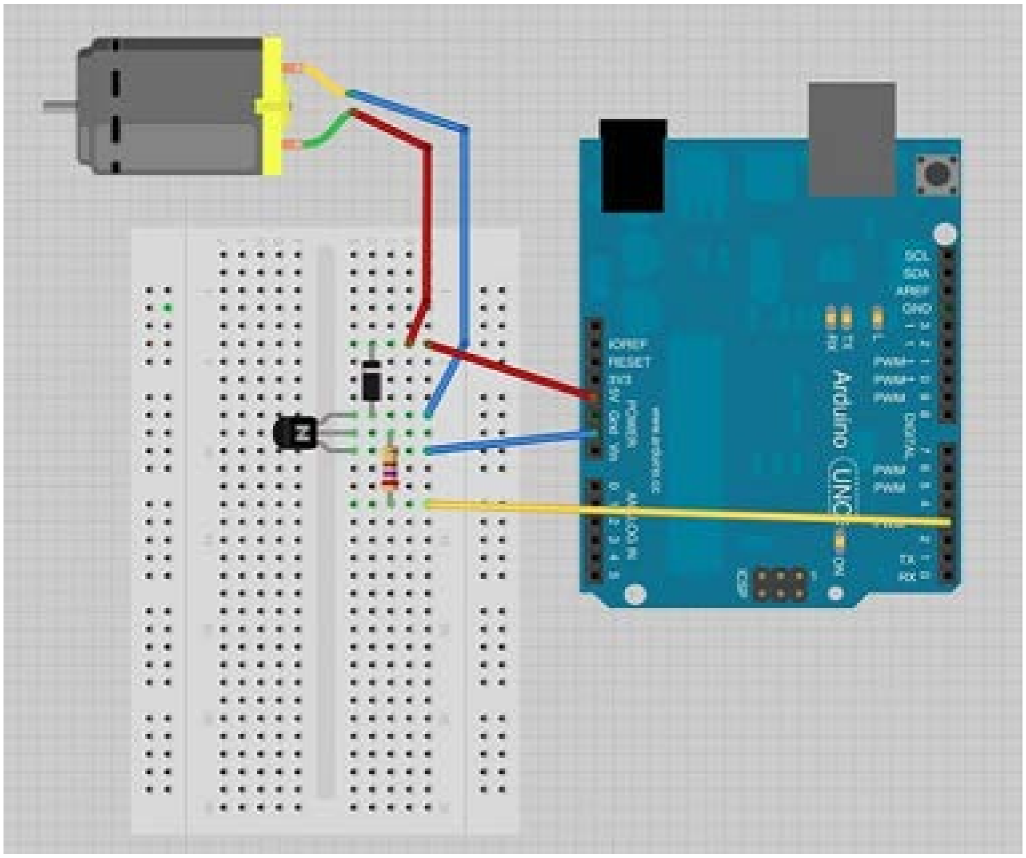
Content by: Katie Day

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

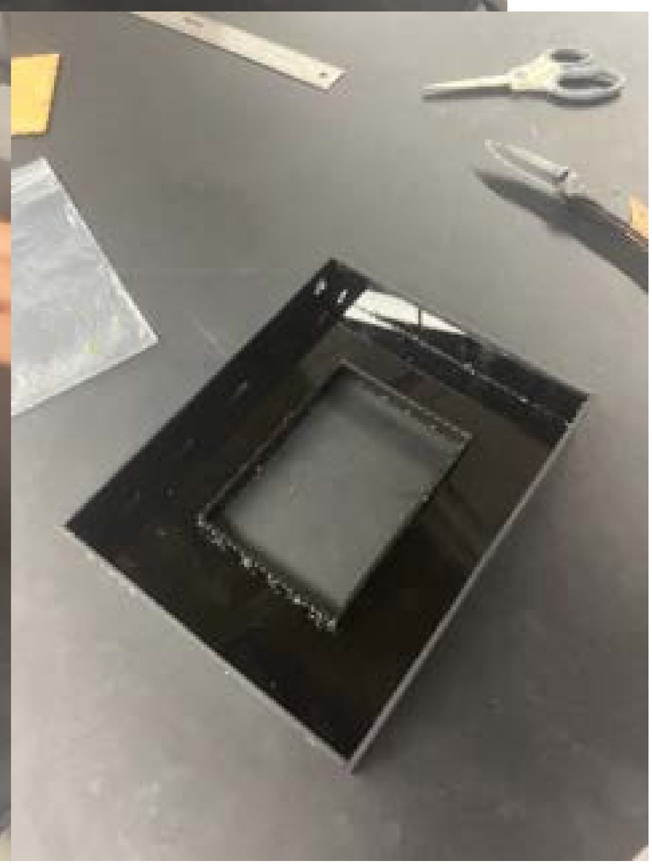
Content by: Katie Day and Sam Bardwell

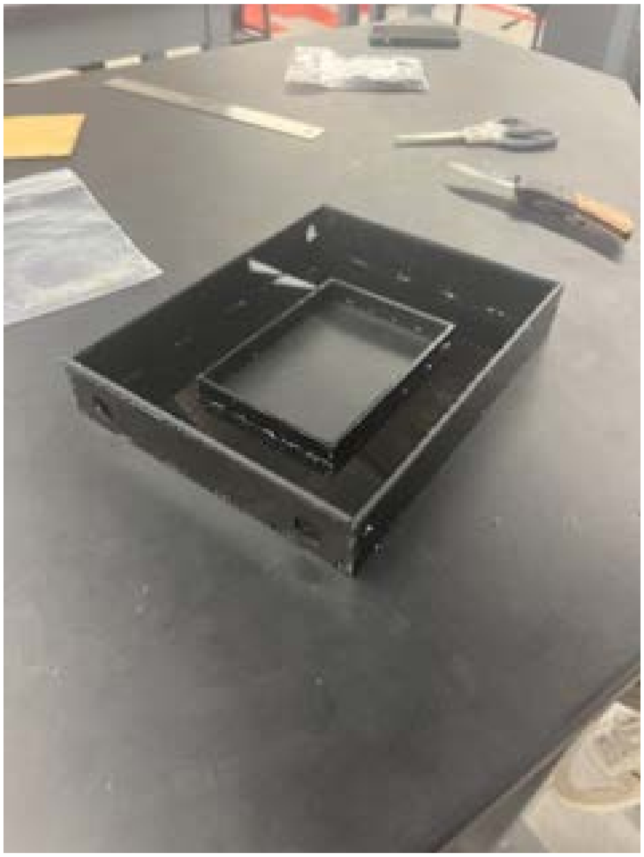
Present:

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 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

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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

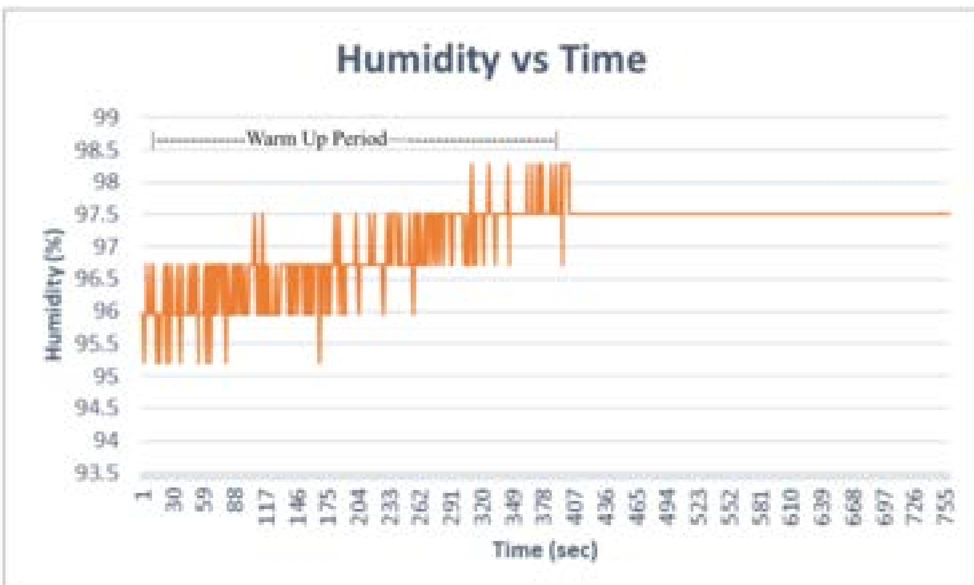
Content by: Katie Day, Maya Tanna, Bella Raykowski, Drew Hardwick, and Sam Bardwell

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.



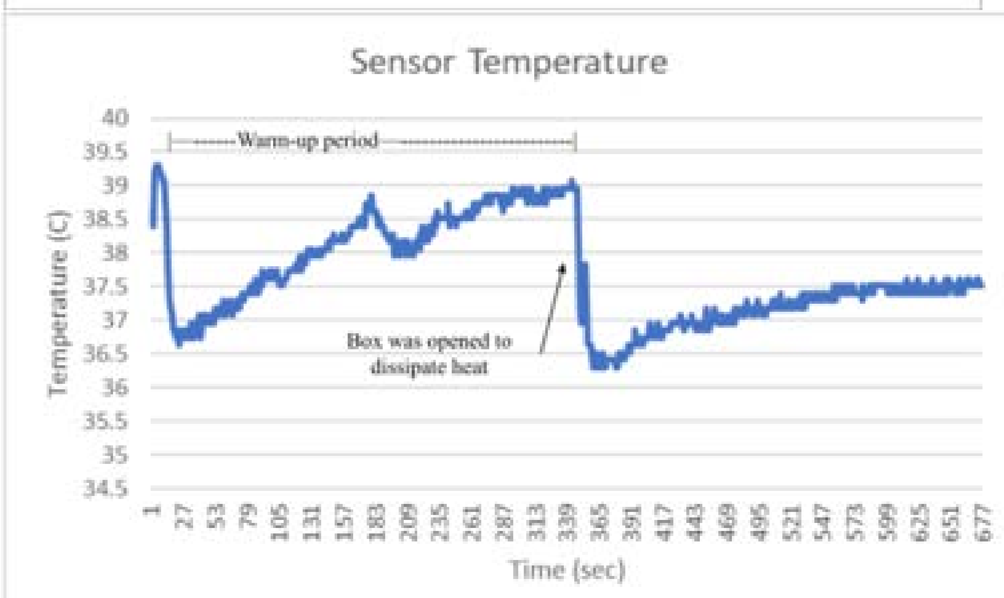


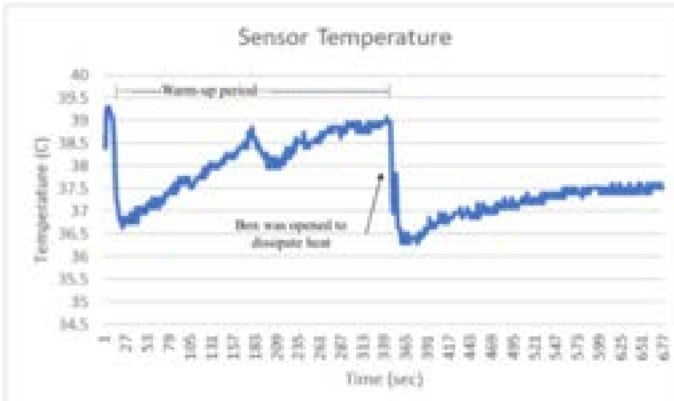
Figure 1: Sensor Humidity Results *Figure 2: Sensor Temperature Results*

See attached for raw data

Conclusions/action items:

Complete recovery testing.

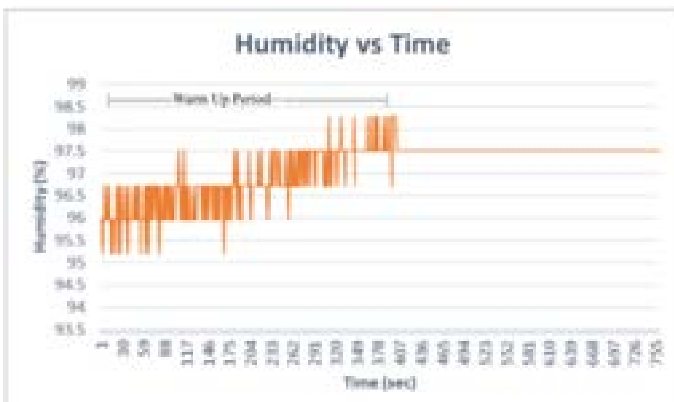
Katie Day - Apr 26, 2022, 9:04 PM CDT



[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

[Download](#)

Incubator_temp_testing.csv (20.1 kB)

Katie Day - Apr 26, 2022, 9:04 PM CDT

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

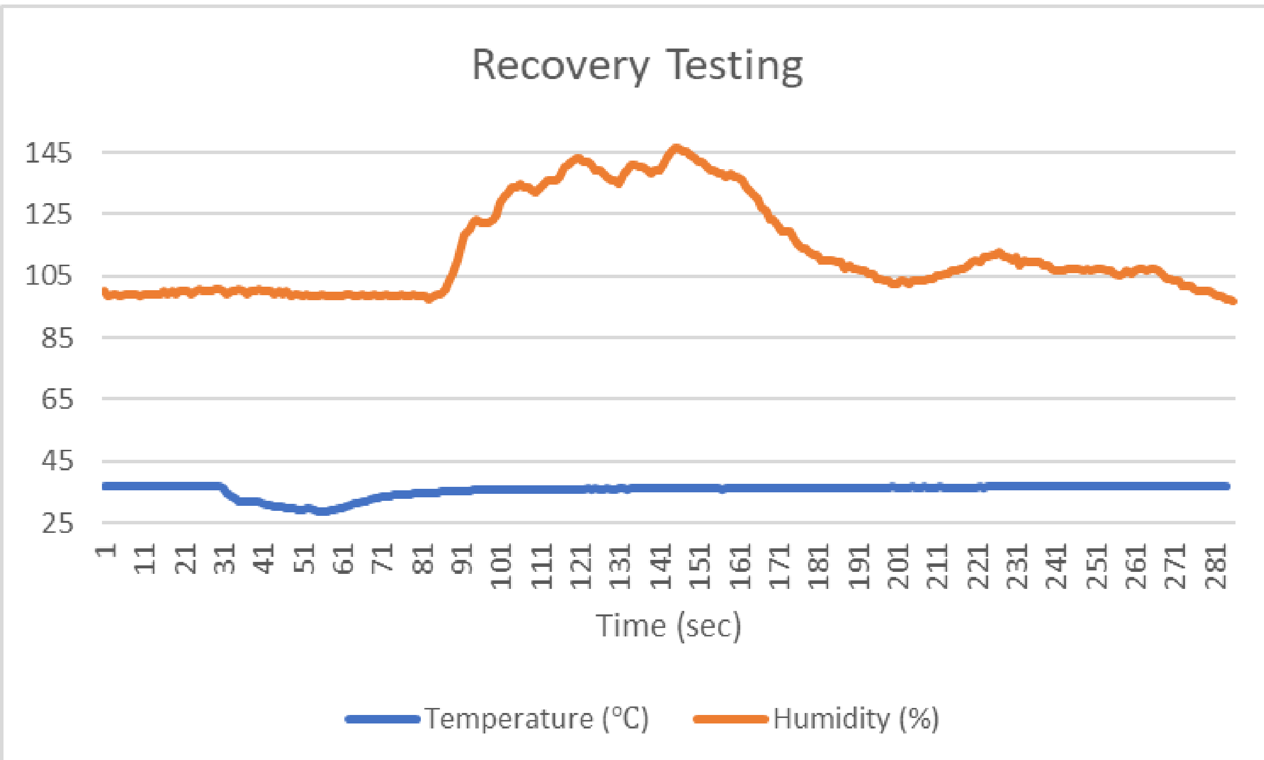
Content by: Katie Day, Maya Tanna, and Bella Raykowski

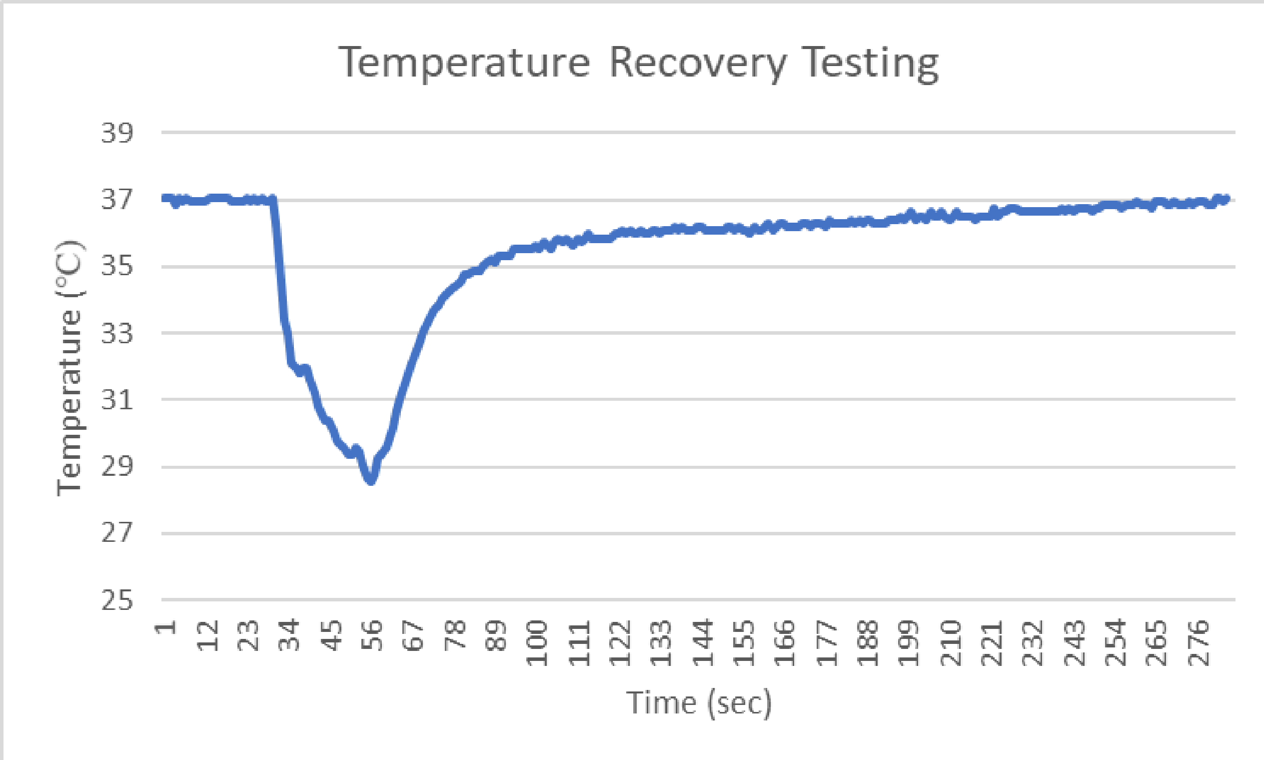
Present: Whole Group

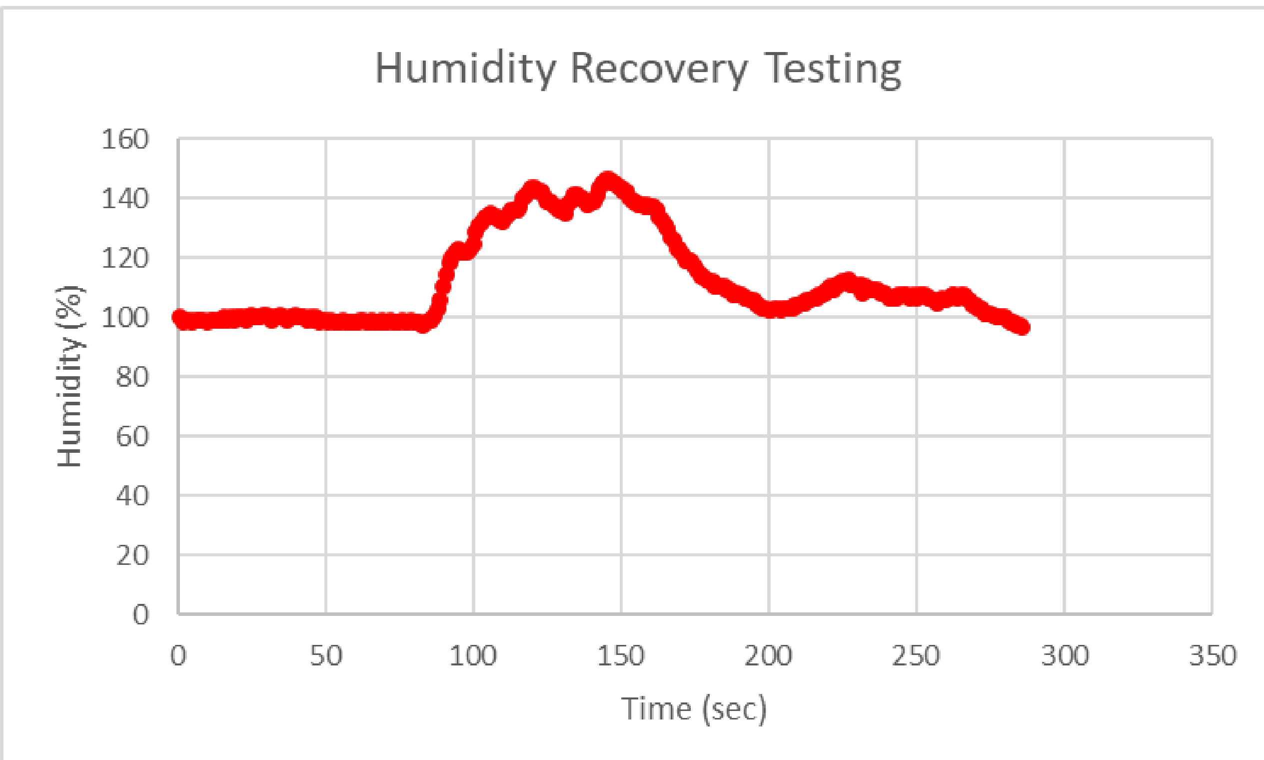
Goals: To determine the amount of time it takes the incubator to return to standard temperature and humidity after opening the box for a short amount of time.

Content:

See attached files.



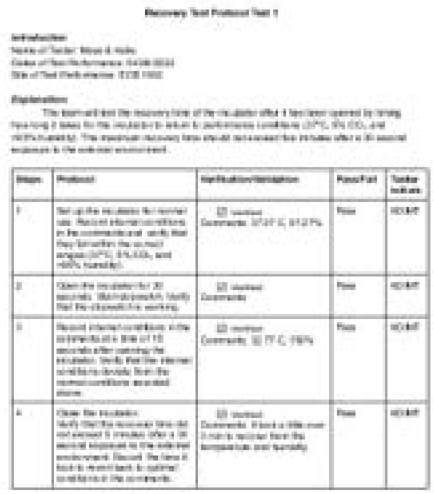




Conclusions/action items:

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

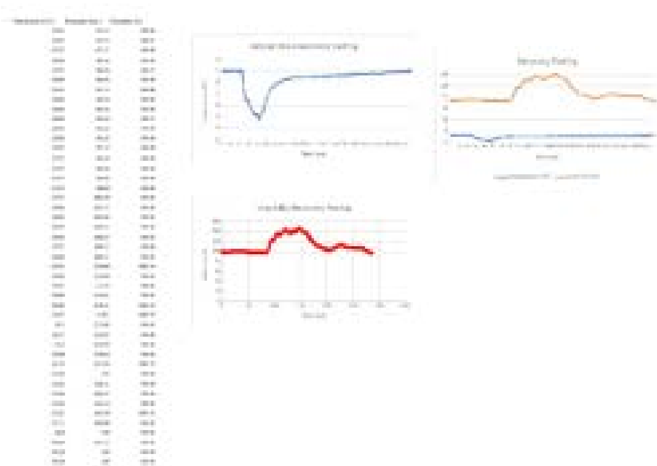
Explanation

Steps	Protocol	Verification/Validation	Pass/Fail	Tester Initials
1	[illegible]	[illegible]	Pass	[illegible]
2	[illegible]	[illegible]	Pass	[illegible]
3	[illegible]	[illegible]	Pass	[illegible]
4	[illegible]	[illegible]	Pass	[illegible]

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)

9/9/22 Affordable Solenoid Vale Options

Katie Day - Sep 09, 2022, 1:02 PM CDT

Title: Affordable Solenoid Valve Options

Date: 09/09/2022

Content by: Katie Day

Present:

Goals: To discover affordable solenoid values for the use in CO_2 monitoring.

Content:

- Solenoid Air Control Valve: 110V AC, Solenoid / Spring, 7.28 cfm Max. CFM - Valves
    - $66.22
    - 5-way/2-position
    - 110 V AC
    - 15-105 psi
    - normally open
- Solenoid Air Control Valve: No Coil, Solenoid / Spring, 1/8 in Pipe Size, 0 to 150 psi
    - $65.55
    - 3-way/2-position
    - No coil
    - 0-150 psi
    - normally closed

Conclusions/action items:

9/20/22 Conductive Glass

Katie Day - Dec 10, 2022, 3:07 PM CST

Title: Conductive Glass

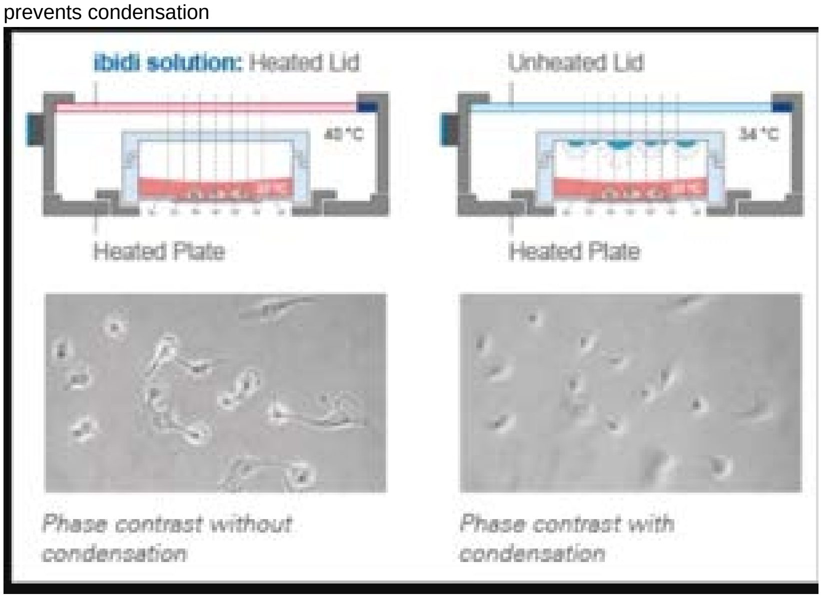
Date: 9/20/2022

Content by: Katie Day

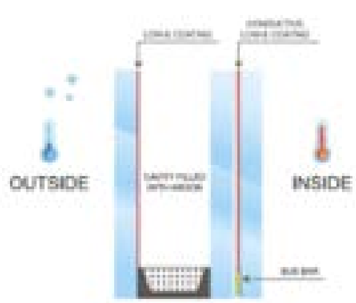
Present:

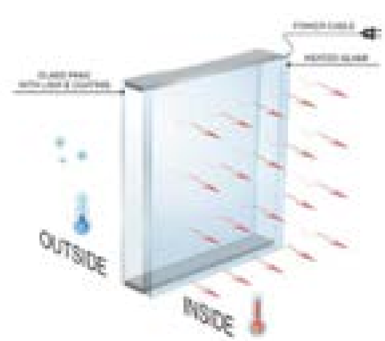
Goals: To determine the electronic basis behind conductive glass and competing design techniques.

Content:

- ibidi Stage top incubator
    - create a vertical temperature gradient by heating the lid to a temp higher than the plate
    - prevents condensation
    - 

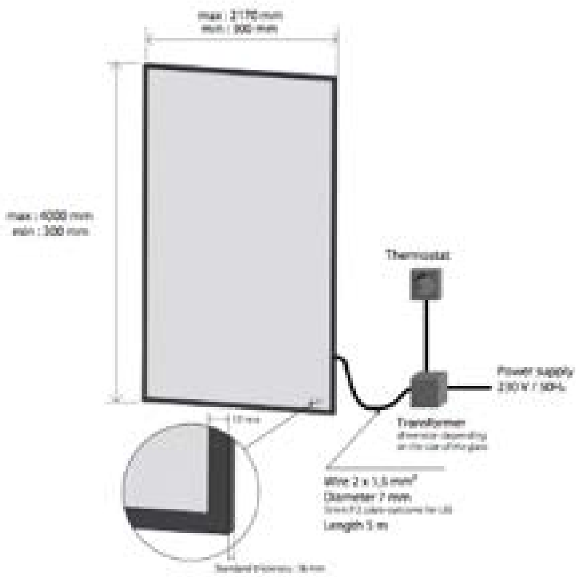
        - “Ibidi stage top incubator Multiwell Plate, CO2 – Silver Line: Live Cell Imaging,” *ibidi*, 2021. [Online]. Available: https://ibidi.com/stage-top-incubators/288-ibidi-stage-top-incubator-multiwell-plate-co2-silver-line.html#heating_system. [Accessed: 10-Dec-2022].
- Heatvision
    - Electrically heated glass = treated glass with a transparent electrically conductive coating
        - electric current passes through cables on coating



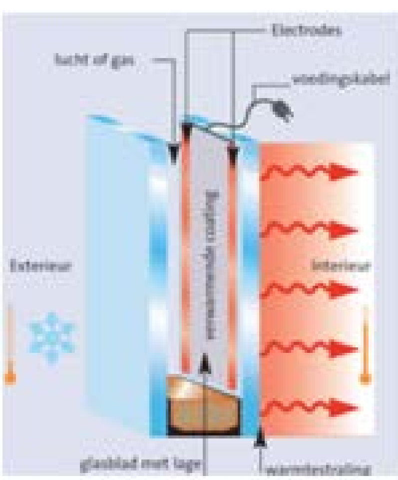


-
    - “HeatVision® electrically heated glass for all your needs,” *HeatVision®*, 02-Nov-2022. [Online]. Available: https://heatvision.info/. [Accessed: 10-Dec-2022].

  - Raises temp beyond the dew point to prevent condensation
  - Voltage: 230V - 50Hz
  - power 100-600W/m^2
- Smartfilmplus
  - Coating conducts light like float glass
  - heat loss reduced to 30%
  - Coating made of metal oxides
  - Anticondensation:
    - Works over 30*C
    - 100-300 W/m^2
    - “Electrically heated glass,” *Smartfilmplus*, 10-Dec-2020. [Online]. Available: https://smartfilmplus.com/solutions/electrically-heated-glass/. [Accessed: 10-Dec-2022].
- New Glass Tech
  - Transparent and optimal light transmission
  - Reduction of low level ventilation
  - Glaze is clear and transparent
  - reduction of mould on the frame
  - Heat surface = low-emissivity glass that when stimulated by electrodes a thin oxide coating over the inner face on the side of the vacuum filled with argon radiates heat
  - Anticondensation: 50-150 W/m^2
  - Surface temp: 20-65*C



  -



  -
  - “Thermo Heat Glass,” *New Glass Tech*, 2022. [Online]. Available: https://www.newglasstech.com/?page=product&cat=Specialities&product=thermo-guard&lang=en. [Accessed: 10-Dec-2022].
  - **Conclusions/action items:**

10/26/22 Flow Rate Testing - Copy

Katie Day - Oct 27, 2022, 10:59 AM CDT

Title: Flow Rate Testing

Date: 10/26/22

Content by: Sam and Katie

Goals: To determine the flow rate of CO2 out of the solenoid valve when the take is set to 17 psi.

Content:

- First we set the CO2 tank to output at a 17 psi pressure

- Then we set the solenoid code to be open for 1 second

- We attached a balloon to the end of the tubing and ran the code. This filled up the balloon with 1 second of CO2 gas.

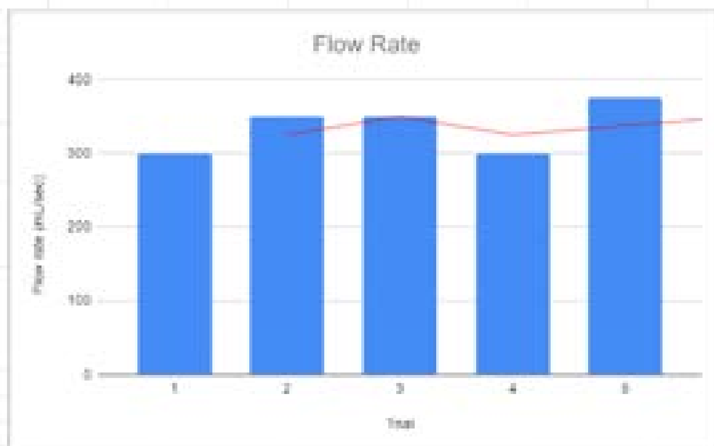
- We obtained a 1L beaker from the lab and filled it up with 550 mL of water

- Then we dunked the balloon into the water, and measured the displacement in order to obtain the volume of gas in the balloon.

- We repeated this for 5 balloons and averaged the amount of mL of gas output in 1 second.

- Since we have the volume of gas outputted from the solenoid in 1 second, we were able to figure out the flow rate of gas from the CO2 tank, trough the solenoid valve in mL/s

Time = 1 sec		Initial Volume = 550 mL
Trial	Total mL	Flow rate (mL/sec)
1	850	300
2	900	350
3	900	350
4	850	300
5	925	375
		335
		Average = 335 mL/s
Incubator Volume = 1759.55 mL	5% = 87.98	Time = 0.26 seconds



- Using the inner volume of the incubator and understanding that we need 5% CO2 levels, We calculated how many mL 5% is (87.98). Since we have the flow rate, we can open the solenoid for 0.26 seconds in order to input 5% CO2 into the incubator when it originally had 0% CO2.

Figure 1: Photo of the filled balloons after the solenoid being opened for one second. Also shown is the beaker with water.

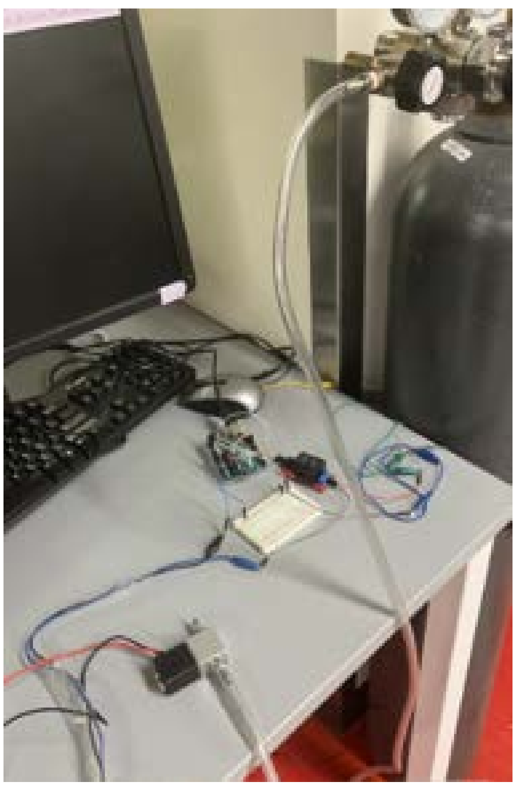


Figure 2: Solenoid flow testing set up to collect the CO2 output.

Conclusions/action items:

The next steps are to use this information to include it into a code that connects CO2 sensor information to the solenoid. This will allow the solenoid to automatically input the correct amount of CO2 into the incubator box when needed.

11/18/22 I2C NDIR

Katie Day - Nov 18, 2022, 1:59 PM CST

Title: I2C NDIR Research

Date: 11/18/22

Content by: Katie Day

Present:

Goals: To determine how to write I2C for the NDIR Sensor in Arduino.

Content:

See Attached links for library.

https://www.youtube.com/watch?v=inVmjXzm2zk&ab_channel=vizlerelektronika

https://sandboxelectronics.com/?p=1126

https://github.com/SandboxElectronics/NDIR/tree/master/NDIR_I2C

Conclusions/action items:

Meet with Dr. Nimunkar to determine how to apply the code to the solenoid valve.

09/26/2022 Solenoid Valve initial coding

Katie Day - Dec 10, 2022, 2:49 PM CST

Title: Solenoid Valve initial coding

Date: 09/26/2022

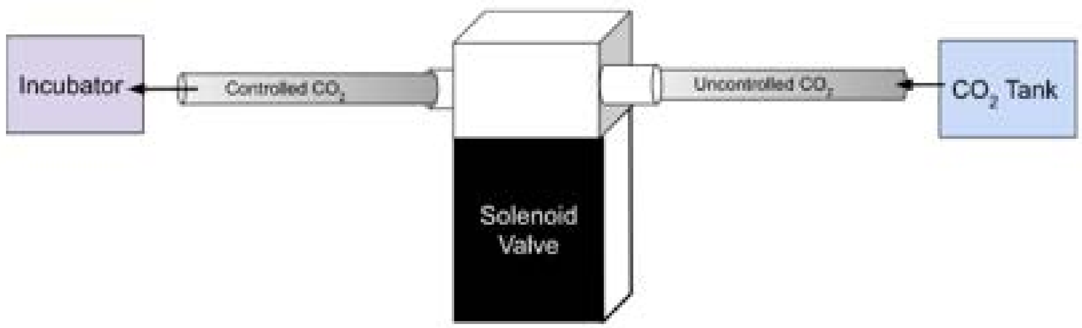
Content by: Katie Day

Present:

Goals: to begin to write code for the solenoid valve.

Content:

See attached file.



Description of code: Upon sending a High or Low signal to the valve it opens for a specific amount of time.

Conclusions/action items:

Test the code.

Katie Day - Sep 26, 2022, 2:10 PM CDT

Download

SolenoidValve.ino (324 B)

09/26/2022 Updated whole sensor code

Katie Day - Dec 10, 2022, 2:25 PM CST

Title: Updated whole sensor code

Date: 9/26/2022

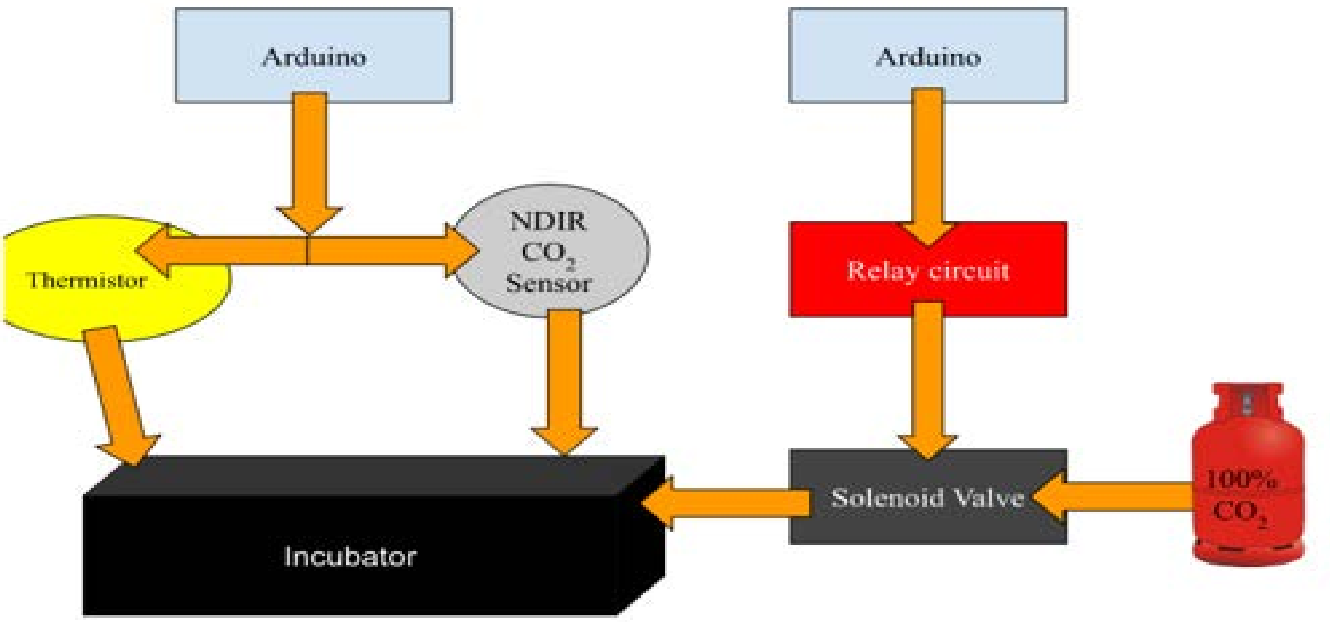
Content by: Katie Day

Present:

Goals: To update the whole sensor code with the solenoid valve config.

Content:

See attached file.



Description of Code: Approximately every minute, the temperature, humidity, and CO2 values are read and outputted onto serial monitor. The Solenoid valve opens if CO2 value is <4.5% and closes when CO2 is >5.5%.

Conclusions/action items:

Test the code to see if it works.

Katie Day - Sep 26, 2022, 2:12 PM CDT

Download

Coding_Spring_22.ino (2.33 kB)

10/19/22 Temperature Homogeneity Testing Code

Katie Day - Oct 19, 2022, 7:43 PM CDT

Title: Temperature Homogeneity Testing Code

Date: 10/19/2022

Content by: Katie Day

Present:

Goals: To present the code for Homogeneity Testing.

Content:

See Attached file.

Conclusions/action items:

Test the code and record results in excel file.

Katie Day - Oct 19, 2022, 7:49 PM CDT

Download

Temp_Homo.ino (792 B)

10/19/22 CO2 Homogeneity Testing Code

Katie Day - Oct 19, 2022, 7:50 PM CDT

Title: CO2 Homogeneity Testing Code

Date: 10/19/2022

Content by: Katie Day

Present:

Goals: To present the code for CO_2 Homogeneity Testing.

Content:

See Attached file.

Conclusions/action items:

Test the code and record results in excel file.

Katie Day - Oct 19, 2022, 7:50 PM CDT

Download

CO2_Homo.ino (1.14 kB)

10/20/22 Solenoid Valve Functionality Testing

Katie Day - Oct 20, 2022, 2:14 PM CDT

Title: Solenoid Valve Functionality Testing

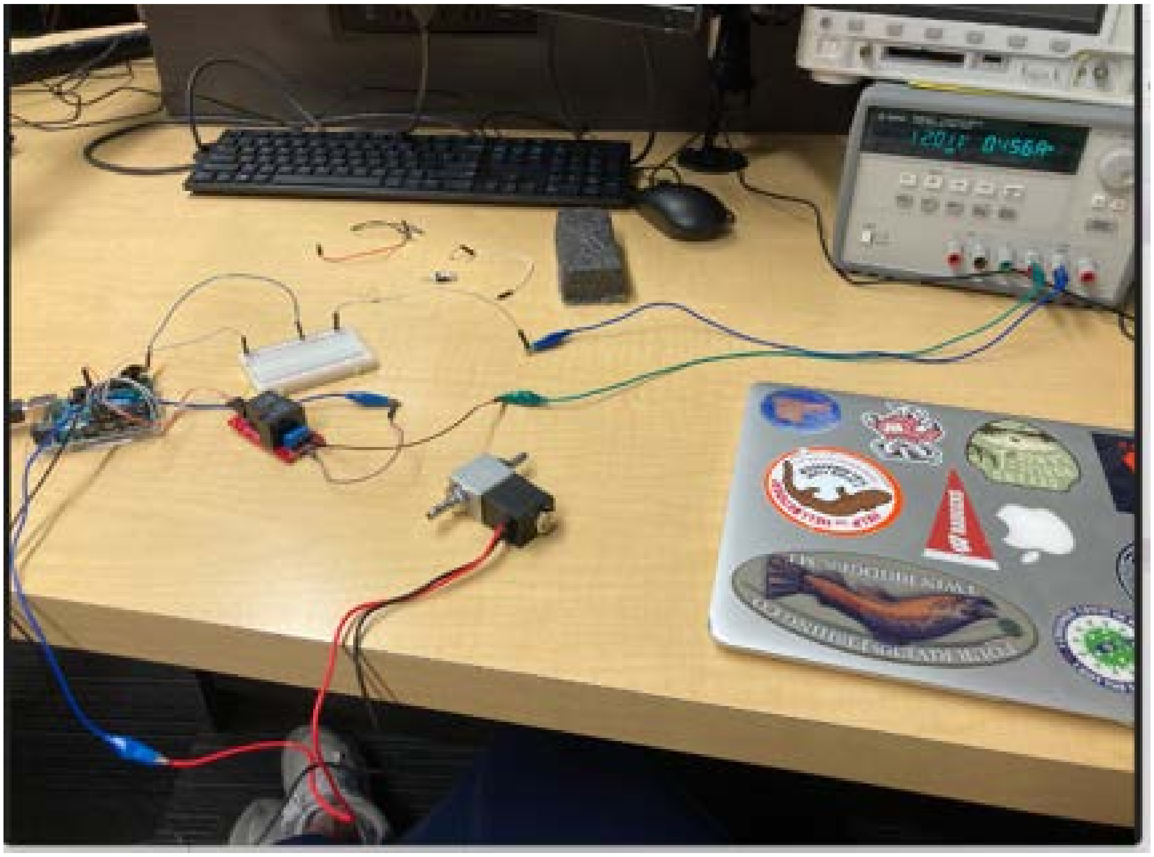
Date: 10/20/2022

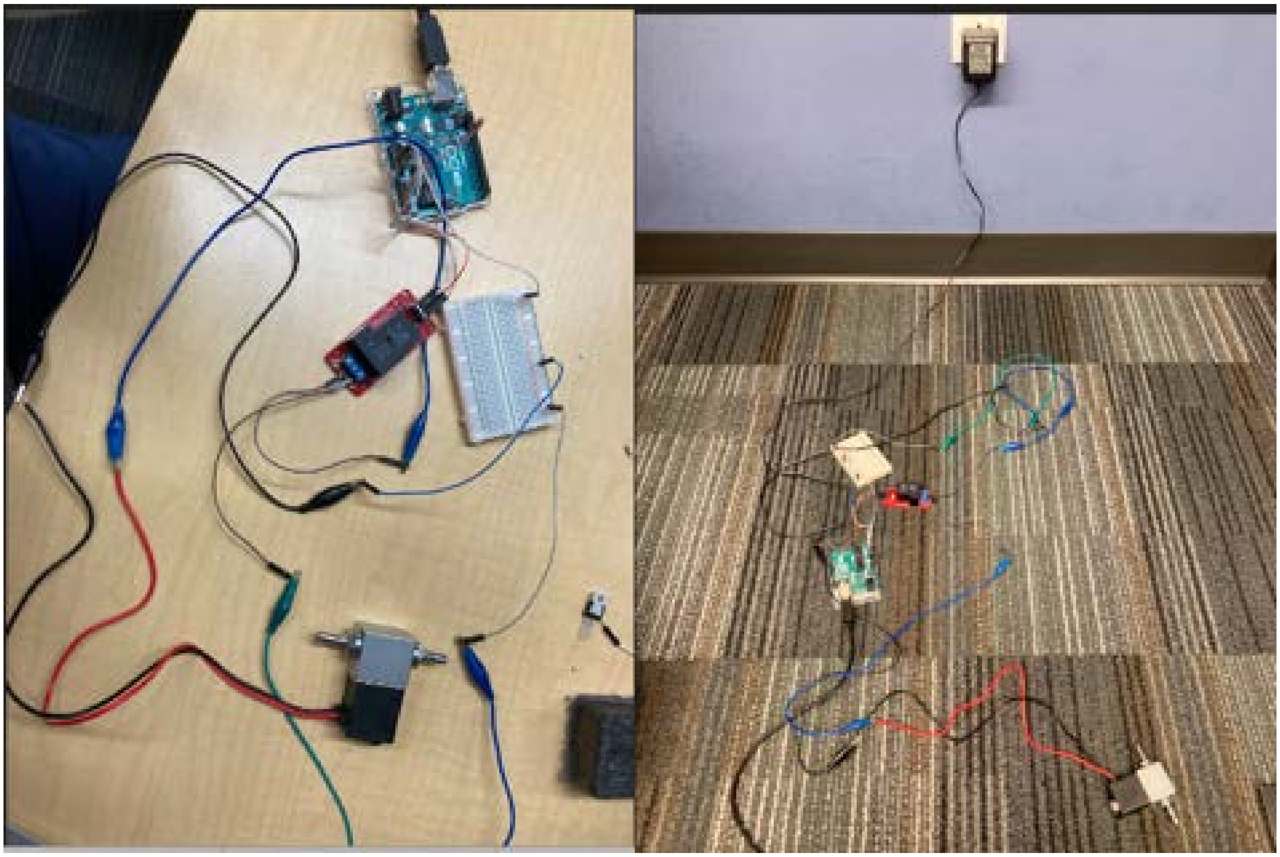
Content by: Katie Day

Present: Katie Day and Drew Hardwick

Goals: To test the functionality of the solenoid valve and determine which power source is right for us.

Content:





See Attached File for Code.

Followed Protocol from BME 201 Lab 7.

Relay circuit connections

You will be performing this activity as a group. Note: many of these connections have been made for you. Refer to Figure 14.

1. Obtain one glass bioreactor, Beefcake Relay, power receptacle cable, Rocker switch, heating element and heating element connector for the entire group from your TA. **In this section you will be making connections between the Beefcake Relay and wall power, please make sure to show your circuit to the TA before connecting the receptacle to the wall power. Do not connect your heating element today.**
2. You will be building some part of this circuit on the breadboard (namely connection to Arduino, Rocker switch and LED will be made on the breadboard). We will be testing the functionality of your circuit. This circuit will be later transferred to your project box. Refer to Figure 14 and identify the Hot (Black or other colors), Neutral (White) and Ground (Green) wires in your wall power cable which is a standard of the National Electrical Code (NEC) and should be followed in your wiring as well.
    1. Hot (**black/brown**): provides the 120V AC current source from the wall.
    2. Neutral (**white/blue**): provides the return path for the current provided by the hot wire
    3. Ground (**green**): earth ground to allow current to flow ground in case of an electrical short.

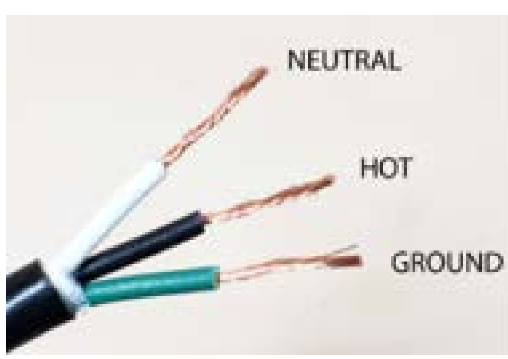


Figure 14. The Hot (Black), Neutral (White) and Ground (Green) wires in a US wall power cable [NEC].

3. Make the following connections for the wall power receptacle cable (WITH IT UNPLUGGED AND EVERYTHING OFF)
    1. Connect the Ground (**green**) wire from the wall power receptacle cable to GND (Ground)
    2. Connect the Hot (**black/brown**) wire from the wall power receptacle cable to the fuse wire as shown in Figure 15. Make sure this wire is properly soldered and heat shrinked with the fuse wire. Connect the fuse wire to the Com terminal of the Beefcake Relay (Figure 15).
    3. Follow the following instructions to connect to the female receptacle connector for the heating element - this also follows National Electrical Code (NEC) for the small prong = hot and the large prong = neutral.
        1. Connect a piece of the Hot (**black/brown**) wire from the small prong/hole of the heating element female electrical receptacle connector to the Normally Open terminal of the Beefcake Relay. Make sure that the terminal is soldered and properly heat shrinked.
        2. Connect the Neutral (**white**) wire to the large prong/hole of the heating element female electrical receptacle connector. Make sure that the terminal is soldered and properly heat shrinked.
    4. Show these connections to your instructor/TA. **Do NOT connect the wall power receptacle cable to the wall power at this time.**
4. Make the following connections for the Arduino and Beefcake Relay
    1. Connect the GND (Ground) terminal of the Beefcake Relay to the GND (Ground) terminal of the Arduino.
    2. Connect the Digital Pin of the Arduino to the CTRL pin of the Beefcake Relay.
    3. Connect the 5 V of the Beefcake Relay to the 5 V pin of Arduino
5. Make connections for the Arduino and Rocker Switch as you did in Arduino Lab I section - **Controlling Beefcake Relay with Arduino and Rocker Switch.** Make sure that the terminal is soldered and properly heat shrinked.
6. Make the following connection for the Arduino and status LED as you did in Arduino Lab I section - **Blinking External LED**
7. Make the connection for the Heating Element and the male connector as shown in Figure 15. Make sure that the terminal is soldered and properly heat shrinked.
8. Show your connections to the Instructor/TA/SA and sign off before you proceed ahead.

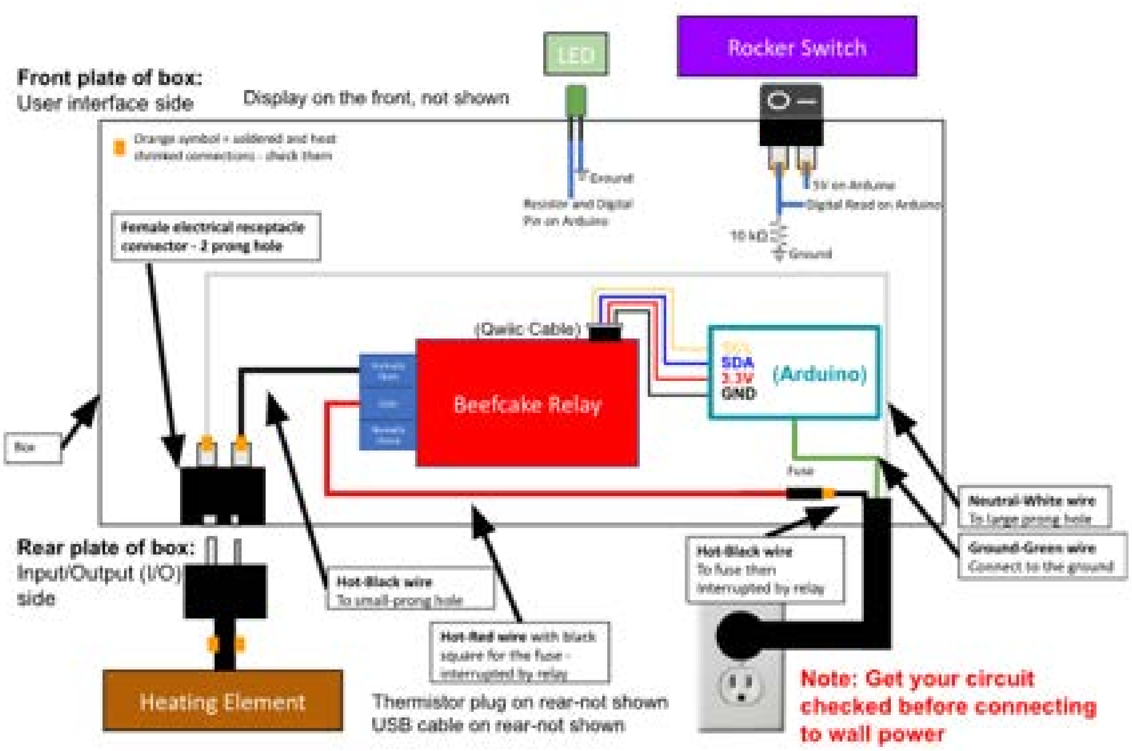


Figure 15. Connections between the Beefcake Relay, wall power, Rocker switch and Arduino.
Note: Have your circuit checked BEFORE connecting to wall power.

The HEATING ELEMENTS become extremely HOT!!! Do NOT leave them on while they are on top of any surface. Do NOT touch them while they are on. They must be wrapped securely around a filled bioreactor bottle with bare wire when they are plugged in. The water acts as a heatsink and prevents overheating.
You will NOT plug the heating elements in today.

Relay circuit and thermistor testing

Now that your bioreactor control system is nearing completion, it is time to test some of the individual components together before connecting them to your bioreactor.

9. In place of the Heating Element, use one multimeter, set it to V (Volt) and insert it into the Female electrical receptacle connector - 2 prong holes: COM to Neutral/large hole and V to the Hot/small hole.

   CAREFUL - Be sure your hands are not touching any medal as you insert the multimeter test leads all of the way in.
   Do NOT connect your bioreactor control system to wall power until an SA/TA checks your connection.

10. Code to convert voltage output from the thermistor circuit into temperature value using calibration curve equation from Arduino I Lab if you have not already done so.
11. Set your code to a temperature set point above room temperature ~ 25 °C (feel free to use another multimeter here with a temperature probe)
12. Turn on your rocker switch - your relay should click on and the LED should turn on indicating that the temperature is below the set point (if it does not - do NOT proceed and check with an SA/TA)
13. Plug your bioreactor control system into wall power
14. Check that your multimeter reads 110-125 V AC (if it does not - do NOT proceed and check with an SA/TA)
15. Check the system is working
    1. Hold the thermistor between your fingers and watch your temperature reading rise
    2. When the temperature reaches the set point +/- an acceptable margin of error, the LED should turn off and the relay should click off and the multimeter being used in place of the heating element should turn off
    3. Release the thermistor and watch the temperature drop
    4. When the temperature reaches the set point +/- an acceptable margin of error, the LED should turn on and the relay should click on and the multimeter being used in place of the heating element should turn on
16. Repeat the step above (a-d) several times
17. Record your methods and results in your notebook to demonstrate that your bioreactor control system properly turns on/off power to the heating elements receptacle.

References

[1].J.G. Webster, J. *Bioinstrumentation*, (Wiley 2003)

[2].J. G. Webster, and A .J. Nimunkar, Ed., *Medical Instrumentation: Application and Design* (Wiley, New York, 2020)

[3] S. Arar, “An introduction to digital signal processing - technical articles,” *An Introduction to Digital Signal Processing*, 30-Jun-2021. [Online]. Available: https://www.allaboutcircuits.com/technical-articles/an-introduction-to-digital-signal-processing/. [Accessed: 20-Oct-2022].

[4] N. Seidle, “Controllable Power Outlet,” *Sparkfun*, 02-Dec-2008. [Online]. Available: https://www.sparkfun.com/tutorials/119?_ga=2.228417371.795773219.1666285857-1001601635.1666285857. [Accessed: 20-Oct-2022].

Conclusions/action items:

Test the solenoid valve's control over CO_2 in the incubator.

Katie Day - Oct 20, 2022, 2:06 PM CDT

Download

SolenoidValve.ino (492 B)

10/20/22 UPDATED_ CO2 Homogeneity Testing Code

Katie Day - Oct 20, 2022, 2:07 PM CDT

Title: Updated CO2 Homogeneity Testing Code

Date: 10/20/2022

Content by: Katie Day

Present:

Goals: To reconfigure the code for CO_2 homogeneity control based on solenoid valve functionality.

Content:

See Attached file.

Conclusions/action items:

Test the code and record results in excel file.

Katie Day - Oct 20, 2022, 2:09 PM CDT

INO

Download

CO2_Homo.ino (1.29 kB)

11/3/22 CO2 and Solenoid Relay Communication Codes

Katie Day - Nov 03, 2022, 2:48 PM CDT

Title: Updated CO2 Homogeneity Testing Code

Date: 10/20/2022

Content by: Katie Day

Present:

Goals: To allow for the CO2 code and the solenoid valve code to communicate with each other.

Content:

See Attached file.

Conclusions/action items:

Test the code and record results in excel file.

Katie Day - Nov 03, 2022, 2:49 PM CDT

Download

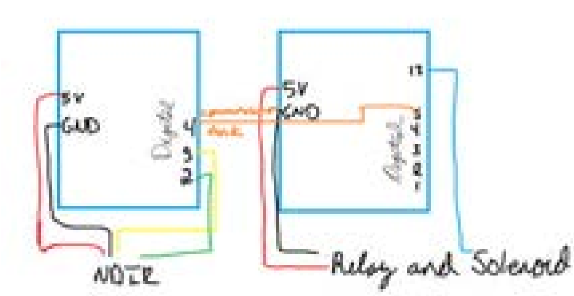
CO2_Homo.ino (978 B)

Katie Day - Nov 03, 2022, 2:49 PM CDT

Download

SolenoidValve.ino (712 B)

Katie Day - Nov 03, 2022, 3:04 PM CDT



Download

Solenoid_and_NDIR_Relay.png (29.1 kB)

11/10/22 NDIR Calibration Data

Katie Day - Nov 17, 2022, 12:06 PM CST

Title: NDIR Calibration Data

Date: 11/10/22

Content by: Katie and Drew

Present:

Goals: To recalibrate the NDIR to standard.

Content:

See attached data files.

Conclusions/action items:

With an offset of 2.2 the NDIR should read correctly.

Katie Day - Nov 17, 2022, 12:07 PM CST

Download

CO2_Calibaration.csv (1.51 kB)

Katie Day - Nov 17, 2022, 12:07 PM CST

Download

CO2_Regulation.csv (1.57 kB)

11/17/22 NDIR with Lightbulb Testing

Katie Day - Nov 17, 2022, 12:12 PM CST

Title: NDIR with Lightbulb Testing

Date: 11/17/22

Content by: Katie Day

Present:

Goals: To determine if the NDIR Sensor works with a lightbulb.

Content:

See photos.

Conclusions/action items:

The NDIR sensor does not work when connected to other appliances.

Katie Day - Nov 17, 2022, 12:12 PM CST

Download

69040104658__DB6202AE-8647-424A-BB6C-EBB9EFF398AE.HEIC (2.71 MB)

Katie Day - Nov 17, 2022, 12:12 PM CST

Download

IMG_7932.HEIC (5.4 MB)

Katie Day - Nov 17, 2022, 12:12 PM CST

Download

IMG_7931.HEIC (1.91 MB)

Katie Day - Nov 17, 2022, 12:12 PM CST

Download

IMG_7930.HEIC (2.31 MB)

11/17/22 FINAL CO2 AND SOLENOID CODE

Katie Day - Nov 17, 2022, 2:26 PM CST

Title: Final Co2 and Solenoid Code

Date: 11/17/22

Content by: Katie Day

Present:

Goals: To determine a code for CO2 and the Solenoid.

Content:

By measuring the time and the flow rate I was able to determine two for loops that work for the solenoid valve that output approximately enough CO2 per percentage to keep the Co2 between 4.5-5.5%.

Conclusions/action items:

See code.

Katie Day - Nov 17, 2022, 2:26 PM CST

Download

sol_test.ino (907 B)

Katie Day - Nov 17, 2022, 2:26 PM CST

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CO2_test.ino (702 B)

Katie Day - Dec 05, 2022, 9:16 AM CST

Download

Coding_Spring_22.ino (1.73 kB)

11/30/2022 CO2 Testing

Katie Day - Nov 30, 2022, 5:16 PM CST

Title: CO2 Testing

Date: 11/30/2022

Content by: Katie Day

Present: Katie Day and Drew Hardwick

Goals: To test the accuracy of the hardcoded solenoid valve at keeping the incubator at 5% +/- 1%.

Content:

Followed CO2 Testing Protocol. See attached files and images.

Conclusions/action items:

The solenoid valve is able to regulate CO2 and can be used in Live-Cell Testing.

Katie Day - Nov 30, 2022, 5:16 PM CST

Download

Hard-code_test.csv (73.5 kB)

Katie Day - Nov 30, 2022, 5:16 PM CST

Download

Custom_Data_-_2022-11-30_-_Recording_1.csv (7.91 kB)

12/12/2022 Concluding Thoughts

Katie Day - Dec 12, 2022, 5:21 PM CST

Title: Concluding Thoughts

Date: 12/12/2022

Content by: Katie Day

Present:

Goals: Outline what I did this semester.

Content:

Motivation: To create a way to see the internal environment of the incubator using sensors and regulate the input of CO2 in order to keep cells alive.

Work: Created code for all sensors. Found code for solenoid valve. This semester we were able to measure the homogeneity of the incubator using the sensors.

Future work: Use I2C to communicate with NDIR sensor and solenoid valve. Create a display.

Conclusions/action items:

2/20/23 Thermistor Accuracy Check

Katie Day - Apr 27, 2023, 4:54 PM CDT

Title: Thermistor Accuracy Check

Date: 2/20/23

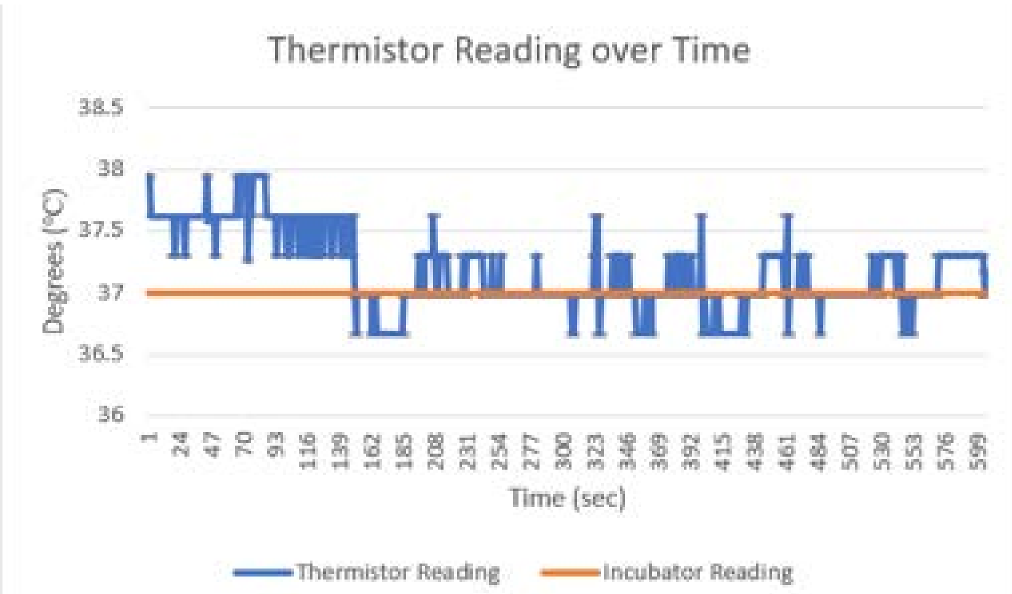
Content by: Katie Day

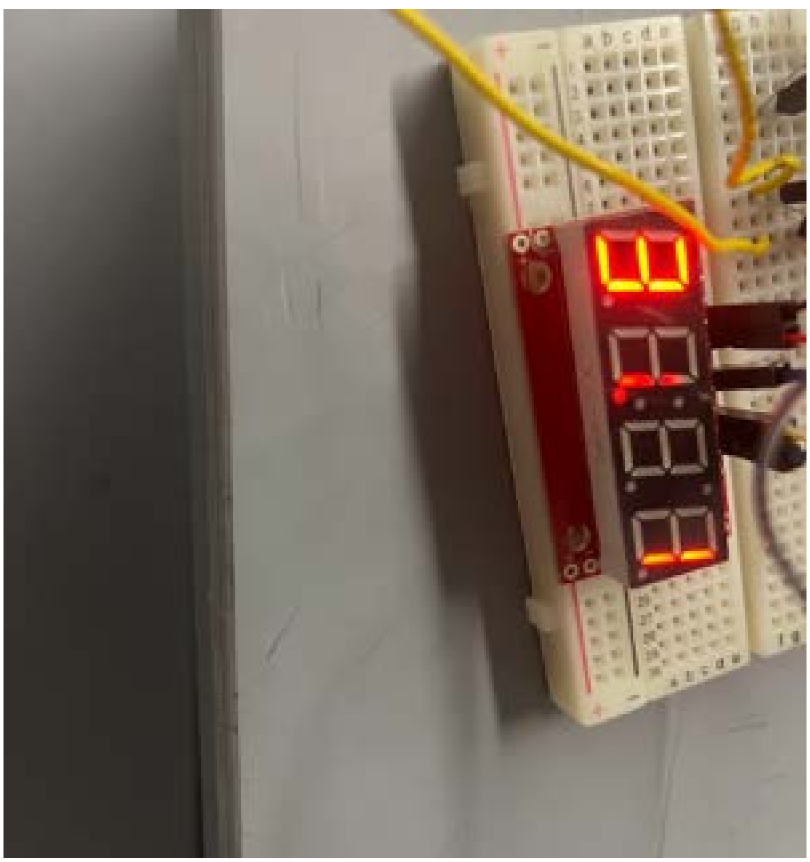
Present:

Goals: To make sure the thermistor is reading accurate values.

Content:

See attached file. p-value = 0.47





Arduino Code:

```
int ThermistorPin = 0;
int Vo;
float R1 = 10000;
```

```
float logR2, R2, T;
float c1 = 1.009249522e-03, c2 = 2.378405444e-04, c3 = 2.019202697e-07;
float Tc;
void setup() {
Serial.begin(9600);
}

void loop() {

  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 - 273.15;


//  Serial.print("Temperature: ");
  Serial.println(Tc);
//  Serial.println(" C");

  delay(1000);
}
```

The code takes the reads the thermistor and depending on the voltage calculates a temperature in Kelvin based on the resistor value. It then converts it to Celsius.

Conclusions/action items: None.

Katie Day - Feb 20, 2023, 4:56 PM CST

Download

Thermistor_Calibrated_Values.csv (6.57 kB)

2/26/23 Whole Set Up Circuitry Goal

Katie Day - Feb 26, 2023, 5:27 PM CST

Title: Whole Set Up Circuitry Reference

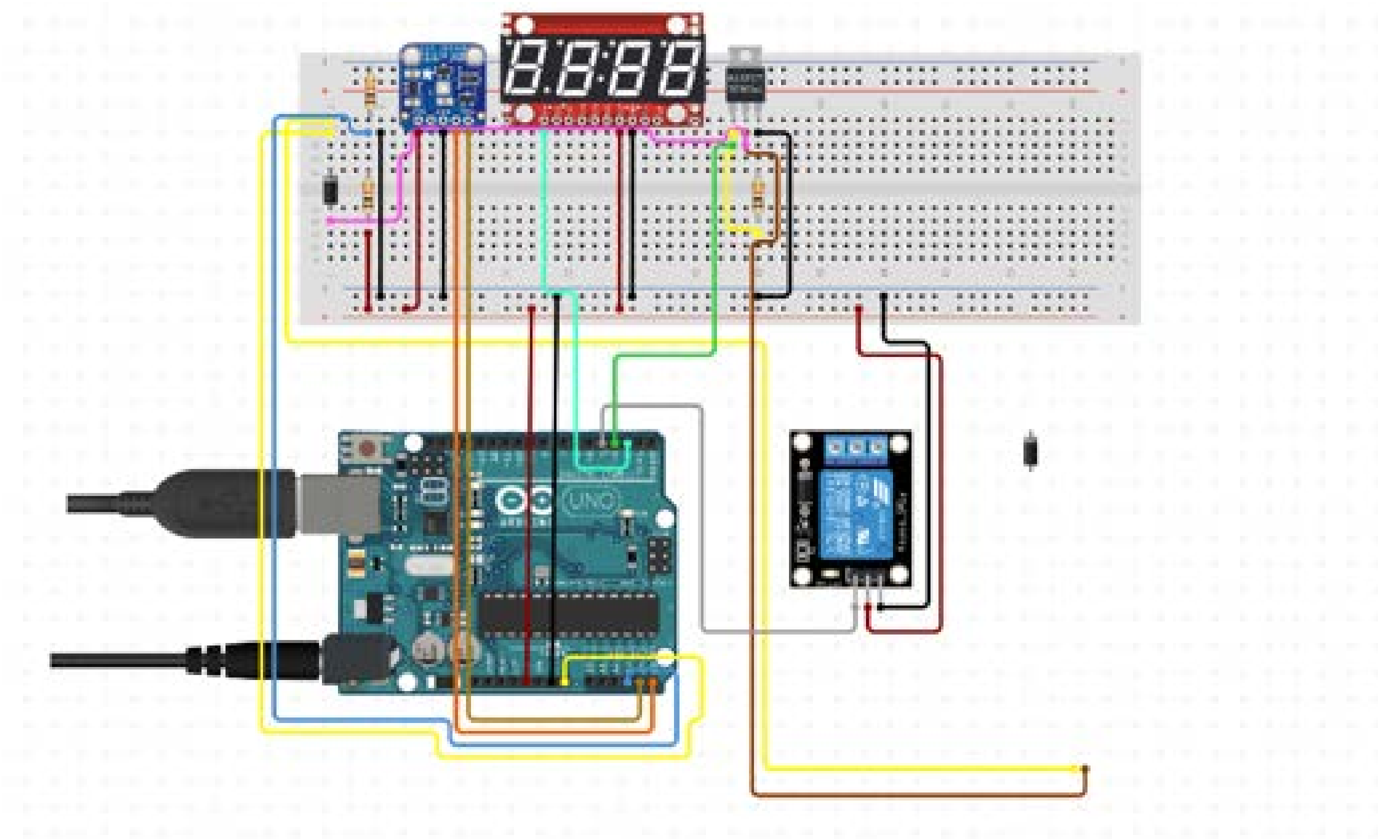
Date: 2/26/23

Content by: Katie Day

Present:

Goals: To get all of the circuitry on one breadboard/Arduino.

Content:



Conclusions/action items: Reference this when creating the circuit.

4/11/2023 NDIR with Cover

Katie Day - Apr 27, 2023, 4:55 PM CDT

Title: Katie Day

Date: 4/11/2023

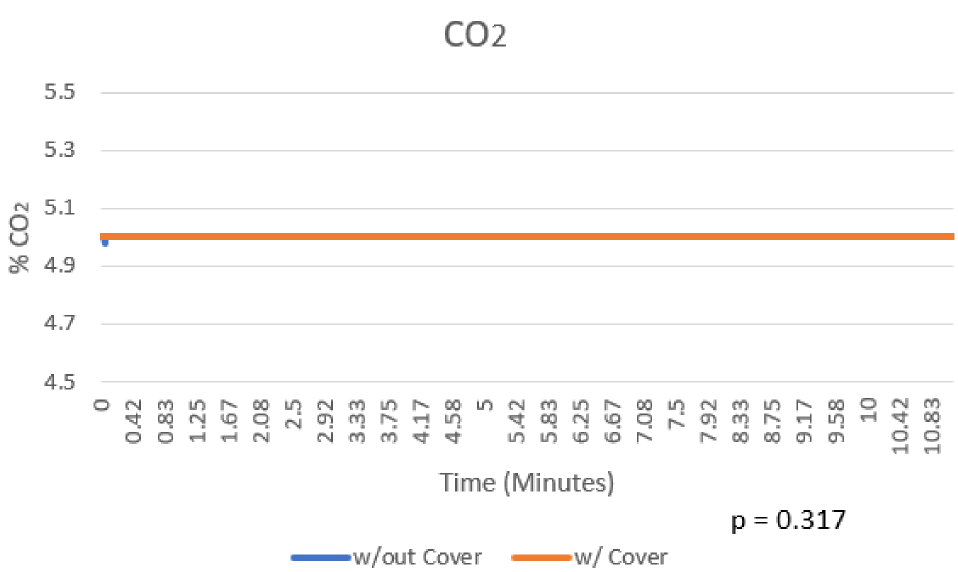
Content by:

Present:

Goals: To determine if the CO2 sensor works with the gas-permeable sensor cover.

Content:

Yes, It does in fact work. This can help prevent against Sensor Communication Errors.



Arduino Code:

```
//Reads from the NDIR sensor and outputs the %CO2.

#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;
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);
  }

}

void loop() {
  if (mySensor.measure()) {
```

```
    // Serial.print("CO2 Concentration is ");
     Serial.println((mySensor.ppm*5.0)/10000);
    // Serial.println("ppm");
    // Serial.print("Percent CO2 is ");
   // Serial.print((mySensor.ppm/10000));
  //  Serial.println("%");
  } else {
     Serial.println("Sensor communication error.");
  }
 delay(1000);
  }
```

Conclusions/action items:

Implement into actual incubator to see if this can help with CO2 regulation.

Katie Day - Apr 11, 2023, 1:07 PM CDT

Download

CO2_Regulation_New_Sensor.csv (15.9 kB)

4/25/2023 Data Streamer Results

Katie Day - Apr 25, 2023, 3:38 PM CDT

Title: Data Streamer Results

Date: 4/25/2023

Content by: Katie Day

Present:

Goals: To place all of the results and recorded values from the data streamer tests into one collective place.

Content:

See attached folder.

Conclusions/action items:

Katie Day - Apr 25, 2023, 3:39 PM CDT

Download

1.5_CO2.csv (8.06 kB)

Katie Day - Apr 25, 2023, 3:39 PM CDT

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1.5_CO2.xlsx (61.4 kB)

Katie Day - Apr 25, 2023, 3:39 PM CDT

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CO2_final_test_day_1.csv (10 kB)

Katie Day - Apr 25, 2023, 3:39 PM CDT

Download

CO2_final_test_day_1.xlsx (119 kB)

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CO2_Hum_Temp_-_Copy.csv (279 kB)

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CO2_Hum_Temp.csv (279 kB)

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CO2_Hum_Temp.xlsx (353 kB)

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Data_Streamer.xlsx (9.11 kB)

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Day_1.csv (4.62 kB)

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Day_1.xlsx (17.5 kB)

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day2.5.csv (170 kB)

Katie Day - Apr 25, 2023, 3:39 PM CDT

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day2.csv (3.56 kB)

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day2.xlsx (13 kB)

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Day3.csv (472 kB)

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Day3.xlsx (313 kB)

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Day4.csv (2.38 kB)

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hour_1.csv (431 B)

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Hum_Data.csv (4.33 kB)

Katie Day - Apr 25, 2023, 3:39 PM CDT

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Hum_Data.xlsx (40.6 kB)

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Katie Day - Apr 25, 2023, 3:39 PM CDT

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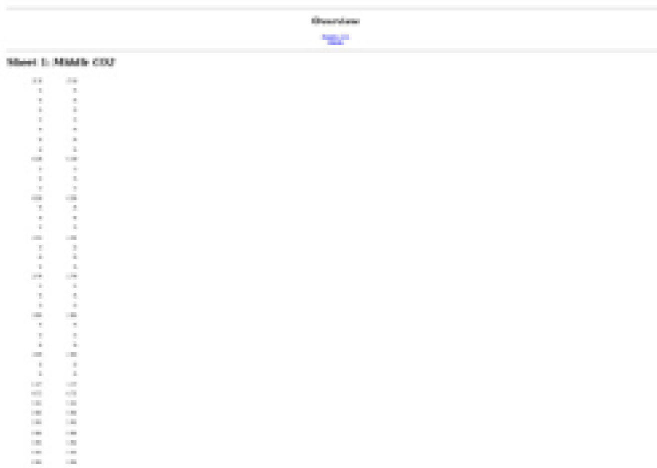
Middle_CO2.csv (17.1 kB)

Katie Day - Apr 25, 2023, 3:39 PM CDT



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Middle_CO2.xlsx (101 kB)

Katie Day - Apr 25, 2023, 3:39 PM CDT

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Overdoing_CO2_test.csv (17.9 kB)

Katie Day - Apr 25, 2023, 3:39 PM CDT

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Round_2_intial_test.csv (240 kB)

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Round_2_intial_test.xlsx (432 kB)

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Round_2_testing.csv (24.2 kB)

Katie Day - Apr 25, 2023, 3:39 PM CDT

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Round_2_testing.xlsx (218 kB)

Background

Drew Hardwick - Dec 13, 2022, 8:13 AM CST

Title: Background

Date:

Content by: Drew Hardwick

Present: N/A

Goals: Describe Project Background

Content:

NOTE: SEE PREVIOUS SEMESTERS WORK FOR MORE BACKGROUND RESEARCH

- Cell cultures - used in the study of cell biology to easily manipulate genes, molecular pathways, and culture systems to remove interfering genetic and environmental variables f
- follow BioSafety Level 2 guidelines
    - describe the safety procedures for working in a lab that can be associated with human diseases
    - incubators being used in conjunction with cell cultures must follow ISO Class 5 air quality standards
- Cell cultures have the ability to work with three different cell types: primary, transformed, and self-renewing cells
    - Primary - directly isolated from human tissue
    - Transformed - can be generated naturally with changes to the genetic code, or genetically manipulated
    - Self-renewing - carry the ability to differentiate into a variety of other cell types with long-term maintenance in vitro
        - Ex = embryonic stem cell
- Incubators used in cell cultures have to maintain a stable microenvironment and can achieve this via regulated temperature, humidity, CO_2, O_2, and pH levels
    - Critical for the viability and growth of the cultured cells
- Aiming to replicate conditions in the body (37 ℃ with a pH of 7.2-7.4)
- CO_2 is needed as a buffer to help with the pH along with a culture medium
    - Basal medium most commonly used - controls the physicochemical properties of the cell cultures' pH and cellular osmotic pressure

Conclusions/action items:

- See PDS and Previous semester research for more background research

3/8/23 - Fog Physics

Drew Hardwick - Mar 08, 2023, 2:42 PM CST

Title: Fog Physics

Date: 3/8/23

Content by: Drew Hardwick

Present: N/A

Goals: Determine why we never noticed fog condensation on bottom of incubator, and will it be an issue

Content:

- interior condensation is really an indication of excess humidity, while exterior condensation, on the other hand, is a form of dew — the glass simply provides a surface on which the moisture can condense.
- To make water vapor from water we need to add a lot of energy, 2256 kJ per kg (liter) of water. To give an impression how much energy this is, it costs 5 times more energy to evaporate a liter of water than to increase the temperature of the same amount of water from 0 to 100 C
- Condensation is the opposite of evaporation. This means that if condensation occurs, the same amount of energy is released. This is important, because if we have condensation on for instance cooling coils, the effectiveness of our cooling system might be less then we think, as heat is released when water vapor is condensating into water.
- fog develops if the temperature drops so much that the capacity of the air to hold the water vapor is exceeded.

- SHOWER FOG MECHANICS:
    - The hot air in the bathroom is hot because it's been heated by the hot water in the shower, so it's hot but also very heavily laden with moisture.
    - When the air hits the coldness of the glass it cools and (opposite to the other answer) cant hold as much water so the water drops out on the mirror.
    - The hot wet air from the shower and the cold dry air from the house form layers, which you can't see with your eyes, but as the hot air escapes around the ceilings of the house the cold dry air rises up the mirror. The moisture on the mirror evaporates only when the cold dry air is on it, so the fog appears to clear from the bottom up.

Conclusions/action items:

- The shower mechanics can be applied to our incubator:
    - The condensation is due to the hot air heated by the incubator hitting the cold glass, and droplets form. However, the hot air rises due to its lower density, and escapes through cracks near the lid, while cold air remains clumped at the bottom of the incubator.
    - This means that, THEORETICALLY, the lower glass sheet should fog up less than the upper glass sheet, and therefore, our revelation last week about the microscope imaging from the bottom should be less of an issue and an easier fix from the top
    - Maybe the fans angled down will be enough?
    - Speak to sam about findings

References:

https://www.goclward.com/wp-content/uploads/2015/01/Guide-to-Understanding-Condensation.pdf

https://bathroomie.com/bathroom-mirrors-fog-taking-a-shower/

3/10/23 - Inverted Microscope Imaging

Drew Hardwick - May 02, 2023, 8:44 AM CDT

Title: Inverted Microscope Imaging Research

Date: 3/10/23

Content by: Drew Hardwick

Present: N/A

Goals: Develop more firm understanding of how microscope images

Content:

- Inverted microscopy is a very popular technique for live cell imaging
  - Living cells are observed through the bottom of a cell culture vessel
  - This technique has several advantages over upright microscopy
  - Most cells naturally sink to the bottom of the vessel and adhere to the surface, meaning that they are spread across one focal plane.
  - When growing in vessels that are suitable for inverted microscopy, cells have access to larger amounts of medium than if they were squeezed between a coverslip and a slide.
  - In addition, sample access from the top is possible, for medium exchange or micropipettes, for example.
  - Another very important advantage is sterility: as there is no contact between the objective and the sample, so sterile working conditions are more so guaranteed.
  - Principle:
    - In an inverted microscope, the source for transmitted light and the condenser are placed on the top of the stage, pointing down toward the stage. The objectives are located below the stage pointing up. The cells are observed through the bottom of the cell culture vessel.
    - To meet the criteria for successful inverted microscopy, the bottom of the culture vessel must have the highest optical features.

Conclusions/action items:

Relay info above in next advisor meeting

References:

https://ibidi.com/content/212-inverted-and-upright-microscopy#:~:text=In%20an%20inverted%20microscope%2C%20the,of%20the%20cell%20culture%20vessel.

Previous Competing Designs

Drew Hardwick - Dec 13, 2022, 8:06 AM CST

Title: **Competing Designs**

Date:

Content by: Drew Hardwick

Present: N/A

Goals: Keep Up to date on current incubators on market

Content:

- SEE PDS FOR MORE COMPETING DESIGNS INFO
- Two types of commonly used methods to maintain temperature in industry cell incubators
    - Direct heat method - tends to gove off heat using electric metal coils surrounding body of incubator
    - programmed to desired temp
- The other method is the water-jacketed incubators
    - Use a controlled circulating water bath cabinet around the body of the incubator for even heating throughout the entirety of the chamber.
- Humidity control achieved by placing a tray of water at the bottom of the incubator
    - Used in both water-jacketed and direct heat incubators
- CO_2 control achieved through a CO_2 tank
    - automatically pumps the desired amount of gas into the incubator
    - Using tubes and a valve connector, the CO_2 tank is able to deliver gas to the inside of both water-jacketed and direct heat incubators
    - Many incubators allow CO_2 reg to adjust when internal conditions are disturbed
        - Ex: opening the incubator door to deliver more cell plates, so that the environment is always stable.
- Direct heat method ex: In-Vitro Cell NU5700
-

- "The NU-5700 CO_2 incubator offers touch panel control and monitoring of temperature and CO_2 levels to meet the demands of a broad range of cell culture applications. Beyond using an infrared sensor for precise control of CO_2 and separately adjustable door and perimeter heaters to balance internal temperature. The air pump outside the 160L growth chamber also constantly draws air through a HEPA filter and cycles it back to create ISO Class 5 quality air at positive pressure and minimize contamination. A touch screen makes it easy to enter set points and view or download historical performance. In addition, this moderately sized incubator can be stacked and still allow the user easy access to the top chamber."

- Price not listed, need to get a quote... --> very very expensive
  - Online estimates ~ $10,000
- Indirect Heat Method Ex: Ibidi Stage Top Incubator Multiwell plate
- 

  - "A stage top incubator for high-throughput live cell imaging on inverted microscopes, with precise temperature regulation, active humidity control, and CO2 regulation
  - Easy installation on inverted microscopes that have a K-frame fitting (160 mm x 110 mm)
  - Ideal for long-term physiologic assays on the microscope: no evaporation due to precise, feedback-controlled humidity regulation
  - Optimal heat distribution and no condensation in the Incubation Chamber
  - Ideal for high-throughput live cell imaging in multiwell plates using motorized stages"
- Price not listed, need to get a quote... --> very very expensive
  - Online estimates ~ $18,000
- THIS IS VERY SIMILAR TO OUR PROJECT

Conclusions/action items:

- Our design is needed
- Current incubators on market far too expensive

1/30/23 - Google Sheets Data Streamer/Arduino Pairing

Drew Hardwick - Feb 01, 2023, 9:24 AM CST

Title: Google Sheets Data Streamer/Arduino Pairing

Date: 1/30/23

Content by: Drew

Present: Drew and Katie

Goals: Figure out a way to stream data live from Arduino to google sheets for better data monitoring during live cell testing

Content:

- Katie and I are trying to find a way to implement an Arduino sketch that sends data direct to google sheets

Attempt 1:

https://www.survivingwithandroid.com/integrate-arduino-google-sheets-iot-project/

- IoT (aka Internet of things) is one of the most important technological trends nowadays.
-
    - The purpose of this project is to build a cloud data logger that records the temperature and humidity and stores these values into the Google cloud platform using *Google sheet*.
- Use Temboo to accomplish this:
    - Temboo = IoT cloud platform that provides several integration services that simplify the process of integrating different systems.
- We ran into issues during first step using the *OAuth2 mechanism.*
    - We could not find the *Client ID* and *Secret key,* and the Google Developer Console was having us create our own webpage, so we decided to switch to another, hopefully simpler tutorial and return to this one if needed

Attempt 2:

https://iotdesignpro.com/articles/esp32-data-logging-to-google-sheets-with-google-scripts

- Nowadays many household appliances are IoT-enabled from light bulbs to washing machines. Even though we may be able to control them over the local area network easily but to control them or store and retrieve their data over the internet, we must use an IoT cloud service
- There are plenty of different IoT cloud services and protocols available but these services are limited in one way or another. Some are free, while others are paid
    - The free services will have a limit on how much data you can collect at a time or how many devices you can attach at a time
    - With the paid services, you have to pay a large sum depending on your data cluster
    - This will not only be a huge financial burden but if you develop a product that depends on a particular third-party service, that will be a huge risk.
- Benefits of using Google Sheets for IoT applications:
    - Data Logging is pretty simple and robust and doesn't need any third-party services.
    - Easy manipulation and analysis of collected data with functions.
    - Supports both desktop and mobile access.
    - Easy to use custom sheet functions and google apps integration through Google scripts.
    - Conditional formatting will make the data monitoring and analysis much easier.
- Setup:
    - Make new google sheet w/ column titles 1 word, no spaces no caps
    - take note of sheet name and sheet ID
        - https://docs.google.com/spreadsheets/d/**1BdQzuTeYr4Tf4zwT-LP1f45rfk63oWZTrQ_cIDfgWfgD**/edit#gid=0
    - Create Google Script
        - See link for specific details
    - Copy Paste Arduino Code from link and make specific edits
- Code Breakdown:
    - ```
      //Include required libraries
      #include "WiFi.h"
      #include <HTTPClient.h>
      #include "time.h"
      ```
        - Includes required libraries
        - PROBLEM FOR US - OUR ARDUINO DOES NOT HAVE THESE LIBRARIES
      ```

- ```
  const char* ntpServer = "pool.ntp.org";
  const long  gmtOffset_sec = 19800;
  const int   daylightOffset_sec = 0;
  ```
  - declare preferred NTP server and GMT time offset
- ```
  // WiFi credentials
  const char* ssid = "Your WiFi SSID";         // change SSID
  const char* password = "Your WiFi password";    // change password
  // Google script ID and required credentials
  String GOOGLE_SCRIPT_ID = "AKfycby-snBh-5j0jsiQBWfC-xxxxxxxxxxxxxxxxxxxxxxxxxxxxx-
  Wv9EcA6a";    // change Gscript ID with yours
  int count = 0;
  ```
  - declare WiFi credientials
  - PROBLEM FOR US - WHAT IS UW NET WIFI PASSWORD - ASK DR. NIMUNKAR
- ```
  void setup() {
    delay(1000);
    Serial.begin(115200);
    delay(1000);
    // connect to WiFi
    Serial.println();
    Serial.print("Connecting to wifi: ");
    Serial.println(ssid);
    Serial.flush();
    WiFi.begin(ssid, password);
    while (WiFi.status() != WL_CONNECTED) {
      delay(500);
      Serial.print(".");
    }  // Init and get the time
    configTime(gmtOffset_sec, daylightOffset_sec, ntpServer);
  }
  ```
  - The setup() function will initialize the serial communication and will establish the WiFi connection with the credentials we have already added. It will also initialize an instance named configTime for grabbing the time from the NTP server.
- ```
  void loop() {
     if (WiFi.status() == WL_CONNECTED) {
      static bool flag = false;
      struct tm timeinfo;
      if (!getLocalTime(&timeinfo)) {
        Serial.println("Failed to obtain time");
        return;
      }
      char timeStringBuff[50]; //50 chars should be enough
      strftime(timeStringBuff, sizeof(timeStringBuff), "%A, %B %d %Y %H:%M:%S",
  &timeinfo);
      String asString(timeStringBuff);
      asString.replace(" ", "-");
      Serial.print("Time:");
      Serial.println(asString);
      String urlFinal =
  "https://script.google.com/macros/s/"+GOOGLE_SCRIPT_ID+"/exec?"+"date=" + asString +
  "&sensor=" + String(count);
      Serial.print("POST data to spreadsheet:");
      Serial.println(urlFinal);
      HTTPClient http;
      http.begin(urlFinal.c_str());
      http.setFollowRedirects(HTTPC_STRICT_FOLLOW_REDIRECTS);
      int httpCode = http.GET();
      Serial.print("HTTP Status Code: ");
      Serial.println(httpCode);
      //---------------------------------------------------------------------
      //getting response from google sheet
      String payload;
      if (httpCode > 0) {
          payload = http.getString();
  ```

```
            Serial.println("Payload: "+payload);
          }
          //---------------------------------------------------------------------
          http.end();
        }
        count++;
        delay(1000);
      }
```

        - In the loop function, if the WiFi connection is active the ESP32 will grab the time from the NTP server
        - Then it will assemble this grabbed time info and the value of the variable count into a URL along with the Google Script ID
        - After that, the ESP32 will establish an HTTP connection to this URL with the help of the HTPPClient library
        - Once the connection is established, the ESP32 will print out the HTTP status code
        - Meanwhile, Google Scripts will grab the data from this HTTP request and it will POST the data to the Google Sheets
        - Then a one-second delay is added and the count is increased. The process will repeat and the time and the variable value will be posted to the Google Sheets continuously.
- This Option had its issues as well, mainly the Wifi and libraries, but I think we are close with a little help
- Will update in further entires:

Conclusions/action items:

- Still need to accomplish this - hopefully sooner rather than later so that live testing can go smoothly when we are ready for that
- Ask Dr. Nimunkar for advice/input at either I2C meeting this week or at advisor meeting

2/1/23 - Initial Display Research

Drew Hardwick - Feb 01, 2023, 9:49 AM CST

Title: Initial Display Research

Date: 2/1/23

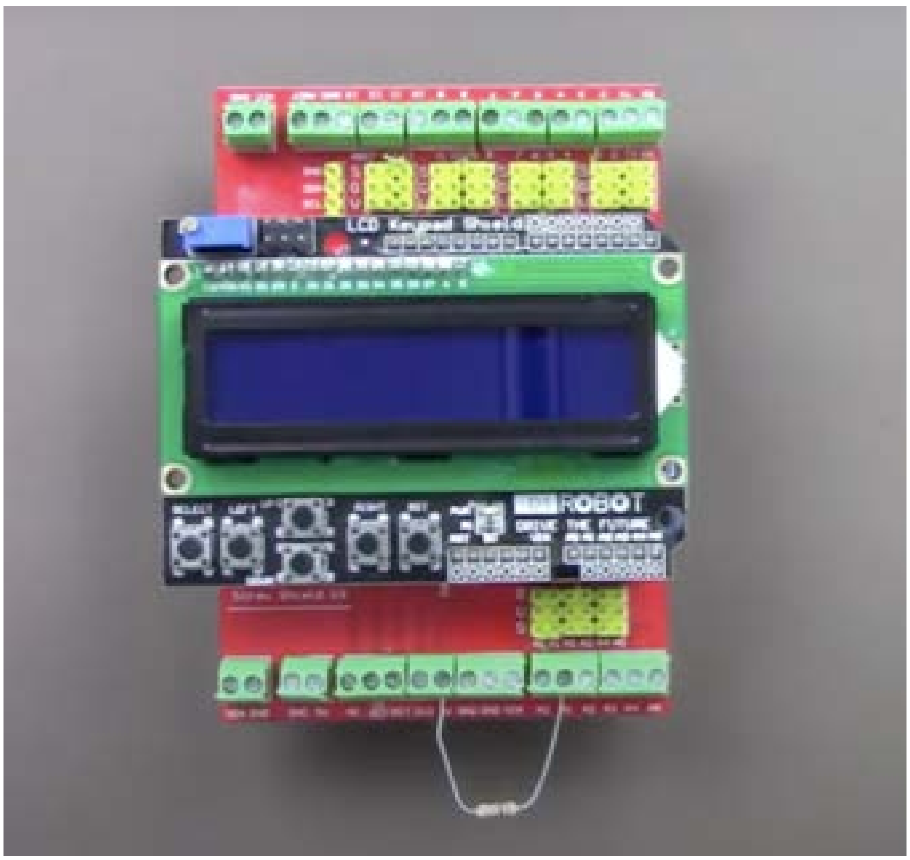
Content by: Drew

Present: N/A

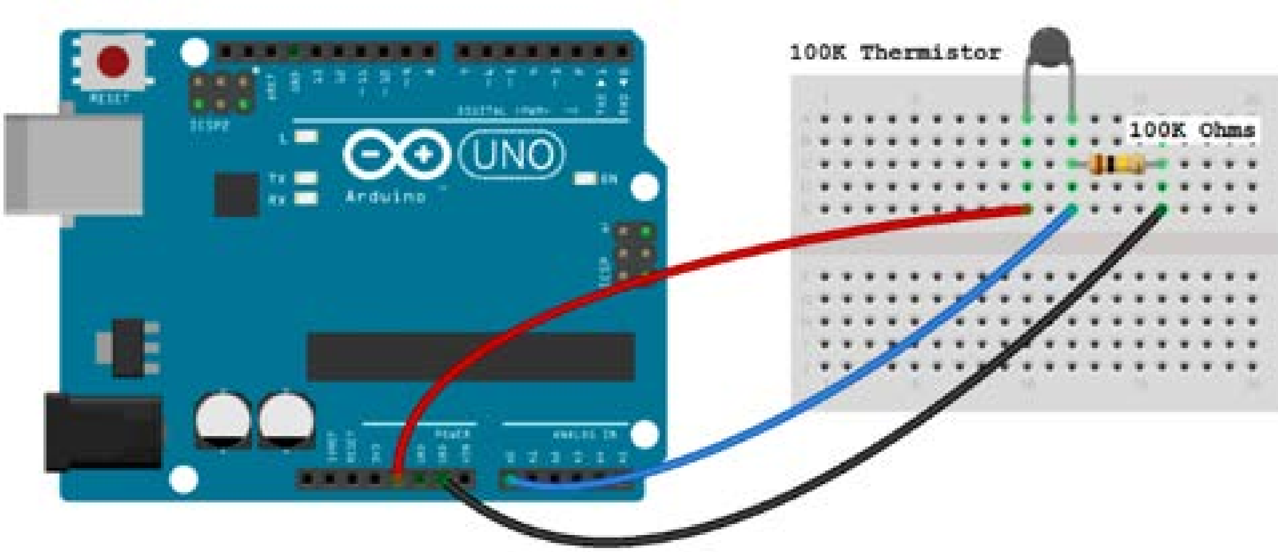
Goals: Find/research a good method to implement a display feature into our design

Content:

https://www.youtube.com/watch?v=Xjiztb7d3IQ

- NTC Thermistor - semiconductor, resistance changes with temp
- Parts:
  - Arduino uno
  - Arduino uno LED display (~$5)
  - Screw Shield (for easy wiring) (~$10)
  - 10kOhm Resistor
  - NTC Thermistor
  - Wires
- Add Screw Shields to Arduino Uno
- Add LED Display on top
- 10k Resisitor Across 5V and A1
- 
- Connect thermistor to ground and A1
- Download Arduino File from https://solarduino.com/how-to-use-ntc-thermistor-to-measure-temperature/

OR (no screw shield)



- Code should be able to be modified to include humidity display, and also similar process for NDIR Sensor

Conclusions/action items:

- Review findings with team and advisor
- Purchase parts needed

2/3/23 - Continued Display Research

Drew Hardwick - Feb 03, 2023, 2:05 PM CST

Title: Display Research

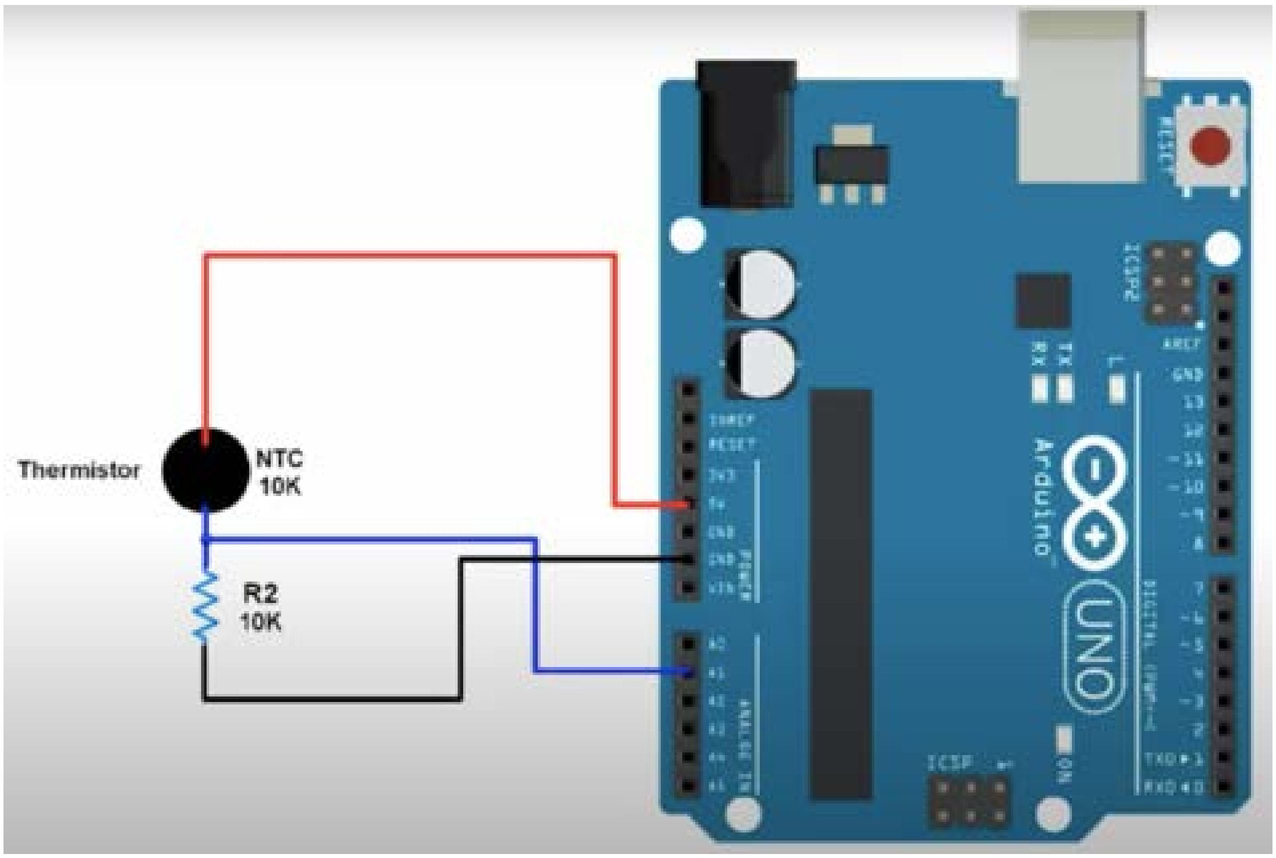
Date: 2/3/23

Content by: Drew

Present: N/A

Goals: Keep finding ways to implement display

Content:



- https://www.youtube.com/watch?v=JmCpjAqToUA
- Use resistor with same resistance as thermistor
- i2c LCD display = gnd, vcc, a4, a5 pins
-

Conclusions/action items:

Drew Hardwick - Feb 03, 2023, 2:05 PM CST

Download

Thermistor_LCD.ino (849 B)

2/5/23 - LCD vs I2C LCD Display Research

Drew Hardwick - Feb 05, 2023, 4:46 PM CST

Title: LCD vs I2C LCD Display Research

Date: 2/5/23

Content by: Drew

Present: N/A

Goals: Determine which type of display to use

Content:

- 2 display options:
- LCD Display ($3.19): https://www.banggood.com/Geekcreit-1602-Character-LCD-Display-Module-Yellow-Backlight-Geekcreit-for-Arduino-products-that-work-with-official-Arduino-boards-p-978155.html?imageAb=2&p=LU070313923481201709&akmClientCountry=America&cur_warehouse=CN
- I2C LCD Display ($19.99): https://usa.banggood.com/5Pcs-Geekcreit-IIC-I2C-1602-Blue-Backlight-LCD-Display-Screen-Module-For-Arduino-p-962346.html?imageAb=2&p=LU070313923481201709&akmClientCountry=America&a=1675635974.7203&akmClientCountry=America&cur_warehouse=CN
- I2C supposedly runs smoother and is easier to set up/run then regular LCD - Further research below:
    - https://lastminuteengineers.com/i2c-lcd-arduino-tutorial/
    - If you've ever tried to connect an LCD display to an Arduino, you might have noticed that it consumes a lot of pins on the Arduino. Even in 4-bit mode, the Arduino still requires a total of seven connections – which is half of the Arduino's available digital I/O pins.
        - Also requires potentiometer use to dim LCD brightness
    - The solution is to use an I2C LCD display. It consumes only two I/O pins that are not even part of the set of digital I/O pins and can be shared with other I2C devices as well.
        - Much easier, takes up less space/wires/connections
        - Can run with 2 devices (i.e. both thermistor and NDIR can report values)
        - How to pair multiple devices: https://www.youtube.com/watch?v=OD3pu1OAnjs
    - The team thinks it makes sense to spend a little more money and purchase the more technically advanced display screen that can accomplish what we need of it with (hopefully) low effort
    - We will purchase $20 I2C LCD display from link above.

Conclusions/action items:

- Purchase I2C LCD Display from here: https://usa.banggood.com/5Pcs-Geekcreit-IIC-I2C-1602-Blue-Backlight-LCD-Display-Screen-Module-For-Arduino-p-962346.html?imageAb=2&p=LU070313923481201709&akmClientCountry=America&a=1675635974.7203&akmClientCountry=America&cur_warehouse=CN

2/1/23 - CO2 Redesign

Drew Hardwick - Feb 01, 2023, 1:56 PM CST

Title: CO2 Redesign

Date: 2/1/23

Content by: Drew

Present: Drew and Katie

Goals: Meet with Dr. Nimunkar to go over our CO2 regulatory system

Content:

- Reviewed Data sheets for sandbox NDIR MH-Z16 CO2 sensor and determined viability of sensor
  - Data Sheet: https://sandboxelectronics.com/wp-content/uploads/2018/08/Z16DS.pdf
  - After reviewing data sheet we determined that the AnalogRead() function should be sufficient in our case, and we should not have to establish I2C as previously thought!!!!!
- Refined Current CO2 sensing code, and then tested withe Multimeter to ensure sensor was reading in atmosphere which it was (0ppm)
  - This makes sense since ppm reading is set to integers, so very hard to make atmosphere of entire room reach 1ppm CO2
- Next we moved on to looking at Beefcake Relay and Solenoid Valve.
- Tested Solenoid on Multimeter and wall outlet to ensure required 12V being supplied, which it was for both
- We then connected the entire system and took a look at the Arduino code
  - For some reason, our code last semester was out of order, and simple changes and suggestions from a more experienced microcontroller user like Dr. Nimunkar was greatly helpful.
- Our System finally works all from 1 microcontroller, and if statement should be able to me modified to be adaptive to incubator environment
- Katie and I went back to lab to fiddle with If statement after our meeting with Dr. Nimunkar concluded
- We determined that even after blowing direct CO2 from the tank/solenoid on the NDIR sensor, sensor communication error is what resulted
- We believe that we need to purchase a new NDIR MH-Z16 sensor to avoid this and continue with accurate CO2 regulation
  - Current sensor is AT LEAST 2-3 years (maybe more) old, and it has been used by our team and other teams in the past
  - Its inaccuracy is likely a signal it is time for replacement
  - We will buy the exact same sensor that we currently have, just a newer model.
- Link for new NDIR sensor (~$70): https://sandboxelectronics.com/?product=mh-z16-ndir-co2-sensor-with-i2cuart-5v3-3v-interface-for-arduinoraspeberry-pi

Conclusions/action items:

- Order new NDIR, and test CO2 reading ASAP when it arrives

2/8/23 - ITO Glass

Drew Hardwick - Feb 08, 2023, 11:04 PM CST

Title: ITO Glass Research

Date: 2/8/23

Content by: Drew

Present: N/A

Goals: Research Potential use of ITO Glass

Content:

ITO Glass: Indium Tin Oxide

- Recommended to produce at Chemisty Department glass lab by Dr. Puccinelli
- Upon email, ITO is not something that they are able to produce.
- do have the capability to cut ITO coated sheet glass if we purchase in sheets
- Professor Bob Hamers group in the chemistry department has the capability to put thin coatings onto substrates.
    - For further information reach out to rjhamers@wisc.edu

Facts:

- An ITO glass is conductive glass that has a property of low sheet resistance and high transmittance
- It is mostly used in research and development
- ITO coated glass substrates are widely used to organic/inorganic heterojunction solar cells, Schottky solar cells, CdTe solar cells and other various thin film solar cells as transparent semiconductor oxide electrode materials since their transparency and high conductivity.

- Specified ITO Sheet resistivity – (~10 ohms/sq), (~20 ohms/sq) & (~100 ohms/sq)
- Typical ITO Sheet resistivity – (8-11 ohms/sq), (18-20 ohms/sq) & (90-100 ohms/sq)
- Transmittance at 550nm – ≥ 87%

- ITO film Thickness – (1800-2000 Å), (1400-1500 Å) & (500-600 Å)
- Electrically conductive and optically transparent coating
- High physical density of coating
- Low specific electrical resistance
- High environmental and temperature stability
- Excellent electrical conductivity and optical transparency
- Coating uniformity
- Capability to shield Electromagnetic Fields
- Can be deposited into thin film
- Low electrical resistance
- Thermally and chemically stable
- Highly degenerate behavior

Conclusions/action items:

- Viable method, but expensive glass, other methods of heating glass preferred
- Glass Sheets also very small - not going to be able to find affordably priced glass that is large enough for our purpose
- Research other potential options

References:

https://www.techinstro.com/ito-coated-glass/

2/9/23 - Alphanumeric Display Setup

Drew Hardwick - Feb 09, 2023, 8:16 AM CST

Title: Qwiic Alphanumeric Display Setup

Date: 8/9/23

Content by: Drew

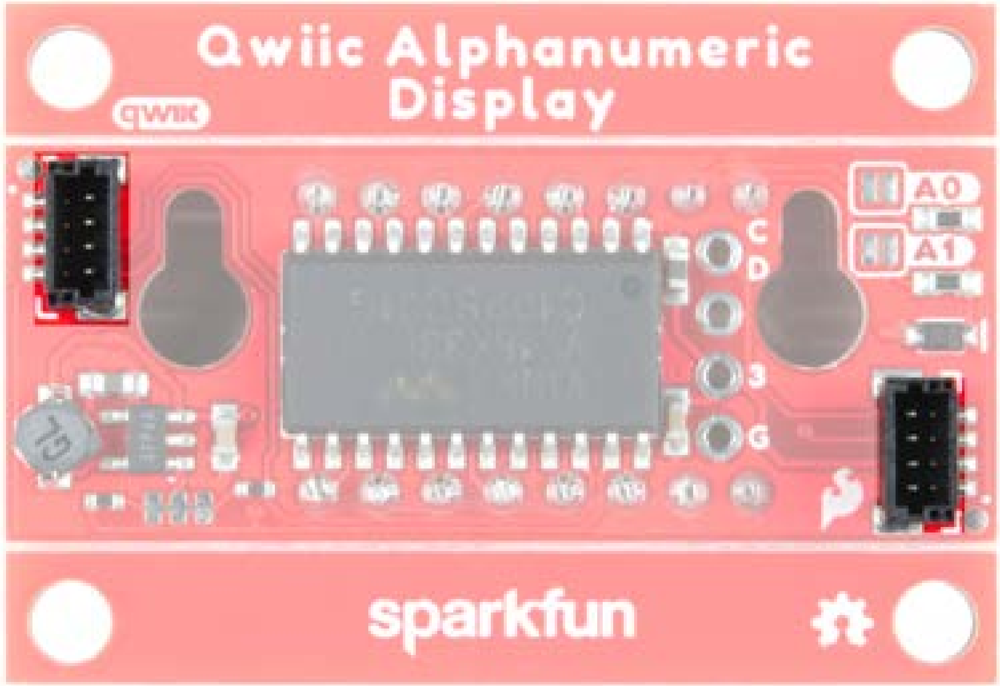
Present: N/A

Goals: Develop better understanding how to setup/run alphanumeric display from arduino

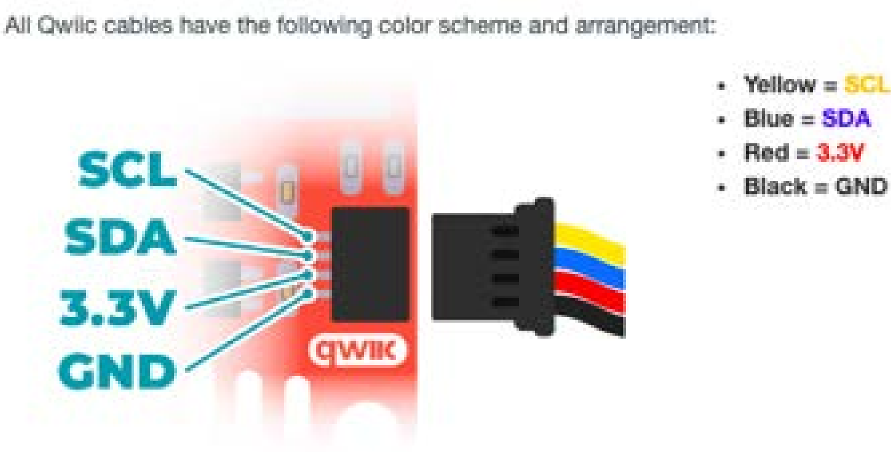
Content:

- SparkFun's Qwiic Connect System uses 4-pin JST connectors to quickly interface development boards with sensors, LCDs, relays and more.
- FRONT:

- BACK:



- QWIIC CABLES:



- No Qwiic adaptor on our arduino, will need to purchase Sparkfun Qwiic Female Adaptor ($1.60) to connect to our arduino
- Qwiic only supports 3.3V boards right now - will work to plug into just 3.3V port of our arduino (? Ask Dr. Nimunkar)
- Need to install Arduino Alphanumeric Display library from this link
- Coding examples here and here

Conclusions/action items:

- Need to purchase adaptors and mess around
- Should be able to print out numbers for CO2 on One display, and Temp on other
- Need to ask Dr. Nimunkar: 2 arduinos for 2 3.3V and 2 displays? or run from 1?

References:

- https://www.sparkfun.com/qwiic?_ga=2.213072276.181714229.1675915119-582562771.1675280861&_gac=1.250185204.1675915119.CjwKCAiArY2fBhB9EiwAWqHK6l3Jz0XyHx9itLzwLf3xYBd4x571F2l4hle-fRUgFxPkhjR9N16_HBoCEHMQAvD_BwE

3/3/23 - CO2 Display Code

Drew Hardwick - Mar 03, 2023, 10:00 AM CST

Title: CO2 Display Code

Date: 3/3/23

Content by: Drew

Present: N/A

Goals: Edit current code to display CO2 when the system is tested and ready for implementation

Content:

```
/* Serial 7-Segment Display Example Code

  SPI Mode Stopwatch
 by: Jim Lindblom
   SparkFun Electronics
 date: November 27, 2012
 license: This code is public domain.

 This example code shows how you could use the Arduino SPI
 library to interface with a Serial 7-Segment Display.

 There are example functions for setting the display's
 brightness, decimals and clearing the display.

 The SPI.transfer() function is used to send a byte of the
 SPI wires. Notice that each SPI transfer(s) is prefaced by
 writing the SS pin LOW and closed by writing it HIGH.

 Each of the custom functions handle the ssPin writes as well
 as the SPI.transfer()'s.

 There's a custom function used to send a sequence of bytes
 over SPI - s7sSendStringSPI, which can be used somewhat like
 the serial print statements.

 Circuit:
 Arduino -------------- Serial 7-Segment
   5V   --------------------  VCC
   GND  --------------------  GND
    8   --------------------  SS
   11   --------------------  SDI
   13   --------------------  SCK
*/
#include <SPI.h> // Include the Arduino SPI library

// Define the SS pin
//  This is the only pin we can move around to any available
//  digital pin.
const int ssPin = 8;

unsigned int counter = 0;  // This variable will count up to 65k
char tempString[10];  // Will be used with sprintf to create strings

//temp
int sensorPin = A0;    // select the input pin for the potentiometer
int ledPin = 13;      // select the pin for the LED
int sensorValue = 0;  // variable to store the value coming from the sensor
float volt_conversion = 5.0/1023.0;
float ADC_voltage = 0;
float K_temperature = 0;
```

```
float C_temp;
void setup()
{
  // -------- SPI initialization
  pinMode(ssPin, OUTPUT);  // Set the SS pin as an output
  digitalWrite(ssPin, HIGH);  // Set the SS pin HIGH
  SPI.begin();  // Begin SPI hardware
  SPI.setClockDivider(SPI_CLOCK_DIV64);  // Slow down SPI clock
  // --------

  // Clear the display, and then turn on all segments and decimals
  clearDisplaySPI();  // Clears display, resets cursor

  // Custom function to send four bytes via SPI
  //  The SPI.transfer function only allows sending of a single
  //  byte at a time.
  s7sSendStringSPI("DEGC");
  setDecimalsSPI(0b11111);  // Turn on all decimals, colon, apos

  // Flash brightness values at the beginning
  setBrightnessSPI(0);  // Lowest brightness
  delay(1500);
  setBrightnessSPI(255);  // High brightness
  delay(1500);

  // Clear the display before jumping into loop
  clearDisplaySPI();
}

void loop()
{

  // Magical sprintf creates a string for us to send to the s7s.
  //  The %4d option creates a 4-digit integer.
 // read the value from the sensor:
  sensorValue = analogRead(sensorPin);
  ADC_voltage = sensorValue * (volt_conversion);
  K_temperature = (ADC_voltage - 0.205) / 0.0153;
  C_temp = K_temperature - 91;
  counter = C_temp*100;
  sprintf(tempString, "%4d", counter);
  // This will output the tempString to the S7S
  s7sSendStringSPI(tempString);

  // Print the decimal at the proper spot
  if (counter < 10000)
    setDecimalsSPI(0b00000010);  // Sets digit 3 decimal on
  else
    setDecimalsSPI(0b00000100);

  counter++;  // Increment the counter
  delay(1000);  // This will make the display update at 100Hz.*/
}

// This custom function works somewhat like a serial.print.
//  You can send it an array of chars (string) and it'll print
//  the first 4 characters in the array.
void s7sSendStringSPI(String toSend)
{
  digitalWrite(ssPin, LOW);
  for (int i=0; i<4; i++)
  {
    SPI.transfer(toSend[i]);
  }
```

```
  digitalWrite(ssPin, HIGH);
}

// Send the clear display command (0x76)
//  This will clear the display and reset the cursor
void clearDisplaySPI()
{
  digitalWrite(ssPin, LOW);
  SPI.transfer(0x76);  // Clear display command
  digitalWrite(ssPin, HIGH);
}

// Set the displays brightness. Should receive byte with the value
//  to set the brightness to
//  dimmest------------->brightest
//     0--------127--------255
void setBrightnessSPI(byte value)
{
  digitalWrite(ssPin, LOW);
  SPI.transfer(0x7A);  // Set brightness command byte
  SPI.transfer(value);  // brightness data byte
  digitalWrite(ssPin, HIGH);
}

// Turn on any, none, or all of the decimals.
//  The six lowest bits in the decimals parameter sets a decimal
//  (or colon, or apostrophe) on or off. A 1 indicates on, 0 off.
//  [MSB] (X)(X)(Apos)(Colon)(Digit 4)(Digit 3)(Digit2)(Digit1)
void setDecimalsSPI(byte decimals)
{
  digitalWrite(ssPin, LOW);
  SPI.transfer(0x77);
  SPI.transfer(decimals);
  digitalWrite(ssPin, HIGH);
}
```

Conclusions/action items:

Requires more testing, but this should be a solid start, if not work outright - Speak with Nimunkar about coding, and test in lab.

2/17/23 - Display Fabrication

Drew Hardwick - Feb 20, 2023, 12:24 PM CST

Title: Display Fabrication

Date: 2/15/23 & 2/17/23

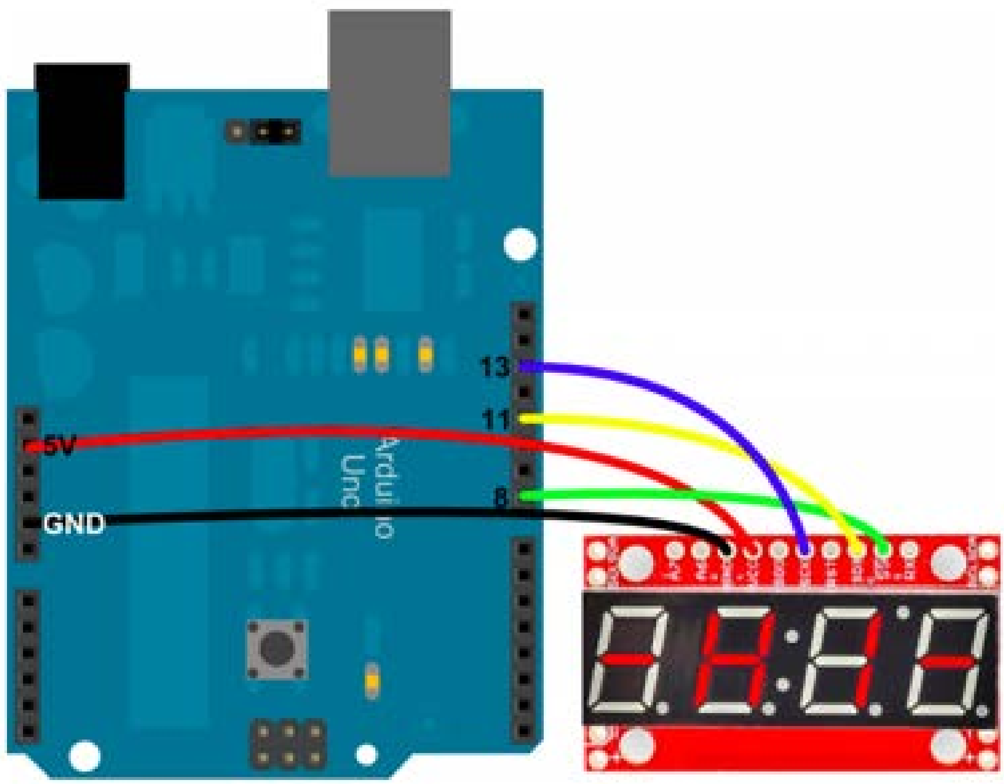
Content by: Katie Day, Drew Hardwick

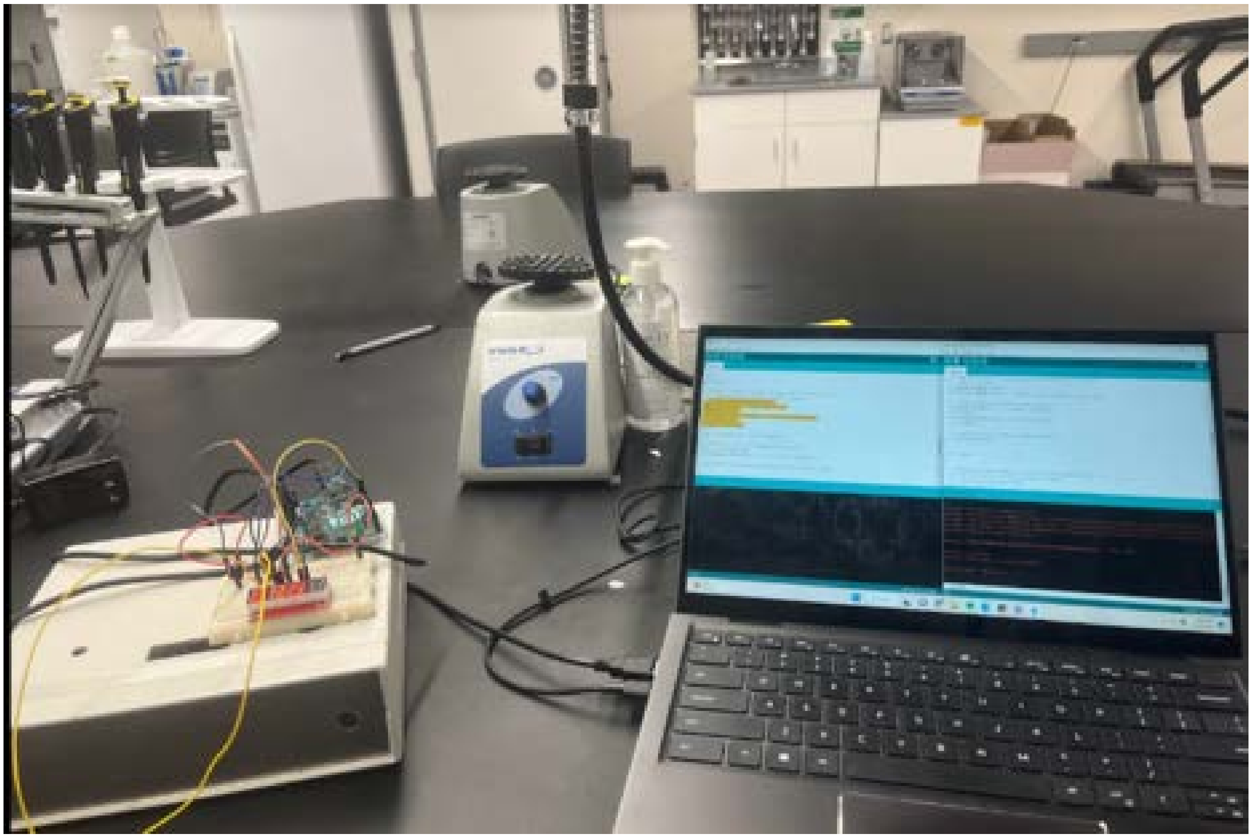
Present: Drew Hardwick, Katie Day

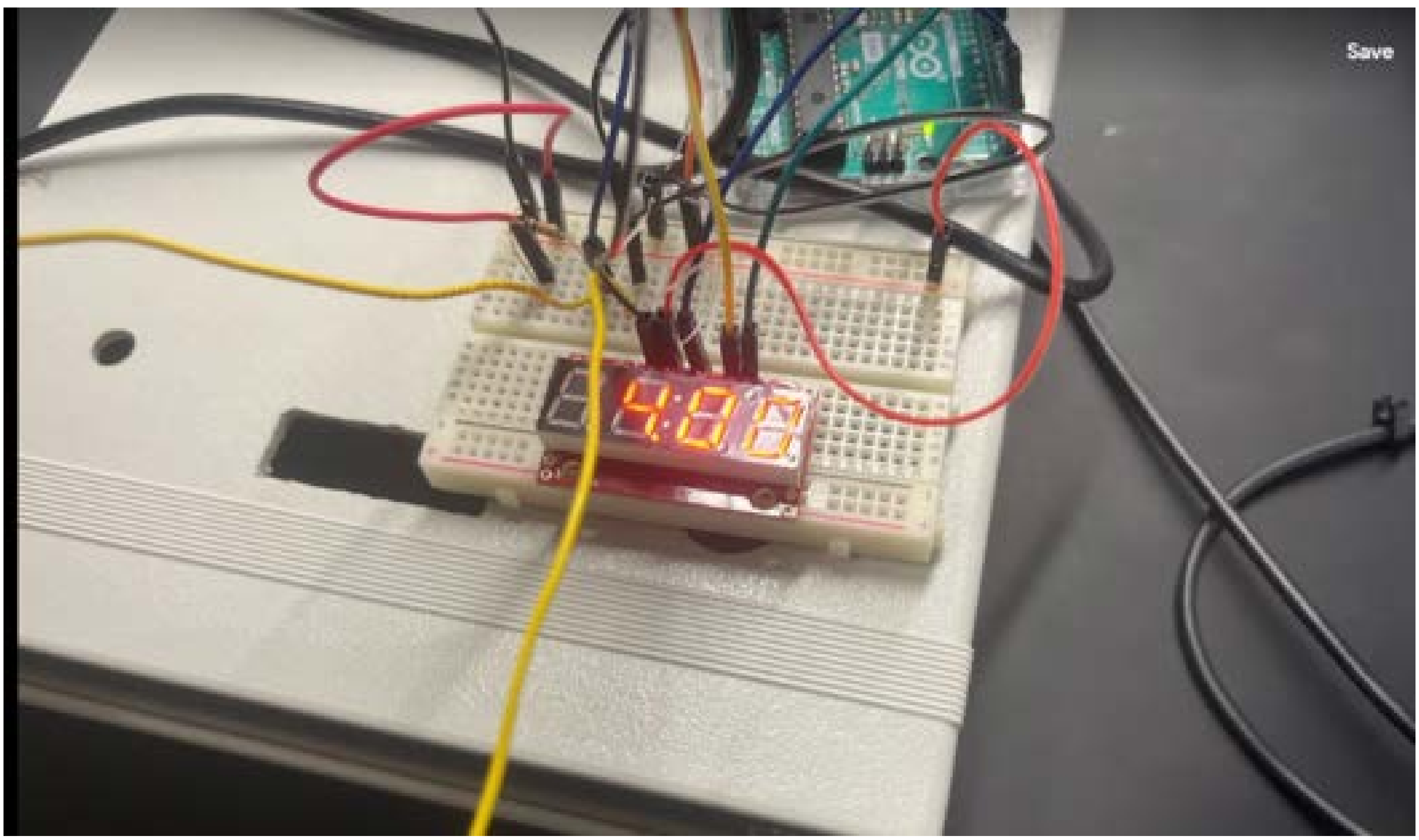
Goals: To code the display to show thermistor values.

Content:

Hardware Setup:







Code:

```
/* Serial 7-Segment Display Example Code
    SPI Mode Stopwatch
   by: Jim Lindblom
     SparkFun Electronics
   date: November 27, 2012
   license: This code is public domain.
```

```
  This example code shows how you could use the Arduino SPI
  library to interface with a Serial 7-Segment Display.

  There are example functions for setting the display's
  brightness, decimals and clearing the display.

  The SPI.transfer() function is used to send a byte of the
  SPI wires. Notice that each SPI transfer(s) is prefaced by
  writing the SS pin LOW and closed by writing it HIGH.

  Each of the custom functions handle the ssPin writes as well
  as the SPI.transfer()'s.

  There's a custom function used to send a sequence of bytes
  over SPI - s7sSendStringSPI, which can be used somewhat like
  the serial print statements.

  Circuit:
  Arduino -------------- Serial 7-Segment
    5V   --------------------  VCC
    GND  --------------------  GND
     8   --------------------  SS
    11   --------------------  SDI
    13   --------------------  SCK
*/
#include <SPI.h> // Include the Arduino SPI library

// Define the SS pin
//  This is the only pin we can move around to any available
//  digital pin.
const int ssPin = 8;

unsigned int counter = 0;  // This variable will count up to 65k
char tempString[10];  // Will be used with sprintf to create strings

//temp
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;
void setup()
{
  // -------- SPI initialization
  pinMode(ssPin, OUTPUT);  // Set the SS pin as an output
  digitalWrite(ssPin, HIGH);  // Set the SS pin HIGH
  SPI.begin();  // Begin SPI hardware
  SPI.setClockDivider(SPI_CLOCK_DIV64);  // Slow down SPI clock
  // --------

  // Clear the display, and then turn on all segments and decimals
  clearDisplaySPI();  // Clears display, resets cursor

  // Custom function to send four bytes via SPI
  //  The SPI.transfer function only allows sending of a single
  //  byte at a time.
  s7sSendStringSPI("DEGC");
  setDecimalsSPI(0b11111);  // Turn on all decimals, colon, apos

  // Flash brightness values at the beginning
  setBrightnessSPI(0);  // Lowest brightness
  delay(1500);
  setBrightnessSPI(255);  // High brightness
  delay(1500);

  // Clear the display before jumping into loop
  clearDisplaySPI();
}

void loop()
{
```

```
  // Magical sprintf creates a string for us to send to the s7s.
  //  The %4d option creates a 4-digit integer.
  Vo = analogRead(ThermistorPin);
  R2 = R1 * (1023.0 / (float)Vo - 1.0);
  logR2 = log(R2);
  T = (1.0 / (c1 + c2*logR2 + c3*logR2*logR2*logR2));
  int Tc = T-251;
  counter = Tc*100;
  sprintf(tempString, "%4d", counter);
  // This will output the tempString to the S7S
  s7sSendStringSPI(tempString);

  // Print the decimal at the proper spot
  if (counter < 10000)
    setDecimalsSPI(0b00000010);  // Sets digit 3 decimal on
  else
    setDecimalsSPI(0b00000100);

  counter++;  // Increment the counter
  delay(100);  // This will make the display update at 100Hz.*/
}

// This custom function works somewhat like a serial.print.
//  You can send it an array of chars (string) and it'll print
//  the first 4 characters in the array.
void s7sSendStringSPI(String toSend)
{
  digitalWrite(ssPin, LOW);
  for (int i=0; i<4; i++)
  {
    SPI.transfer(toSend[i]);
  }
  digitalWrite(ssPin, HIGH);
}

// Send the clear display command (0x76)
//  This will clear the display and reset the cursor
void clearDisplaySPI()
{
  digitalWrite(ssPin, LOW);
  SPI.transfer(0x76);  // Clear display command
  digitalWrite(ssPin, HIGH);
}

// Set the displays brightness. Should receive byte with the value
//  to set the brightness to
//  dimmest------------->brightest
//     0--------127--------255
void setBrightnessSPI(byte value)
{
  digitalWrite(ssPin, LOW);
  SPI.transfer(0x7A);  // Set brightness command byte
  SPI.transfer(value);  // brightness data byte
  digitalWrite(ssPin, HIGH);
}

// Turn on any, none, or all of the decimals.
//  The six lowest bits in the decimals parameter sets a decimal
//  (or colon, or apostrophe) on or off. A 1 indicates on, 0 off.
//  [MSB] (X)(X)(Apos)(Colon)(Digit 4)(Digit 3)(Digit2)(Digit1)
void setDecimalsSPI(byte decimals)
{
  digitalWrite(ssPin, LOW);
  SPI.transfer(0x77);
  SPI.transfer(decimals);
  digitalWrite(ssPin, HIGH);
}
```

Conclusions/action items:

- Display was able to show the temperature values. Thermistor should be recalibrated just for accuracy. Issues with temp value changing? Show Dr. Nimunkar in advisor meeting.

Team Fabrication

Drew Hardwick - May 02, 2023, 9:05 AM CDT

Title: Fabrication

Date: 5/2/23

Content by: Drew

Present: N/A

Goals: N/A

Content:

- **SEE TEAM NOTEBOOK FOR FURTHER FABRICATION DETAILS**

Conclusions/action items:

N/A

3/24/23 - Microscope Use Research

Drew Hardwick - Mar 27, 2023, 2:37 PM CDT

Title: Microscope Use Research

Date: 3/24/23

Content by: Drew Hardwick

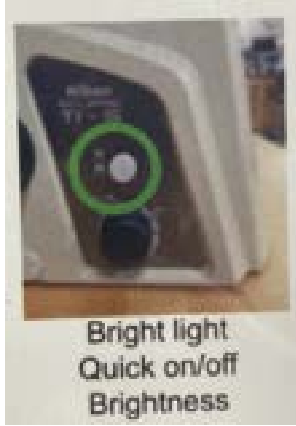
Present: N/A

Goals: Understand how to image and use more complex microscope in BME Teaching Lab

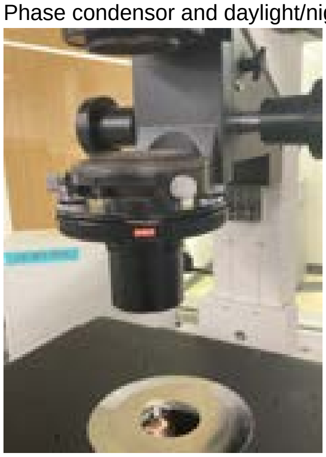
Content:

- Live cell testing has been delayed while waiting on cells to become more viable/be replenished
- Dr. P. warned the team that during the week of 3/27 - 3/31 BME 201 will be using the lab microscopes we have been using
- The larger, more complex microscopes by the MTS machines might still be available for our use, so I am attempting to learn how to properly image and use these microscopes
- Ziess Axiovert Microscope:

- 
- 
- NO FLUORESCENT IMAGING REQUIRED
  - Although Microscope can do both, just use inverted imaging capabilities.
- STEPS:
- Log into computer with user info
- Turn on switches below:



- Open "NIS - Elements" on computer desktop, and check "BF" for bright field under advanced
- Use Dials on right side of microscope to focus image
- Select "Capture" to take image
- Take screen shot, or save image and place into the drive
- Turn off all switches and power down computer.

- Microscope Facts:
  - Camera port included with microscope, but camera itself must be added/purchased seperately
  - Phase condensor and daylight/nightlight filter are installed:
  - 
  - Stage mounting plate controlled by side dial - 2 DOF

- 
- Light intensity knob + on/off on left side
- **Main Features:**
  - Mounting Frame on Stage is able to hold a 65mm petri dish as well as a standard glass slide 25x75mm.
  - XY stage slider movement.
  - Six-place objective nosepiece.
  - Light path selector - Camera - Eyepieces.Two positions.100% to eyepieces or 70% to photo port and 30% to eyepieces.
  - Ability to shut out extraneous light from the eyepieces that may enter the camera optics.
  - Eyepieces: Pl 10x/20 High Eyepoint with ability to use eyeglasses when viewing. Note these are the better field of view 20mm instead of the cheaper 18mm.
  - Includes rubber cupping eyeguards for cutting out light from the room, important for viewing low illumination fluorescing.
  - Included all needed power cords.
  - DOES NOT INCLUDE CAMERA OR LAPTOP. Camera is shown in images to demonstrate that one can be connected.
  - Includes original Zeiss C-mount adapter for attaching a camera.

Fluorescent Illumination - Rear Light System:

- HBO 100 Lamp Housing and External Power Supply for included 100W Mercury Bulb.
- Luminous Field Iris Diaphragm on epifluorescence light path.
- Filter slider / shutter for epifluorescence. Has ND filter installed. This can be used when the full intensity of the 100W bulb is not needed. Full intensity will increase autofluorescence and bleach your probes faster. Has two other empty slots capable of holding other ND filters. Pushed all the way to the side will engage the shutter to block all light.
- Open filter slot for holding loose exciter filters, 32mm diameter.

Transmitted Light - Upper Light System:

- 12V-100W Halogen.
- Transformer is built into the main frame and not an external unit.
- Rotary Turret style light Condenser with phase contrast settings.
- Numerical Aperature. 0.3 N.A.
- Settings for: Ph1, Ph2, Brightfield. With iris diaphragm.With centering ability.
- Compare this higher grade transmitted light system to the cheaper version that is 6V-20W and with a simple phase slider bar.
- Daylight blue compensation filter. Plus one empty filter slot that could be used for an optional Interference Green filter.

Objective Lenses:

- AchroPlan, 4x/0.10, Infinity/-. Part# 440020. (some text lettering is worn off)
- AchroPlan 10x/0.25 Ph1, Infinity/-. Part#440031.
- LD AchroPlan 20x/0.40, Korr, Ph2, Infinity/0-1.5. Part#440845
- LD AchroPlan 40x/0.60, Korr, Infinity/0-2.Ph2. Part#440865.

Fluorescence Dichroic Filters:

- Filter Slider with three settings:
- UV: Ex. 360/40. (no visible wear). (tested great)
- Blue: Ex. 450-490 (no visible wear). (tested great)
- Green: Ex. 545/30 (significant wear). (tested great)
- There is no open space for Brightfield and Phase Contrast Observation. So to view those, you need to pull out the slider tray. You could also remove one filter set and that be your setting for brightfield and phase.

Comments:

- This microscope is in great condition.
- We are including a phase centering telescope for viewing alignment of phase annulus in condenser with phase ring in objective. We are also including the needed tools for centering the phase annulus.

Quality:

- This is a high quality Zeiss (Made in Germany) optical instrument. We also sell Chinese made fluorescence microscopes but the quality is substantially lower. We highly discourage buying the Chinese microscopes due to the problems that incur after the sale. Even years old Zeiss equipment still beats any brand new Chinese microscope with image quality.

References:

- https://www.fluorescencemicroscopes.com/zeiss-axiovert-100-inverted-fluorescence-and-phase-contrast-microscope/

Conclusions/action items:

- I should be familiar enough to use this microscope for imaging and teach other team members how to use it if current microscopes are being used by 201 students

Team Testing

Drew Hardwick - May 02, 2023, 9:06 AM CDT

Title: Testing

Date: 5/2/23

Content by: Drew

Present: N/A

Goals: N/A

Content:

- **SEE TEAM NOTEBOOK FOR FURTHER TESTING DETAILS/INVOLVEMENT**

Conclusions/action items:

N/A

2/17/23 - BPAG Meeting

Drew Hardwick - Feb 17, 2023, 12:22 PM CST

Title: BPAG Training Meeting

Date: 2/17/23

Content by: Drew Hardwick

Present: N/A

Goals: Understand BPAG resposibilities

Content:

- Get client to purchase for us = :)
- Pay and get reimbursed = :(MORE DIFFICULT
- Get all purchases approved by client prior to purchasing
- Keep spreadsheet/record of al receipts to maintain product reproducibility
- Use preferred vendor list on shop UW+, to utilize university connections VERY IMPORTANT
    - For purchasing outside of UW+ must prove item not for sale on UW plus
    - Almost impossible yo reimburse if you purchase on your own
- Buy electronics at Newark - doesn't matter if $10 cheaper on amazon... Use preferred vendors!
- Set up account at makerspace for 3d printing needs
    - send funding link from slide deck to clients
    - Class Number: "BMEDesign_team_catchphrase"
- $50 dollar team lab/shop fee for students - non reimbursable...
    - "educational value far exceeds the cost"...
- TEAM lab stockroom can get materials from stockroom for free with paid materials/shop fee
- Poster non reimbursable purchase also - ~$15/team member
- Keep track of all original receipts for client reimbursement
    - UW reimbursement is last last resort - only 90 days from purchase date to get reimbursement restarted
    - takes 10 days to finalize process and move through channels of approval
    - Work with accountant Cindy - contact info on BME website
- No 90 day rule for non-UW clients, but common courtesy to stay on top of reimbursements
- Make purchasing table formatted nice - don't take up 3 pages of progress report
- Purchasing table should appear in progress reports, notebook, and final report apendicies

Conclusions/action items:

- Make future purchases according to UW BME BPAG Guidelines

Background

Drew Hardwick - Dec 13, 2022, 8:13 AM CST

Title: Background

Date:

Content by: Drew Hardwick

Present: N/A

Goals: Describe Project Background

Content:

NOTE: SEE PREVIOUS SEMESTERS WORK FOR MORE BACKGROUND RESEARCH

- Cell cultures - used in the study of cell biology to easily manipulate genes, molecular pathways, and culture systems to remove interfering genetic and environmental variables f
- follow BioSafety Level 2 guidelines
    - describe the safety procedures for working in a lab that can be associated with human diseases
    - incubators being used in conjunction with cell cultures must follow ISO Class 5 air quality standards
- Cell cultures have the ability to work with three different cell types: primary, transformed, and self-renewing cells
    - Primary - directly isolated from human tissue
    - Transformed - can be generated naturally with changes to the genetic code, or genetically manipulated
    - Self-renewing - carry the ability to differentiate into a variety of other cell types with long-term maintenance in vitro
        - Ex = embryonic stem cell
- Incubators used in cell cultures have to maintain a stable microenvironment and can achieve this via regulated temperature, humidity, CO_2, O_2, and pH levels
    - Critical for the viability and growth of the cultured cells
- Aiming to replicate conditions in the body (37 ℃ with a pH of 7.2-7.4)
- CO_2 is needed as a buffer to help with the pH along with a culture medium
    - Basal medium most commonly used - controls the physicochemical properties of the cell cultures' pH and cellular osmotic pressure

Conclusions/action items:

- See PDS and Previous semester research for more background research

9/20/22 - Conductive Glass

Drew Hardwick - Sep 23, 2022, 8:58 AM CDT

Title: Conductive Glass Research

Date: 9/20/22

Content by: Drew Hardwick

Present: N/A

Goals: Learn more about how conductive Glass works and its applications

Content:

- commercial method involves sputtering indium-tin oxide, which means a high vacuum and some high voltages
  - Expensive and difficult - not worth purchase or time for us
- DIY:
  - stannous (tin) chloride and ammonium bifluoride in solution
  - sprayed uniformly onto the heated glass (350-400° C), and after it's evaporated there is a thin, strong, and transparent layer of fluorine-doped tin oxide
  - Results in resistances down in the single-digit Ohms per square
  - https://www.youtube.com/watch?v=R9_5HOSZ0_k&t=124s
- This would be a lot of work and require the purchase of a Cl/Ammonium Bifluoride solution
  - Maybe could be found in TEAM Lab/ECB??

Conclusions/action items:

- I am unsure how effective conductive glass will be - it will be lots of work and cost a significant chunk of the budget, plus, with our current design we will only be able to heat the top glass plate because otherwise, we will be heating the cells, which are resting on top of the plate
- Seems like it is more trouble than it is worth

References:

[] "DIY Conductive Glass You Could Actually Make | Hackaday." https://hackaday.com/2017/03/20/diy-conductive-glass-you-could-actually-make/ (accessed Sep. 23, 2022).

9/20/22 - How a solenoid Valve works

Drew Hardwick - Dec 10, 2022, 6:50 PM CST

Title: How a Solenoid Valve Works

Date: 9/20/21

Content by: Drew Hardwick

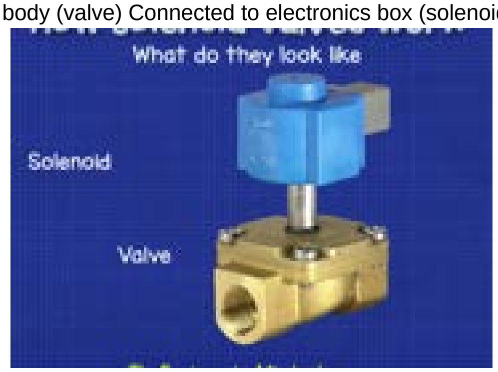
Present: N/A

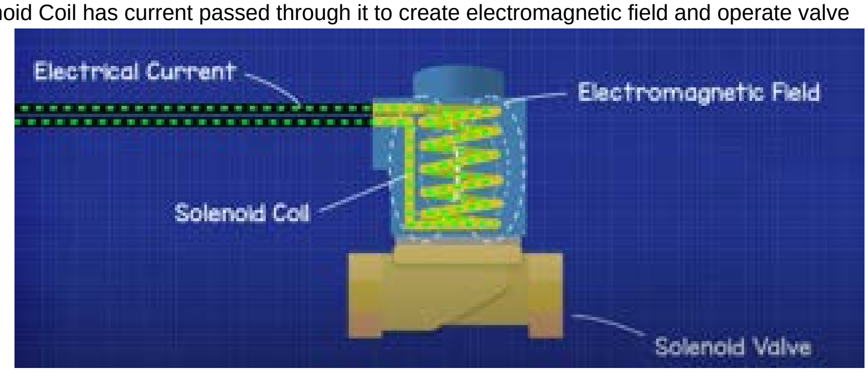
Goals: Learn exactly how a Solenoid Valve Works

Content:

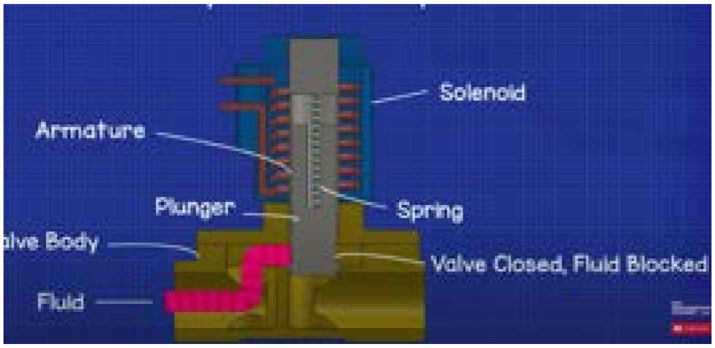
CONTEXT: looking into using a solenoid valve to autonomously control the flow of CO2 gas into the incubator. We need something that can be controlled via arduino, and can quickly and accurately adjust to allow the incubator's internal environment to stay at 5% CO2.

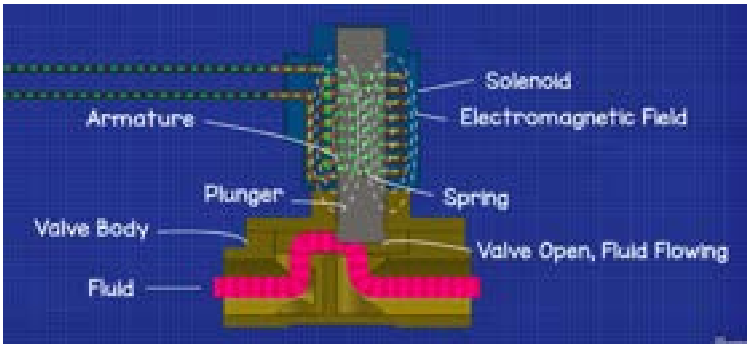
https://www.youtube.com/watch?v=-MLGr1_Fw0c

- Converts electrical energy to mechanical energy
- Valve body (valve) Connected to electronics box (solenoid)
    - 

- Shape of valve depends on capacity, pressure, and different internal mechanisms
- these valves Allow engineers to autonomously and remotely control flow (liquid or gas) within a system - no need to physically open valves
    - more efficient and safer
- Solenoid Coil has current passed through it to create electromagnetic field and operate valve
    - 

- Solenoid valves EVERYWHERE:
    - Washing Machines, HVAC, Space Rockets, and everything in between
- Can purchase NO (normally open) or NC (normally closed) valves depending on needs
- Solenoid Placed OVER armature

- 

- Inside Armature is plunger and spring - spring pushes plunger down in NC valve, indefinitely blocking flow
- If coil recieves electric signal, generates electromagnetic field, passes through spring/plunger and causes it to move up and the fluid/gas flows through valve
- 

- @ center of coil, magnetic field lines are most compact and therefore the strongest - why plunger is in center
- When current stopes, electromagnetic field disappears, and spring forces plunger down to close valve indefinitely again

* NO valve is the same, but spring keeps plunger up, not down - everything reversed
* Direction of current into coil is what determines whether it is a NO or NC valve

Conclusions/action items:

- We should use a solenoid valve
- FIND A CHEAP ONE!
- This is the best option for us to control the input of CO_2 into the incubator system.

References:

[] The Engineering Mindset, *How Solenoid Valves Work - Basics actuator control valve working principle*, (Mar. 03, 2019). Accessed: Sep. 23, 2022. [Online Video]. Available: https://www.youtube.com/watch?v=-MLGr1_Fw0c

Previous Competing Designs

Drew Hardwick - Dec 13, 2022, 8:06 AM CST

Title: **Competing Designs**

Date:

Content by: Drew Hardwick

Present: N/A

Goals: Keep Up to date on current incubators on market

Content:

- SEE PDS FOR MORE COMPETING DESIGNS INFO
- Two types of commonly used methods to maintain temperature in industry cell incubators
  - Direct heat method - tends to gove off heat using electric metal coils surrounding body of incubator
  - programmed to desired temp
- The other method is the water-jacketed incubators
  - Use a controlled circulating water bath cabinet around the body of the incubator for even heating throughout the entirety of the chamber.
- Humidity control achieved by placing a tray of water at the bottom of the incubator
  - Used in both water-jacketed and direct heat incubators
- CO_2 control achieved through a CO_2 tank
  - automatically pumps the desired amount of gas into the incubator
  - Using tubes and a valve connector, the CO_2 tank is able to deliver gas to the inside of both water-jacketed and direct heat incubators
  - Many incubators allow CO_2 reg to adjust when internal conditions are disturbed
    - Ex: opening the incubator door to deliver more cell plates, so that the environment is always stable.
- Direct heat method ex: In-Vitro Cell NU5700
-

- "The NU-5700 CO_2 incubator offers touch panel control and monitoring of temperature and CO_2 levels to meet the demands of a broad range of cell culture applications. Beyond using an infrared sensor for precise control of CO_2 and separately adjustable door and perimeter heaters to balance internal temperature. The air pump outside the 160L growth chamber also constantly draws air through a HEPA filter and cycles it back to create ISO Class 5 quality air at positive pressure and minimize contamination. A touch screen makes it easy to enter set points and view or download historical performance. In addition, this moderately sized incubator can be stacked and still allow the user easy access to the top chamber."

- Price not listed, need to get a quote... --> very very expensive
  - Online estimates ~ $10,000
- Indirect Heat Method Ex: Ibidi Stage Top Incubator Multiwell plate
- 

  - "A stage top incubator for high-throughput live cell imaging on inverted microscopes, with precise temperature regulation, active humidity control, and CO2 regulation
  - Easy installation on inverted microscopes that have a K-frame fitting (160 mm x 110 mm)
  - Ideal for long-term physiologic assays on the microscope: no evaporation due to precise, feedback-controlled humidity regulation
  - Optimal heat distribution and no condensation in the Incubation Chamber
  - Ideal for high-throughput live cell imaging in multiwell plates using motorized stages"
- Price not listed, need to get a quote... --> very very expensive
  - Online estimates ~ $18,000
- THIS IS VERY SIMILAR TO OUR PROJECT

Conclusions/action items:

- Our design is needed
- Current incubators on market far too expensive

10/18/2022 Voltage Relay

Drew Hardwick - Oct 19, 2022, 1:17 PM CDT

Title: Voltage Relay Research

Date: 10/18/22

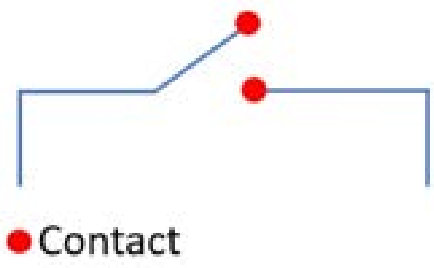
Content by: Drew Hardwick

Present: N/A

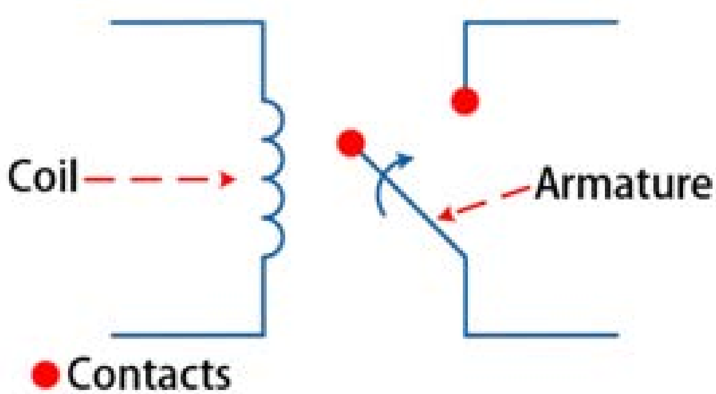
Goals: Understand how we could potentially use a relay if power supply for Solenoid does not work

Content:

- The relay module is an electrically operated switch that can be turned on or off deciding to let current flow through or not. They are designed to be controlled with low voltages like 3.3V or 5V like your Arduino.
- The relay is an electrically operated switch where the relay opens when the two contacts are disconnected, while the relay is closed when the two contacts touch. When set to high, the relay will close allowing current to flow.



- Even though there are many types of relays, electromechanical relays are the most commonly used. They consist of coils, armatures, and contacts:



- When the coil is energized, the induced magnetic field moves the armature, which opens or closes the contact.
- Each contact connects to an input or output terminal. The input terminal is called **Pole**, and the output terminal is called **Throw**
- The SPST is the simplest relay, you can consider it as a button. They have 2 terminals that can be connected or disconnected. Including 2 for the coil, an SPST relay has 4 terminals in total
    - This switch is normally open and when the trigger signal comes, the pole contact will connect to the throw contact which causes the switch to be closed.
    - Use Grove Relay for this:
        - This is a simple electromechanical relay that can work low voltages like 3.3V like the ESP32, ESP8266 etc or the 5V like your Arduino with a max switching voltage 250VAC / 30VDC and current of 5A.
        - There is an indicator LED on the board, which will light up when the controlled terminals get closed.
        - This is an SPST relay which is great for applications that need only an on or off state.

- HOW TO SETUP:
  - Firstly connect Grove-Relay to port D4 of Grove-Base Shield.
  - Connect Grove-Button#1 to port **D2** of Grove-Base Shield and connect Grove-Button#2 to port **D3** of Grove-Base Shield.
  - Plug Grove – Base Shield into Seeeduino.
  - Connect Seeeduino to PC via a Micro-USB cable.
  - Your connection should look something like this:
  - 
  - If you do not have the base shield, you can directly connect the relay and button to the Arduino board by following the below connection:

Grove – Relay	Arduino	Grove Cable
GND	GND	Black
VCC	5V	Red
SIG	D4	Yellow

  - CODE:

```
// Relay Control

void setup()
{
  pinMode(2, INPUT);
  pinMode(3, INPUT);
  pinMode(4, OUTPUT);
}

void loop()
{
  if (digitalRead(2)==HIGH)
  {
    digitalWrite(4, HIGH);
    delay(100);
```

```
    }
    if (digitalRead(3)==HIGH)
    {
      digitalWrite(4, LOW);
    }
  }
```

Conclusions/action items:

- This is a good option if power cord does not work

References:

[] "Arduino Relay Tutorial: Control High Voltage Devices with Relay Modules," *Latest Open Tech From Seeed*, Jan. 03, 2020. https://www.seeedstudio.com/blog/2020/01/03/arduino-tutorial-control-high-voltage-devices-with-relay-modules/ (accessed Oct. 18, 2022).

9/15/22 - Solenoid Valve Purchasing

Drew Hardwick - Sep 15, 2022, 8:32 PM CDT

Title: Grainger Solenoid Valve Options

Date: 9/15/22

Content by: Drew Hardwick

Present: N/A

Goals: Find affordable purchasing options

2-Way/2-Position, Normally Closed Remote Piloted Dust Collector Valves

These remote, piloted dust collector valves feature a normally closed valve configuration. They are ideal for use with air and inert gases. Rated for indoor and outdoor environments. Aluminum body construction.

Aluminum Body Material

Pipe Size - Valves	Min. Operating Pressure Differential	Max. Operating Pressure Differential Air/Inert Gas	Environmental Rating - Valves	Media - Valves	Price
3/4 in	5 psi	125 psi	Indoor Outdoor	Air, Inert Gases	$111.01

Content:

- This looks like a good potential Item to purchase - I will need to further research use and how compatible this item is
- 3/4 inch might be very big for the amount of CO_2 we will be using - see below, smaller options

2-Way/2-Position, Normally Open Solenoid Valves

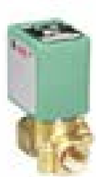
These solenoid valves feature a normally open valve configuration, and are ideal for use with air, inert gases, and water. Use in indoor or outdoor work environments. Normally open valves operate at low pressures with no minimum required. They are well suited for venting systems.

Brass Body Material

Pipe Size - Valves	Voltage	Min. Operating Pressure Differential	Max. Operating Pressure Differential Air/Inert Gas	Max. Operating Pressure Differential Water	Environmental Rating - Valves	Media - Valves	Price
1/8 in	120V AC	0 psi	160 psi	145 psi	Indoor Outdoor	Air; Inert Gases; Light Oil; Water	$131.88
1/4 in	120V AC	0 psi	30 psi	30 psi	Indoor Outdoor	Air; Inert Gases; Light Oil; Water	$136.62
1/4 in	120V AC	0 psi	90 psi	90 psi	Indoor Outdoor	Air; Inert Gases; Light Oil; Water	$136.62
1/4 in	120V AC	0 psi	160 psi	145 psi	Indoor Outdoor	Air; Inert Gases; Light Oil; Water	$139.46
1/4 in	120V AC	0 psi	275 psi	230 psi	Indoor Outdoor	Air; Inert Gases; Light Oil; Water	$130.18

- These options are a little more expensive, but have smaller diameters and deal with higher pressures

1/8 in	120V AC	0 psi	145 psi	145 psi	Indoor Outdoor	Air; Inert Gases; Light Oil; Water	$78.99



Solenoid Valve: 1/8 in Pipe Size - Valves, 120V AC, 0 psi Min. Op Pressure Differential, Brass, F

Item **44U335**

Mfr. Model **SC8356A002V**

View Product Details

Web Price
$78.99 / each

Expected to arrive **Mon. Sep 19.**

Ship to 53701

Qty 1

Add to Cart

- Cheapest option

- Similar to above, but 1/4in diameter

Conclusions/action items:

- Need to further research how each valve attaches and works this week, but it appears possible to find decently cheap option on Grainger

References:

[] "Air, Oil and Water Solenoid Valves - Grainger Industrial Supply." https://www.grainger.com/search/plumbing/plumbing-valves/solenoid-valves-and-coils/air-oil-and-water-solenoid-valves?tv_optin=true&searchQuery=solenoid+valve&searchBar=true&tier=Not+Applicable (accessed Sep. 15, 2022).

9/21/22 - Makerspace Meeting

Title: Makerspace Meeting

Date: 9/21/22

Content by: Drew Hardwick

Present: N/A

Goals: Speak to UW Makerspace Staff Members to learn about Valve Options

Content:

- Spoke with Makerspace experts about any Valve Guidance they could possibly help with.
- I was hoping they would have cheap valves available for purchase at the Makerspace like the DC motor we purchased there for a couple of bucks last year
  - I figured that we did not need a large or expensive valve, just need it to open/close reliably enough to allow small incubator to fill to 5% +/- 0.5% CO_2 at 14psi - very small amoun
- Makerspace does NOT sell valves
- Still offered Guidance on project:
  - Recommended Solenoid Valve over ball valve or pin valve because solenoid valve can just have electrical signal applied and it opens/closes.
  - Ball valve or pin valve will need to hook up a servo or actuator to the valve to power the opening/closing and that just adds an extra step to the process
  - Just an extra step and extra complication involved with these valves that could me minimized if solenoid valve is used
  - Make sure to purchase a valve graded for gas, not just liquid, as the gas grade will have a better seal
  - The pressure should not be an issue for us, as the CO_2 comes out at 14psi, and atmospheric pressure is very close at about 14.6psi
- Makerspace staff recommended speaking with someone at ACE hardware for more info on solenoid valves and potential cheap purchasing options
- They also reccommended looking at McMaster Carr instead of Grainger for prices:

Compact Solenoid On/Off Valves

CAD For technical drawings and 3-D models, click on a part number.

Brass Body with DIN Connection—Buna-N Rubber Seal

- For Use With: Water, Air, Argon, Helium, Neon, Xenon, Krypton

Pipe Size	Gender	Thread Type	Flow Coefficient (Cv)	Max. Pressure	Pressure Drop	Temp. Range, °F	Valve Lg.	O'all Ht.		Each
Normally Closed—24V AC										
1/4	Female	NPT	0.17	290 psi @ 140° F	Zero Pressure Drop	15° to 190°	1 5/8"	3"	8077K216	$114.98
1/4	Female	NPT	0.29	100 psi @ 140° F	Zero Pressure Drop	15° to 190°	1 11/16"	2 9/16"	8077K226	83.82
1/4	Female	NPT	0.35	48 psi @ 140° F	Zero Pressure Drop	15° to 190°	1 9/16"	3 3/16"	8077K246	86.47
1/4	Female	NPT	0.58	110 psi @ 140° F	Zero Pressure Drop	15° to 190°	1 9/16"	3 3/16"	8077K236	86.47
Normally Closed—24V DC										
1/4	Female	NPT	0.17	230 psi @ 140° F	Zero Pressure Drop	15° to 190°	1 5/8"	3"	8077K217	114.98
1/4	Female	NPT	0.29	50 psi @ 140° F	Zero Pressure Drop	15° to 190°	1 11/16"	2 9/16"	8077K227	83.82
1/4	Female	NPT	0.35	20 psi @ 140° F	Zero Pressure Drop	15° to 190°	1 9/16"	3 3/16"	8077K247	86.47
1/4	Female	NPT	0.58	55 psi @ 140° F	Zero Pressure Drop	15° to 190°	1 9/16"	3 3/16"	8077K237	86.47
Normally Closed—120V AC										
1/4	Female	NPT	0.17	290 psi @ 140° F	Zero Pressure Drop	15° to 190°	1 5/8"	3"	8077K215	114.98
1/4	Female	NPT	0.29	100 psi @ 140° F	Zero Pressure Drop	15° to 190°	1 11/16"	2 9/16"	8077K225	83.82
1/4	Female	NPT	0.35	48 psi @ 140° F	Zero Pressure Drop	15° to 190°	1 9/16"	3 3/16"	8077K245	86.47
1/4	Female	NPT	0.58	110 psi @ 140° F	Zero Pressure Drop	15° to 190°	1 9/16"	3 3/16"	8077K235	86.47

Solenoid On/Off Valves

These solenoid valves operate on electricity to automatically start and stop flow. The actuator is directly mounted to the valve body to minimize movement and reduce wear.

Normally closed valves are closed unless actuated. **Normally open** valves are open unless actuated.

316 and **316L stainless steel** valves are more corrosion resistant than brass and bronze valves.

Zero pressure drop valves don't require a minimum pressure drop between the inlet and outlet for operation. **Pressure drop assisted** valves require a minimum pressure drop between the inlet and the outlet for operation; the upstream pressure must be greater than the downstream pressure.

All **IP-** or **NEMA-rated** valves stand up to dust and washdowns. **IP69** valves resist high-temperature, high-pressure washdowns. **NEMA 4X** valves withstand corrosive liquid.

Flow coefficient (Cv) is the amount of water (in gallons per minute) at 60° F that will flow through a fully open valve with a difference of 1 psi between the inlet and the outlet.

CAD For technical drawings and 3-D models, click on a part number.

Normally Closed—24V AC

- For Use With: Water, Oil, Air, Argon, Helium, Neon, Xenon, Krypton
- Specifications Met: See table

Valves											Replacement Solenoid Coils		Repair Kits for Flow-Control Valves	
Pipe Size	Flow Coefficient (Cv)	Max. Pressure	Pressure Drop	Temp. Range, °F	Valve Lg.	O'all Ht.	Environmental Rating	Specifications Met		Each		Each		Each
Brass Body with DIN Connection—Buna-N Rubber Seal														
NPT Female														
1/4	1.4	200 psi @ 70° F	Zero Pressure Drop	15° to 195°	2 1/4"	3 1/2"	IP65, NEMA 4	CE Marked	4711K513	$123.78	2881N13	$32.57	2875N16	$57.43
1/4	1.4	300 psi @ 70° F	Pressure Drop Assisted	15° to 195°	2"	3 1/4"	IP65, NEMA 4	CE Marked	4738K137	96.22	2881N13	32.57	2875N16	40.23
3/8	1.4	200 psi @ 70° F	Zero Pressure Drop	15° to 195°	2 11/32"	3 1/2"	IP65, NEMA 4	CE Marked	4711K523	123.78	2881N13	32.57	2875N16	57.43

  - Prices are about the same, maybe a little cheaper on McMaster Carr

- Sam found $9 solenoid valve on Amazon here:
  - https://www.amazon.com/4inch-Normally-Closed-Electric-Solenoid/dp/B074Z5SDG3/ref=asc_df_B074Z5SDG3/?tag=hyprod-20&linkCode=df0&hvadid=198072472254&hvpos=&hvnetw=g&hvrand=12924945941706346746&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=360267761983&psc=1

Conclusions/action items:

- Grainger and McMaster Carr prices for the valve will eat up our budget
- I think that we should see if Pucc will allow us to purchase the amazon solenoid valve for budgeting purposes
- If not, we should check with experts and prices at ACE/Home Depot and consider purchasing externally as a team before we eat up our budget on Grainger or McMaster Carr

References:

[] "McMaster-Carr." https://www.mcmaster.com/ (accessed Sep. 21, 2022).

9/21/22 - First Materials Purchasing Order

Drew Hardwick - Sep 23, 2022, 8:45 AM CDT

Title: First Materials Purchasing Request

Date: 9/21/22

Content by: Drew Hardwick

Present: All

Goals: Send our first Materials Purchasing Request to Puccinelli

Content:

Hi Dr. Puccinelli,

Attached to this email is the first Materials Purchasing Request of the year for our team! The team is picking up where we left off this semester by replacing the glass plates on the incubator with fresh, clear plates, and purchasing antifog spray to prevent the buildup of condensation due to humidity on the inside of these plates. We are also purchasing a solenoid valve to regulate the CO2 input and start work with the circuitry and fabrication associated with that. Please let me know if you have any questions.

Thank you!
-Drew Hardwick

University of Wisconsin - Madison, Class of 2023
Biomedical Engineering
dphardwick@wisc.edu
314-305-4739

Conclusions/action items:

Drew Hardwick - Sep 23, 2022, 8:45 AM CDT

Microscope Cell Culture Incubator

Download

Materials_Purchasing_Request_Fall_2022-_Microscope_Cell_Culture_Incubator.pdf (49.2 kB)

12/12/22 - BPAG Final Expenses

Drew Hardwick - Dec 12, 2022, 5:11 PM CST

Title: Final Expenses

Date: 12/12/22

Content by: Drew Hardwick

Present: N/A

Goals: Finalize Budget

Content:

Expenses

Item	Description	Manufacturer	Part Number	Date	QTY	Cost Each	Total	Link
Component 1								
Glass	Polycarbonate Transparent Thermal Insulation Sheets	RADNOR	64005034	9/21/22	4	$1.21	$4.84	Link
Component 2								
Solenoid Valve	¼ inch DC 12V 2 Way NC Electric Solenoid Air Valve	Plum Garden	PL-220101	9/21/22	1	$9.35	$9.35	Link
Component 3								
Anti-Fog Solution	Lens Cleaning Solution: Anti-fog/Anti-Static Silicone	Grainger	4T932	9/21/22	1	$6.58	$6.58	Link
Component 4								
G1/4” Soft Tubing Barbed Adaptor	Barbed Adaptors that screw into Solenoid Valve and attach plastic tubing connected to CO2 tank to valve, to incubator	E-outstanding	N/A	9/29/22	4	$2.40	$9.59	Link
Component 5								
TIP120 Transistor	Transistor needed to power the solenoid valve using an Arduino Circuit.	NTE Electronics, Inc	2368-TIP120-ND	10/3/22	1	$1.00	$1.00	Link
Component 6								
Black Acrylic	Black Acrylic needed to create the homogeneity testing lid. (⅛ x 18 x 24)	UW-Makerspace	N/A	10/17/22	1	$10.75	$10.75	Link
TOTAL:	$42.11							

Conclusions/action items:

9/13/22 - CO2 Valve Types Research

Drew Hardwick - Sep 15, 2022, 8:21 PM CDT

Title: Potential CO2 Valves

Date: 9/13/22

Content by: Drew Hardwick

Present: N/A

Goals: Research Potential Gas Regulation Valves

Content:

- **Gate Valve:**
  - Gate system to open or close a pipeline entirely
  - Excellent choice if the flow rate needs to be controlled and maintained
  - When the actuator completely opens the valve, the channel is unobstructed, allowing even slurry fluids like crude oil to flow easier
  - Not an ideal candidate if throttling is required in an application, there is not a noticeable pressure drop when this valve is used.
  - 
  - Only appropriately Prices Gate Valves on Grainger are manual, so we need another option
- **Ball Valve**
  - A ball valve is a shut-off valve that allows, obstructs, and controls the flow of liquids, gases, and vapors in a piping system by rotating the ball having a bore inside the valve
  - The ball is mounted against two seats and has a shaft that connects it to the operating and control mechanism that rotates the ball
  - When the cross-section of the bore is perpendicular to the area of the flow, the fluid is not permitted to pass through the valve. The fluid flows through from the valve, and the fluid flow rate depends on the area of the bore exposed to the floor.
  - Can be motorized like below GOOD POTENTIAL OPTION ($89.95 @ www.electricsolenoidvalves.com)
  - 
- **Solenoid Valve**
  - A solenoid valve is an electrically controlled valve. The valve features a solenoid, an electric coil w/ movable ferromagnetic core (plunger like) at center
  - In rest position, plunger closes off small orifice
  - Electric current through coil creates magnetic field, exerting upwards force on plunger to open orifice
  - Relatively Cheap, motorized

Conclusions:

- Ball and Solenoid Valves are good types to pursue

References:

[] wsisme-norgascontrols, “7 Types of Gas Valves Used in the Oil & Gas Industry,” *Norgas Controls*, Dec. 10, 2021. https://norgascontrols.com/blog/valves/7-types-of-gas-valves-used-in-the-oil-gas-industry/ (accessed Sep. 13, 2022).

[] “Gate Valves - Grainger Industrial Supply.” https://www.grainger.com/search/plumbing/plumbing-valves/shut-off-valves/gate-valves?tv_optin=true&searchQuery=gate+valve&searchBar=true&tier=Not+Applicable (accessed Sep. 13, 2022).

[] “1" Stainless Electric Ball Valve - 2 Wire Auto Return,” *Electricsolenoidvalves.com*. https://www.electricsolenoidvalves.com/1-inch-stainless-steel-motorized-electric-ball-valve-2-wire-auto-return/ (accessed Sep. 15, 2022).

[] “Solenoid Valve - How They Work | Tameson.com,” *Tameson*. https://tameson.com/solenoid-valve-types.html (accessed Sep. 15, 2022).

9/28/22 - Solenoid Control Code via Arduino

Drew Hardwick - Dec 13, 2022, 7:37 AM CST

Title: Solenoid Control Via Arduino

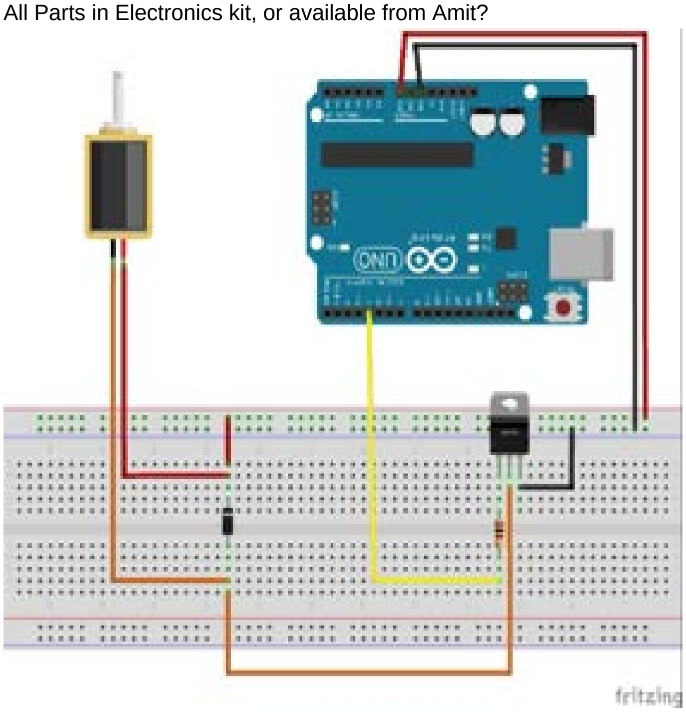
Date: 9/28/22

Content by: Drew Hardwick

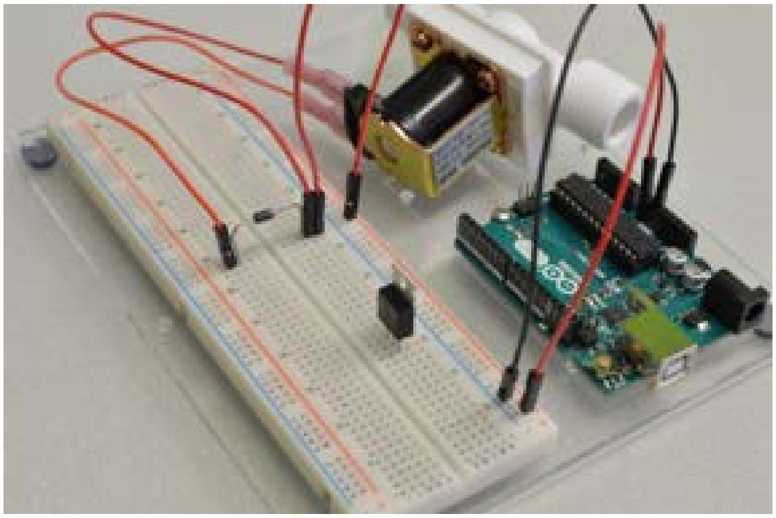
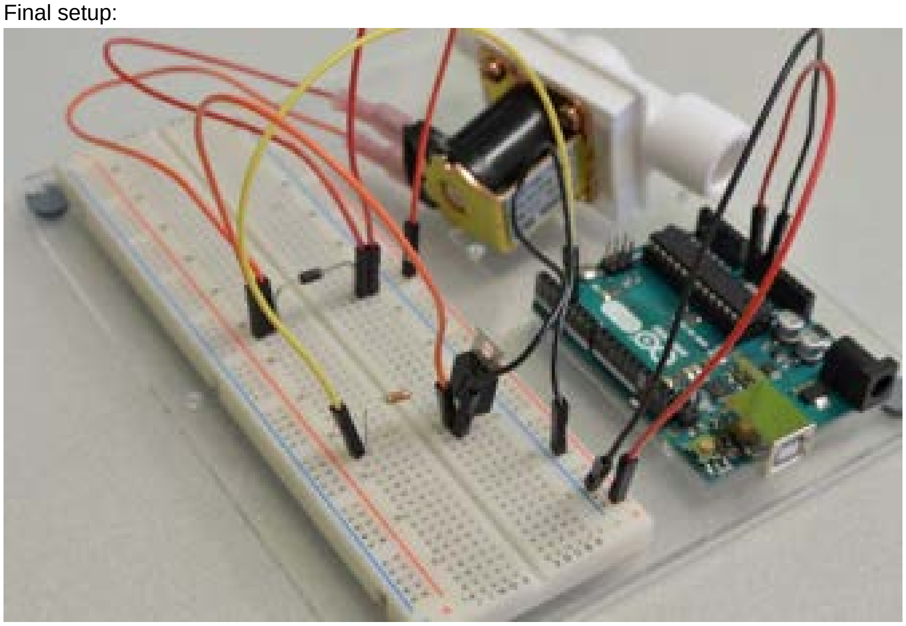
Present: N/A

Goals: Research Possible circuits/code to control solenoid

Content:

- Method uses Arduino and Transistor, can be used on most solenoids/DC motors
  - Similar setup to last semester
- Parts:
  - 1 x Solenoid Valve
  - 1 x Arduino Uno or compatible microcontroller
  - 1 x Solderless Breadboard
  - 1 x TIP120 Darlington Transistor
  - 1 x 1K Ohm Resistor
  - 1 x 1N4001 Diode
  - Hookup Wires - We recommend Premium Male/Male Jumper Wire
- All Parts in Electronics kit, or available from Amit?
- 

- 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 the solenoid to the breadboard – we will need to add a diode between the two contacts so we will leave some space for that.
- Since a solenoid is an inductive load we need to include a snubber diode across the contacts.
  - Snubber diodes help eliminate transient voltages caused when a magnetic coil (such as those found in a motor, relay, or solenoid) suddenly loses powerWithout 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

- The solenoid gets constant power because we will using low side switching to turn on and off this solenoid. Low side switching means we will be interrupting the circuit between the negative side of the solenoid and the ground rather than between the power and the solenoid
- The current draw of this solenoid is higher than a standard transistor can handle so we will be using a TIP120 Darlington Transistor. A Darlington transistor is actually a pair of transistors that act as a single transistor with a high current gain.
- Current setup:
- 
- A base resistor is exactly what it sounds like – it is a resistor placed on the base pin of the transistor. This resistor limits the current going to the base (control line) of the transistor; no resistor would result in no current limit, and could result in a transistor blowing up! We will be using a 1K ohm resistor
- Connect to solenoid, arduino and ground
- Final setup:
- 
- Arduino code shouldn't be very difficult/extensive
- Modify this to meet our demands:

```
int solenoidPin = 4; //This is the output pin on the Arduino we are using

void setup() {
// put your setup code here, to run once:
pinMode(solenoidPin, OUTPUT); //Sets the pin as an output
}

void loop() {
// put your main code here, to run repeatedly:
digitalWrite(solenoidPin, HIGH); //Switch Solenoid ON
delay(1000); //Wait 1 Second
digitalWrite(solenoidPin, LOW); //Switch Solenoid OFF
delay(1000); //Wait 1 Second
}
```

Conclusions/action items:

- Check what Katie was thinking and see if this setup would work. Speak with Amit for help.

References:

https://learn.sparkfun.com/tutorials/transistors/applications-i-switches

[] "Controlling A Solenoid Valve With Arduino," *BC Robotics*. https://bc-robotics.com/tutorials/controlling-a-solenoid-valve-with-arduino/ (accessed Sep. 28, 2022).

9/29/22 - Materials Check

Drew Hardwick - Sep 30, 2022, 8:24 AM CDT

Title: First Materials Check in

Date: 9/29/22

Content by: Drew Hardwick

Present: N/A

Goals: Check on our materials

Content:

- Pucc put our first materials order in our locker
- Anti-condensation bottle is HUGE - should last us all this and next semester
- Glass looks good, and solenoid is small and compact like we wanted
- He played with solenoid valve and tubing first:
    - He has 1/4" NPT fittings that adapt to the white tubing in the lab nicely (that would also connect to the regulator nicely), however, they did not fit.

      After looking closer at the description, it says G1/4 which is a British standard pipe (metric) fitting standard that I do not have and the TEAMLab probably does not have either. Looking for G1/4 fittings like the one above that adapt to 1/4" tube is next step
- Sam found this adaptor on amazon for $10:

    -
    - https://www.amazon.com/outstanding-Fitting-Connector-Barb-Fitting-Accessory/dp/B08LMMJG1S/ref=sr_1_3?keywords=g+1%2F4+to+1%2F4+barb&qid=1664467167&qu=eyJxc2MiOiIwLjg4IiwicXNhIjoiMC42NSIsInFzcCI6IjAuMDAifQ%3D%3D&sr=8-3
    - Slide plastic tube on CO_2 tank over barb and screw adaptor into valve
    - Just need to make sure plastic will fit over
    - Plastic in lab measurements:
        - 4.5mm inner diameter, 12.5mm outer diameter
    - Thread Size: G1/4"; Barb OD Size: 6mm / 1/4"; Applicable Hose Diameter: 4.5-5mm/0.17-.0.20Inch; What you get: 4 x G1/4" Barb Fitting.
- This should fit, after looking at the tube, my only concern is that it will be difficult to pull the tube over the barbs since it is pretty thick and it is on the smaller side of the reccommended hose diameter
- On the flip side, this will create a tight seal like we want if it works
- I reached out to Pucc and he ordered this adaptor, so we should test CO_2 next week when it comes in

Conclusions/action items:

- Set up CO_2 circuit and test regulation next week with Katie!!!!

11/3/22 - Linking 2 Arduinos to Communicate with one another

Drew Hardwick - Nov 03, 2022, 8:00 PM CDT

Title: Researching Ways to Link 2 Arduinos Together to Communicate

Date: 11/3/22

Content by: Drew Hardwick

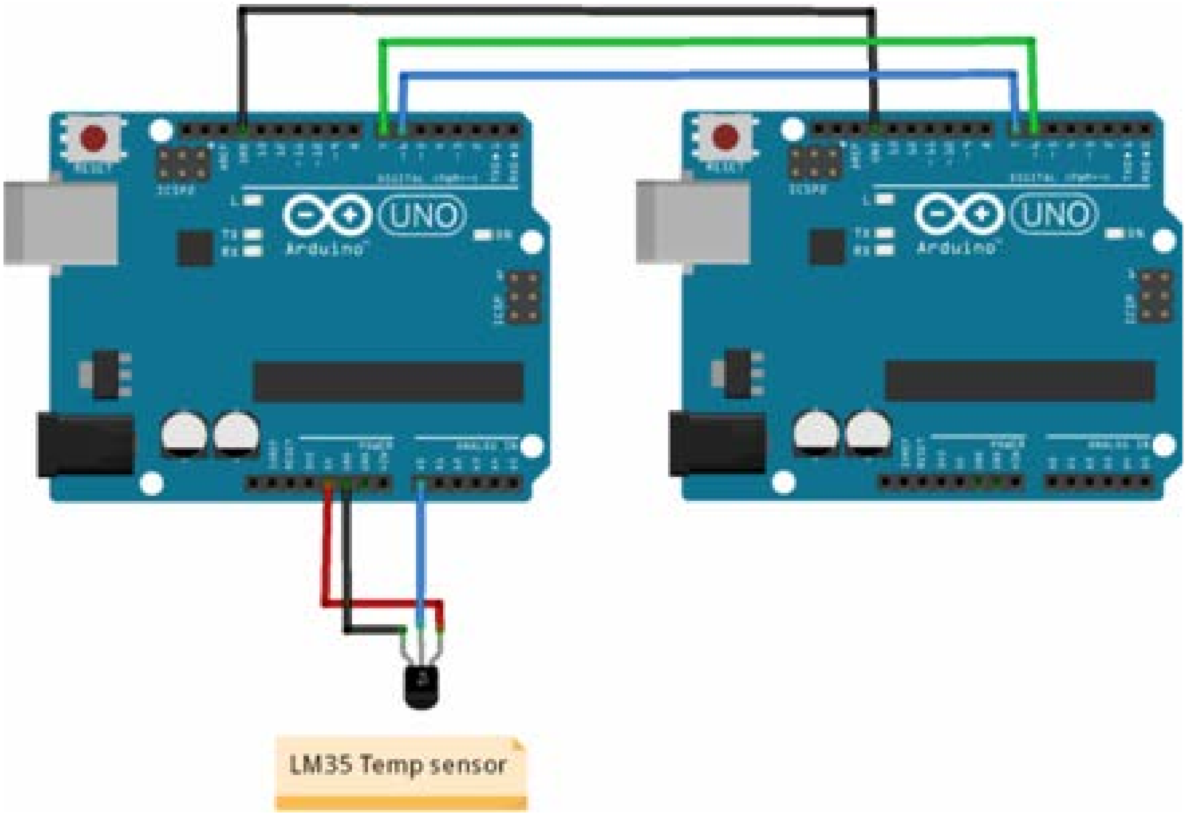
Present: Katie

Goals: Research how we could possibly split our Solenoid/Relay and our NDIR onto different arduinos, but still communicate

Content:

- If you want use two Arduino, you can use a simple I/O port to communicate.
- The point of question is the Ground. When you connect two Arduino with each other, you have to connect their ground. In this tutorial when the Arduino UNO number 1 lights ON the onboard LED, the Arduino UNO number 2 connects to the computer, prints HIGH on the serial port and switches ON the onboard LED.

  The result is two Arduino UNO that blink together.
- https://www.youtube.com/watch?v=E-9_5vwxGUk
- This youtube video seemed very promising but did not help us
- Katie and I tried exactly like they said, and inserted an "int val" from the sensor into our code like they did in the video, but we still could not get any communication between sensor and solenoid
- We were skeptical one wasn't working, but we unplugged and ran both devices on 2 arduinos and 2 computers, so that each of us ran 1 component
  - We then used this seperate setup to turn on the solenoid, blowing CO_2, and held it up to our NDIR sensor
  - This sensor accuately read that CO_2 was being blown into it, so we were able to debunk the thought that maybe our sensor was faulty
  - It is definitely something to do with our code and voltage supply/linking of our 2 board
- We tried to connect them like this(another article told us):

- 

    - This did not work either

- Dr. Nimunkar reccommended looking into the Master/Slave approach, so we will look into that for next session, and hopefully get his help

Conclusions/action items:

- Keep fiddling/researching
- Try I2C Master/Slave

11/3/22 - I2C Arduino Communication

Drew Hardwick - Nov 03, 2022, 7:52 PM CDT

Title: I2C Arduino Communication

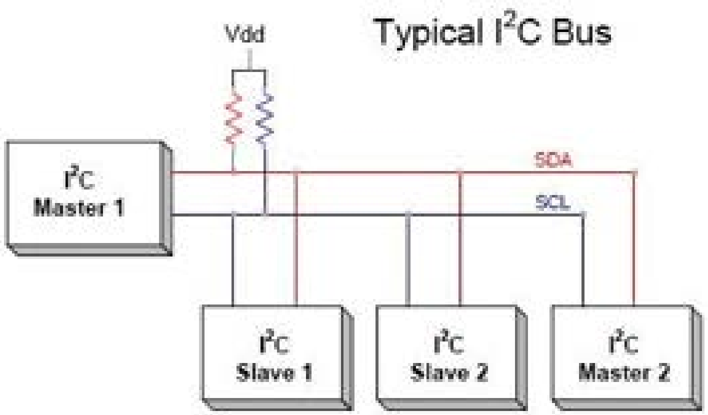
Date: 11/3/22

Content by: Drew Hardwick

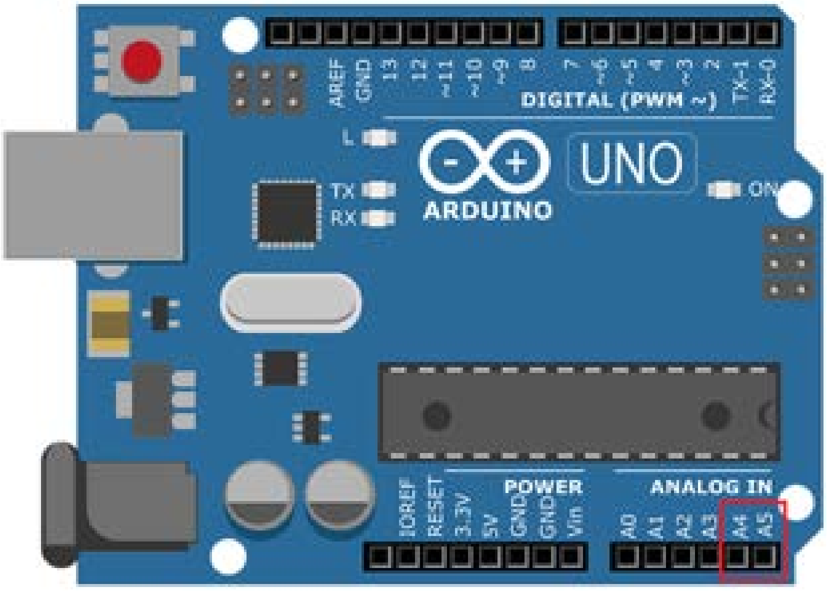
Present: N/A

Goals: Figure out how to link 2 separate arduino boards to communicate

Content:

- I2C is a synchronous communication protocol meaning, both the devices that are sharing the information must share a common clock signal.
- It has only two wires to share information out of which one is used for the cock signal and the other is used for sending and receiving data.
- two wires will be connected across two devices.
- Here one device is called a **master** and the other device is called as **slave.**
- Communication should and will always occur between two a **Master and a Slave.**
- The advantage of I2C communication is that more than one slave can be connected to a Master.
- 

- The complete communication takes place through these two wires namely, Serial Clock (SCL) and Serial Data (SDA).
  - **Serial Clock (SCL):** Shares the clock signal generated by the master with the slave
  - **Serial Data (SDA):** Sends the data to and from between the Master and slave.
- The **voltage levels of I2C are not predefined.** I2C communication is flexible, means the device which is powered by 5v volt, can use 5v for I2C and the 3.3v devices can use 3v for I2C communication. But what if two devices which are running on different voltages, need to communicate using I2C? A **5V I2C bus can't be connected with 3.3V device.** In this case voltage shifters are used to match the voltage levels between two I2C buses.
- I2C communication is used only for **short distance communication.**
  - It is certainly reliable to an extent since it has a synchronised clock pulse to make it smart.
  - This protocol is mainly used to communicate with sensor or other devices which has to send information to a master.
  - It is very handy when a microcontroller has to communicate with many other slave modules using a minimum of only wires.



- **1. Wire.begin(address):**

  Use: This library is used for making communication with I2C devices. This Initiate the Wire library and join the I2C bus as a master or slave.

  Address: The 7-bit slave address is optional and if the address is not specified, it joins the bus as a master like this [Wire.begin()].

  2. Wire.read():

  Use: This function is used to read a byte that was received from master or slave device, either that was transmitted from a slave device to a master device after a call to *requestFrom()* or was transmitted from a master to a slave.

  3. Wire.write():

  Use: This function is used to write data to a slave or master device.

  Slave to Master: Slave writes data to a master when *Wire.RequestFrom()* is used in master.

  Master to Slave: For transmission from a master to slave device *Wire.write()* is used in-between calls to *Wire.beginTransmission()* and *Wire.endTransmission().*

  Wire.write() can be written as:

- Wire.write(value)
- value: a value to send as a single byte.
- Wire.write(string) :
- string: a string to send as a series of bytes.
- Wire.write(data, length):
- data: an array of data to send as bytes

  length: the number of bytes to transmit.

  4. Wire.beginTransmission(address):

  Use: This function is used to begin a transmission to the I2C device with the given slave address. Subsequently, build queue of bytes for transmission with the *write()* function and then transmit them by calling *endTransmission()* function. 7-bit address of the device is transmitted.

  5. Wire.endTransmission();

  Use: This function is used to end a transmission to a slave device that was begun by *beginTransmission()* and transmits the bytes that were queued by *Wire.write().*

6. Wire.onRequest();

Use: This function gets called when a master requests data using *Wire.requestFrom()* from the slave device. Here we can include *Wire.write()* function to send data to the master.

7. Wire.onReceive();

Use: This function gets called when a slave device receives a data from a master. Here we can include *Wire.read();* function to read the data sent from master.

8. Wire.requestFrom(address,quantity);

Use: This function is used in the master to request bytes from a slave device. The function *Wire.read()* is used to read the data sent from the slave device.

address: the 7-bit address of the device to request bytes from

quantity: the number of bytes to request

Conclusions/action items:

- I need to find Dr. Nimunkar for some help on how to populate this system with our own custom code, but this looks like exactly what we should be looking for

References:

- https://circuitdigest.com/microcontroller-projects/arduino-i2c-tutorial-communication-between-two-arduino
-

11/9/22 - Window Wiper Sketch Idea

Drew Hardwick - Nov 10, 2022, 3:20 PM CST

Title: Window Wiper Sketch Idea

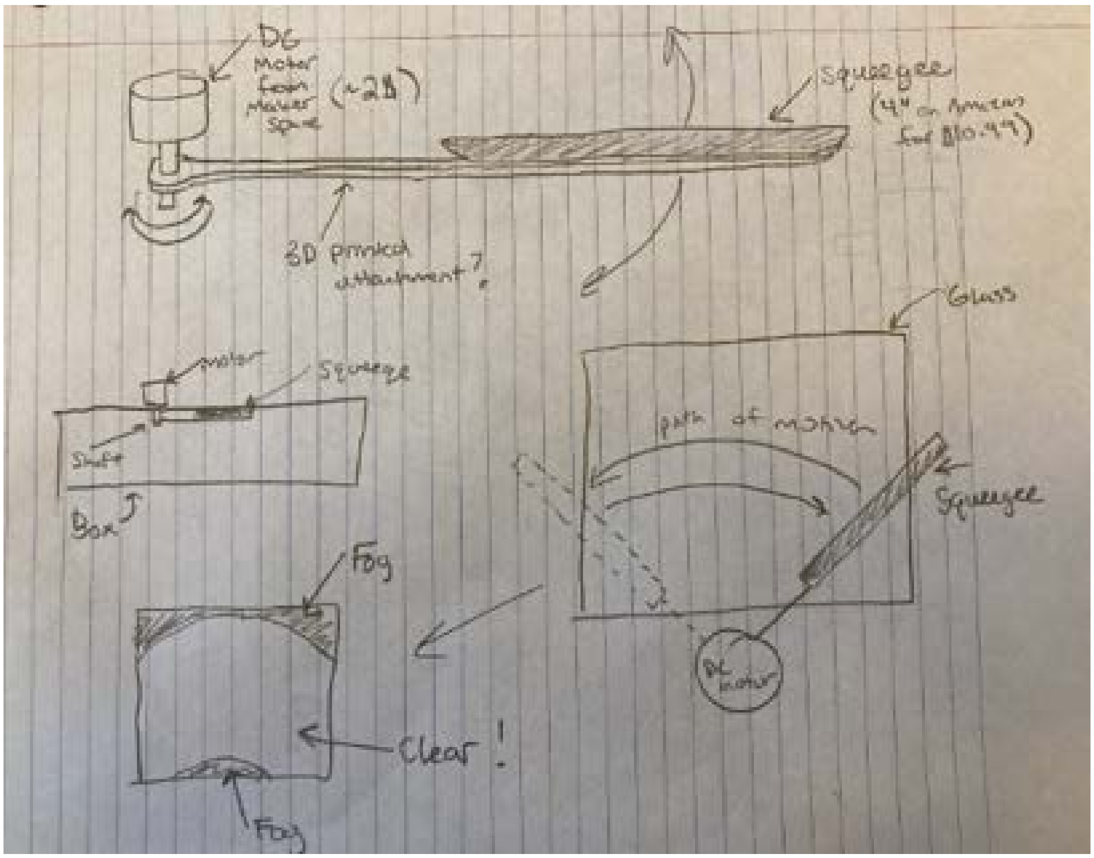
Date: 11/9/22

Content by: Drew Hardwick

Present: N/A

Goals: Sketch out idea for "Window Wiper" Condensation Prevention System

Content:



Conclusions/action items:

Speak to team about design and potentially order parts

10/3/22 - Circuit Design

Title: Solenoid Circuit/Code Design

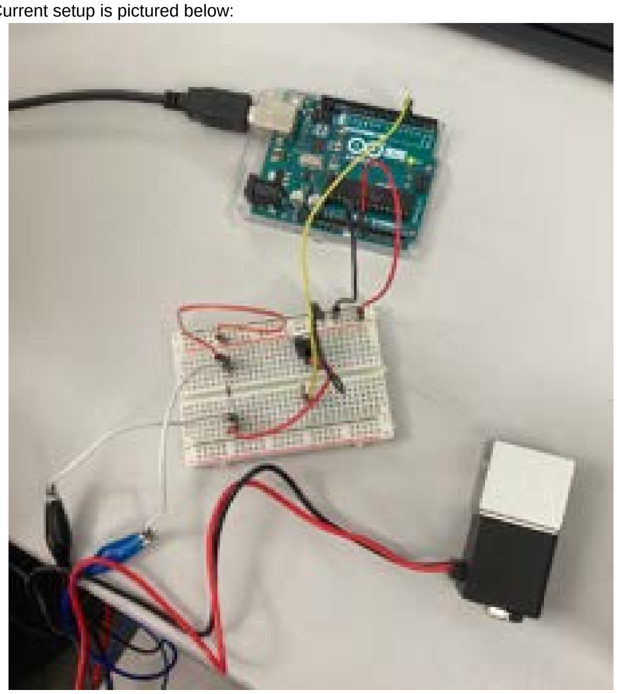
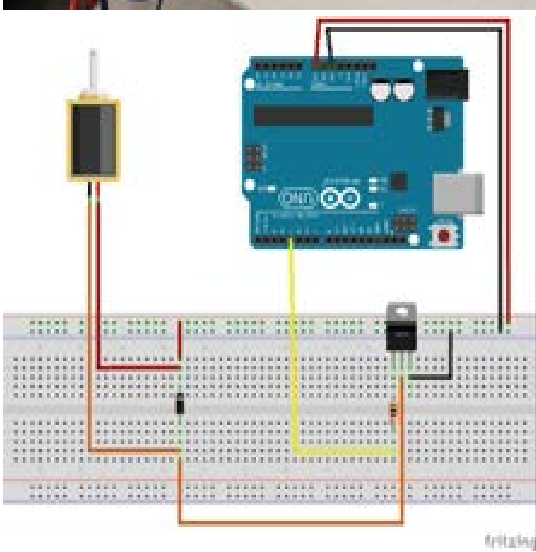
Date: 10/3/22

Content by: Drew Hardwick

Present: Katie Day

Goals: Set up and Test the Solenoid Circuit/Code

Content:

- Katie and I met to set up our circuitry and write our code using our BME 201/310 electronics kits, and the website that we both found detailing simple and easy solenoid control via Ardu
- We also were able to find Dr. Nimunkar and he gave us access to the 301 supply closet for the Transistor and Diode that we required to set up this circuit.
- The diode worked well (we think) but the Transistor needed a larger voltage capacity to handle the 9V necessary to operate this solenoid valve
- The team will have to purchase the TIP120 Transistor (link below) to combat this issue. It is cheap, and it is the reccommended Transistor from the DIY instructions
    - https://www.digikey.com/en/products/detail/nte-electronics,-inc/TIP120/11655270?utm_adgroup=Discrete%20Semiconductor%20Products&utm_source=google&utm_medium=cpc&utm_campaign=Shopping_DK%2BSupplier_NTE%20Electronics&utm_term=&NoQZMjD8RmT5YQKKf2Aplqqt44pZ_tBpg4XXP0z2lCM5caAhU6EALw_wcB
    - Already sent purchasing request to Puccinelli
- The Current setup is pictured below:
    - 
    - 

Conclusions/action items:

- Get Transistor from Puccinelli and Test ASAP.

10/20/22 - Relay Schematic

Drew Hardwick - Dec 13, 2022, 7:46 AM CST

Title: Relay Schematic

Date: 10/20/22

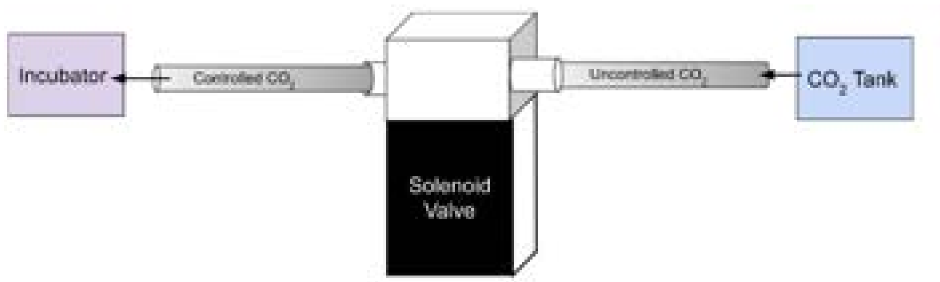
Content by: Drew Hardwick

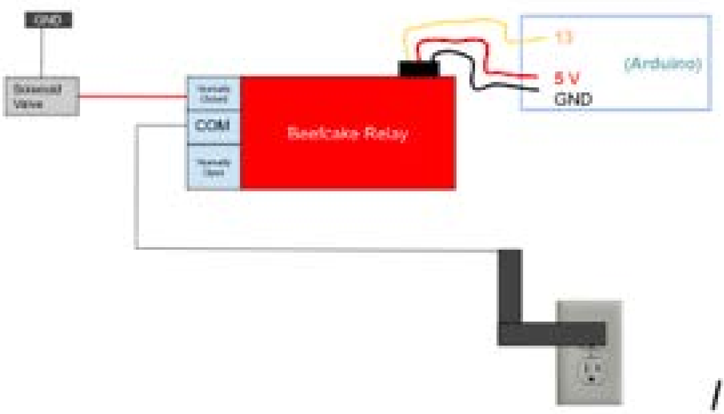
Present: N/A

Goals: Show Relay Setup for Solenoid Control

Content:

- Below are the schematics/block diagrams used to cobtrol the Solenoid valve using outlet power and a Beefcake Relay





Conclusions/action items:

- Link to NDIR Sensing code to properly adapt incubator CO2 internal environment
- Research I2C Code

References:

- https://www.sparkfun.com/products/13815

10/20/22 - Solenoid Testing

Drew Hardwick - Oct 20, 2022, 1:42 PM CDT

Title: Solenoid Testing

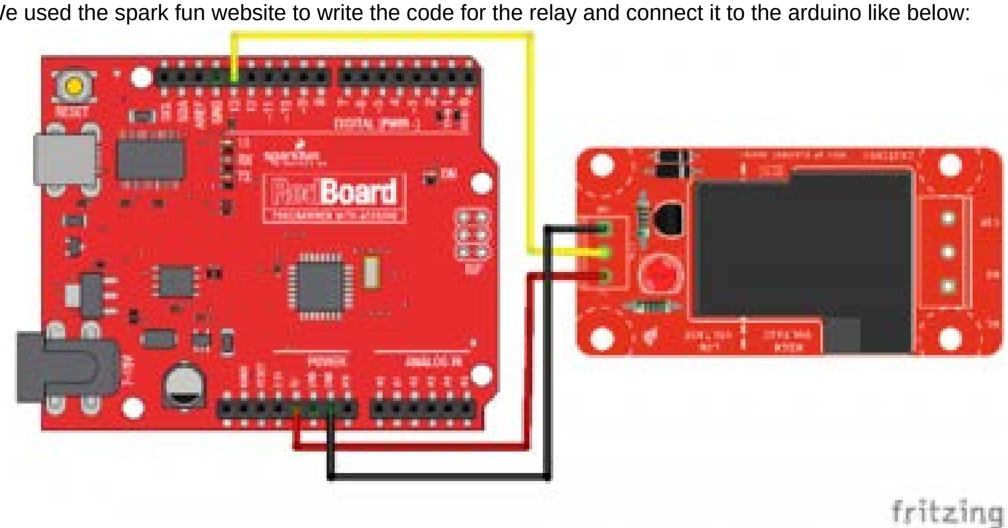
Date: 10/20/22

Content by: Drew Hardwick

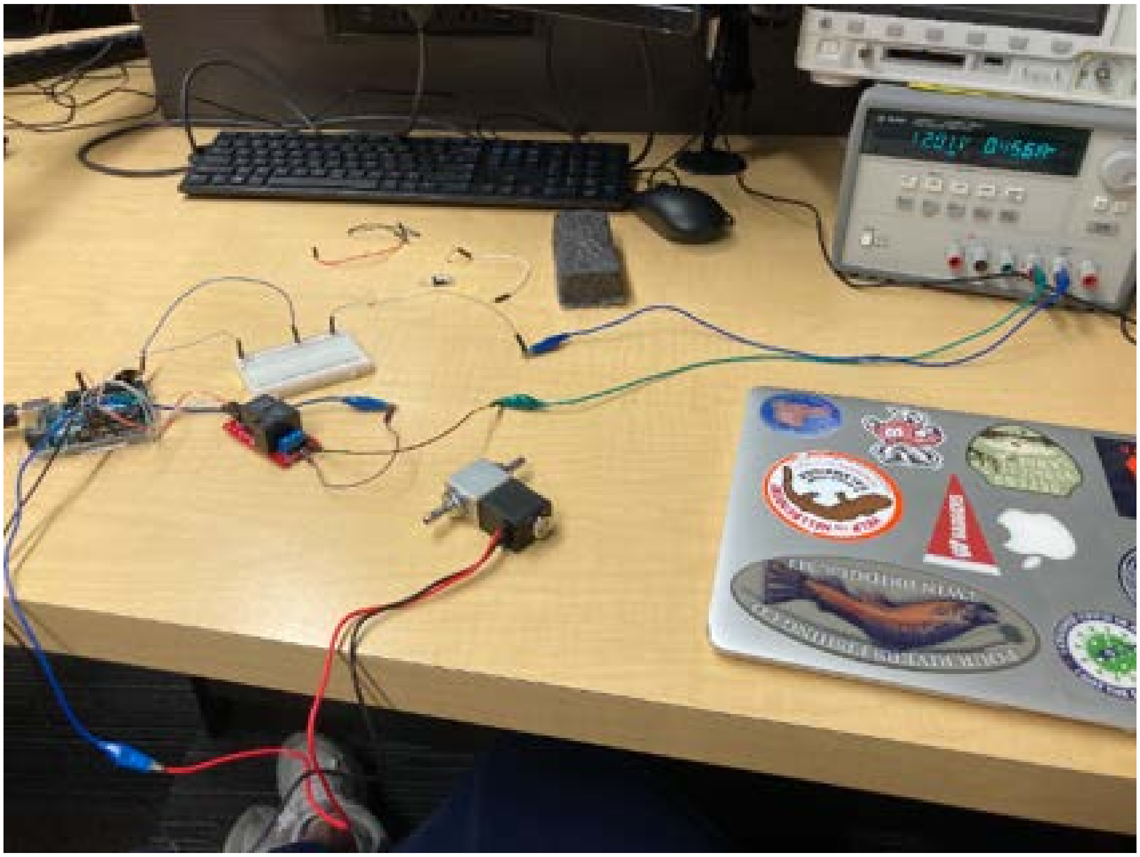
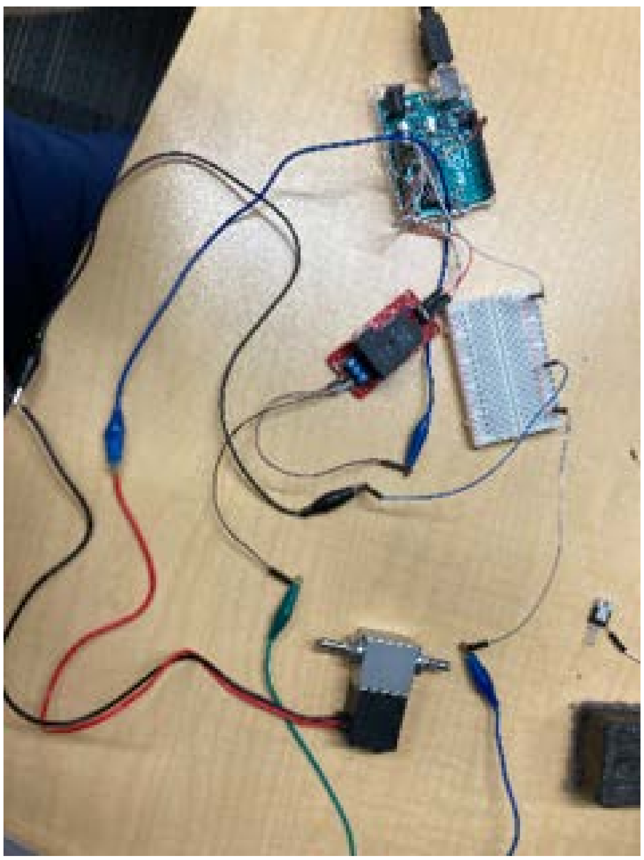
Present: Katie Day

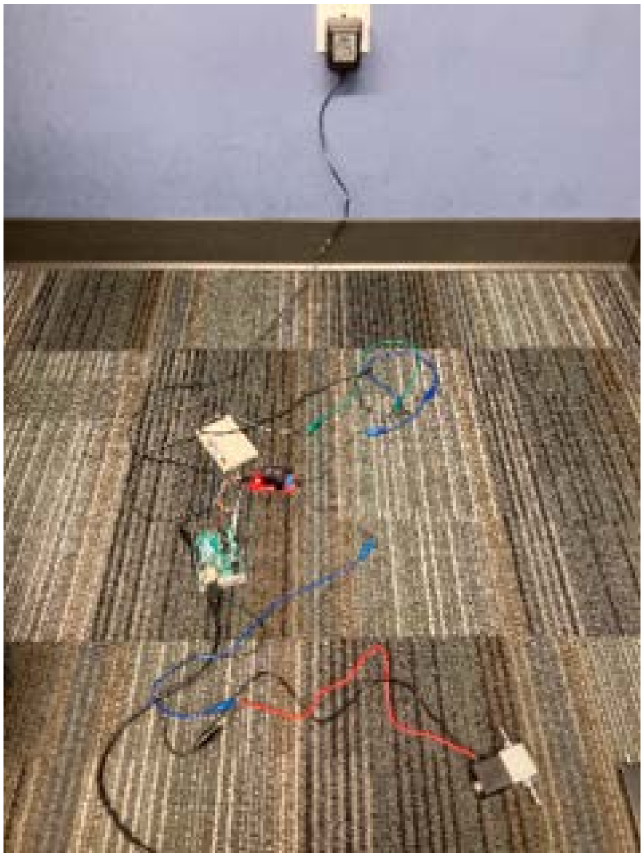
Goals: Get Solenoid Circuit up and running and attached to CO2 tank properly.

Content:

- Katie and I met with Dr. Nimunkar in the 201 lab (ECB 1080) and he gave us a 201 Sparkfun, Beefeater relay and explained to us how to hook it up to the DC power supply
- We used the spark fun website to write the code for the relay and connect it to the arduino like below:
- 

- We then tested our circuit with power from the DC voltage supply and IT WORKED!!!
- Below is our setup:

- 
- 
- Then Katie and I turned our attention towards adapting our circuit to function with power from a wall outlet
    - It is not feasible to be near a DC voltage supply anytime we want to incubate
- We again spoke with Dr. Nimunkar, and he directed us towards the supply room where we sorted through buckets and tangles for a wall adaptor with proper voltage and current values.
- We finally found one, cut and stripped the wires and attached it to our circuit and it ALSO WORKED
- Our setup is below:

- 
- We should be ready for full incubator CO_2 testing now!

Conclusions/action items:

- Test CO_2 in full incubator next week

References:

[] "Beefcake Relay Control Hookup Guide - SparkFun Learn." https://learn.sparkfun.com/tutorials/beefcake-relay-control-hookup-guide/example-arduino-control (accessed Oct. 20, 2022).

10/26/22 Solenoid CO2 Sensor Coding and Testing

Drew Hardwick - Nov 03, 2022, 7:43 PM CDT

Title: Solenoid CO2 Sensor Coding and Testing

Date: 10/26/22

Content by: Drew Hardwick

Present: Katie, Sam

Goals: See if Solenoid Can effectively regulate CO2 input and code a feedback mechanism

Content:

- Katie and I spent this session testing our solenoid code to link the NDIR sensor to our Solenoid valve
- Sam thought it best to write our code based on our flow-rate calculations that we tested, so that we use the flow-rate to keep the valve open for a specific amount of time depending on how much CO2 is needed in the system to always keep the environment right at 5%
  - The flow rate we tested and got was: 335mL/sec
- Here is the code we wrote for that:
  - ```
    NDIR_SoftwareSerial mySensor(2, 3);
    double percent = mySensor.ppm/10000;
    int solenoidPin = 4;   //output pin
    int relayPin = 13;
    double value = (50000-mySensor.ppm)/100; // difference in percent
    double totVol = 1759.55;
    double FR = 335.0;
    double openTime;


    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(solenoidPin,OUTPUT); //sets valve as output
        pinMode(relayPin, OUTPUT);


    }

    void loop() {
      //Concentration
       if (mySensor.measure()) {
          Serial.println((mySensor.ppm/10000));
          delay(1000);
          //communicate with solenoid
          if (mySensor.ppm < 50001){
           openTime = totVol * value / FR;
           digitalWrite(relayPin, HIGH);
           digitalWrite(solenoidPin,HIGH); //switch Solenoid ON
           delay(openTime);
           }else{
             digitalWrite(relayPin, LOW); //switch relay off
             digitalWrite(solenoidPin, LOW); //switch solenoid off
          }
    ```
    ```

```
      delay(5000);
    } else {
      Serial.println("Sensor communication error.");
    }
   delay(1000);
 }
```

- However, after speaking to each other and to Dr. Nimunkar, Katie and I thought that this code seemed too complicated, and difficult since we would be dealing with the valve constantly opening and closing for milliseconds at a time
  - We calculated (using our flow-rate) that for the box to go from 0% CO2 to 5%, the valve only needs to be open .26 seconds.
  - This means that to go from 4.5% or 4% to 5%, the valve would only open for a tenth or less of a second, and we don't think it is realistic to keep opening and closing our valve constantly like that.
- Thus, Katie and I decided to write a second code that converted our ppm from the NDIR sensor into a percent. volume CO2
- When this value drops below 4.5%, the valve will open until it reaches 5.5%, and then close
- This always ensures we keep our CO2 input at 5% +/- 0.5%
- The Code we wrote is below:
  - ```
    NDIR_SoftwareSerial mySensor(2, 3);
    double percent = mySensor.ppm/10000;
    int solenoidPin = 4;   //output pin
    int relayPin = 13;
    double totVol = 1759.55;
    double FR = 335.0;



    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(solenoidPin,OUTPUT); //sets valve as output
      pinMode(relayPin, OUTPUT);  //sets relay as output


    }

    void loop() {
      if (mySensor.measure()) {
        Serial.println((mySensor.ppm/10000));
       }else {
           Serial.println("Sensor communication error.");
       }
       if (percent < 5){
         digitalWrite(relayPin, HIGH);
          digitalWrite(solenoidPin, HIGH);
         delay(1000);
       }else{
         digitalWrite(relayPin, LOW);
          digitalWrite(solenoidPin, LOW);
          delay(1000);
        }
        delay(1000);
    }
    ```
- We tested this code, and found that it works separately (so does the sensor code) but the two cannot communicate when we hook them up together on the same arduino board
- Do we need to link 2 arduinos together?? Ask Dr. Nimunkar at weekly meeting for help

Conclusions/action items:

- Ask Dr. Nimunkar why our system will not communicate
    ```

11/10/22 - CO2 Feedback Testing

Drew Hardwick - Nov 10, 2022, 3:04 PM CST

Title: CO2 Regulation Feedback Testing

Date: 11/10/22

Content by: Drew

Present: Drew and Katie

Goals: Figure out how to link our Solenoid and NDIR Sensor and get them to talk

Content:

- We have been running into issues getting our solenoid to communicate with our NDIR sensor
- We had previously separated them on to different arduinos but they still would not communicate and we got very confused trying I2C and making 1 controller a master and 1 controller a slave
- Today, we tried a different approach of running the solenoid and the sensor from both different microcontrollers and from different computers with 2 separate arduino codes.
- It worked.... kinda
- The sensors were able to communicate, but it was inputting far too much CO2, to the point that it was saturating our sensor at 10% max
- Clearly our code was not working how we wanted it too
- To combat this, we have changed the code to use the flow-rate so that it inputs roughly 1% CO2 every minute and gradually climbs up to 5%
- The issue with this that it keeps constantly climbing AFTER it hits 5% as well
- We have tried to edit the code with a counter shown below, but testing this will take a significant chunk of time, so we have not ran it yet, we will test further next week
- Overall we are happy with the breakthrough in this session :)))

```
#include <SoftwareSerial.h>
```

```
int solenoidPin = 4; //Output pin
int relayPin = 13;
int NDIR = 2;
int val;
int x;

void setup() {
  pinMode(solenoidPin, OUTPUT);    //sets the pin as an output
  pinMode(relayPin, OUTPUT);
 // pinMode(NDIR, INPUT);   //sets the Sensor value as an
}

void loop() {
  //val = digitalRead(NDIR); //reads the values from the NDIR
  //if (val == 1 ){
   //digitalWrite(relayPin, HIGH);   //switch relay on
   //digitalWrite(solenoidPin,HIGH); //Switch Solenoid ON
   //delay(100);                    //wait 5 milisecond
  //}if (val==0){
    //digitalWrite(relayPin, LOW);    //switch relay off
    //delay(100);
  //}
 //delay(1000);
  for (int counter = 0; counter <= 300; counter = counter +1){
    digitalWrite(relayPin, HIGH); //switch relay on
    digitalWrite(solenoidPin, HIGH); //switch solenoid on
    delay(50);
    digitalWrite(relayPin, LOW); //switch relay off
    digitalWrite(solenoidPin, LOW); //switch solenoid off
    delay(72000);  // wait 1.2 minutes
  }
  delay(300000);

}
```

Conclusions/action items:

- Test New Code Next week

11/15/22 & 11/21/22 - Wiper Fabrication

Drew Hardwick - Nov 22, 2022, 8:28 AM CST

Title: Wiper Fabrication for Condensation Buildup

Date: 11/15/22 & 11/21/22

Content by: Drew and Sam

Present: Drew and Sam

Goals: Build a serviceable wiper device to clear condensation and allow for proper cell imaging

Content:

- Sam and I worked together these two days to create what we think is a serviceable wiper
- It may not be perfect, but it is a good short term fix that works well enough
- It can be improved upon next semester when we have more time, and that is something Sam and I will continue to tackle.
    - For this semester, this temporary design thrown together from just items from team lab and no purchasing will work!
- See the **"11/15/22 Wiper Fabrication"** Page under the **Fabrication** folder in the team notebook for images and specifics of our fabrication process

Conclusions/action items:

- This design is functionable short term fix
- Sam and I will make more capable design for next semester iteration of box.

11/30/22 - CO2 Testing with Hard Coded Solenoid

Drew Hardwick - Dec 07, 2022, 8:28 AM CST

Title: CO2 Testing with Hard Coded Solenoid

Date: 11/30/22

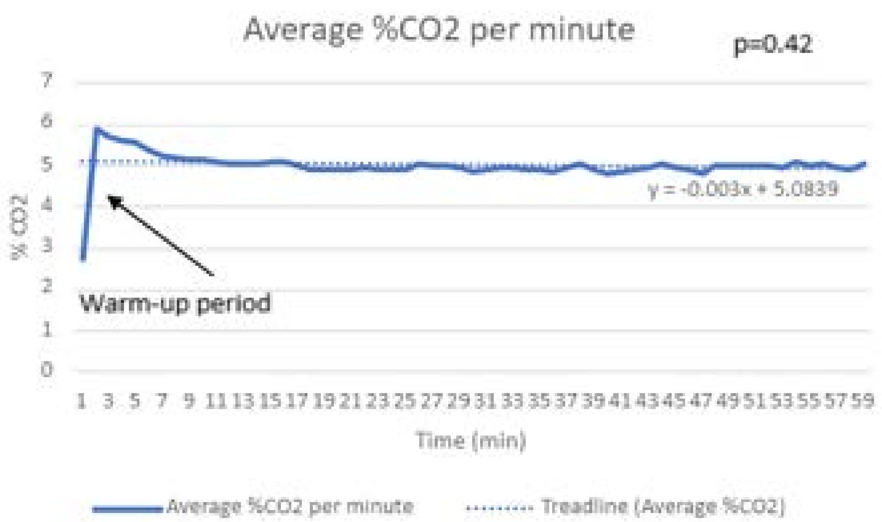
Content by: Drew Hardwick

Present: Drew Hardwick and Katie Day

Goals: Test our Hard Coded CO2 input code

Content:

- Katie and I met with Dr. Nimunkar attempting to learn I2C communication better, but we established that we do not have the time this semester to write our own I2C protocol
- Thus we determined that hard coding the system to be at roughly 5% CO2 was our best short term fix, and we should tackle I2C first thing next semester
- The Hard Code we used is attached to this page
- The Hard Coded Solenoid valve was tested for roughtly 1 hour according to the CO2 Testing Protocol
- The results are shown below:



- We calculated a standard deviation of .28. and a t-test yielded a value of .42
- This is conclusive in shoeing the results are not statistically significant and therefore this system can be used in live-cell testing

Conclusions/action items:

- Write up findings in report/poster
- conduct live cell testing
- write I2C protocol next semester with Dr. Nimunkar's help

Drew Hardwick - Dec 07, 2022, 8:30 AM CST

Download

Hard-code_test.csv (73.5 kB)

Drew Hardwick - Dec 07, 2022, 8:30 AM CST

Download

Custom_Data_-_2022-11-30_-_Recording_1.csv (7.91 kB)

12/5/22 - 12/6/22 Live Cell Testing

Drew Hardwick - Dec 13, 2022, 7:40 AM CST

Title: Live Cell Testing

Date: 12/5/22 - 12/6/22

Content by: Drew Hardwick

Present: Drew, Sam, Bella, Maya, Katie

Goals: Conduct live cell testing over a period of 36 hours

Content:

- We set up our entire incubator with temperature/humidity input and CO_2 input on the microscope for the first time ever!
- We then got it heated up and started the CO_2 regulation system
  - The CO_2 proved a bit tricky, we had to connect to two computers
  - The Solenoid control was connected to the tank (which we had to move) and the lab computer where the images from the microscope would be captured
  - The NDIR sensor had to be run from Katie's Laptop so that we could capture the data we needed with the data-streamer function
    - Could not download onto lab computers because of administrator restrictions
  - We then had to play 48 hour youtube videos on both computers to ensure they did not go to "sleep" and stop running our arduino code - Code is detailed in CO_2 testing file entry
- Live cells were then put into our incubator for the first time!
  - We were looking to establish a curve for cell growth/death to compare to our cell confluency testing control from earlier in the semester - protocol/results from that are attached to this page
- We imaged the cells every 12 hours by changing the cell media, and then taking off the incubator lid to take an image on the microscope according to Bella's cell imaging protocols attached to this page.
  - The CO_2 system had to be restarted any time lid was taken off to image
-
- I helped set up the initial test 9am 12/5, and I also took cell images/restarted CO_2 9am 12/6 and 9pm 12/6
- Adhered to Biosafety Standards 2.

Results:

- CO_2 issues and incubator decay caused premature death of the cells
- See final poster/final exam for in depth data analysis of results

Conclusions/action items:

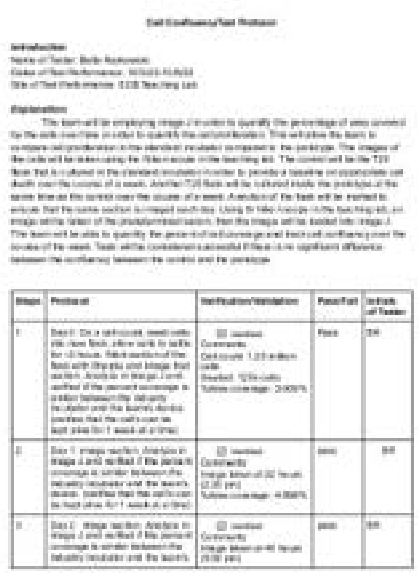
- Use I2C next semester in order to maintain the pH of the cells natural environment and refabricate incubator.

Drew Hardwick - Dec 07, 2022, 8:43 AM CST

Download

Cell_Imaging_Protocol.pdf (1.11 MB)

Drew Hardwick - Dec 07, 2022, 8:34 AM CST



Download

Cell_Confluency_Test_Protocol_-_Control_Completed.pdf (79 kB)

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

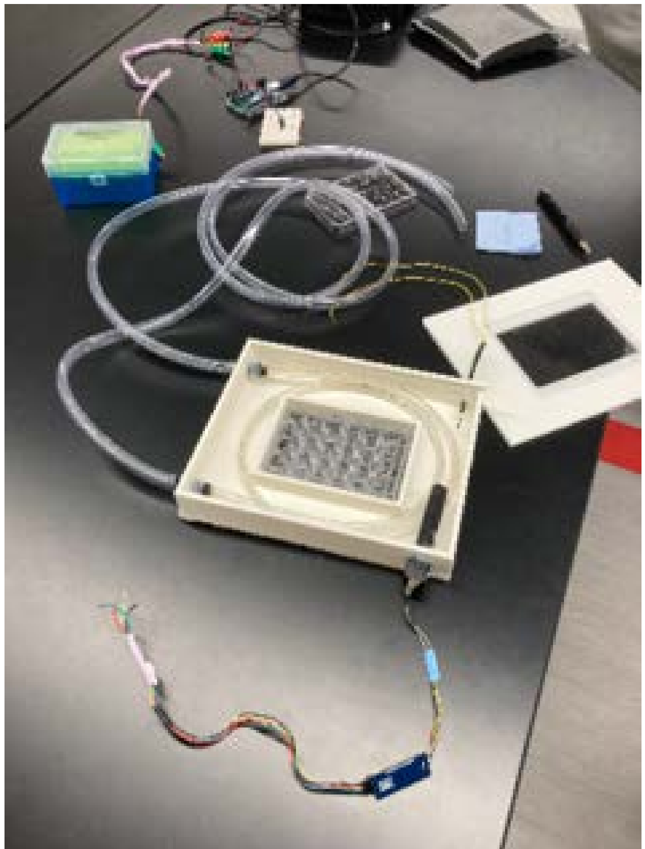
Content by: Drew Hardwick

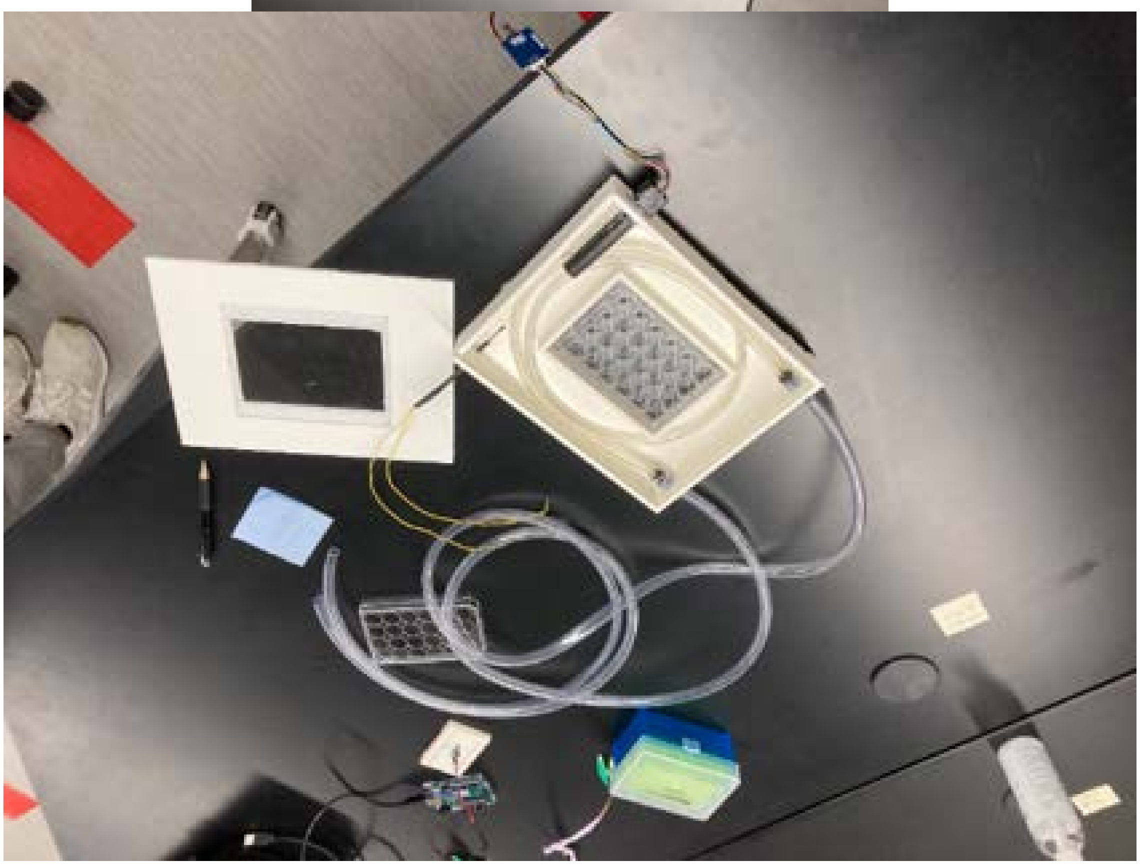
Present: Sam Bardwell

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% CO_2 and 95-100% humidity should be the primary goal of the semester
    - To reach this a CO_2 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 CO_2 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:

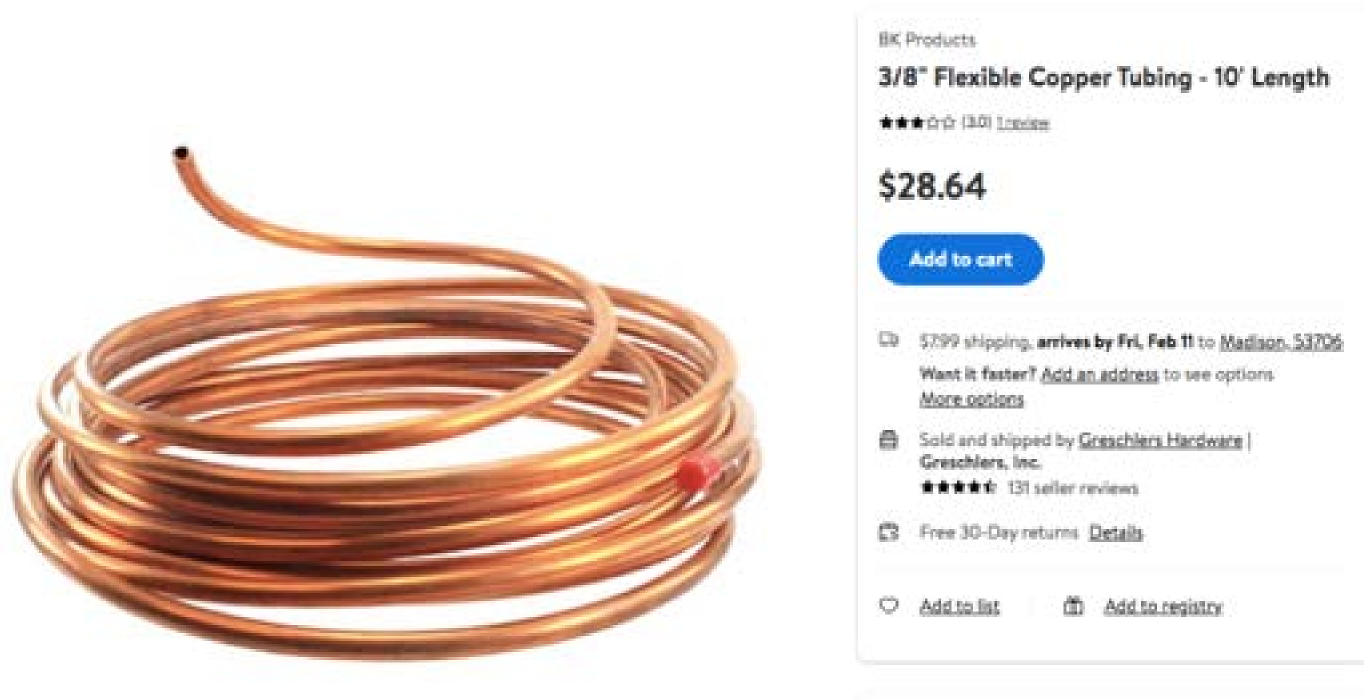


Figure (1): Flexible Copper Wire Available for Purchase at Walmart

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

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:

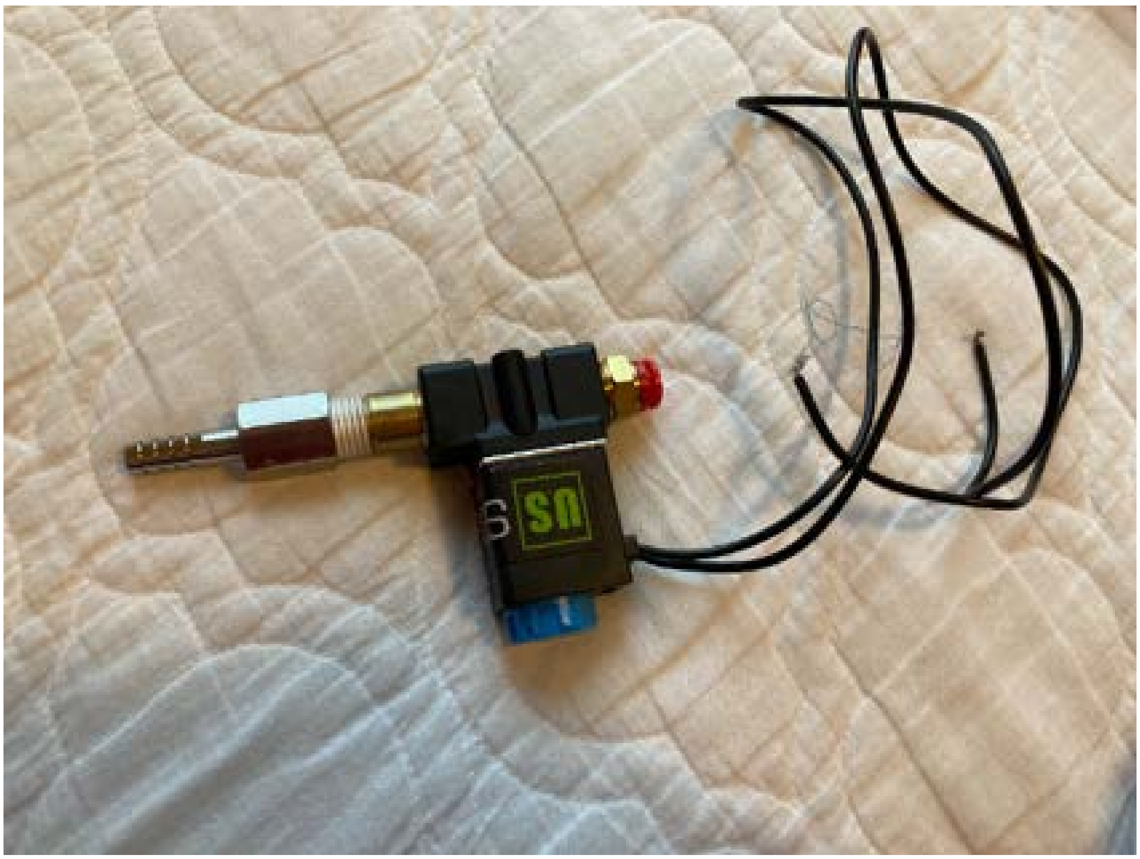


Figure 1: Previous Team's Valve

- 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:

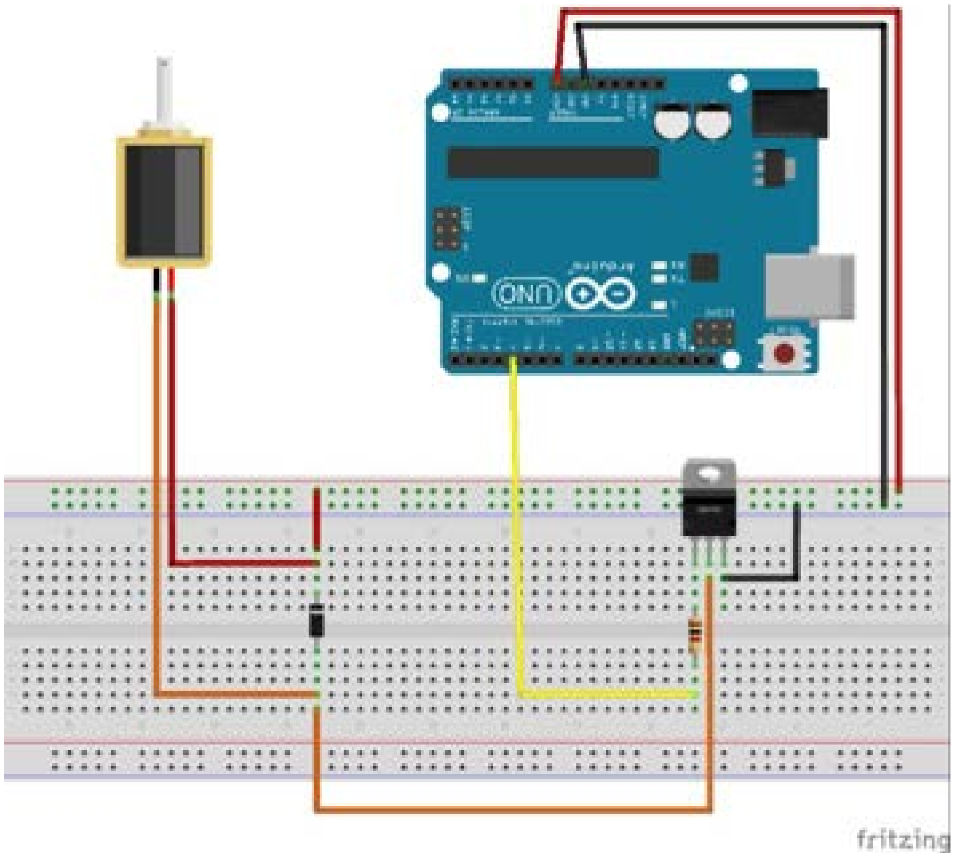


Figure 2: Solenoid Valve Schematic Diagram

- 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

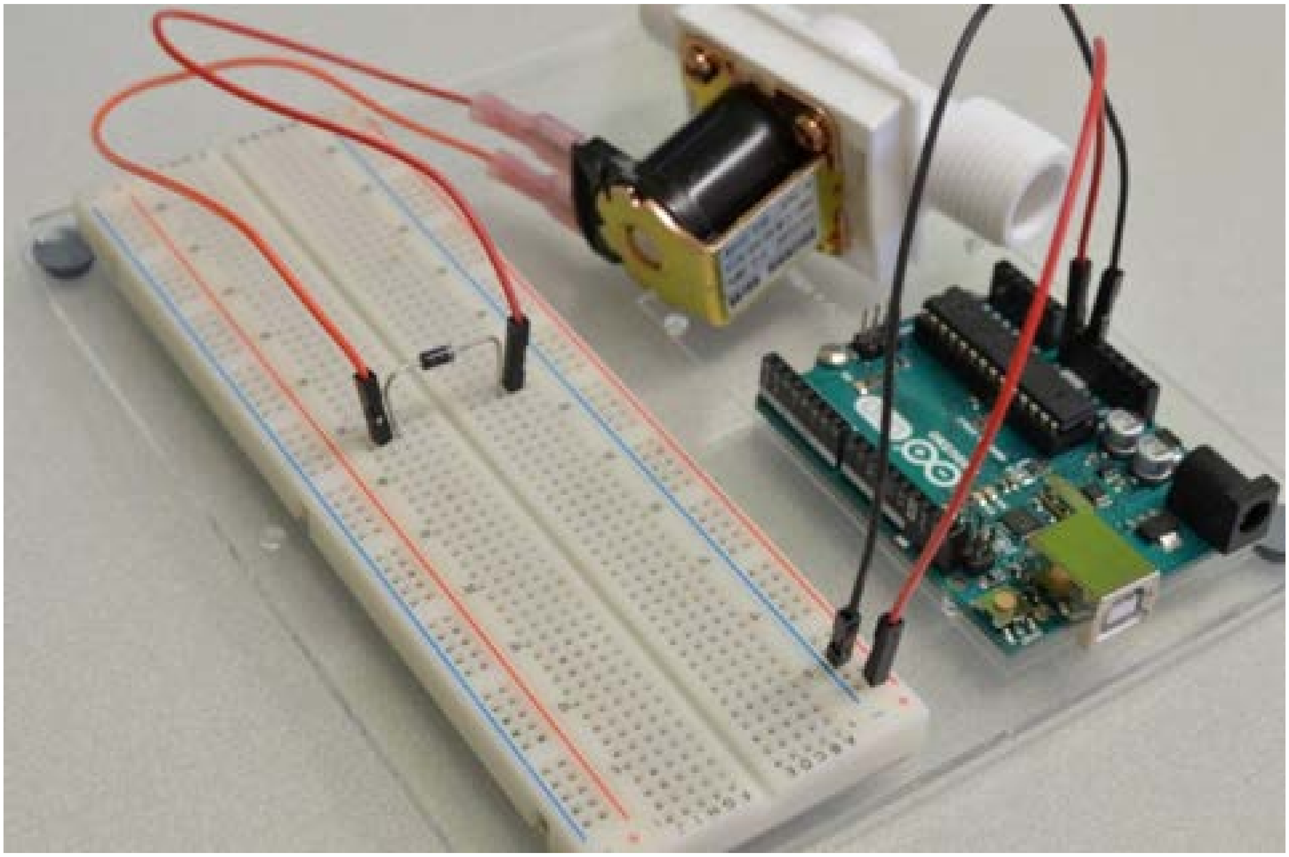


Figure 3: Setup thus far

- 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:

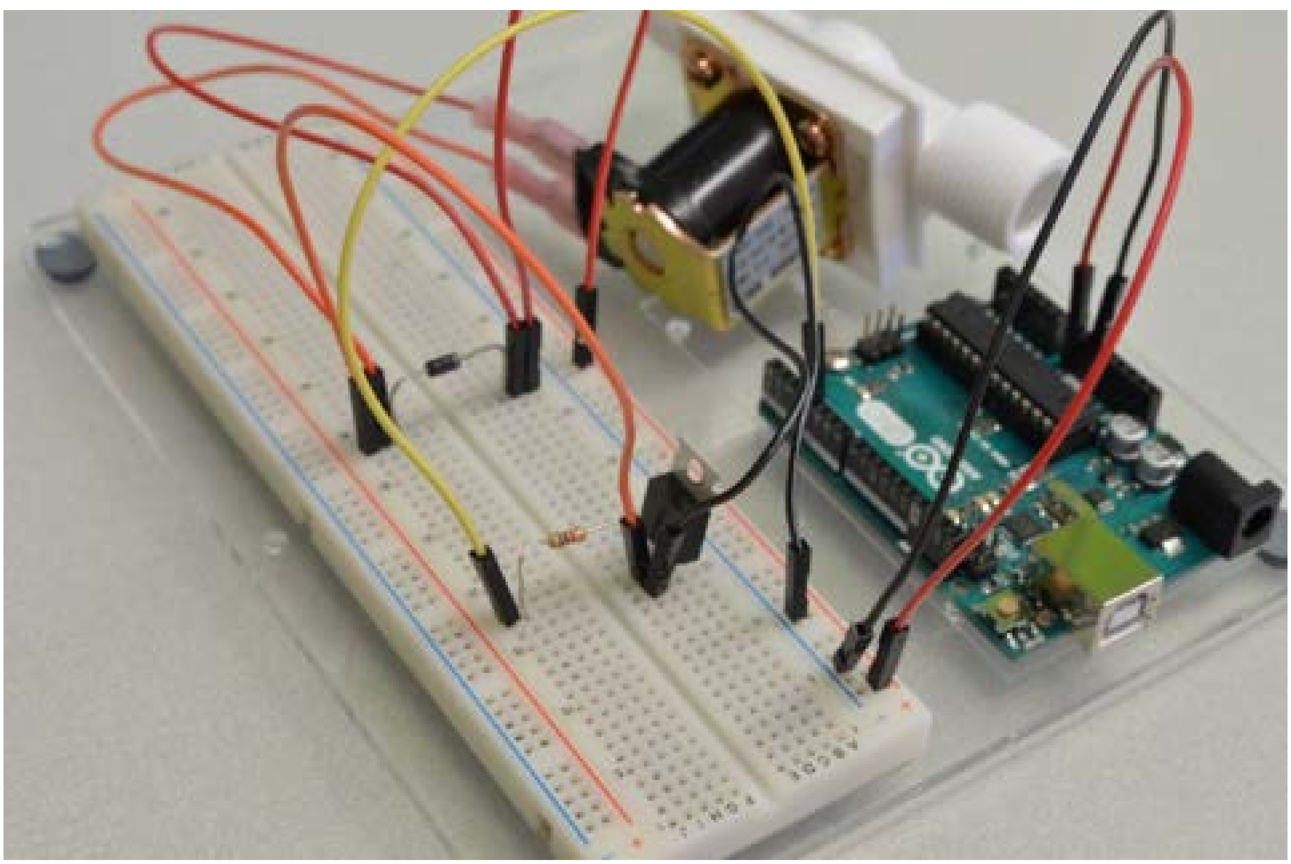


Figure 4: Final Solenoid Valve Arduino Setup

- Start writing/testing the code, which can be found at https://bc-robotics.com/tutorials/controlling-a-solenoid-valve-with-arduino/

Reflection:

- 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:
- 

- 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

---

Drew Hardwick - May 03, 2022, 6:34 PM CDT

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								
›lycarbonate 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								
) 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								
⊂ Motor	Actual motor used for CO2 regulation	UW Makerspace	1	4/11/2022	1	$2.00	$2.00	Link
)TAL:	$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:

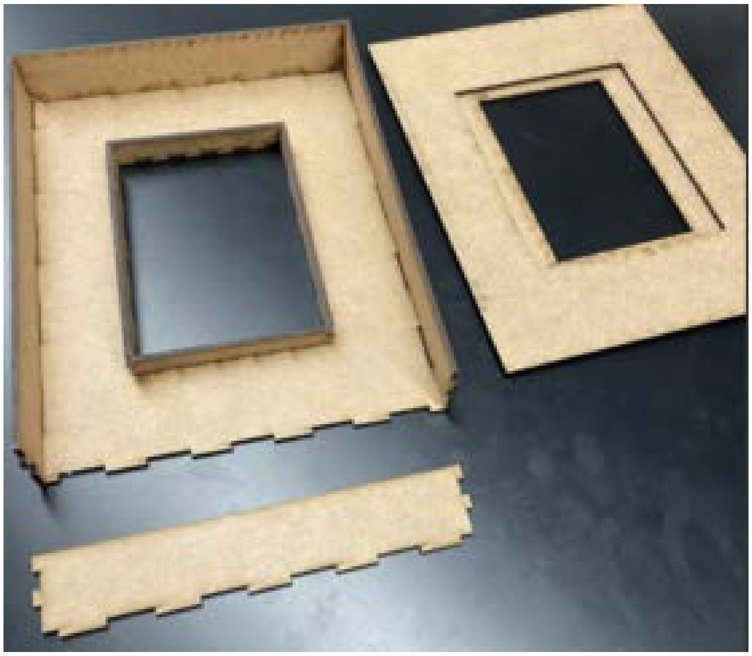


FIGURE 1: Wood Prototype

- 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

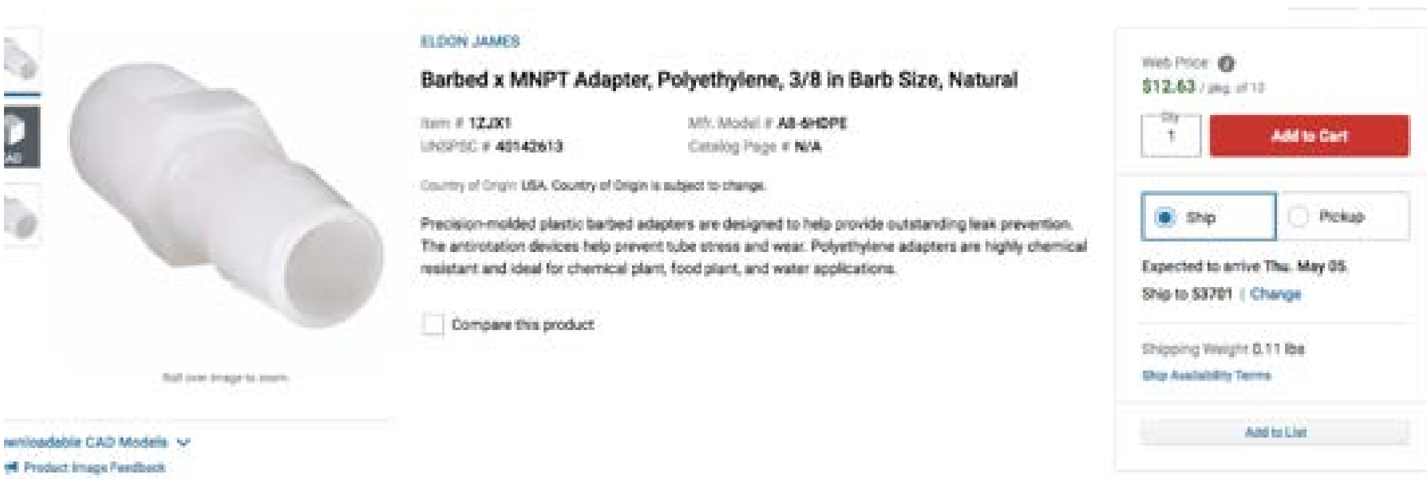


FIGURE 2: Barbed Adaptor Purchased

- 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	ILS9150D-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:

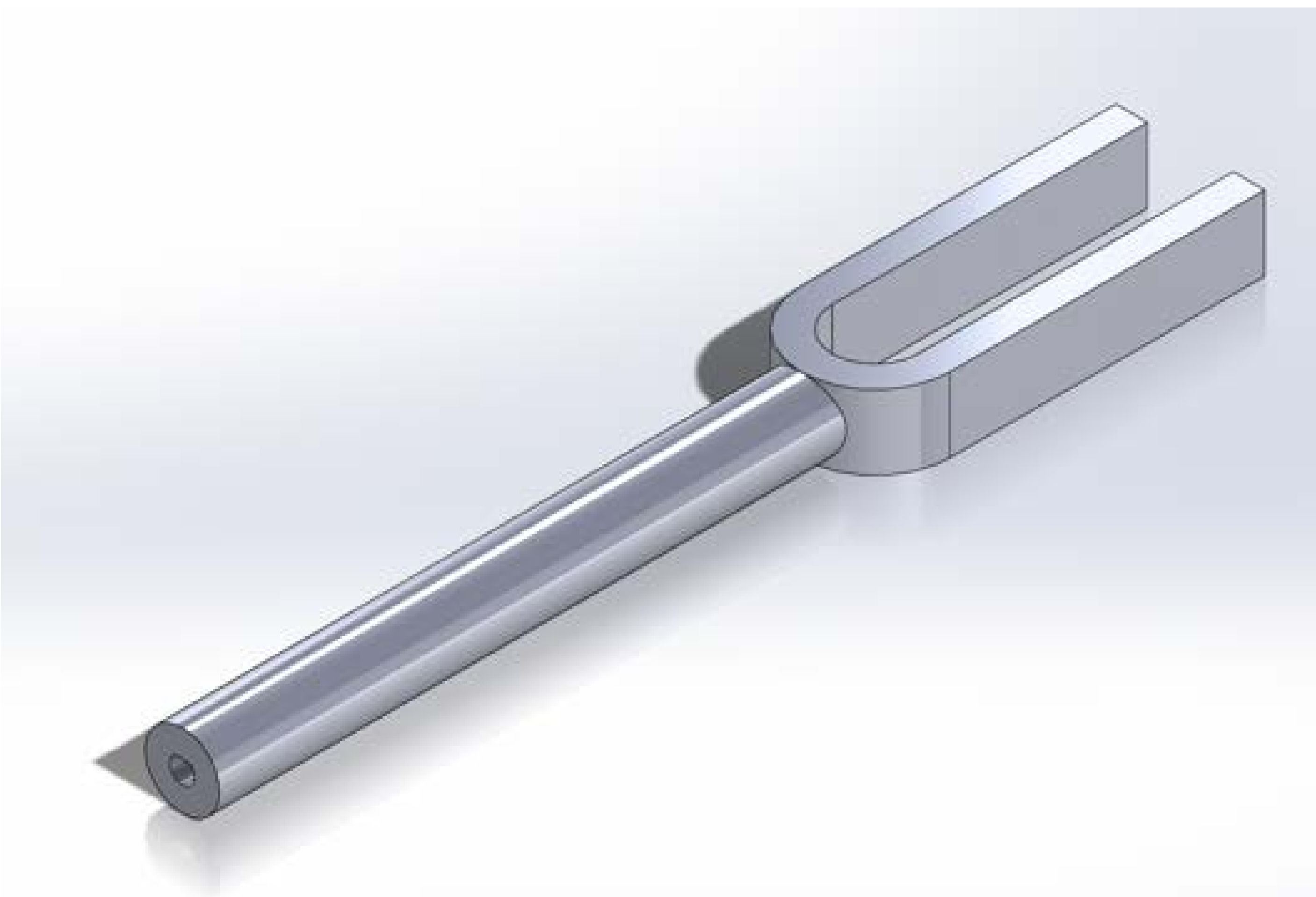


FIGURE 1: Tuning fork from BME 300 on SOLIDWORKS

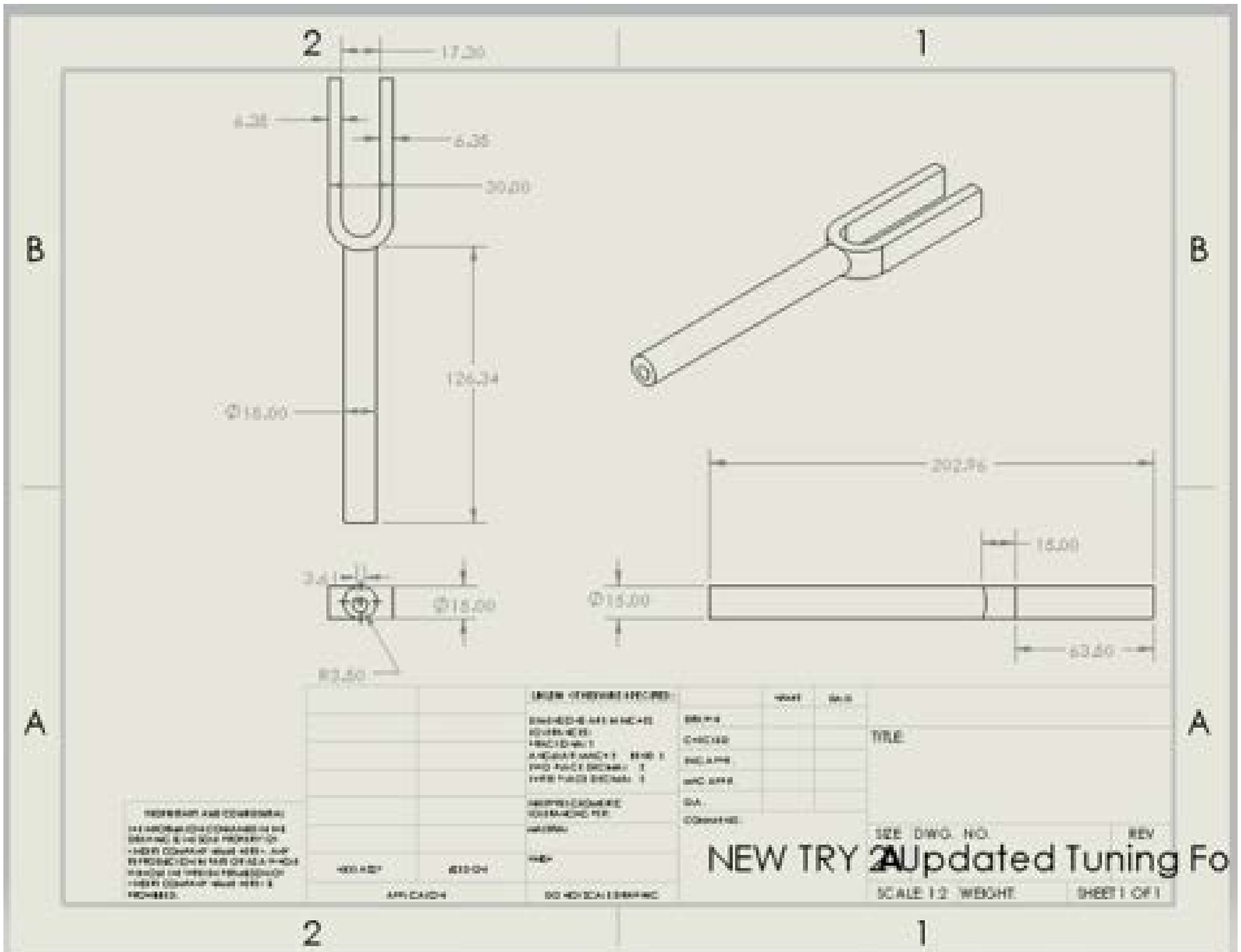


FIGURE 2: Tuning Fork Drawing

- 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)

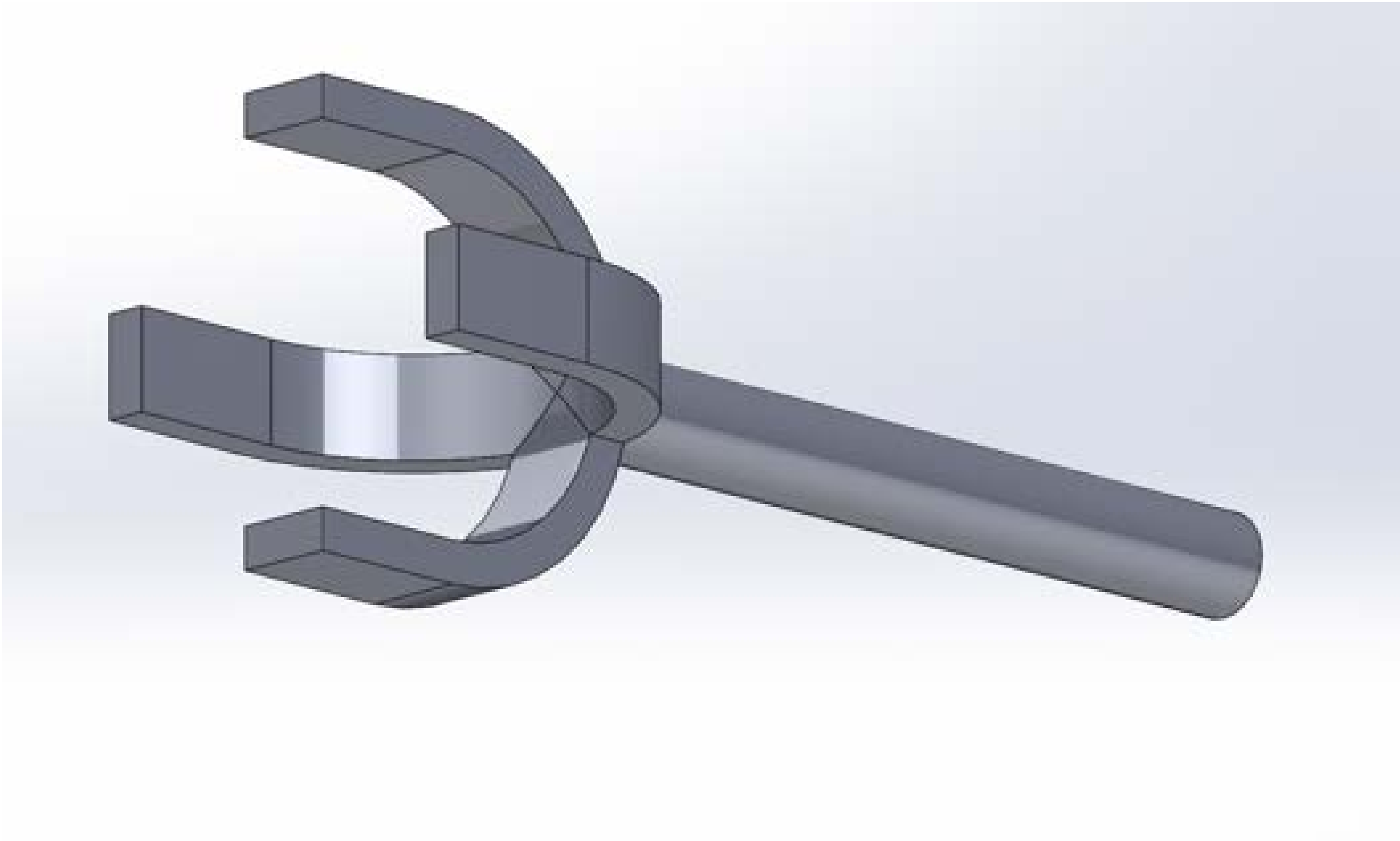


FIGURE 3: Initial Valve Connector SOLIDWORKS Design

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:

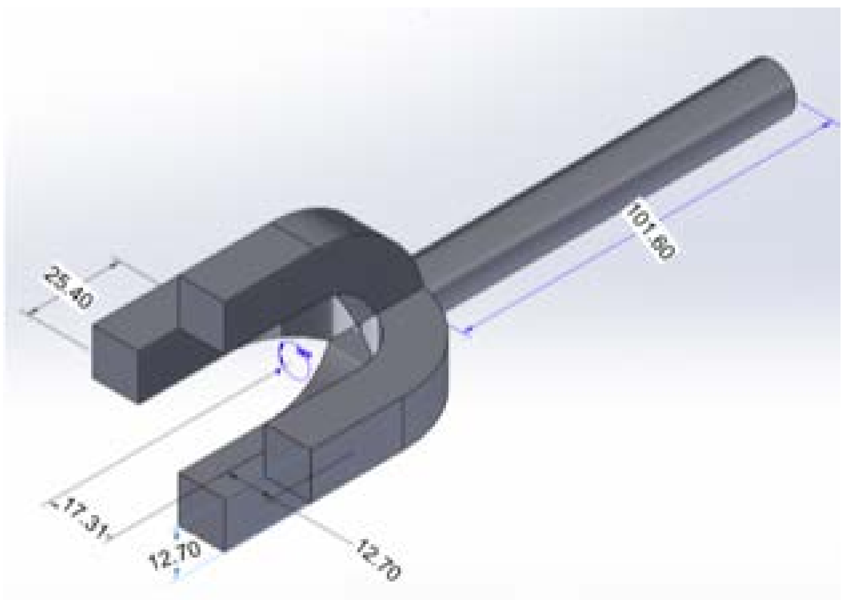


FIGURE 1: SOLIDWORKS image of edited Valve holder with dimensions in mm

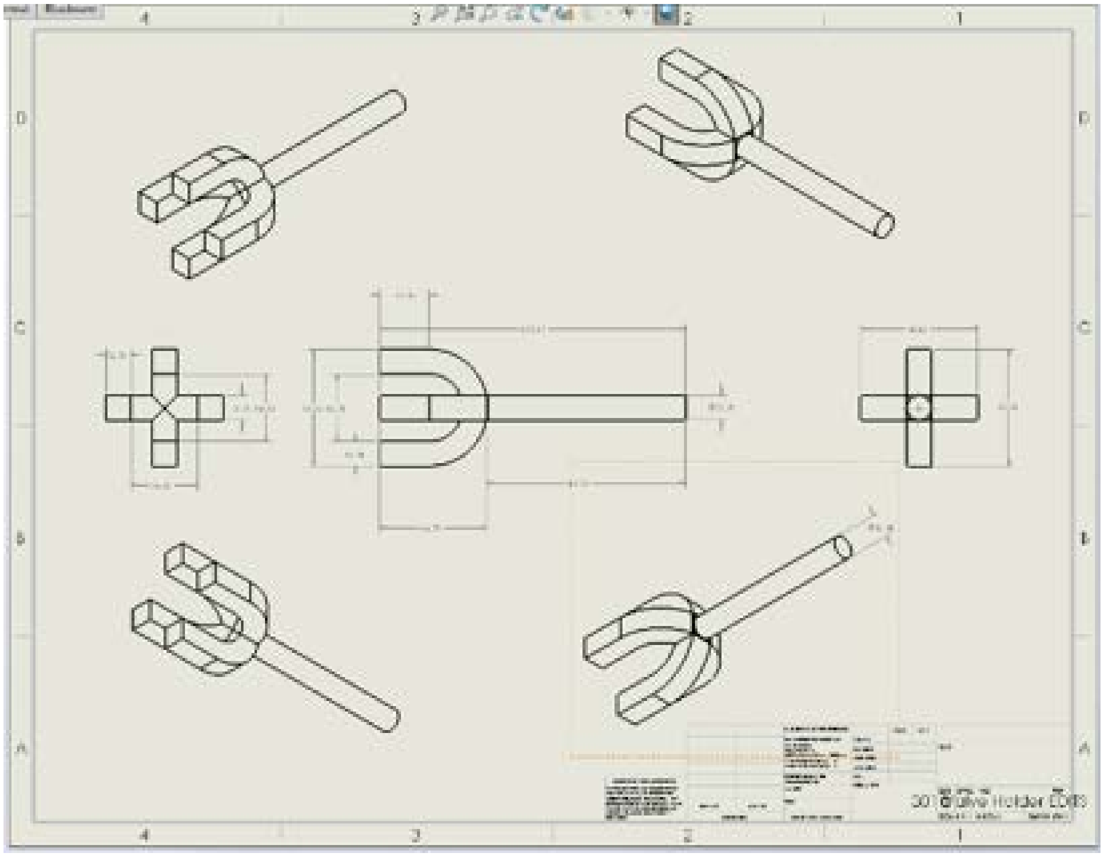


FIGURE 2: Edited Part Drawing with dimensions (in mm)

- 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

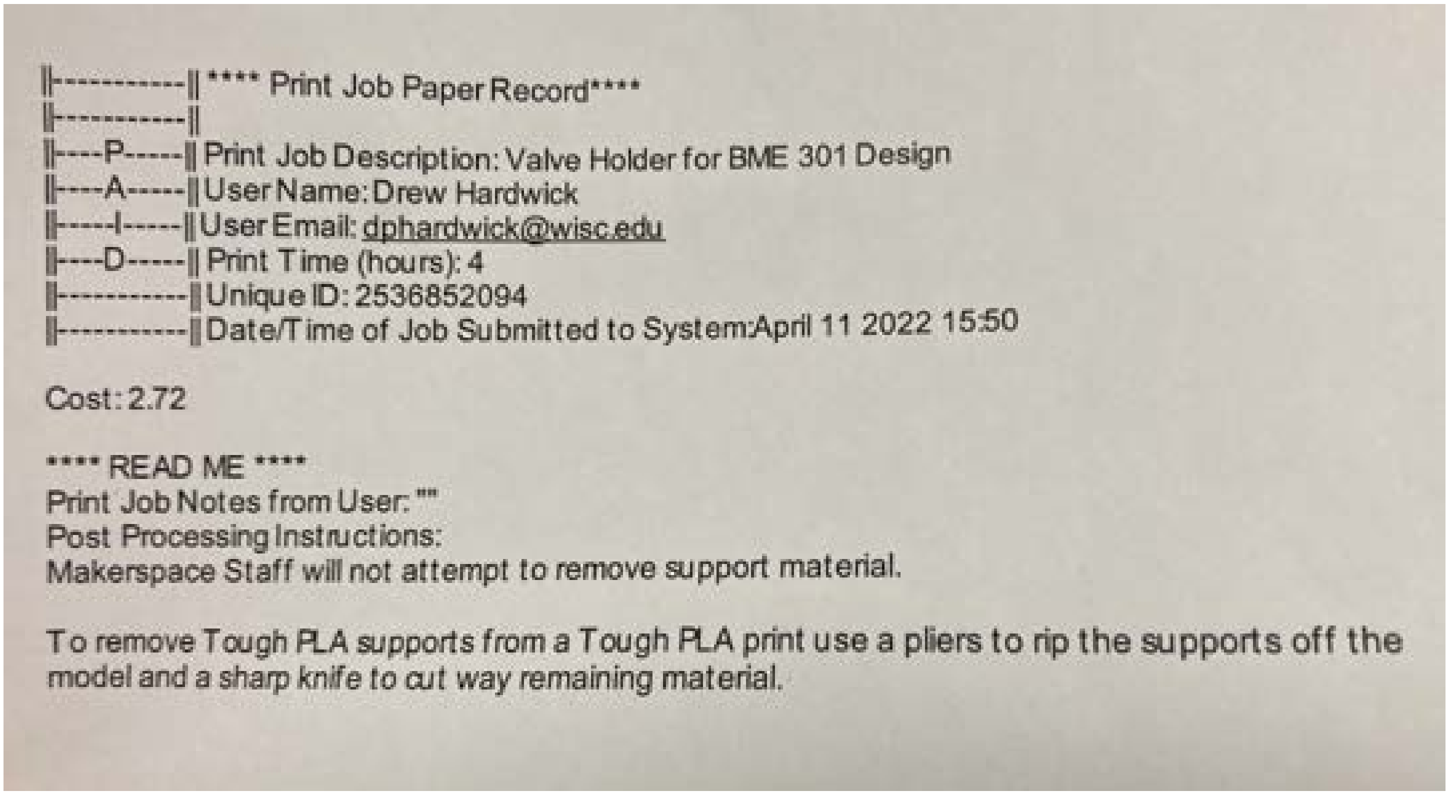
Present: N/A

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.

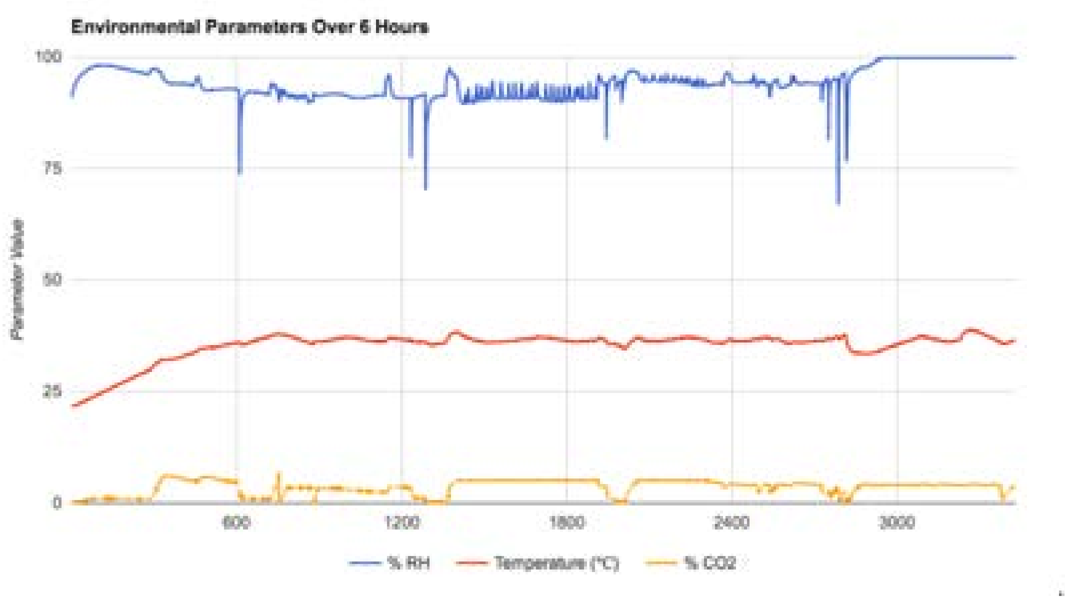


Figure 1: 2017 team environmental testing results

- 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 CO2 buffering must be performed prior to application in research

2016:

- While testing proved the control system accuracy and stability over time, the CO2 set point, 0.65%, was significantly below the desired specification of 5%.
- Could have injected enough CO2 to reach this concentration in the chamber, the sensor that was purchased was unable to detect any amount of CO2 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 CO2 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:

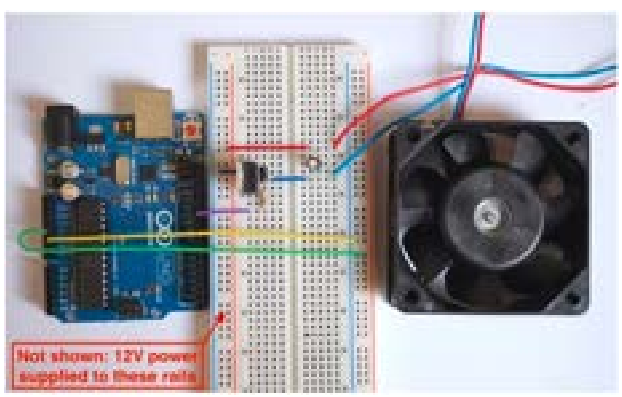


Figure 1: Circuit for Fan Control

- 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

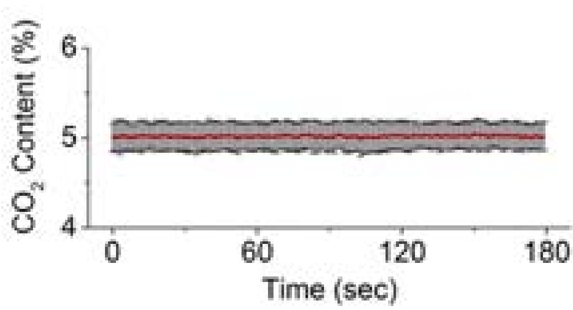


Figure (3): CO2 sensor testing

-
  - 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

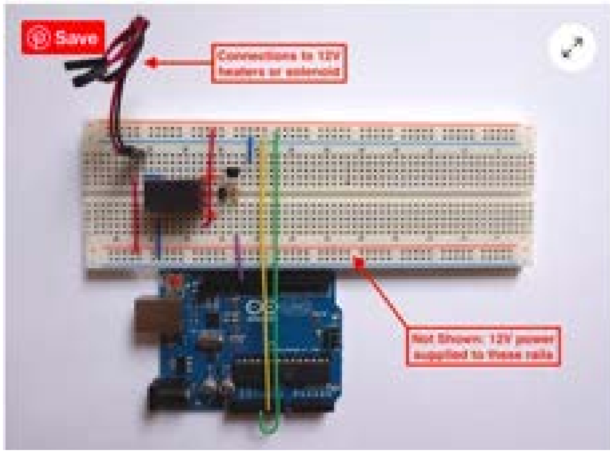


Figure (4): Solenoid arduino setup

Perfboard Setup:

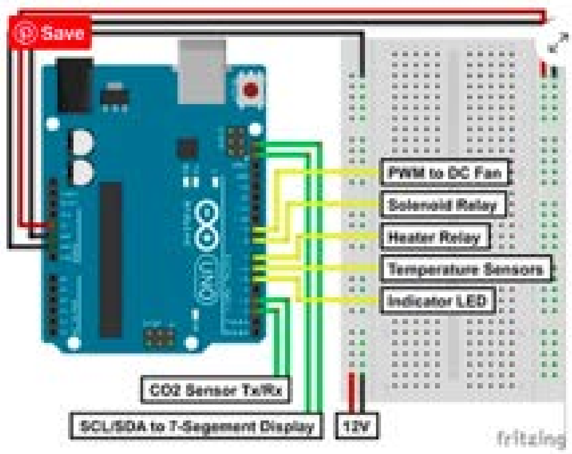


Figure (5): Perfboard setup

- 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

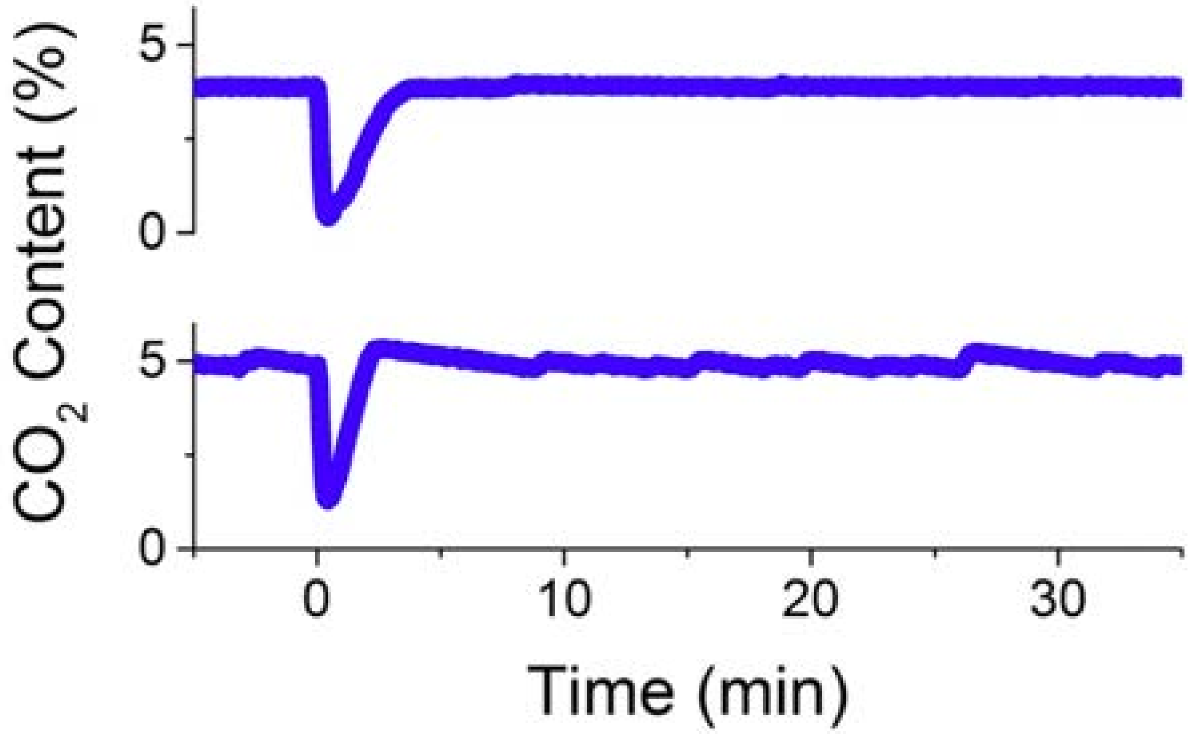


Figure (6): CO2 Testing Results

- 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:

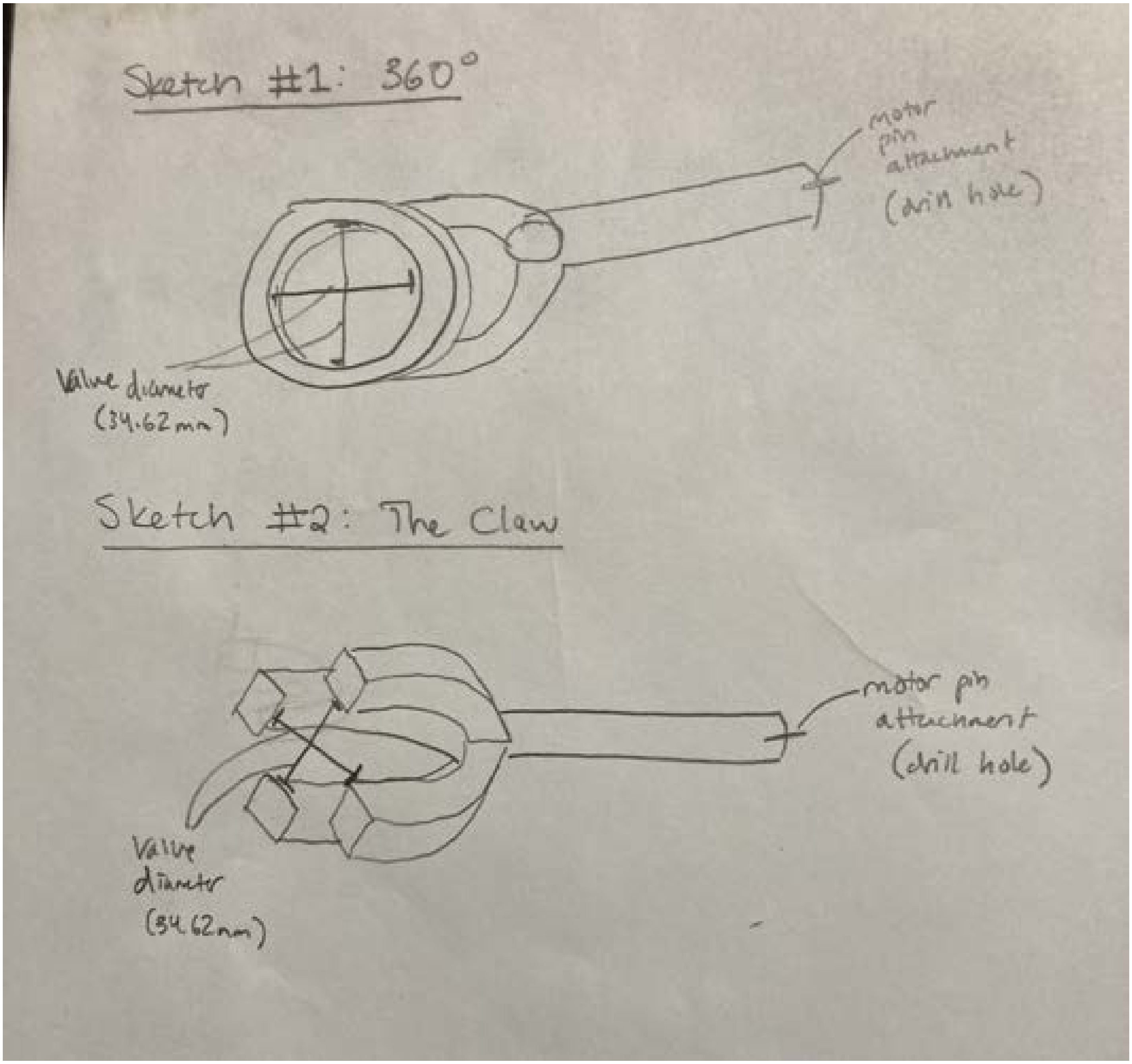


FIGURE 1: Design Sketches for CO2 Valve Adaptor

- 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℃.

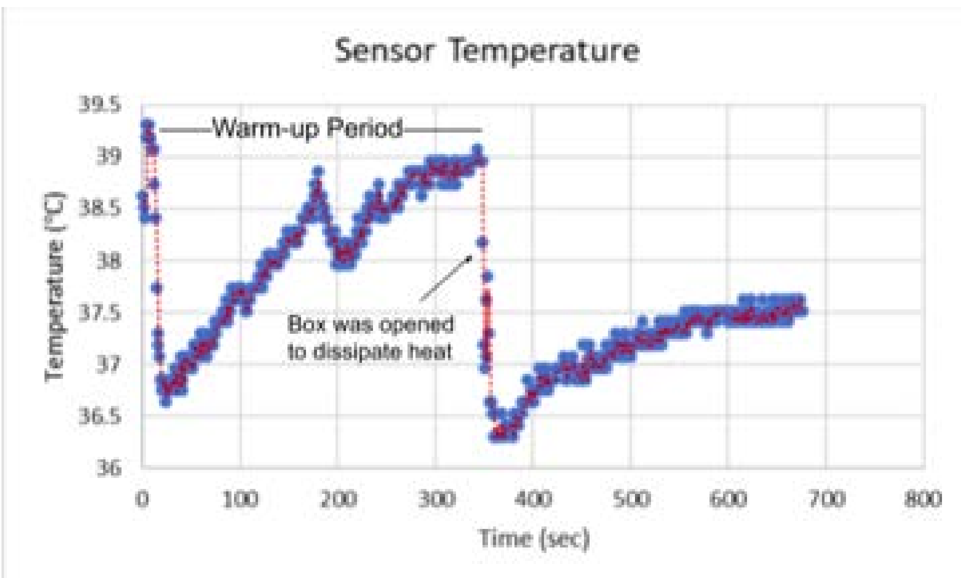


FIGURE 1: Full Incubator Temperature Testing results

- 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

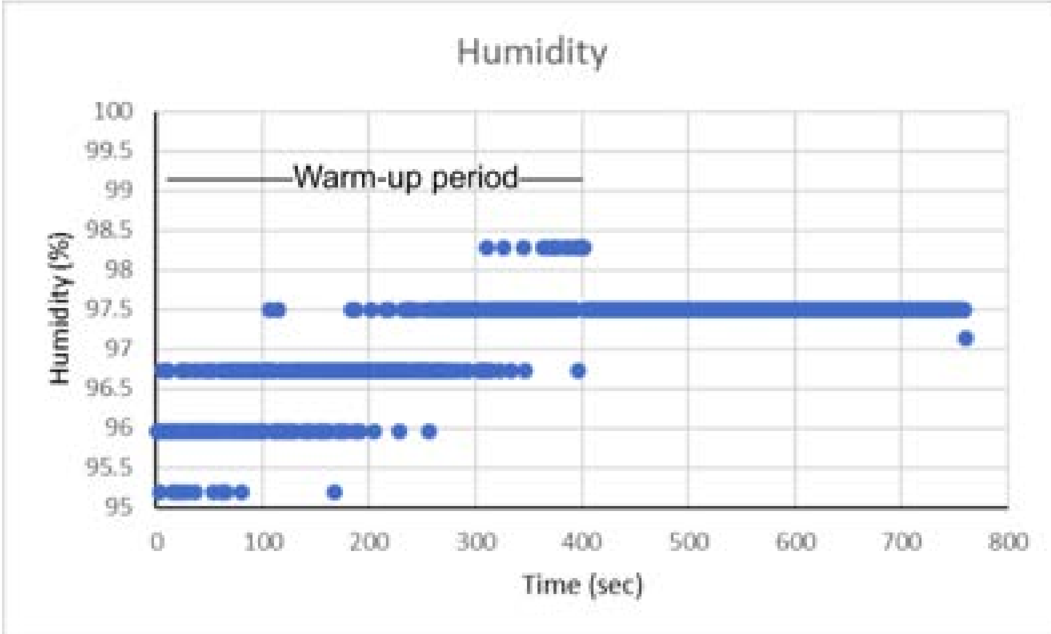


FIGURE 2: Full Incubator Humidity Testing results

- 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:

CO2 Testing

- 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

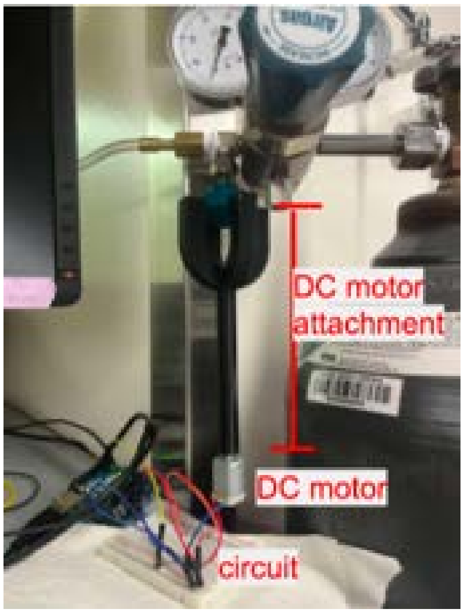


FIGURE 1: CO2 Testing Setup

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)

Recovery Testing:

- 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.

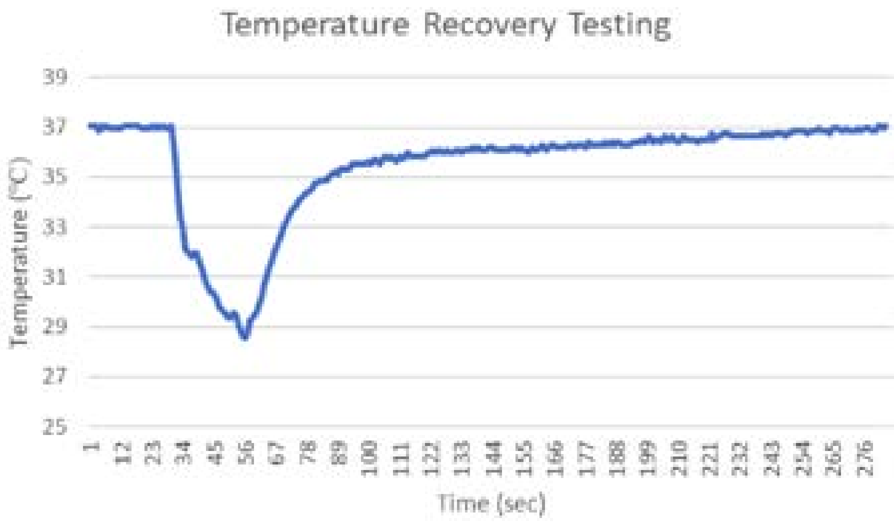


FIGURE 3: Temperature Recovery Testing results

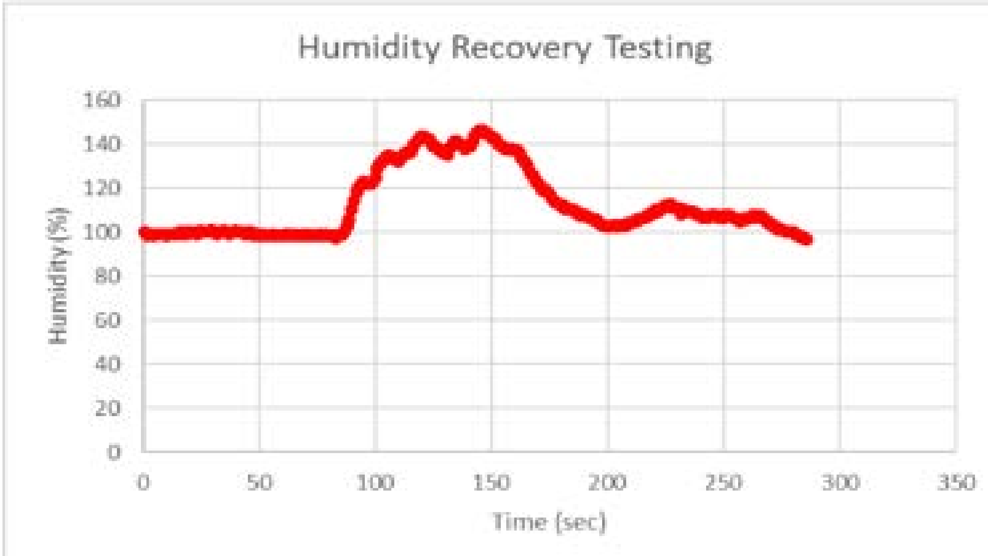


FIGURE 4: Humidity Recovery Testing results

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:

2/3/23: Laplacian Filter Article

Bella Raykowski - Feb 03, 2023, 2:04 PM CST

Title: Laplacian Filter

Goal: Learn more about laplacian energy and how we can use it to measure image focus quality

Content:

- The Laplacian of an image highlights regions of rapid intensity change and is an example of a second-order method of enhancement

- It is particularly good at finding the fine details of an image

- A Laplacian operator will enhance any feature with a sharp discontinuity

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$

- The Laplacian measures the divergence of the intensity gradient and therefore has the greatest magnitude in areas that are local peaks and valleys of intensity – a negative sign for the former and positive for the latter

- it naturally separates concentrations of darkness and lightness, independent of the absolute local intensity level

- it provides a scalar field (unitless)?

Conclusion: Was unable to determine if there even are units for Laplacian energy after checking multiple sources

Bella Raykowski - Feb 03, 2023, 2:04 PM CST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laplacian_energy_article.pdf (3.09 MB)

3/10/23: Inverted Microscope

Bella Raykowski - Mar 10, 2023, 11:30 AM CST

Title: Inverted Microscope

Date: 3/10/23

Goal: Determine how an inverted microscope images cells and how condensation affects that imaging

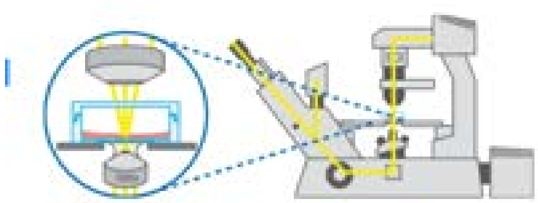
Content:

- an inverted microscope observes the cells through the bottom of the culture vessel (flask or well plate)

- this is done because most cells sink to and adhere to the bottom of the flask and are therefore spread across one focal plane

- light is emitted from the top part of the microscope which allows for the objective to pick up the cells due to contrast

- the bottom of the culture flask must have the highest optical features but the top should also still be clear as to not scatter the light



Schematic of an inverted microscope. Note the thin vessel bottom, through which the cells are observed.

Conclusion: the microscope is imaging the cells from the bottom but the top part of the flask still needs to be clear for adequate imaging

Link: https://ibidi.com/content/212-inverted-and-upright-microscopy#:~:text=In%20an%20inverted%20microscope%2C%20the,of%20the%20cell%20culture%20vessel.

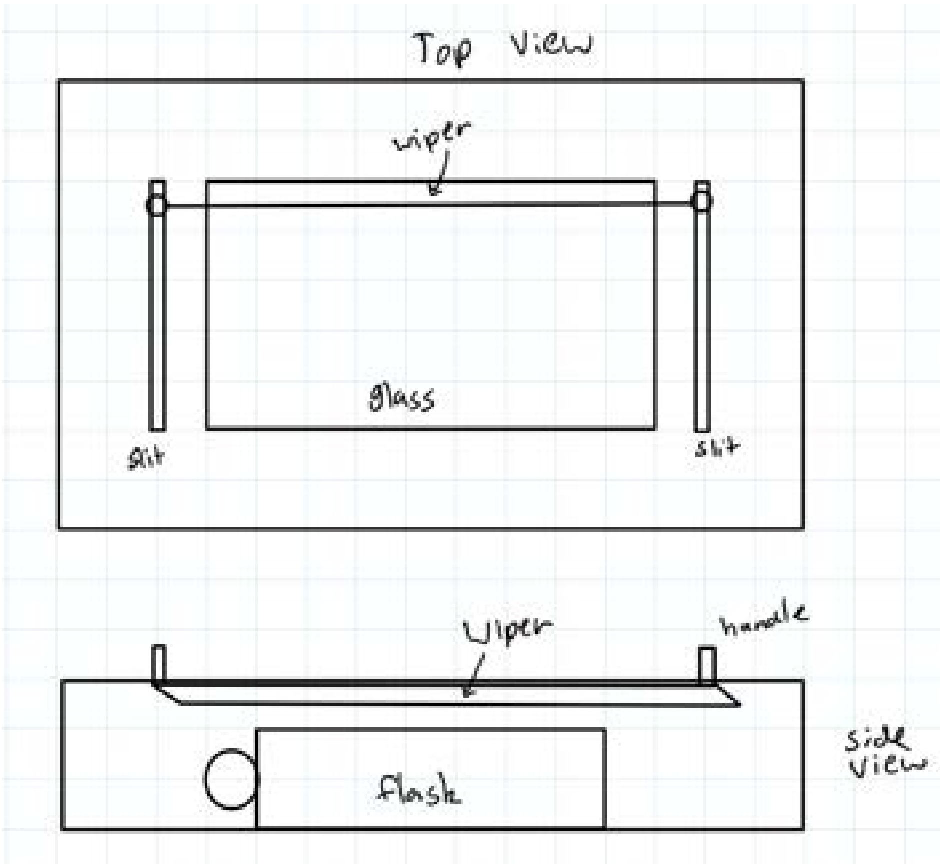
2/3/23: Sliding Wind-Shield Wiper

Bella Raykowski - Feb 03, 2023, 11:12 AM CST

Title: Sliding Windshield Wiper

Goal: Design a possible way to use a wind shield wiper to remove the condensation

Content:



- this design utilizes a dual handle sliding approach in order to support the wiper on both sides

- slits will be cut on either side of the glass to allow for movement, and space providing the can be linded with rubber to help reduce the loss of environment (heat, CO_2, etc.)

- a rubber wiper will be cut to be a small as possible in order to not disturb the flask when moving

- attaching the rubber to the handles could happen a few ways

- one idea would be to use mini clamps attached to the handle that clamp onto the rubber (this could reduce the need of metal lining to support the rubber)

Conclusion: this is a possible design we could go with should Dr. P decide he does want the box to have a window

2/3/23: Week 1 Progress

Bella Raykowski - Feb 03, 2023, 11:15 AM CST

Title: Week 1 progress

Goal: Document what I completed this week and what I want to complete next week

Content:

- this week I emailed Dr. P in order to obtain cells and will likely be receiving those on Monday

- I also designed a possible way to utilize the windshield wiper in the box that would hopefully fit in the small space that we have for it (see design ideas "sliding wind-shield wiper page")

- next week I hope to start live cell testing in the standard incubator in order to establish a baseline

- I also hope to analyze all the images taken and make the graph

- will meet with Dr. P to determine the necessity of the glass window or if we could do a solid box

Conclusion: I have a plan for the coming week and will continue to work with the team on anything that needs/wants help

2/10/23: Week 2 Progress

Bella Raykowski - Feb 10, 2023, 1:56 PM CST

Title: Week 2 progress

Goal: Document what I completed this week and what I want to complete next week

Content:

This week:

1. I researched the sanitation requirements of incubators and wrote a sanitation protocol for our prototype (see Team Activities --> Testing and Results --> Protocols ---> Sanitation)
2. Worked with the team to develop our preliminary presentation, running through the design matrices for the CO2 sensor and the heated glass element.

Next week:

1. I hope to start cell testing in order to develop a baseline
2. work on the preliminary report/journal

Conclusion: I have a plan for them next week in order to stay on track with the project

2/17/23: Week 3 Progress

Bella Raykowski - Feb 19, 2023, 1:48 PM CST

Title: Week 3 progress

Date: 02/19/2023

Goal: Document what I completed this week and make a rough plan for next week

Content:

Completed:

- worked with Sam to test the mini fan in the prototype by hooking the heated water bath in order to simulate the temperature and humidity environment

- placed the fan in the top left corner so that it was angled towards the top piece of glass and allowed the system to run for 45 min

- found that the fan can prevent condensation to an extent but will likely need a second one in order to cover the whole piece of glass

- see Team Activities ---> Testing and Results ---> Experimentation ---> Mini Fan Preliminary Testing

Next week:

- get cells from Dr. P in order to start live cell testing

- help out where it is needed on the team

- work on the preliminary deliverables

2/24/23: Week 4 Progress

Bella Raykowski - Feb 27, 2023, 11:36 AM CST

Title: Week 4 progress

Date: 02/27/2023

Goal: Document what I completed this week and make a rough plan for next week

Content:

Completed:

- Made trypsin to use in the cell testing

- Obtained cells from Dr. P, passaged them into a new T25 flask (200,000 cells), and started cell confluency testing

- imaged cells on day 0, 1, 3 and will continue into the next week

- analyzed the first few images and started the graphical representation of the data

Next week:

- finish live cell testing in the control incubator

- finish the preliminary deliverables

- help where needed

2/30/23: Week 5 Progress Report

Bella Raykowski - Feb 28, 2023, 6:03 PM CST

Title: Week 5 progress

Date: 02/30/2023

Goal: Document what I completed this week and make a rough plan for next week

Content:

Completed:

- finished control cell testing, analyzed all images, and compiled the data into a graph (see Team Activities --> Testing and Results --> Experimentation --> Control Cell Confluency Test)

- finished the preliminary report

Next week:

- possibly to a preliminary prototype cell confluency test to see if we need to troubleshoot the CO2 input

- help where needed (possibly on fan installation)

3/24/23: Week 8 Progress

Bella Raykowski - Mar 27, 2023, 1:26 PM CDT

Title: Week 8 progress

Date: 03/24/2023

Goal: Document what I completed this week and make a rough plan for next week

Content:

Completed:

- attempted to complete cell testing but found on Monday (3/20) that all the cells were dead

- Talked to Dr. P and determined that they likely died due to the lack of nutrients (no media was changed over the 10 days) and the water tray in the incubator was empty therefore humidity was low

- Obtained new mice osteoblast cells from Parker on Thursday (3/23), thawed and seeded them into a T25 flask

- a quick check on the microscope showed that the cells were very confluent and would need to be passaged soon (this was good because we wanted to start cell testing the next day)

- Unforuntently most if not all the cells appeared dead on Friday (3/24), I talked with Dr. P and we think this was due to too much overcrowding and that they should have been seeded into a T75 flask or multiple T25 flasks (also this is when we noticed that the water bath in the incubator was empty which could have contributed to the issue)

- Contacted Parker again to get more cells and should have more by Tuesday (3/28) and will start live cell testing immediately

Next week:

- will hopefully start live cell testing and do extensive troubleshooting if cells die for a 3rd time

- will analyze images of cells and help team where needed

3/31/23: Week 9 Progress

Bella Raykowski - Apr 02, 2023, 9:37 PM CDT

Title: Week 9 progress

Date: 03/31/2023

Goal: Document what I completed this week and make a rough plan for next week

Content:

Completed:

- worked on addressing comments left by our advisor on our preliminary report

- began updating the final report

- obtained LIVING cells on Thursday and passaged them into a new flask on Friday

- cells should be ready by Monday for cell testing

Next week:

- LIVE CELL TESTING!!!!!!!!!

- work on final report

4/7/23: Week 10 Progress

Bella Raykowski - Apr 06, 2023, 1:51 PM CDT

Title: Week 10 progress

Date: 04/07/2023

Goal: Document what I completed this week and make a rough plan for next week

Content:

Completed:

- ran the first comparative cell proliferation test

- analyzed all the data from the cell proliferation test (see Team Activities --> Testing and Results --> Experimentation --> 4/6/23 Cell Proliferation test 1)

Next week:

- run a second comparative cell proliferation test

- work on final deliverables

4/14/23: Week 11 Progress

Bella Raykowski - Apr 17, 2023, 2:33 PM CDT

Title: Progress report week 11

Date: 4/14/23

Goal: Document my work from week 11

Content:

- completed cell proliferation test 2 (see Team Activities --> Testing and Results --> Experimentation --> 4/17/23 Cell proliferation test 2)

- analyzed all cell data

- next week I will trouble shoot the cell death and work on the final deliverables

9/19/22 Initial Client Meeting

MAYA TANNA - Sep 19, 2022, 2:03 PM CDT

Title: Initial Client Meeting

Date: 9/19/22

Content by: All

Present: All

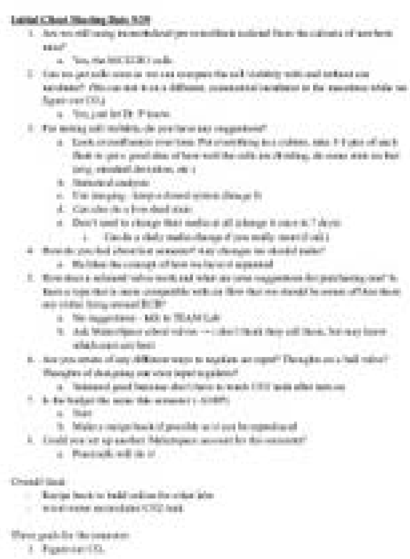
Goals: Ask the client any follow-up questions that will better help us meet our semester goals

Content:

See attached document.

Conclusion: We will use these answers to help guide us this semester.

MAYA TANNA - Sep 19, 2022, 2:03 PM CDT



Download

Client_Meeting_Questions.pdf (56.2 kB)

9/16/22 - Advisor Meeting

Drew Hardwick - Sep 16, 2022, 12:35 PM CDT

Title: Advisor Meeting

Date: 9/16/22

Content by: Drew

Present: All

Goals: Show Previous Project Progress

Content:

- Went over previous Final report to update Professor Nimunkar on our design ideas, for the box, temperature/humidity, testing and previous CO_2 design
- For CO_2 can we put the air flow into a seperate container and control the flow from that? - Nimunkar
- Katie Discussed Solenoid Valves
- Maya discussed Testing Plans
    - Get Cells from Pucc
    - anti fogging agent
- How to prevent Fogging
    - Conductive Glass, current heats up glass
    - Swim Goggle spray
- Sam discussed new $19,000 similar product and ball valves
    - Heated glass - good idea for ours
    - DC/stepper motor to turn ball valve
    - Keep looking for valve controls
- Drew discussed ball, solenoid, and gate valves
    - motorized ball and solenoid valves depending on grainger price
    - Action item: what circuitry would we need? How would we connect it to the CO_2 tank?
        - don't wanna have to keep adjusting the torque for the motor based on the tank.
        - should be human control --> completely open
- Trap door design
- Bella - Live cells
    - Get access from Pucc

Conclusions/action items:

9/23/22 - Advisor Meeting

MAYA TANNA - Sep 23, 2022, 3:32 PM CDT

Title: Advisor Meeting

Date: 9/23/22

Content by: Maya

Present: All

Goals: Document what was discussed at our meeting with advisor

Content:

- **Katie**: looked more into conductive glass and how that application would work, look into the mechanism of making conductive glass and if the budget was viable (it would be), in order to get the condensation reaction we are looking for it would have to be 40 degrees Celsius
    - Conclusion: Not the method we should go with because we would be cooking the cells at the bottom or top
    - Looked into some waterproofing applications that were non-toxic but wasn't successful
    - Better strengthened her knowledge on Arduino coding with solenoid valves
    - **Action Item**: when we get solenoid valve, start writing code to test it on the CO_2 tank
- **Maya**: Created a new test protocol to ensure homogeneity within the system and updated the overall testing protocol template document. Attended client meeting with the team and helped take meeting notes. Researched anti-fogging options on Grainger, and started coordinating purchasing with Drew. Emailed Dr. Puccinelli to obtain cells. Read over the PDS and helped finalize it. Uploaded team progress report to the website.
    - **Action Item**: write another test protocol on testing how often the anti-fog solution needs to be applied to the system, as well as help Bella with live-cell testing
- **Bella**: passaged cells, did research on quantitative methods to test cell viability/cell confluency in ImageJ
    - **Action Item**: help Maya with live-cell testing and getting image calculations set up and continue passaging
- **Drew**: researched more on CO_2 regulation, watched videos on how solenoid valves work, met with the MakerSpace to see if they had valves (they didn't but gave good insight), sent purchase request
    - **Action Item**: help with design matrices, secure ordered materials, help Katie with CO_2 and coding
- **Sam**: worked on design matrix options - specifically solenoid and pin valves
    - **Action Item**: finish design matrix, make test lid with holes for homogeneity test protocol

Conclusions/action items: Use these notes to ensure that action items are completed next week and everyone is accountable for their own contribution to the project.

10/14/22 - Advisor Meeting

Bella Raykowski - Oct 14, 2022, 12:33 PM CDT

Title: Advisor Meeting

Date: 10/14/22

Content by: Bella

Present: All

Goal: document what was discussed in the meeting

Content:

Design Presentation:

- add a note about cell viability in the PDS, cells should be kept alive for 1 week in the prototype

- in the design matrix, accuracy and reliability should be weighted even more

- put photo references in the design matrix and all following images (not just the first slide that the image appears on)

- explain more about competing designs, cost per year

- how is our device novel and different current commercially available incubators

Solenoid Valve

- when the valve is powered by the Aurdino, nothing seems to happen

- are you getting the correct voltage? need 12 volts, appears to only be getting 3-6 volts

- you don't want to source the voltage from the Aurdino, you will need an outside power source in order to get to 12 volts

- use the DC power supply in the lab to find the needed current and get the power supply from 310 stock room

- there are 2 sections of the power supply, connect to the +/-25 section, this will show you the max current needed to turn it on

- if it doesn't produce enough power, the stock room does have power supplies for computers that would definitely power it

- start looking into the protoboard because a lot of heat is being generated that will mess with the breadboard

- look into using a relay (see 201 documents for how to use it), which can switch large amounts of current on and off

- send an email reminder to Amit to set supplies out for Tuesday

Action item:

Katie and Drew: set up solenoid

Sam: print the homogeneity testing lid

Maya and Bella: reassemble the box with new glass, put the new glass on, and run temperature/optical testing

10/21/22 - Advisor Meeting

MAYA TANNA - Oct 21, 2022, 3:08 PM CDT

Title: Advisor Meeting

Date: 10/21/22

Content by: Maya

Present: Maya, Bella, Sam, Drew

Goals: To document everyone's contributions this week and future plans to ensure that project deadlines are met

Content:

See attached meeting notes.

Conclusions/action items: Use the action items in the document to guide future work and responsibilities.

MAYA TANNA - Oct 21, 2022, 3:08 PM CDT

Download

Advisor_Meeting_Notes_10_21.pdf (36.6 kB)

10/28/22 - Advisor Meeting #5

Drew Hardwick - Oct 28, 2022, 12:35 PM CDT

Title: Advisor Meeting #5

Date: 10/28/22

Content by: Drew

Present: Whole team

Goals: Update Dr. Nimunkar on design progress

Content:

- Team
  - Different team members juggling Optical, Homogeneity, and CO2 testing all at once
- Drew
  - This week:
    - syncing CO2 tank, solenoid, and CO2 sensor - problem! gives error
    - Decide between 2 feedback CO2 mechanisms, % based (selected) or flow rate, time based
  - Action Items:
    - separate arduinos w/ Katie - 1 to solenoid, 1 to sensors --> test again
- Katie
  - This week:
    - Flow rate testing - less than .5 seconds to get whole box to 5% CO2
    - syncing CO2 tank, solenoid, and CO2 sensor - problem! gives error
  - Action Items:
    - separate out arduinos w/ Drew
    - homogeneity testing w/ Sam --> specifically get thermistor up and running
- Maya
  - This week:
    - Optical Testing - working on data analysis
    - 1 hour test, image ever 10 min
  - Action Items:
    - 3, hour long imaging trials w/ Bella
- Sam
  - This Week:
    - Laser Cut/ glued homogeneity testing lid
    - Flow rate testing - less than .5 seconds to get whole box to 5% CO2
  - Action Items:
    - Homogeneity testing w/ Katie
- Bella
  - This week:
    - Optical Testing - working on data analysis
    - 1 hour test, image every 10 min
  - Action Items:
    - 3 hour long imaging trials w/ Maya

Conclusions/action items:

- Complete action items above!!

11/14/22 Advisor Meeting 6

SAMUEL BARDWELL - Nov 14, 2022, 2:29 PM CST

Title: Advisor Meeting 6

Date: 11/14/22

Content by: Everyone

Goals: To discuss weekly activities

Content:

Katie:

- Figured out how to talk between Arduino's for the CO2 sensor and solenoid valve

- Conducted homogeneity temperature and humidity sensing

Action Items

- Try LED to use with sensor to figure out Arduino communication error

Drew:

- Figured out how to talk between Arduino's for the CO2 sensor and solenoid valve

Action Items

- Try LED to use with sensor to figure out Arduino communication error

Sam:

- Came up with a new idea to implement the squeegee idea without using a DC motor

Action Items

- Fabricating the squeegee and helping with CO2 testing if needed

Bella:

- Tried to do O2 plasma deposition and tried chemical methods to make the glass hydrophobic to help with anti fog resistance, found Laplacian filter that measures the focus quality for us in MATLAB to analyze current data

Action Items

- Continue troubleshooting data analysis on anti fog testing, potentially take out the bottom glass piece

Maya:

- Researched MATLAB code and ways to data analysis with the anti fog data

Action Items

- Continue troubleshooting data analysis on anti fog testing and test out MATLAB ideas

Conclusions/action items:

11/18/22 Advisor Meeting

MAYA TANNA - Nov 18, 2022, 12:35 PM CST

Title: Advisor Meeting

Date: 11/18/22

Content by: Everyone

Goals: To discuss weekly activities

Content:

Katie:

- Tried LED and used with sensor to figure out Arduino communication error

Action Item: See if there are other issues that people are facing, read about libraries I2C, work with Dr. Nimunkar to fix code

Drew:

- Tried LED and used with sensor to figure out Arduino communication error, helped Sam with fabrication

Action Item: See if there are other issues that people are facing, read about libraries I2C, work with Dr. Nimunkar to fix code

Sam:

- Fabricated makeshift wiper blade as a prototype

Action Items

- Create a knob, recut the rubber to be more flushed, and do some testing on it

-Next semester: implement slider idea

Bella:

- Troubleshooted MATLAB

Action Items

- Continue troubleshooting data analysis on anti fog testing, potentially take out the bottom glass piece

Maya:

- Troubleshooted MATLAB

Action Items

- Continue troubleshooting data analysis on anti fog testing and test out MATLAB ideas

12/2/22 Advisor Meeting

MAYA TANNA - Dec 02, 2022, 12:28 PM CST

Title: Advisor Meeting

Date: 12/1/22

Content by: Maya

Present: Everyone

Goals: To discuss weekly activities

Content:

Katie:

-Did CO2 testing over the course of an hour to see if there was any error

Action Item: learn and complete live cell testing from Monday 9am-Tuesday 9pm, get data every 5 min

Drew:

-Did CO2 testing over the course of an hour to see if there was any error

-Finished wiper fabrication and tested in lab

Action Item: learn and complete live cell testing from Monday 9am-Tuesday 9pm, get data every 5 min

Sam:

-Finished wiper fabrication and tested in lab

Action Item: learn and complete live cell testing from Monday 9am-Tuesday 9pm, get data every 5 min

Bella:

- Figured out MATLAB image analysis

Action Items: Convert to greyscale image, live cell testing Monday 9am-Tuesday 9pm, teach rest of team how to image cells

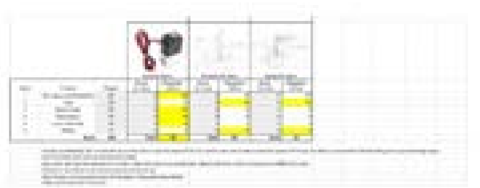
Maya:

- Figured out Image J analysis that we originally tried

Action Items: Pair Image J analysis with MATLAB Bella figured out.

9/28/22: CO2 Valve Design Matrix

Bella Raykowski - Sep 28, 2022, 5:19 PM CDT



Download

Design_Matrix.pdf (596 kB)

First Materials Purchasing Order

Drew Hardwick - Dec 12, 2022, 5:20 PM CST

Title: First Materials Purchasing Request

Date: 9/21/22

Content by: Drew Hardwick

Present: All

Goals: Send our first Materials Purchasing Request to Puccinelli

Content:

Hi Dr. Puccinelli,

Attached to this email is the first Materials Purchasing Request of the year for our team! The team is picking up where we left off this semester by replacing the glass plates on the incubator with fresh, clear plates, and purchasing antifog spray to prevent the buildup of condensation due to humidity on the inside of these plates. We are also purchasing a solenoid valve to regulate the CO2 input and start work with the circuitry and fabrication associated with that. Please let me know if you have any questions.

Thank you!
-Drew Hardwick

University of Wisconsin - Madison, Class of 2023
Biomedical Engineering
dphardwick@wisc.edu
314-305-4739

Conclusions/action items:

Drew Hardwick - Dec 12, 2022, 5:20 PM CST


Microscope Cell Culture Incubator

Download

Materials_Purchasing_Request_Fall_2022-_Microscope_Cell_Culture_Incubator.pdf (49.2 kB)

Final Expenses

Drew Hardwick - Dec 12, 2022, 5:22 PM CST

Title: Final Expenses

Date: 12/12/22

Content by: Drew Hardwick

Present: N/A

Goals: Finalize Budget

Content:

Expenses

Item	Description	Manufacturer	Part Number	Date	QTY	Cost Each	Total	Link
Component 1								
Glass	Polycarbonate Transparent Thermal Insulation Sheets	RADNOR	64005034	9/21/22	4	$1.21	$4.84	Link
Component 2								
Solenoid Valve	¼ inch DC 12V 2 Way NC Electric Solenoid Air Valve	Plum Garden	PL-220101	9/21/22	1	$9.35	$9.35	Link
Component 3								
Anti-Fog Solution	Lens Cleaning Solution: Anti-fog/Anti-Static Silicone	Grainger	4T932	9/21/22	1	$6.58	$6.58	Link
Component 4								
G1/4” Soft Tubing Barbed Adaptor	Barbed Adaptors that screw into Solenoid Valve and attach plastic tubing connected to CO2 tank to valve, to incubator	E-outstanding	N/A	9/29/22	4	$2.40	$9.59	Link
Component 5								
TIP120 Transistor	Transistor needed to power the solenoid valve using an Arduino Circuit.	NTE Electronics, Inc	2368-TIP120-ND	10/3/22	1	$1.00	$1.00	Link
Component 6								
Black Acrylic	Black Acrylic needed to create the homogeneity testing lid. (⅛ x 18 x 24)	UW-Makerspace	N/A	10/17/22	1	$10.75	$10.75	Link
TOTAL:	$42.11							

Conclusions/action items:

Standards/Specifications

Drew Hardwick - Dec 13, 2022, 8:27 AM CST

Title: Standards/Specifications

Content:

- The incubator would need to adhere to the ISO 13485 regulation which outlines requirements for regulatory purposes of Medical Devices [1]. The incubator would also need to follow the FDA's Code of Federal Regulations Title 21, Volume 8 where it outlines the requirements for Cell and Tissue Culture products [2].
- Make sure to follow these regulations and refer to them during fabrication process

References:

1. "ISO 13485:2016," ISO, 21-Jan-2020. [Online]. Available: https://www.iso.org/standard/59752.html. [Accessed: 20-Sep-2021].
2. "CFR - Code of Federal Regulations Title 21," accessdata.fda.gov, 01-Apr-2020. [Online]. Available: https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm?fr=864.2240. [Accessed: 20-Sep-2021].

10/20/22 - Relay Schematic

Drew Hardwick - Dec 13, 2022, 7:47 AM CST

Title: Relay Schematic

Date: 10/20/22

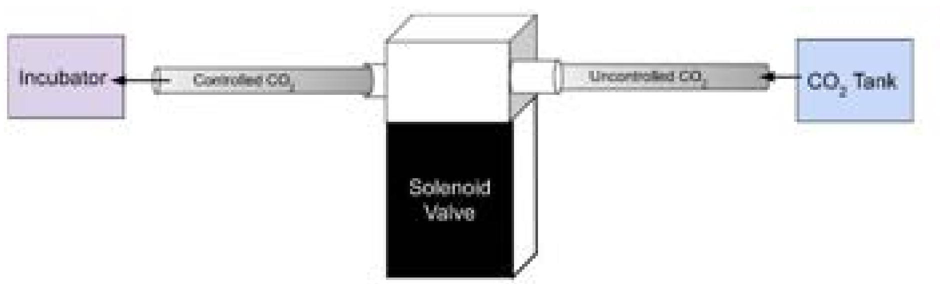
Content by: Drew Hardwick

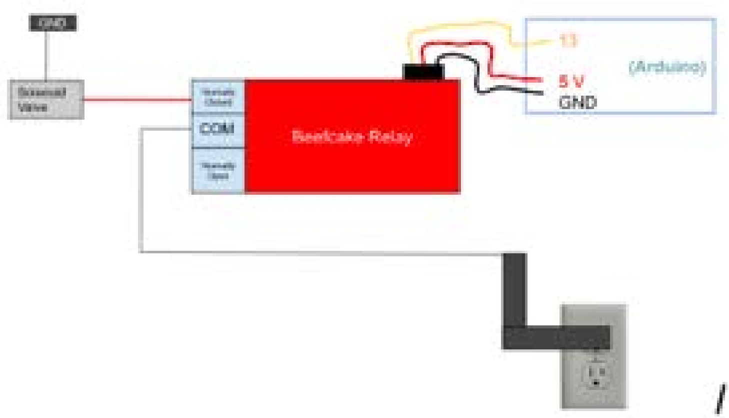
Present: N/A

Goals: Show Relay Setup for Solenoid Control

Content:

- Below are the schematics/block diagrams used to cobtrol the Solenoid valve using outlet power and a Beefcake Relay





Conclusions/action items:

- Link to NDIR Sensing code to properly adapt incubator CO2 internal environment
- Research I2C Code

References:

- https://www.sparkfun.com/products/13815

10/24/22 Testing Lid Fabrication

SAMUEL BARDWELL - Oct 25, 2022, 10:09 AM CDT

Title: Testing Lid Fabrication

Date: 10/24/22

Content by: Sam and Katie

Goals: To fabricate a testing lid to use for homogeneity testing.

Content:

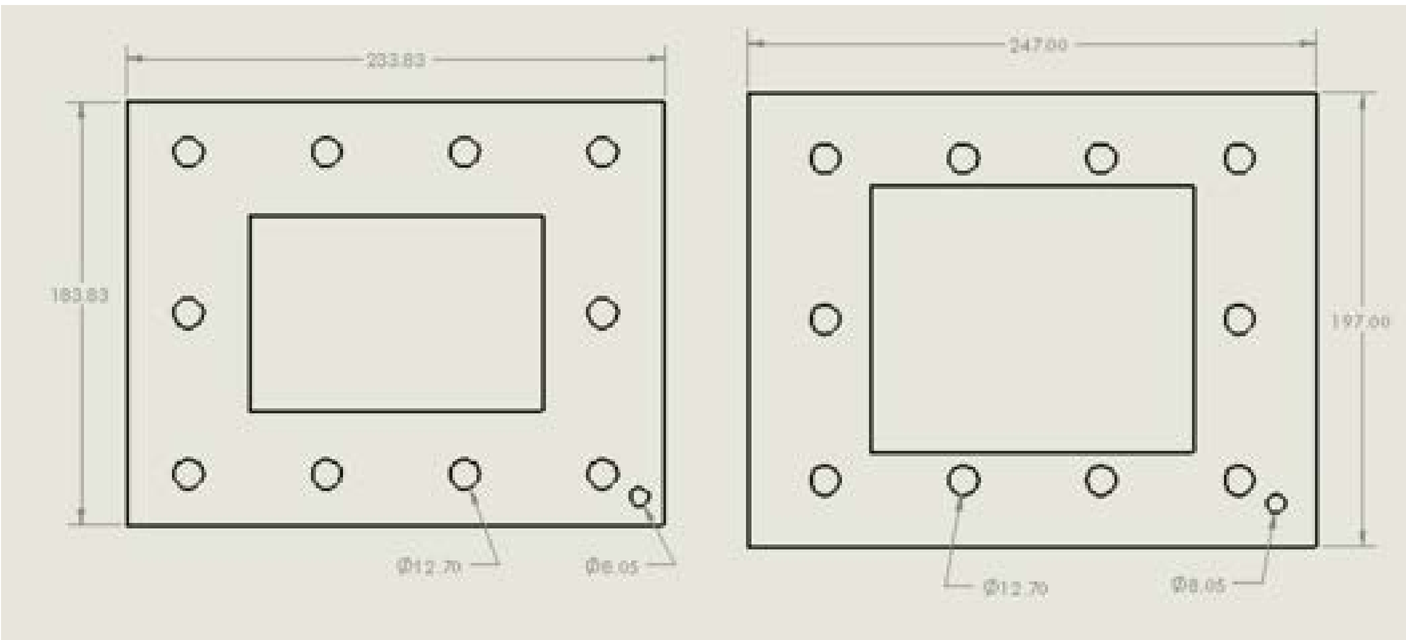


Figure 1: Incubator test lid drawing

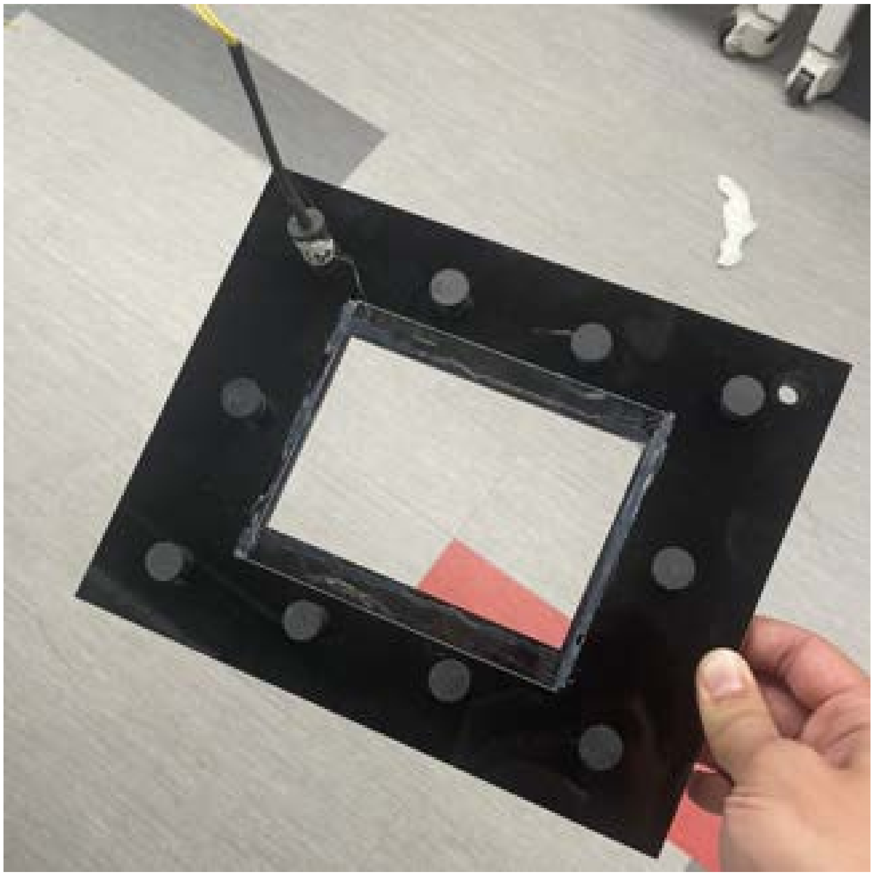


Figure 2: Laser cut incubator test lid with rubber plugs and thermistor.

- The thermistor was inserted into the rubber stopper by drilling a 13/32" size hole into the middle of the rubber stopper and then inserting the thermistor. Different height values can be achieved by moving the head of the thermistor.

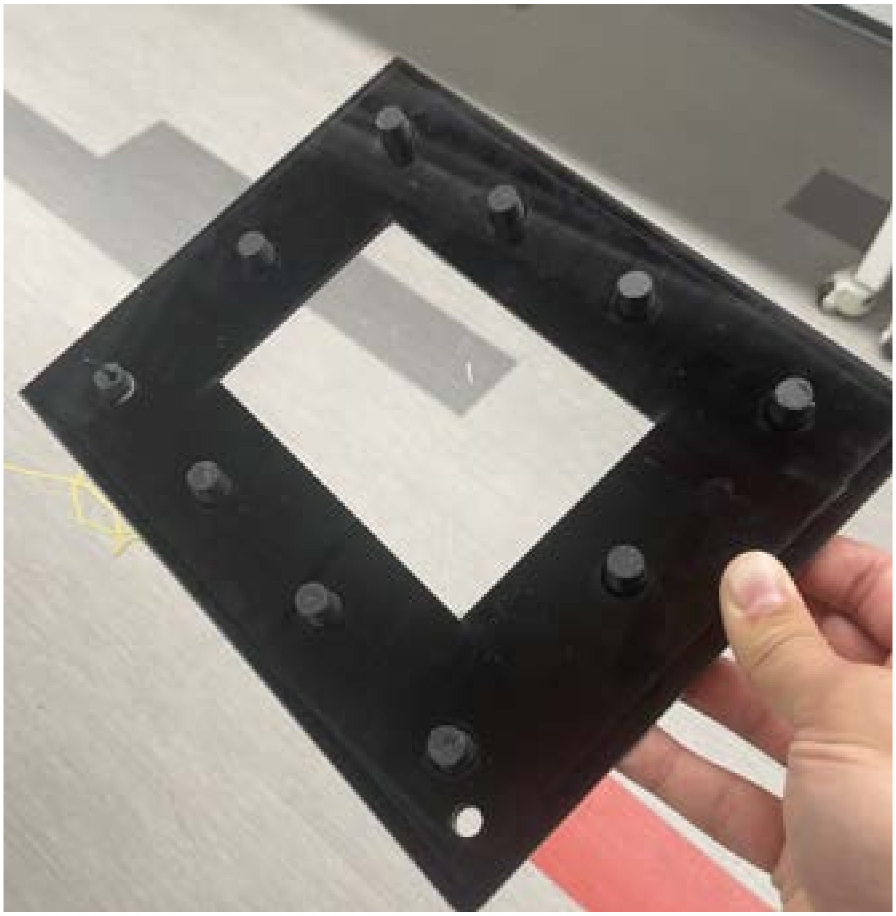


Figure 3: Incubator test lid bottom with plugs and thermistor in.

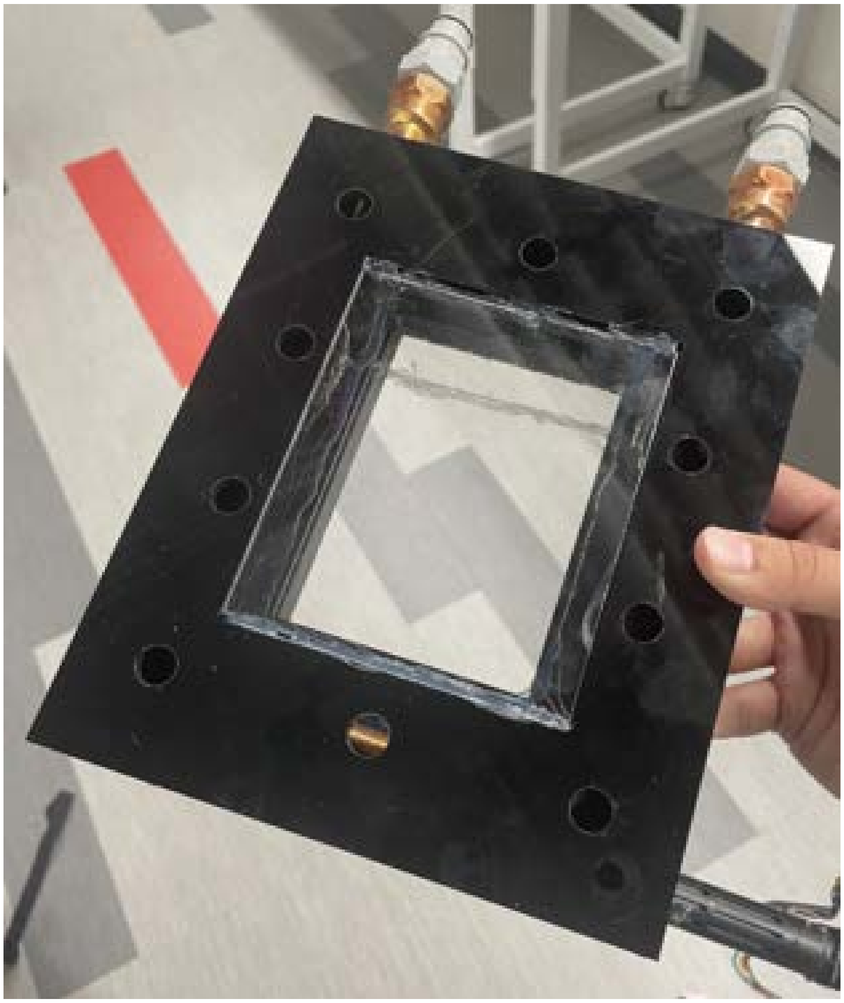


Figure 4: Incubator test lid on the box without rubber stoppers.

Conclusions/action items:

The incubator test lid is ready to begin homogeneity testing. There is an extra hole to insert the CO2 tubing and to conduct homogeneity testing for the CO2 as well.

10/26/2022 CO2 Regulation System

Katie Day - Oct 27, 2022, 11:02 AM CDT

Title: CO2 Regulation System

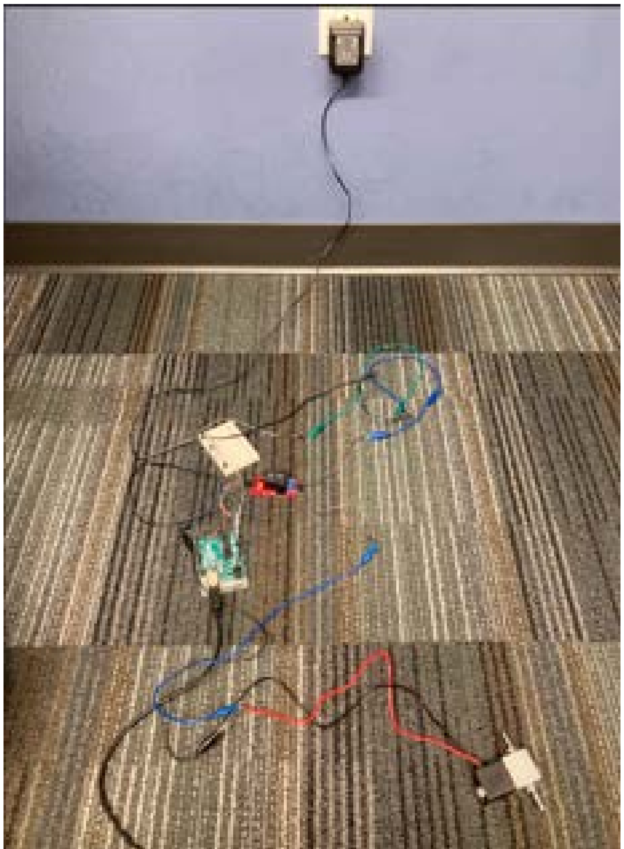
Date: 10/26/2022

Content by: Katie Day and Drew Hardwick

Present:

Goals: To set up a system that connects to the CO2 tank, solenoid valve, and incubator.

Content:



Conclusions/action items:

Figure out a better feedback loop between the NDIR sensor and solenoid valve.

11/10/22 - CO2 Regulation Feedback Testing

Drew Hardwick - Nov 10, 2022, 3:03 PM CST

Title: CO2 Regulation Feedback Testing

Date: 11/10/22

Content by: Drew

Present: Drew and Katie

Goals: Figure out how to link our Solenoid and NDIR Sensor and get them to talk

Content:

- We have been running into issues getting our solenoid to communicate with our NDIR sensor
- We had previously separated them on to different arduinos but they still would not communicate and we got very confused trying I2C and making 1 controller a master and 1 controller a slave
- Today, we tried a different approach of running the solenoid and the sensor from both different microcontrollers and from different computers with 2 separate arduino codes.
- It worked.... kinda
- The sensors were able to communicate, but it was inputting far too much CO2, to the point that it was saturating our sensor at 10% max
- Clearly our code was not working how we wanted it too
- To combat this, we have changed the code to use the flow-rate so that it inputs roughly 1% CO2 every minute and gradually climbs up to 5%
- The issue with this that it keeps constantly climbing AFTER it hits 5% as well
- We have tried to edit the code with a counter shown below, but testing this will take a significant chunk of time, so we have not ran it yet, we will test further next week
- Overall we are happy with the breakthrough in this session :)))

```
#include <SoftwareSerial.h>
```

```
int solenoidPin = 4; //Output pin
int relayPin = 13;
int NDIR = 2;
int val;
int x;

void setup() {
  pinMode(solenoidPin, OUTPUT);    //sets the pin as an output
  pinMode(relayPin, OUTPUT);
 // pinMode(NDIR, INPUT);   //sets the Sensor value as an
}

void loop() {
  //val = digitalRead(NDIR); //reads the values from the NDIR
  //if (val == 1 ){
   //digitalWrite(relayPin, HIGH);   //switch relay on
   //digitalWrite(solenoidPin,HIGH); //Switch Solenoid ON
   //delay(100);                    //wait 5 milisecond
  //}if (val==0){
    //digitalWrite(relayPin, LOW);    //switch relay off
    //delay(100);
  //}
 //delay(1000);
  for (int counter = 0; counter <= 300; counter = counter +1){
    digitalWrite(relayPin, HIGH); //switch relay on
    digitalWrite(solenoidPin, HIGH); //switch solenoid on
    delay(50);
    digitalWrite(relayPin, LOW); //switch relay off
    digitalWrite(solenoidPin, LOW); //switch solenoid off
    delay(72000);  // wait 1.2 minutes
  }
  delay(300000);

}
```

Conclusions/action items:

- Test New Code Next week

11/15/22 Wiper Fabrication

SAMUEL BARDWELL - Nov 21, 2022, 4:14 PM CST

Title: Wiper Fabrication

Date: 11/15/22

Content by: Sam and Drew

Goals: To make a functioning wiper to clear condensation off of the upper glass piece on the incubator.

Content:

- The shower squeegee was cut to fit the glass inside the box and to not interfere with the copper piping using a drop saw and metal shears

- The rubber was cut shorter to fit inside the incubator box using an exacto knife and at a 45 degree angle to provide a nice clean removal of water droplets

- 1/8th inch metal rod was inserted into the circular part of the squeegee head

- The metal rod was inserted into a rubber stopper to attempt to twist and clean the water

Wiper bought off of Amazon

Wiper Link: https://www.amazon.com/AmazerBath-Squeegee-Bathroom-Adhesive-All-Purpose/dp/B08BS1F677/ref=sr_1_7?crid=3DFL63J1G47X0&keywords=shower%2Bsqueegee&qid=1668548503&sprefix=shower%2Bsqueege%2Caps%2C97&sr=8-7&th=1

- A piece of a brass rod was cut and drilled into with an 1/8th inch drill bit both axially and transversely

- The 1/8th inch stainless steel was then inserted into both the axial and transverse holes and joined with super glue. This design allowed for the wiper to be controlled from outside the incubator box. The user will rotate the axial stainless steel rod which will create a wiping motion on the glass to clear the condensation.

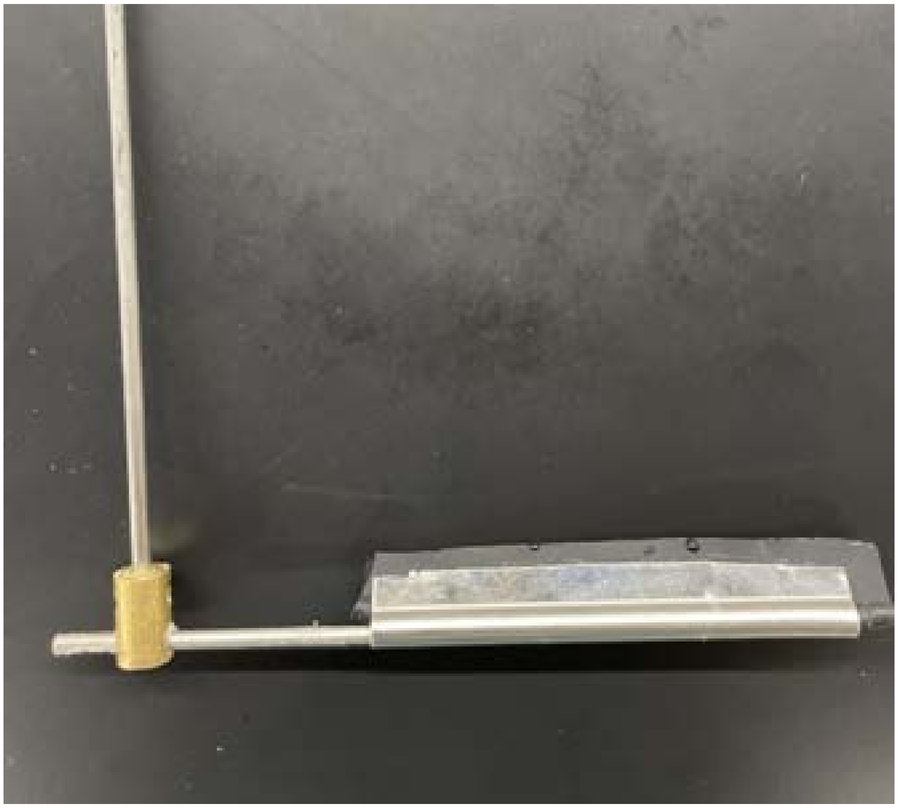


Figure: How the wiper is intended to be used.

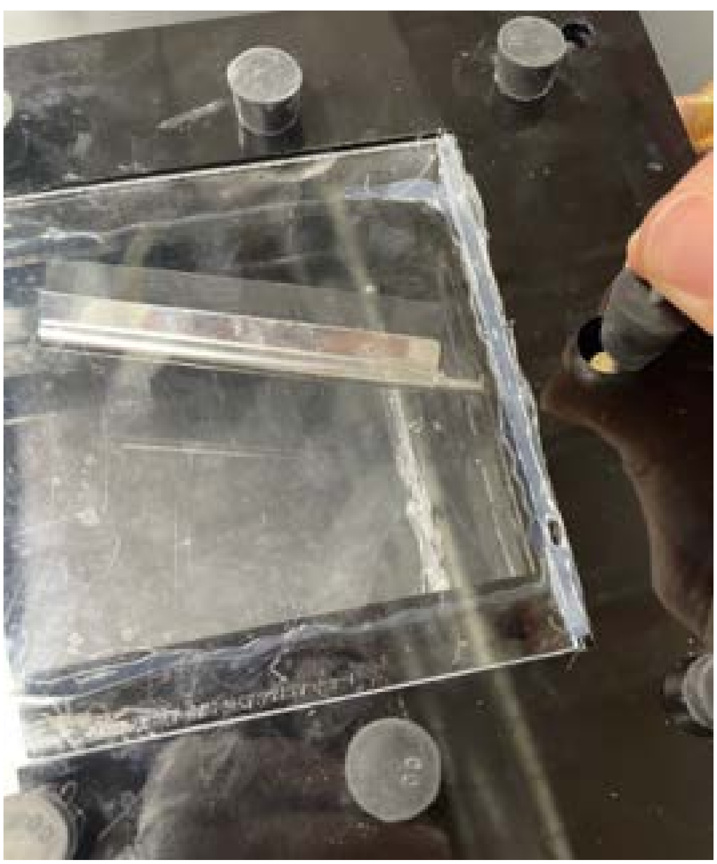


Figure: Wiper fabrication with rubber stopper as knob.

Figure: Inside view of the wiper blade

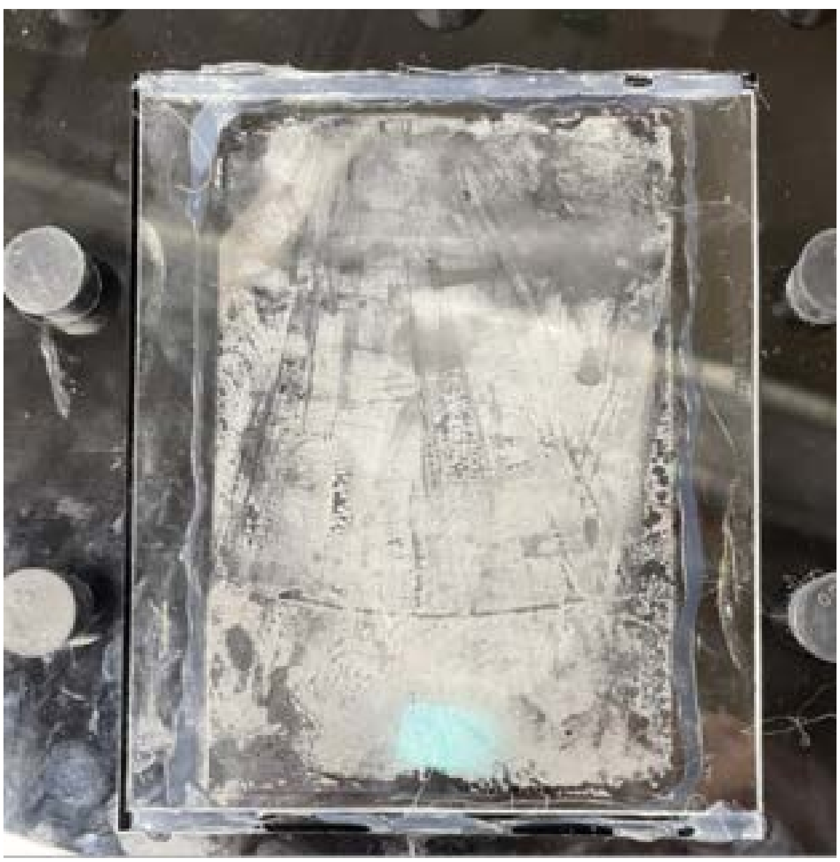


Figure: Glass before using wiper blade

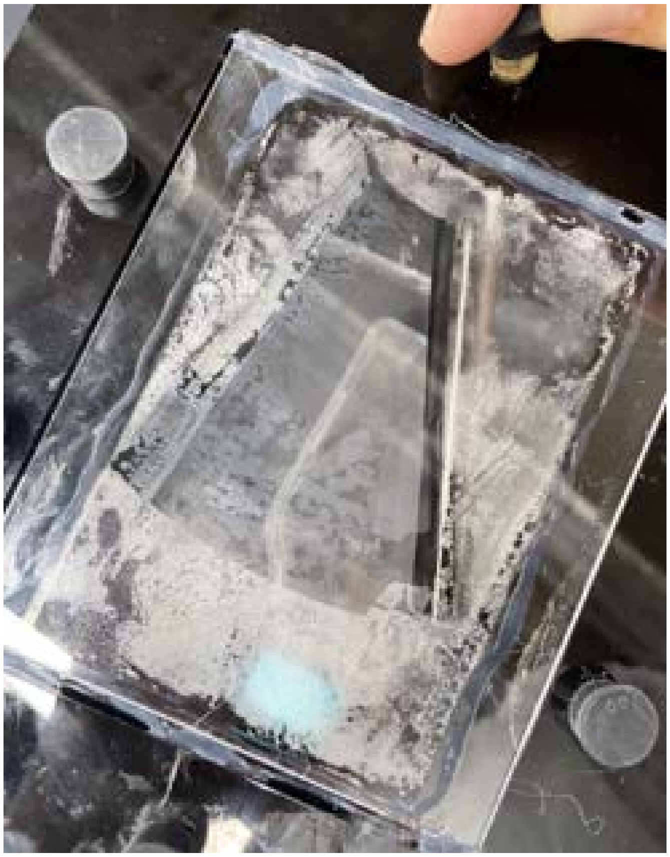


Figure: Glass after using wiper blade.

- Wiper blade was fabricated using an 1/8th inch stainless steel rod, rubber wiper blade, metal rubber wiper blade holder, and a brass joiner with 1/8th inch holes drilled in axially and transversely where, the stainless steel rods can be super glues within at a 90 degree angle. One the horizontal stainless steel rod was inserted into the wiper blade metal holder and the glue in place at a 45 degree angle. A rubber stopper was cut and added to the vertical stainless steel rod end to allow for easier rotation of the wiper blade and also allow the user to remove the wiper mechanism if necessary.

Conclusions/action items:

Need to find a better joiner between both metal rods to allow for manual rotation. The metal rods are being connected at 90 degrees so drilling into a thicker cylinder axially and transversely and then using epoxy to secure the rods in place is the plan. The wiper will be manually controlled from a knob on the top of the lid that is inserted between the entry and exit of the copper piping.

Need to refabricate the rubber and add the joiner. Other ideas is to add a slider into the lid design. Might be a next semester project.

Edit: Joiner was fabricated and works well. Need to recut the rubber to have a crisper angled surface. Might look into purchasing new rubber ends and cutting the flat part shorter and then crimping the metal to fasten it. Knob fabrication will also need to be further looked into. Some worry with spacing between the cell flask and the wiper, but the angled wiper was created to combat this problem and save some space.

Edit Part 2: The wiper blade was fabricated as a whole. There is some difficulty having a perfect edge when wiping the glass because it is difficult to have a clean mechanism with the current design. Next semester a slider wiper will be fabricated which will great help the user control the wiper blade and provide a cleaner wipe. One problem we noticed when testing the wiper is that the glass fogs up fairly quick after being wiped, so the user would have to image the cells fairly quickly if they want to get a clear photo. Other than those, this is good progress on the condensation problem this semester.

11/17/22 FINAL CO2 AND SOLENOID CODE - Copy

Katie Day - Dec 10, 2022, 3:12 PM CST

Title: Final Co2 and Solenoid Code

Date: 11/17/22

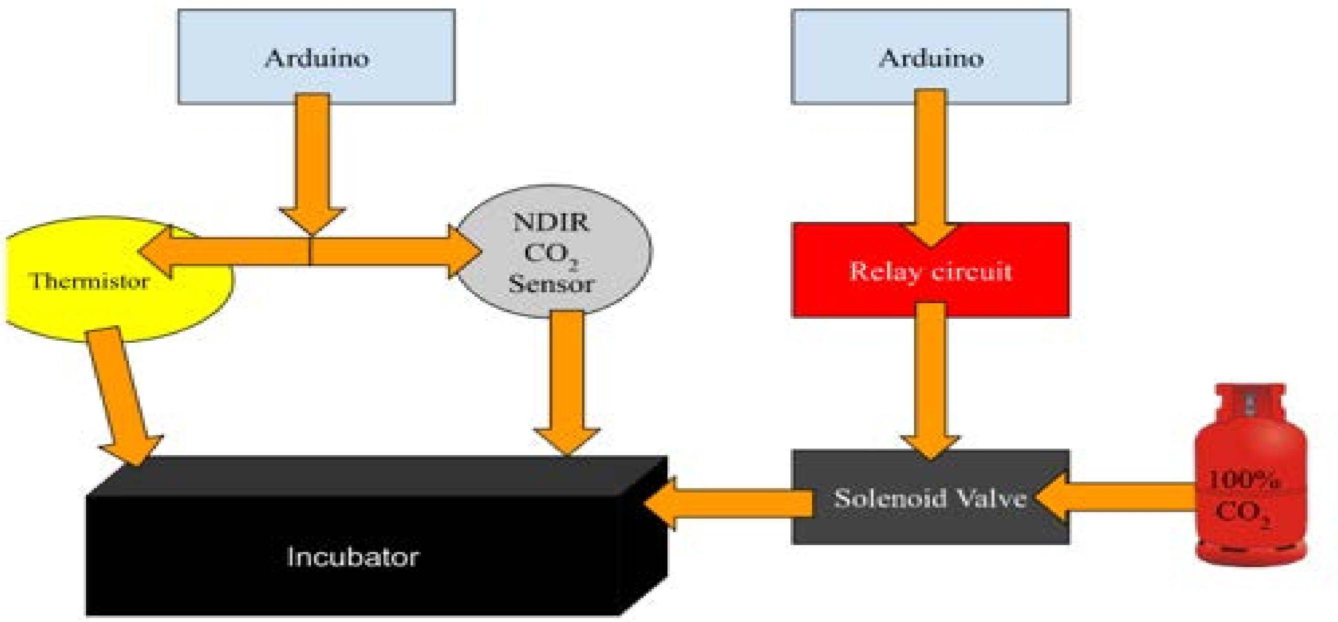
Content by: Katie Day

Present:

Goals: To determine a code for CO2 and the Solenoid.

Content:

By measuring the time and the flow rate I was able to determine two for loops that work for the solenoid valve that output approximately enough CO2 per percentage to keep the Co2 between 4.5-5.5%.



Conclusions/action items:

See code.

Katie Day - Dec 10, 2022, 3:11 PM CST

Download

sol_test.ino (907 B)

Katie Day - Dec 10, 2022, 3:11 PM CST

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CO2_test.ino (702 B)

Katie Day - Dec 10, 2022, 3:11 PM CST

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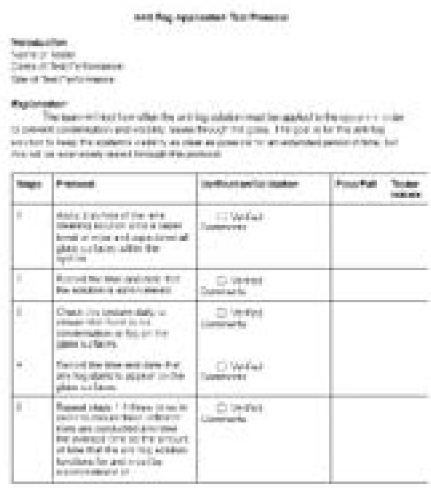
Coding_Spring_22.ino (1.73 kB)

Anti-Fog Protocol

Bella Raykowski - Oct 11, 2022, 11:04 AM CDT



Anti-Fog Application Test Protocol

Introduction
Name of Tester
Date of Test Performance
Site of Test Performance

Explanation
[illegible]

Steps	Protocol	Verification/Calculation	Pass/Fail	Tester Initials
[illegible]	[illegible]	☐ Verified Comments:		
[illegible]	[illegible]	☐ Verified Comments:		
[illegible]	[illegible]	☐ Verified Comments:		
[illegible]	[illegible]	☐ Verified Comments:		
[illegible]	[illegible]	☐ Verified Comments:		

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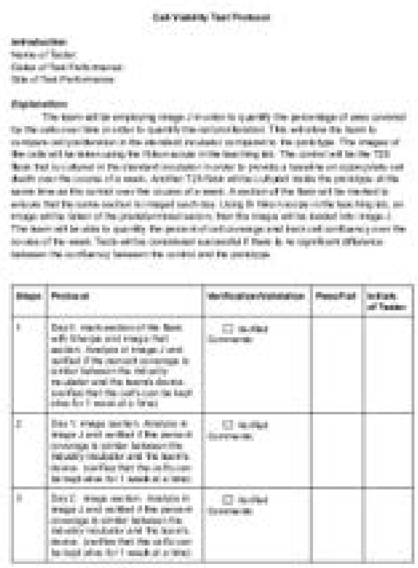
Anti_Fog_Application_Test_Protocol_-_Google_Docs.pdf (43.4 kB)

Cell Confluency Protocol

Bella Raykowski - Oct 11, 2022, 11:05 AM CDT



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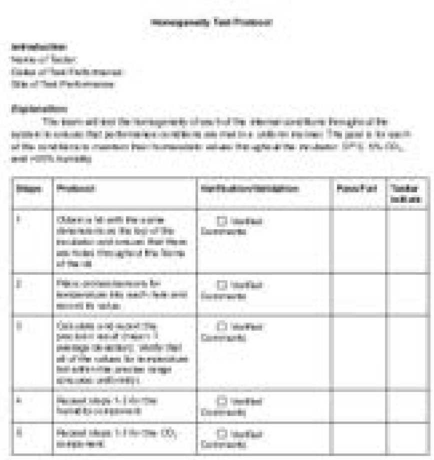
Cell_viability_testing_-_Google_Docs.pdf (70.9 kB)

Homogeneity Protocol

Bella Raykowski - Oct 11, 2022, 11:05 AM CDT



Homogeneity Test Protocol

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

Explanation
[illegible]

Steps	Protocol	Verification/Validation	Pass/Fail	Tester Initials
1	[illegible]	☐ Verified Comments:		
2	[illegible]	☐ Verified Comments:		
3	[illegible]	☐ Verified Comments:		
4	Repeat steps 1-3 for the humidity component	☐ Verified Comments:		
5	Repeat steps 1-3 for the CO_2 component	☐ Verified Comments:		

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Homogeneity_Test_Protocol_-_Google_Docs.pdf (71.7 kB)

Temperature and Humidity Protocol

Bella Raykowski - Oct 11, 2022, 11:06 AM CDT

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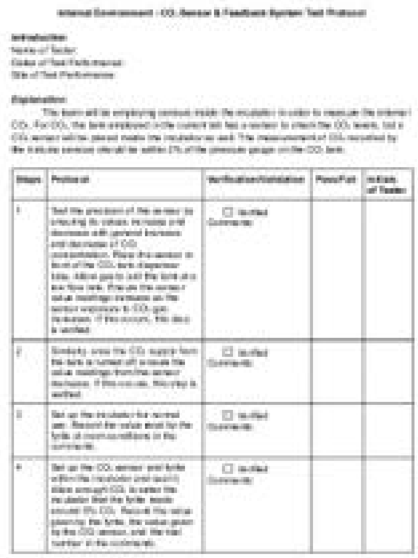
temperature_protocol.pdf (87.2 kB)

CO2 Sensor Protocol

Bella Raykowski - Oct 11, 2022, 11:07 AM CDT



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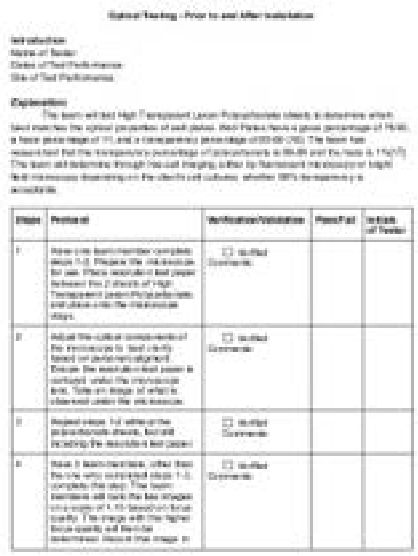
co2_protocol.pdf (87.6 kB)

Optical Testing Protocol

Bella Raykowski - Oct 11, 2022, 11:08 AM CDT



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optical_protocol.pdf (65.4 kB)

Recovery Testing Protocol

Bella Raykowski - Oct 11, 2022, 11:09 AM CDT

Recovery Test Protocol

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

Explanation
[illegible]

Steps	Protocol	Verification/Validation	Pass/Fail	Tester Initials
1	[illegible]	☐ Verified Comments:		
2	[illegible]	☐ Verified Comments:		
3	[illegible]	☐ Verified Comments:		
4	[illegible]	☐ Verified Comments:		

Download

recovery_protocol.pdf (69.1 kB)

10/26/22 Flow Rate Testing

SAMUEL BARDWELL - Oct 26, 2022, 7:02 PM CDT

Title: Flow Rate Testing

Date: 10/26/22

Content by: Sam and Katie

Goals: To determine the flow rate of CO2 out of the solenoid valve when the take is set to 17 psi.

Content:

- First we set the CO2 tank to output at a 17 psi pressure

- Then we set the solenoid code to be open for 1 second

- We attached a balloon to the end of the tubing and ran the code. This filled up the balloon with 1 second of CO2 gas.

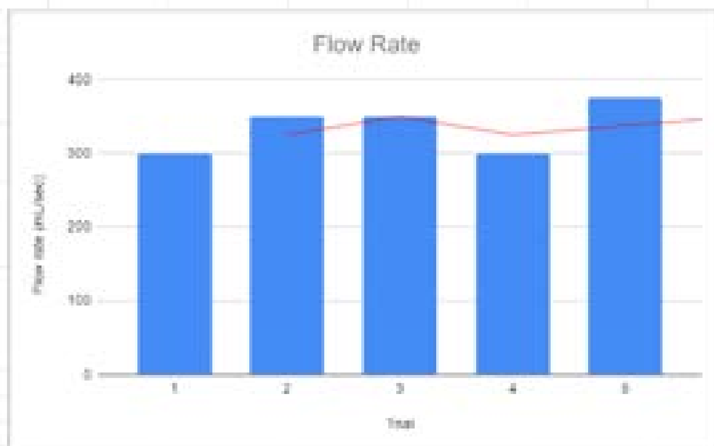
- We obtained a 1L beaker from the lab and filled it up with 550 mL of water

- Then we dunked the balloon into the water, and measured the displacement in order to obtain the volume of gas in the balloon.

- We repeated this for 5 balloons and averaged the amount of mL of gas output in 1 second.

- Since we have the volume of gas outputted from the solenoid in 1 second, we were able to figure out the flow rate of gas from the CO2 tank, trough the solenoid valve in mL/s

Time = 1 sec		Initial Volume = 550 mL	
Trial	Total mL	Flow rate (mL/sec)	
1	850		300
2	900		350
3	900		350
4	850		300
5	925		375
			335
		Average = 335 mL/s	
Incubator Volume = 1759.55 mL	5% = 87.98	Time = 0.26 seconds	



- Using the inner volume of the incubator and understanding that we need 5% CO2 levels, We calculated how many mL 5% is (87.98). Since we have the flow rate, we can open the solenoid for 0.26 seconds in order to input 5% CO2 into the incubator when it originally had 0% CO2.

Figure 1: Photo of the filled balloons after the solenoid being opened for one second. Also shown is the beaker with water.

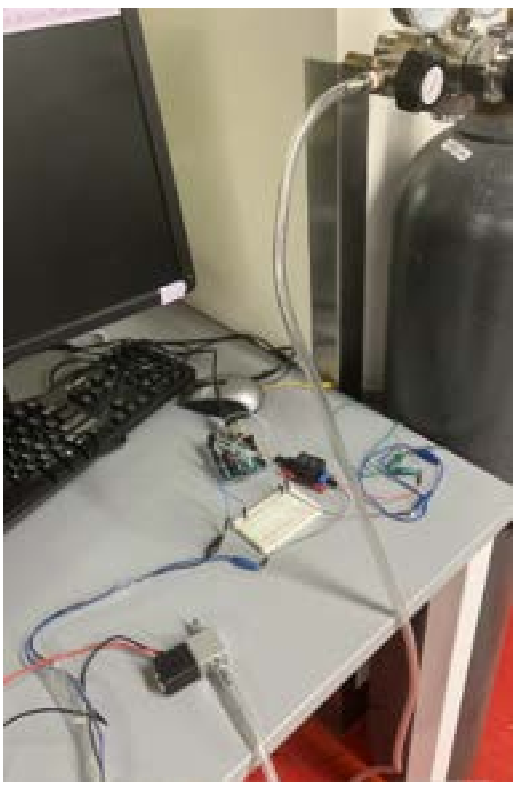


Figure 2: Solenoid flow testing set up to collect the CO2 output.

Conclusions/action items:

The next steps are to use this information to include it into a code that connects CO2 sensor information to the solenoid. This will allow the solenoid to automatically input the correct amount of CO2 into the incubator box when needed.

11/2/22 Temperature Homogeneity Testing

SAMUEL BARDWELL - Nov 02, 2022, 6:40 PM CDT

Title: Temperature Homogeneity Testing

Date: 11/2/22

Content by: Sam and Katie

Goals: To conduct temperature homogeneity testing.

Content:

Homogeneity testing for temperature set up.

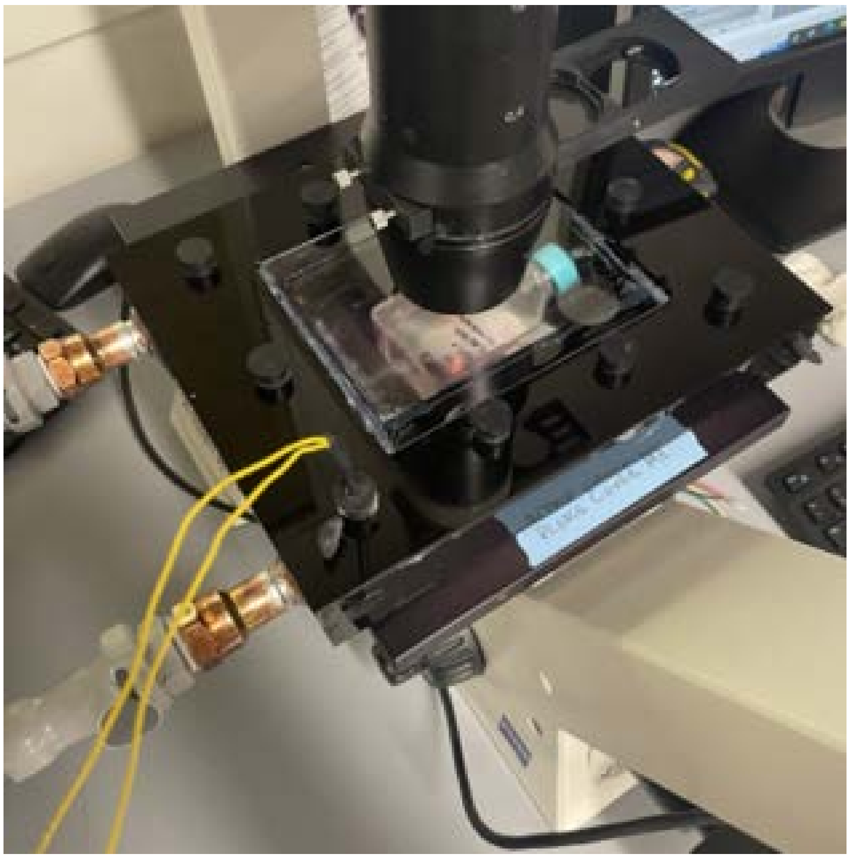


Figure 1: Homogeneity temperature testing lid set up.

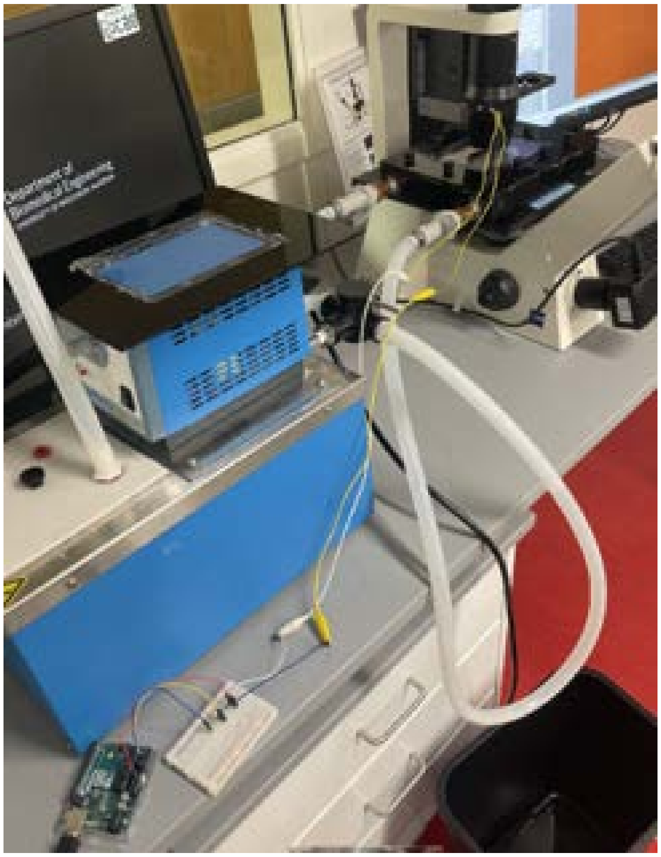


Figure 2: Homogeneity testing for temperature whole set up.

Steps:

1. Start at the hole closest to the input of heated water in the homogeneity testing lid to place the thermistor in.

2. Allow heated water pump on the incubator 10 minutes to warm up

3. Begin temperature testing at each hole for 5 minutes, moving in a CCW rotation around the lid (Following the flow of water in the copper pipe).

4. Average temperature data out for those 5 minutes at each spot.

5. Compare the temperature differences at each spot.

Conclusions/action items:

Discuss results and make improvements to the incubator. Conduct another round of homogeneity testing.

Katie Day - Nov 02, 2022, 8:12 PM CDT

Download

Homo_Data.xlsx (28.4 kB)

11/7/22 Temperature and Humidity Homogeneity Testing

SAMUEL BARDWELL - Nov 09, 2022, 10:38 AM CST

Title: Temperature and Humidity Homogeneity Testing

Date: 11/7/22

Content by: Sam and Katie

Goals: To conduct temperature and humidity homogeneity testing.

Content:

Homogeneity testing for temperature and humidity set up.

Steps:

1. Start at the hole closest to the input of heated water in the homogeneity testing lid to place the thermistor in.

2. Bend the thermistor tip 90 degrees from the rubber stopper and rotate the rubber stopper so the thermistor tip is facing the middle of the incubator

3. Allow heated water pump on the incubator 10 minutes to warm up to appropriate temperature values.

4. Begin temperature and humidity testing at each hole for 5 minutes, moving in a CCW rotation around the lid (Following the flow of water in the copper pipe).

5. Average temperature and humidity data out for those 5 minutes at each spot.

6. Compare the temperature and humidity differences at each spot.

Conclusions/action items:

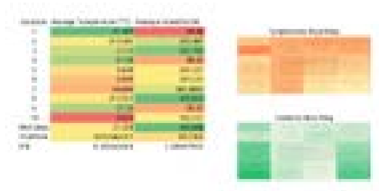
Discuss results and make improvements to the incubator. Temperature and humidity had an average within our threshold for both tests which certifies our temperature and humidity methods. Next is to certify the CO_2 input and conduct homogeneity testing for CO_2.

Katie Day - Nov 07, 2022, 3:40 PM CST

Download

Temp_and_Hum_Homo_Testing.xlsx (47.1 kB)

Katie Day - Nov 29, 2022, 11:45 AM CST



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Final_Heat_Maps.pdf (242 kB)

11/20/22 CO2 Sensor Evaluation

Katie Day - Dec 01, 2022, 12:34 PM CST

Title: CO2 Sensor Evaluation

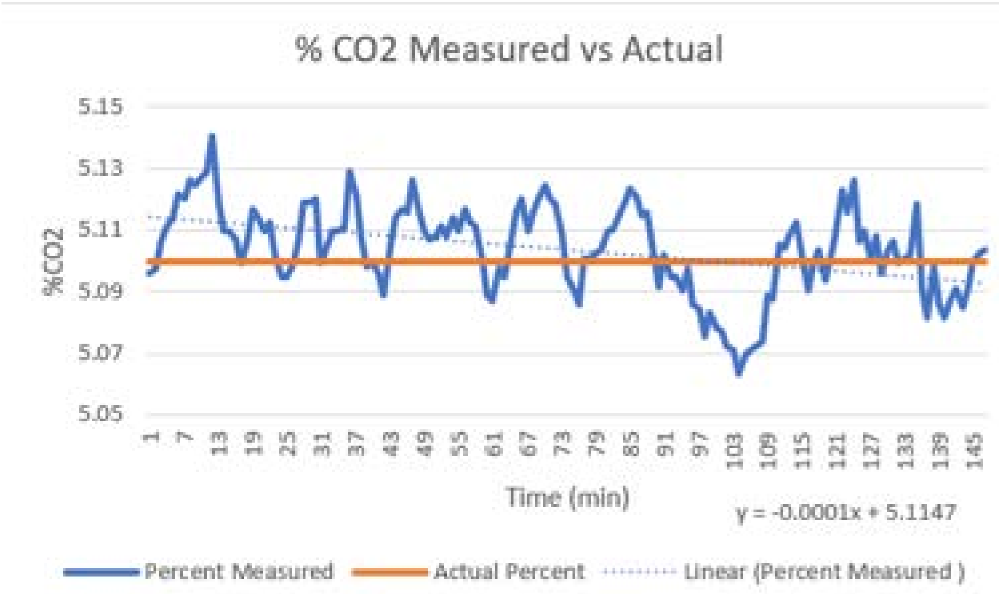
Date: 11/20/22

Content by: Katie Day

Present:

Goals: To evaluate the accuracy of the sensor according to CO2 Test Protocol.

Content:



See attached files.

Conclusions/action items:

The sensor is working properly and ready to use.

Katie Day - Dec 01, 2022, 12:35 PM CST

Download

CO2_Calibaration.csv (2.7 kB)

Katie Day - Dec 01, 2022, 12:35 PM CST

Download

CO2_Calibaration.xlsx (20.7 kB)

11/30/2022 CO2 Testing via Solenoid Valve

Katie Day - Nov 30, 2022, 5:17 PM CST

Title: CO2 Testing

Date: 11/30/2022

Content by: Katie Day

Present: Katie Day and Drew Hardwick

Goals: To test the accuracy of the hardcoded solenoid valve at keeping the incubator at 5% +/- 1%.

Content:

Followed CO2 Testing Protocol. See attached files and images.

Conclusions/action items:

The solenoid valve is able to regulate CO2 and can be used in Live-Cell Testing.

Katie Day - Nov 30, 2022, 5:17 PM CST

Download

Hard-code_test.csv (73.5 kB)

Katie Day - Nov 30, 2022, 5:17 PM CST

Download

Custom_Data_-_2022-11-30_-_Recording_1.csv (7.91 kB)

10/10/22: Cell Confluency Test Protocol - Control (Completed)

Bella Raykowski - Oct 10, 2022, 11:24 AM CDT

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Cell_Confluency_Test_Protocol_-_Control_Completed_-_Google_Docs.pdf (93.1 kB)

12/5/22 - 12/6/22 Live Cell Testing

Drew Hardwick - Dec 07, 2022, 8:45 AM CST

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Cell_Imaging_Protocol.pdf (1.11 MB)

Drew Hardwick - Dec 13, 2022, 7:39 AM CST

Title: Live Cell Testing

Date: 12/5/22 - 12/6/22

Content by: Drew Hardwick

Present: Drew, Sam, Bella, Maya, Katie

Goals: Conduct live cell testing over a period of 36 hours

Content:

- We set up our entire incubator with temperature/humidity input and CO2 input on the microscope for the first time ever!
- We then got it heated up and started the CO2 regulation system
    - The CO2 proved a bit tricky, we had to connect to two computers
    - The Solenoid control was connected to the tank (which we had to move) and the lab computer where the images from the microscope would be captured
    - The NDIR sensor had to be run from Katie's Laptop so that we could capture the data we needed with the data-streamer function
        - Could not download onto lab computers because of administrator restrictions
    - We then had to play 48 hour youtube videos on both computers to ensure they did not go to "sleep" and stop running our arduino code - Code is detailed in CO2 testing file entry
- Live cells were then put into our incubator for the first time!
    - We were looking to establish a curve for cell growth/death to compare to our cell confluency testing control from earlier in the semester - protocol/results from that are attached to this page
- We imaged the cells every 12 hours by changing the cell media, and then taking off the incubator lid to take an image on the microscope according to Bella's cell imaging protocols attached to this page.
    - The CO2 system had to be restarted any time lid was taken off to image
- Adhered to Biosafety Standards 2.

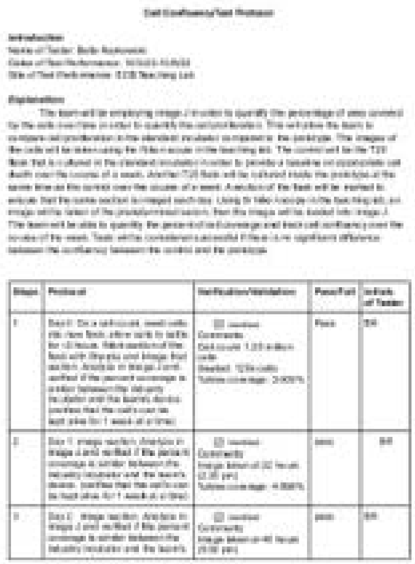
Results:

- CO2 issues and incubator decay caused premature death of the cells

Conclusions/action items:

- Use I2C next semester in order to maintain the pH of the cells natural environment and refabricate incubator

Drew Hardwick - Dec 07, 2022, 8:45 AM CST



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Cell_Confluency_Test_Protocol_-_Control_Completed.pdf (79 kB)

Katie Day - Dec 08, 2022, 10:12 AM CST

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LCT_8.csv (268 B)

Katie Day - Dec 08, 2022, 10:12 AM CST

Download

LCT7.csv (1.48 kB)

Katie Day - Dec 08, 2022, 10:12 AM CST

Download

Live_Cell_Test_Pt_3.csv (1.3 kB)

Katie Day - Dec 08, 2022, 10:12 AM CST

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Live_Cell_Test_Pt_5.csv (2.29 kB)

Katie Day - Dec 08, 2022, 10:12 AM CST

Download

Live_Cell_Test_Pt_6.csv (773 B)

Katie Day - Dec 08, 2022, 10:12 AM CST

Download

Live_Cell_Testing_Pt_2.csv (222 B)

Katie Day - Dec 08, 2022, 10:12 AM CST

Download

Live_Cell_Testing_Pt_4.csv (16.1 kB)

Katie Day - Dec 08, 2022, 10:12 AM CST

Download

Live_Cell_Testing.csv (131 B)

Katie Day - Dec 08, 2022, 10:12 AM CST

Download

LTC_9.csv (77 B)

12/12/22 Optical Testing

Bella Raykowski - Dec 12, 2022, 5:25 PM CST

Title: Optical Testing

Date: 10/24/22

Content by: Bella Raykowski

Goal: document the optical testing process and images

Content:

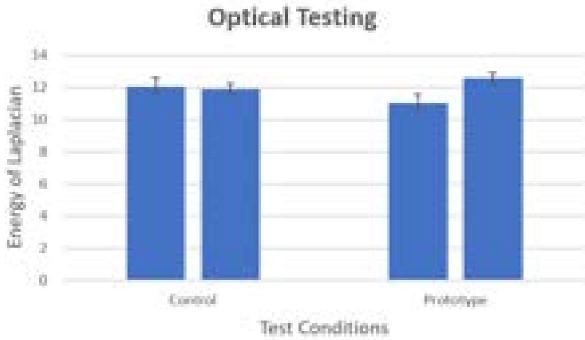
- each glass slide was sprayed 3 times with the anti-fog spray to clean off any fingerprints and dust

- control: the T25 flask of cells was imaged by itself (not in prototype) twice, each time at a different location


- experiment: the T25 flask of cells was placed inside the prototype (no water/heating element was added) and was imaged twice, each time at a different location


Conclusion: we will now to ImageJ analysis to determine if the glass with spray affects the optics of the microscope

Bella Raykowski - Dec 12, 2022, 5:27 PM CST



Bella Raykowski - Dec 12, 2022, 5:28 PM CST

Download

Optical_testing_matlab_code.pdf (7.43 kB)

12/12/22 Anti-Fog Testing

Bella Raykowski - Dec 12, 2022, 5:29 PM CST

Title: Anti-fog test with 8 pumps of spray

Date: 11/01/22

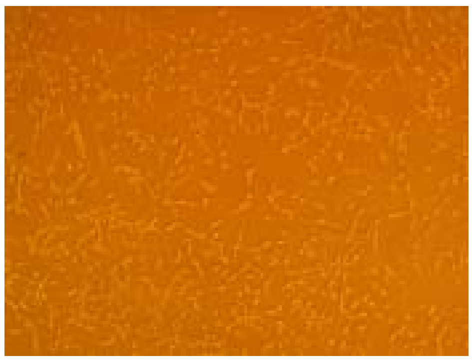
Goal: Document the process of testing the effectiveness of our anti-fog spray

Content:

- applied 4 pumps of anti-fog spray to each inside piece of glass, allowed to sit for 5 minutes before wiping off with a Kemi wipe

Control 1

Control 2



Time = 0 min

Time = 10 min

Time = 20 min

Time = 30 min

Time = 40 min

Time = 50 min

Time = 60 min

Conclusion: Upon visual examination of the glass, one could see that condensation had formed after 10 minutes of running the system, and optics slowly deteriorated. 8 pumps are not enough to prevent the formation of condensation. Will quantify this data soon.

Bella Raykowski - Dec 12, 2022, 5:29 PM CST

Title: Anti-fog test with 12 pumps of spray

Date: 11/02/22

Goal: Document the process of testing the effectiveness of our anti-fog spray

Content:

- applied 4 pumps of anti-fog spray to each inside piece of glass, allowed to sit for 5 minutes before wiping off with a Kemi wipe

Control 1

Control 2

Time = 0 min

Time = 10 min

Time = 20 min

Time = 30 min

Time = 40 min

Time = 50 min

Time = 60 min

Conclusion: Upon visual examination of the glass, one could see that condensation had formed after 10 minutes of running the system, and optics slowly deteriorated. 12 pumps are not enough to prevent the formation of condensation. Will quantify this data soon.

Bella Raykowski - Dec 12, 2022, 5:30 PM CST

Title: MATLAB analysis of anti-fog testing

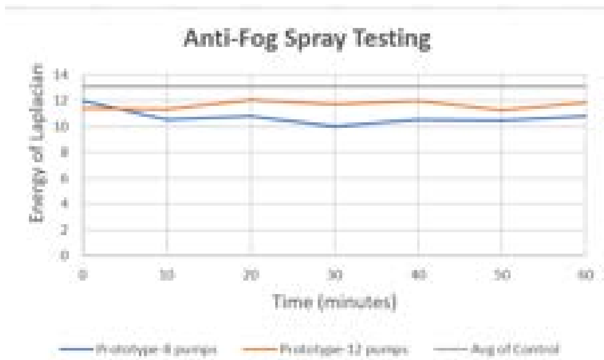
Date: 12/10/22

Goal: quantify the difference in optical quality over time while condensation forms

Content:

- the Energy of Laplacian of each image was measured in MATLAB

- this measures the intensity changes throughout the image; high energy indicates a clear image and low energy indicates a less clear image



- the above graph demonstrates how the 12 pumps had higher energy than that of the 8 pumps but still not as high as the control images

- the team could visibly see condensation quickly forming on the glass slides during both tests

Conclusion: the team decided that because of the condensation formation and low energy levels they would abandon the anti-fog spray and look to new methods to prevent/remove condensation

Bella Raykowski - Dec 12, 2022, 5:30 PM CST

Download

anti_fog_analysis.pdf (15.8 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:

- CO_2 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, CO_2, 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

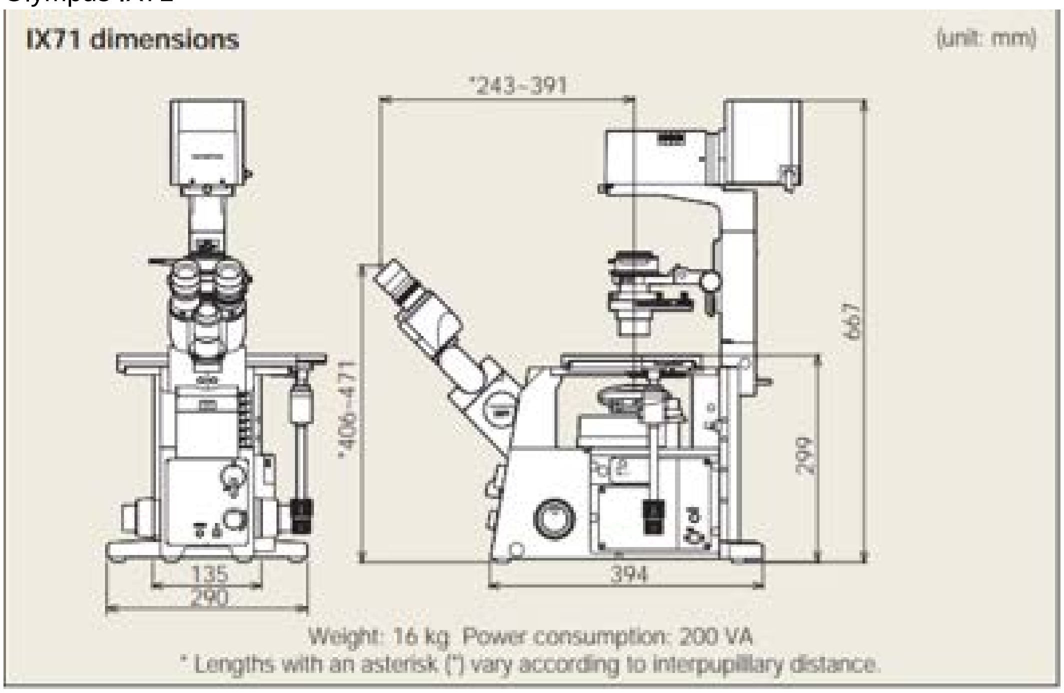
Date: 9/28/21

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 → CO2 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 CO2 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.

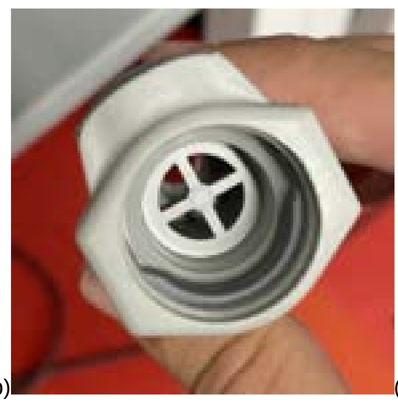
(a)  (b)  (c) 

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

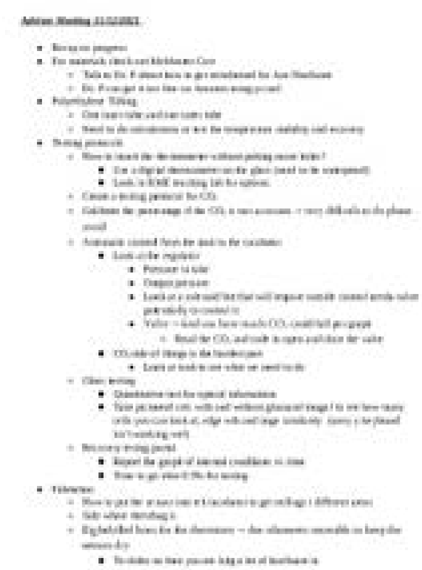
Goals: To document notes and conversation from our sixth advisor meeting with Dr. Kinney

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 CO_2. Investigate CO_2 sensors and go in depth with this component of the project.

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



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

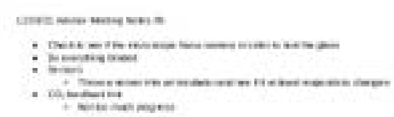
Goals: To document advice given by Dr. Kinney at our weekly meeting

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



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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

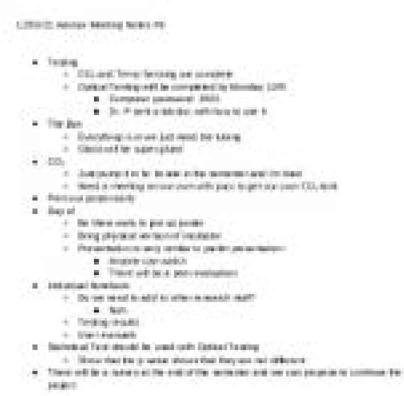
Goals: To document advice given by Dr. Kinney at our weekly meeting

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



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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

[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

Download

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

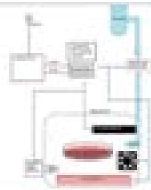
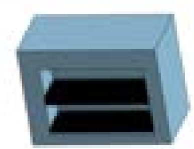
Date: 10/04/2021

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

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

Supplies/Materials for purchasing:

Implementation of Materials into Design:

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

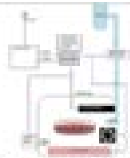
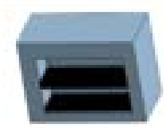
Date: 9/28/2021

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

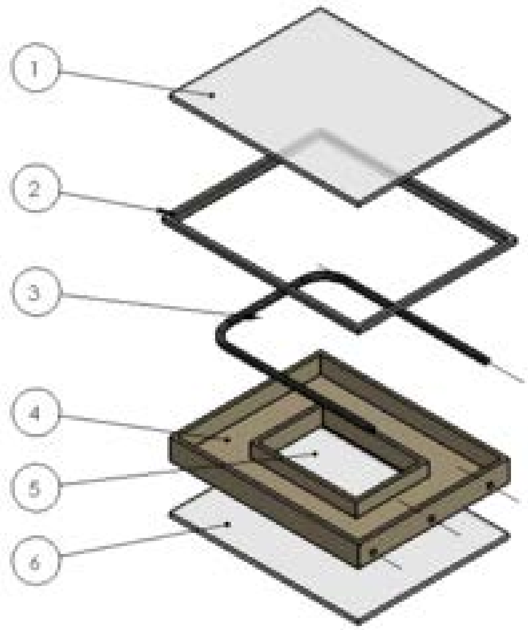


Figure 1: Exploded view of the Solidworks drawing showing the part names and descriptions.

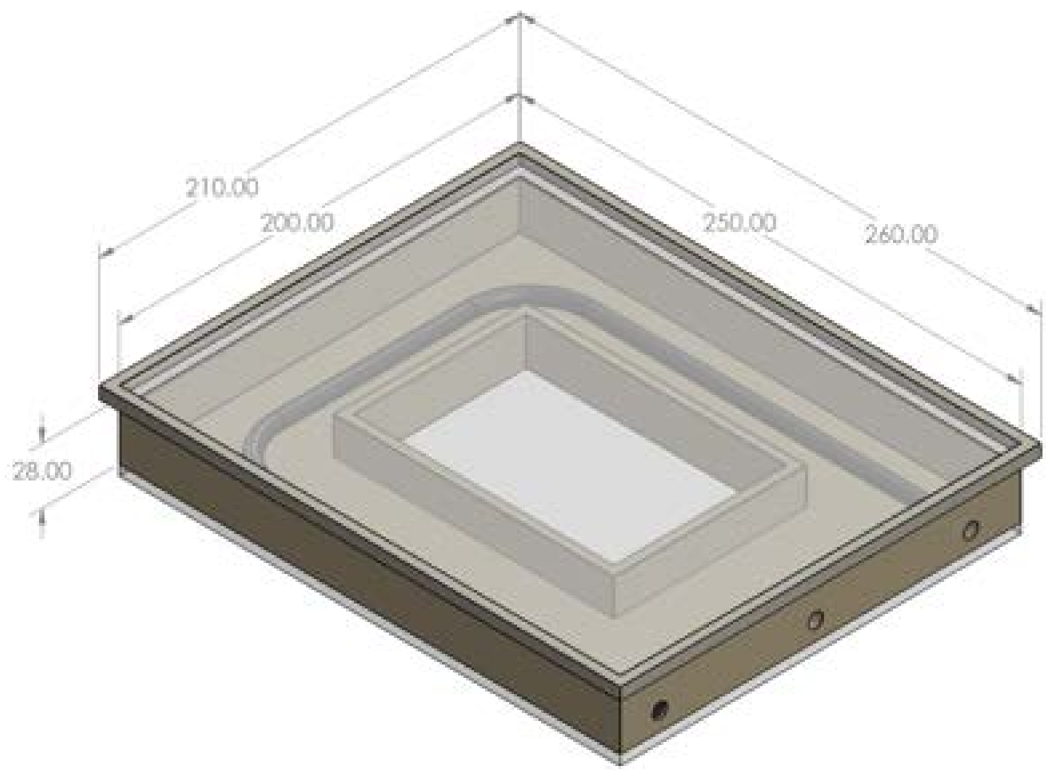


Figure 2: Collapsed view of incubator with dimensions of the box.

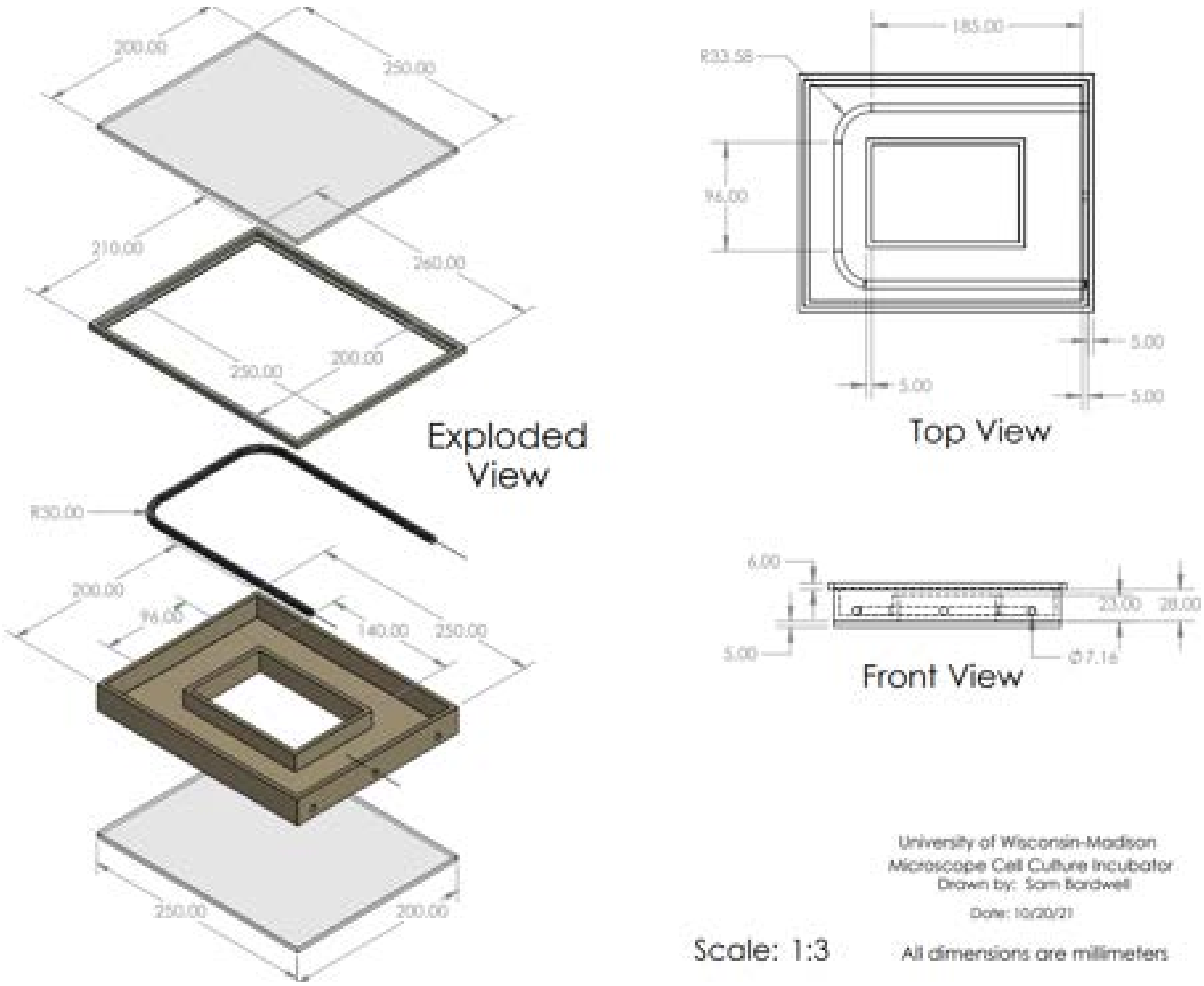
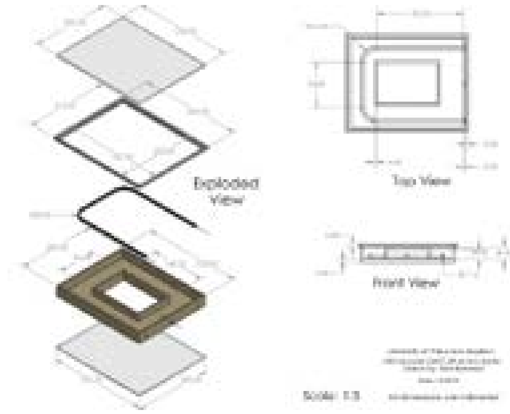


Figure 3: Solidworks drawing showing more detailed dimensions of all the parts in the incubator.

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



Download

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

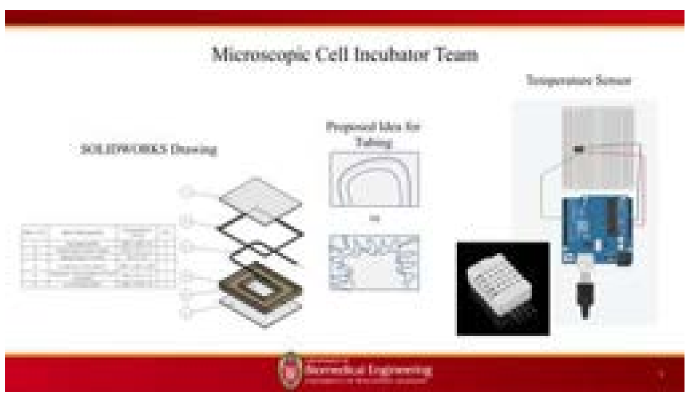
Goals: To document work done to prepare for show and tell

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 Gener
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	5ZMH8	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:

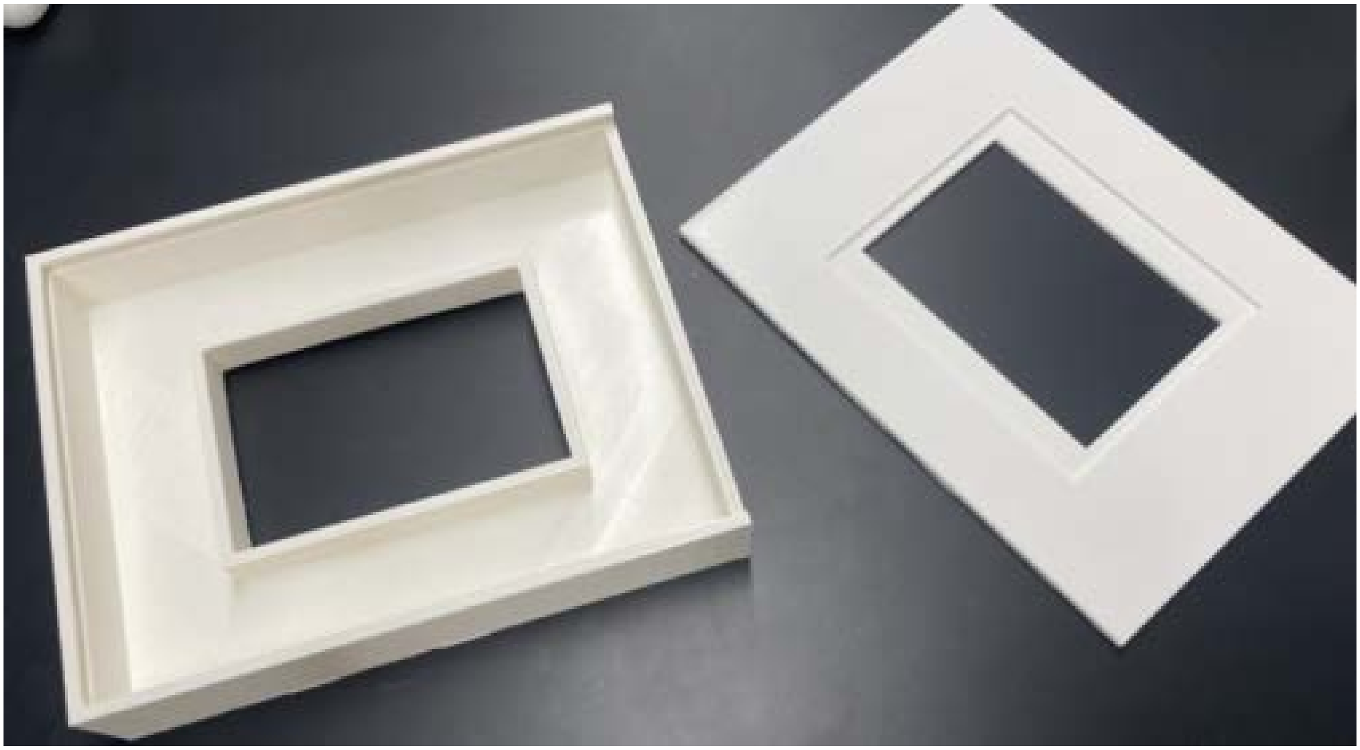


Figure 1: Top view of incubator box and crown 3D prints

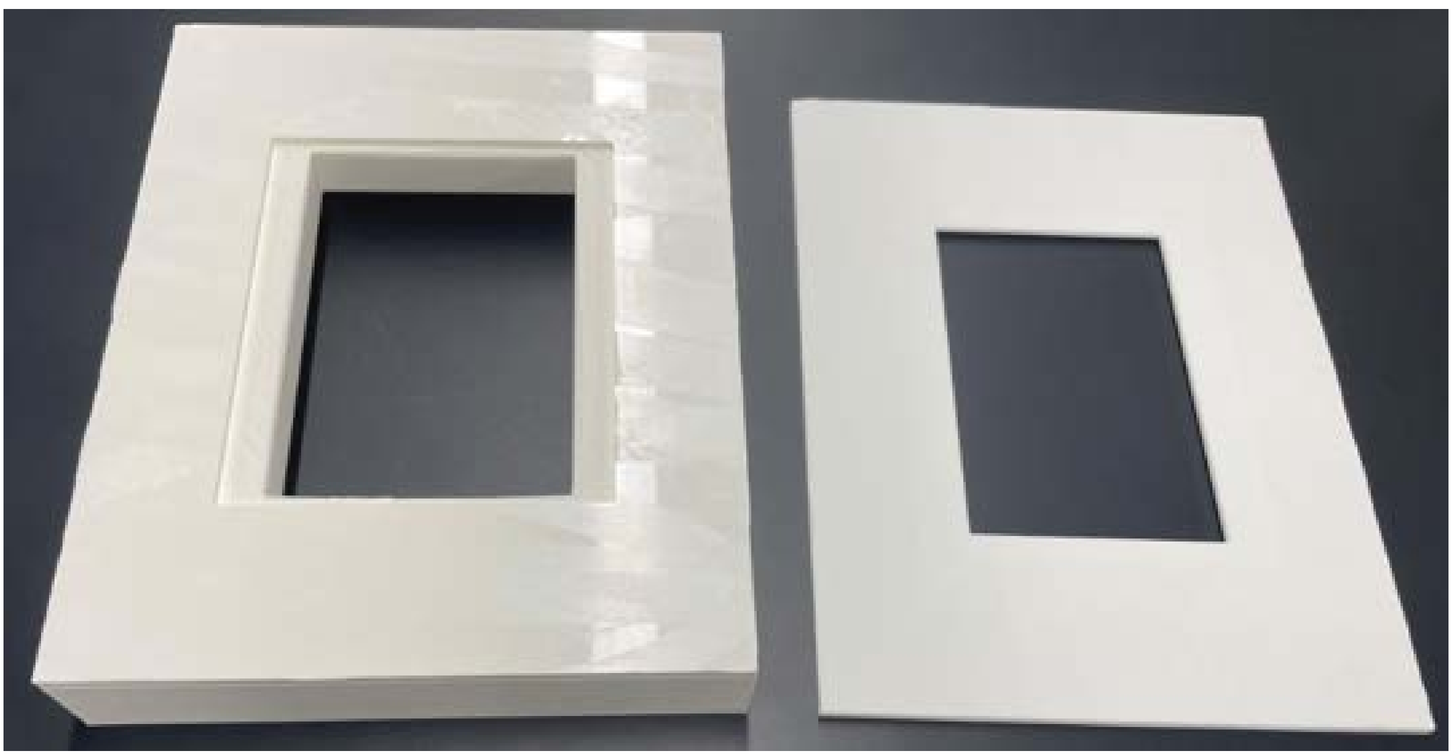


Figure 2: Bottom view of incubator box and crown 3D prints

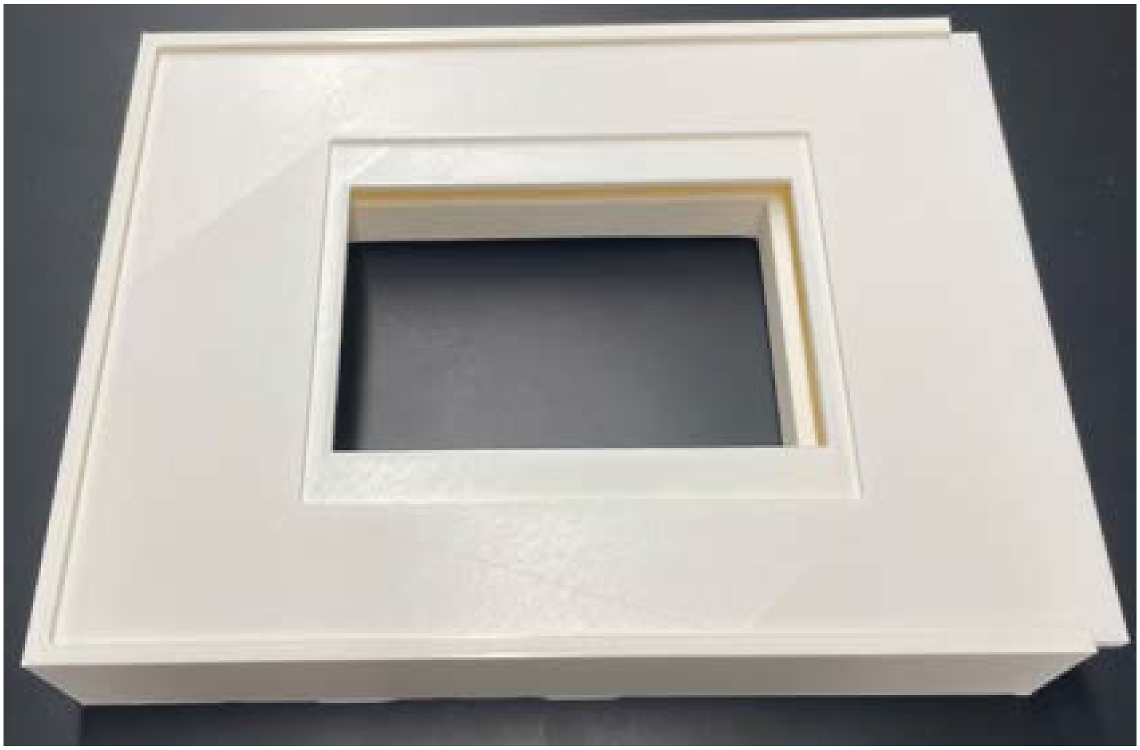


Figure 3: Assembled 3D printed incubator box.

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

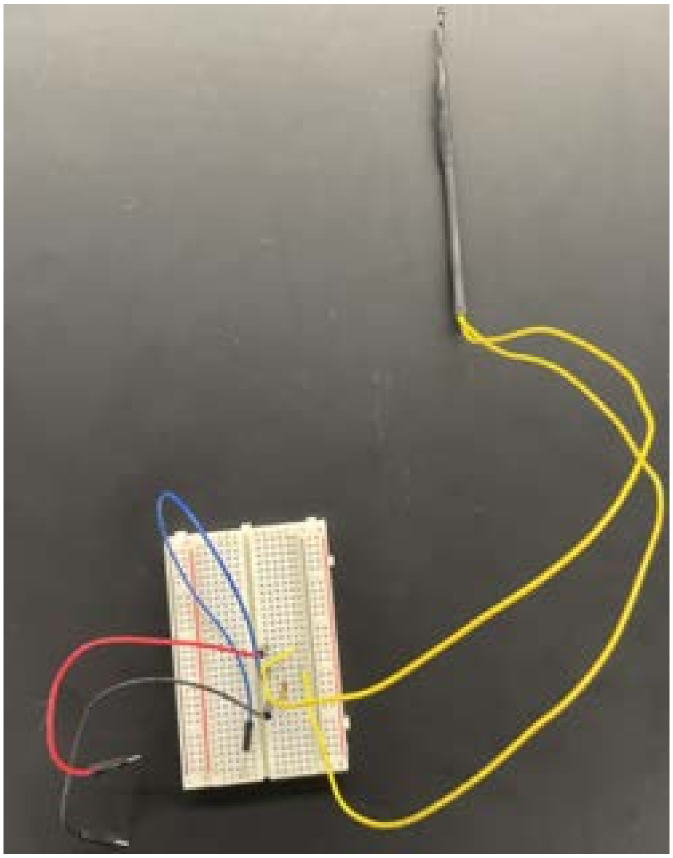
SAMUEL BARDWELL - Dec 09, 2021, 1:26 PM CST

Title: Hardware Setups

Date: 11/29/21

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

Content:



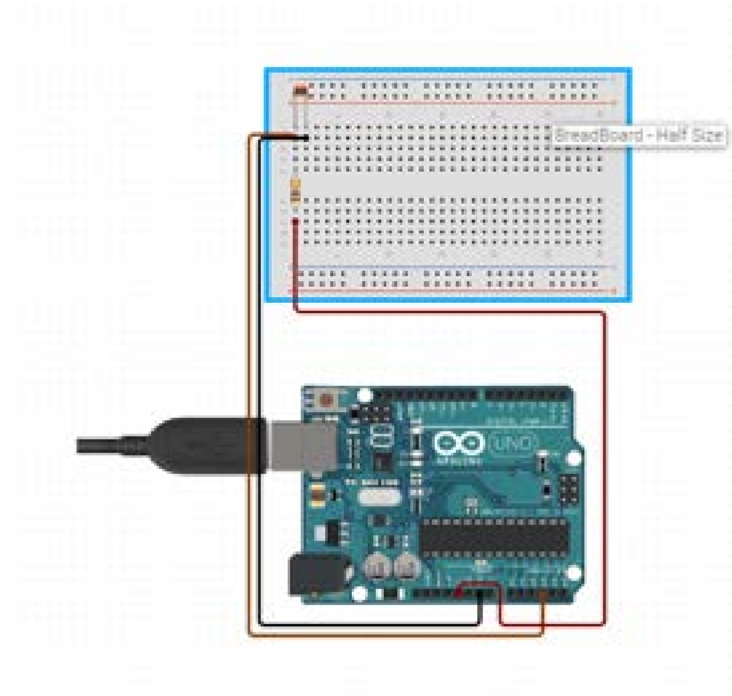


Figure 1: Thermistor hardware set up.

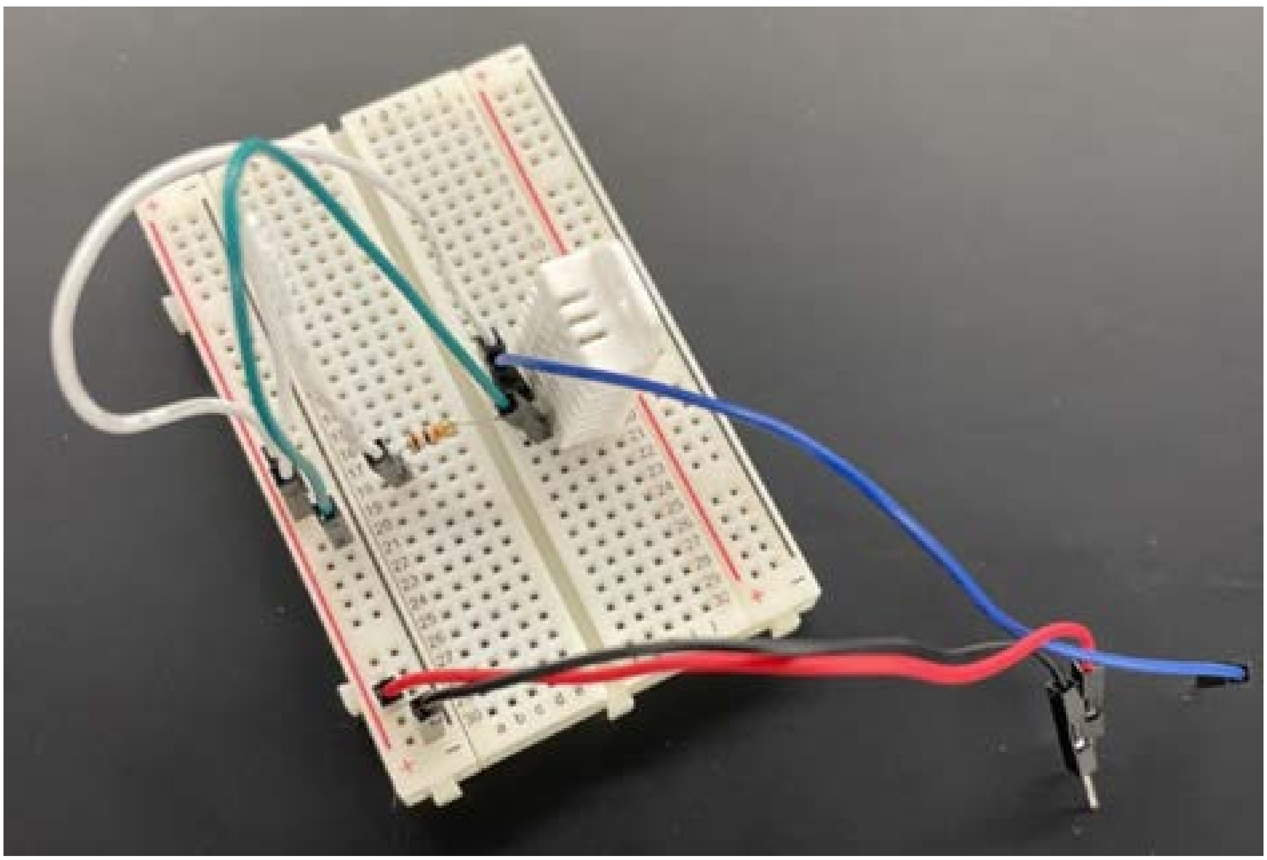


Figure 2: DHT22 sensor hardware set up

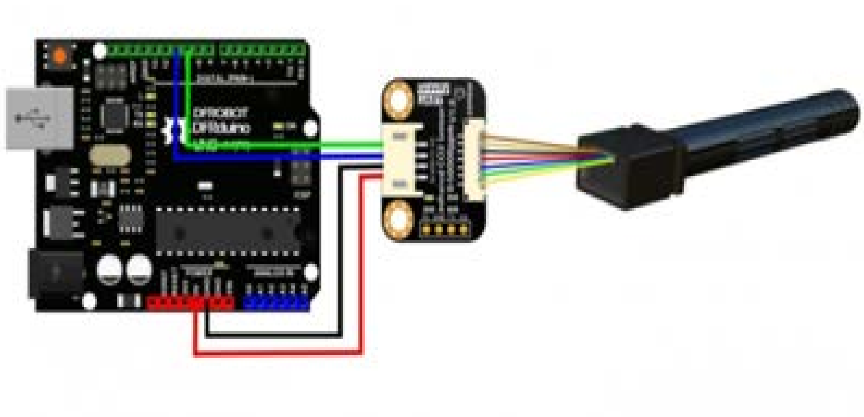


Figure 3: CO2 sensor hardware set up

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.

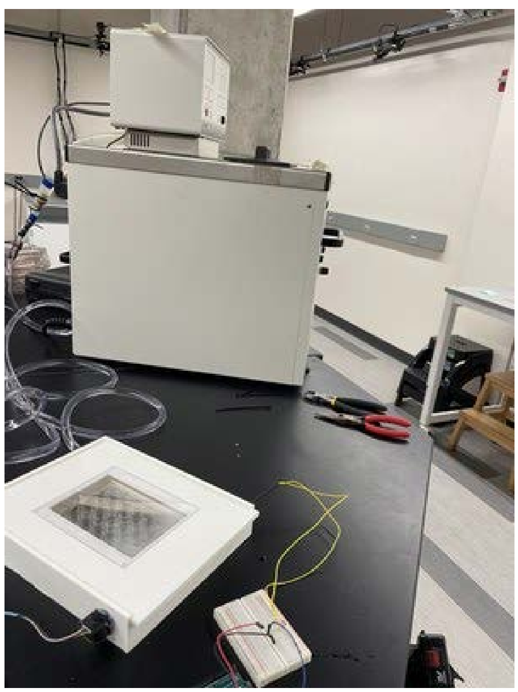
Content:

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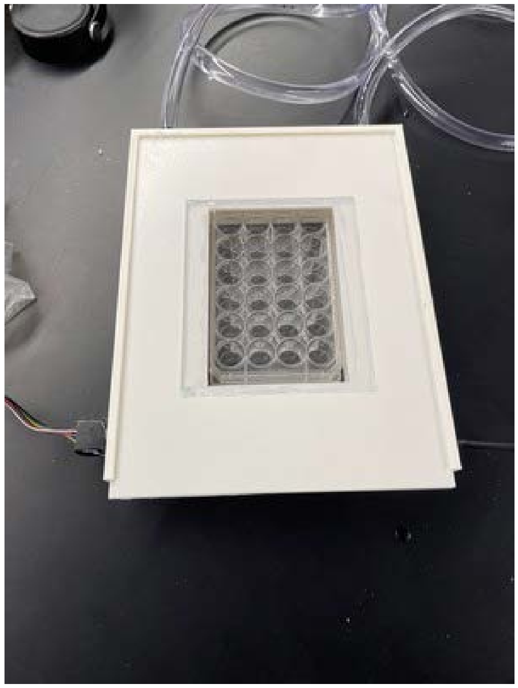
Katie Day - Dec 07, 2021, 8:04 PM CST



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

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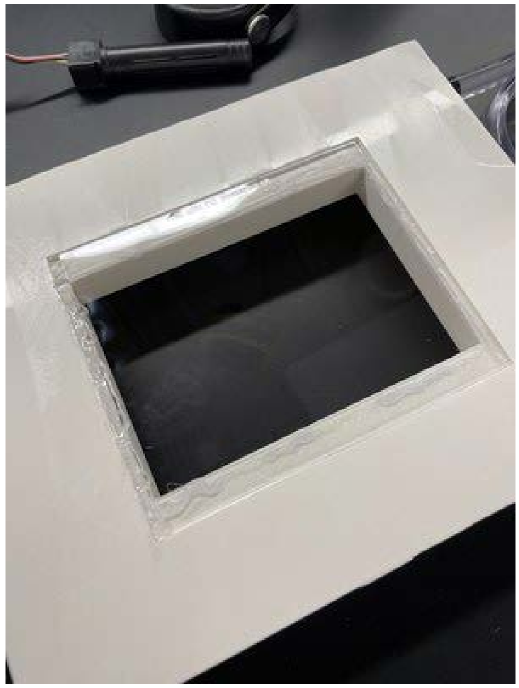
IMG_5893.jpg (1.19 MB)

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



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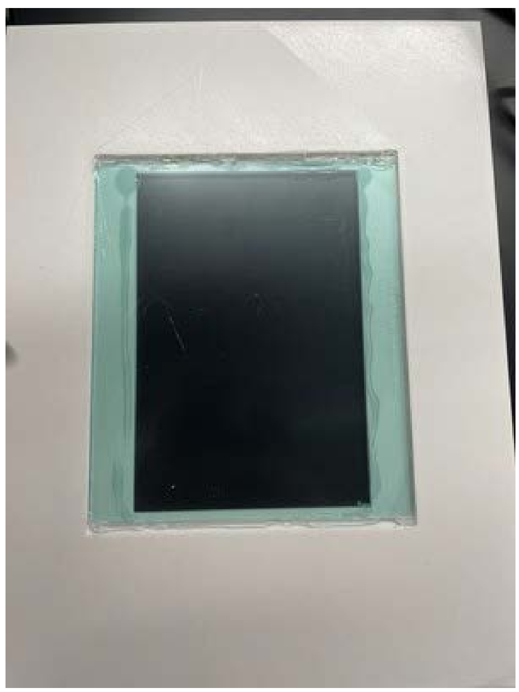
IMG_5892.jpg (597 kB)

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



Download

IMG_5891.jpg (875 kB)

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

Download

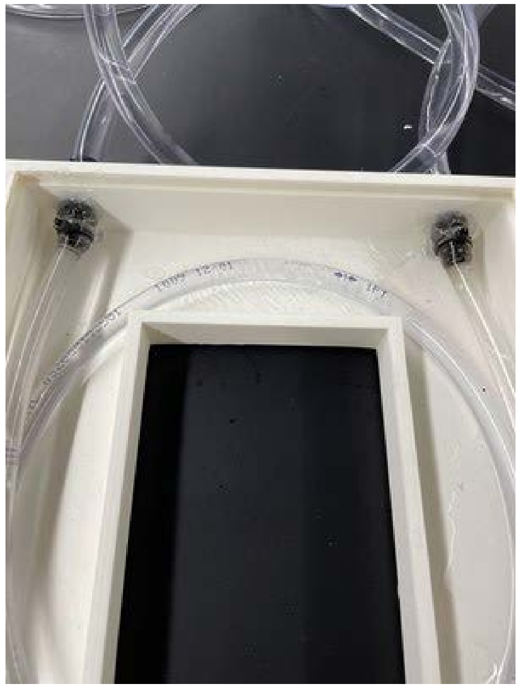
IMG_5890.jpg (404 kB)

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

Download

IMG_5889.jpg (1.27 MB)

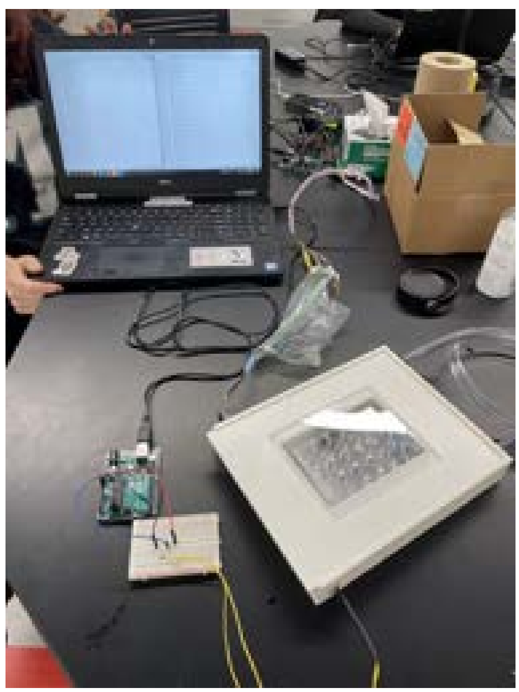
Katie Day - Dec 07, 2021, 8:04 PM CST



Download

IMG_5888.jpg (780 kB)

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



Download

IMG_5895.jpg (693 kB)

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

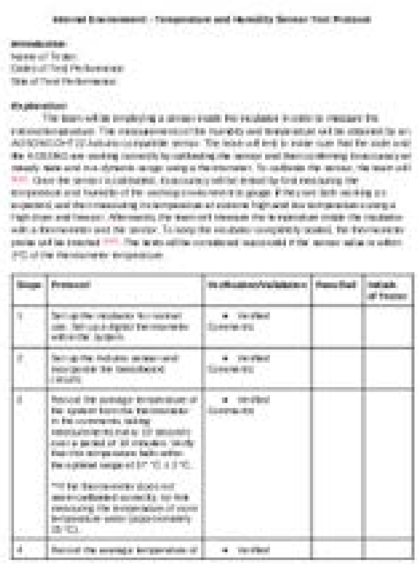
Goals: To document the initial draft of test protocols that were sent to Dr. Kinney for review/approval

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



Download

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:

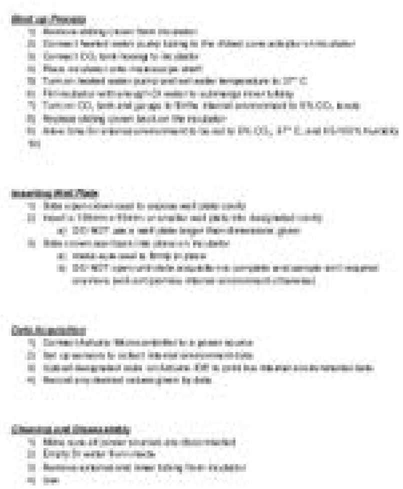
Goals: To establish a user manual to determine how to use the incubator once printed.

Content:

See attached user manual.

Conclusions/action items:

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



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

Download

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

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

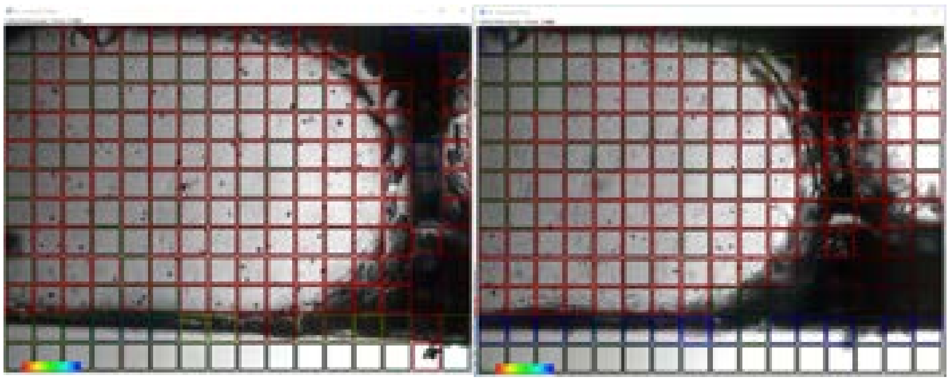


Figure 13: Optical analysis from ImageJ of microscopic cells with glass (left) and without glass (right)

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

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.

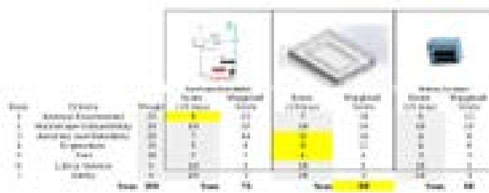
Content:

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



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.

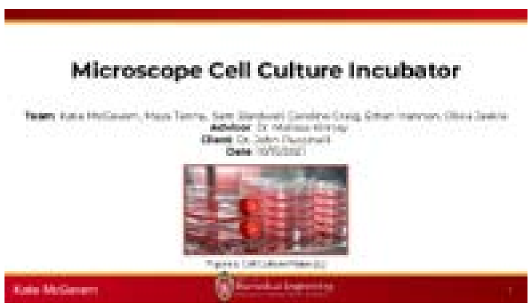
Content:

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

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.

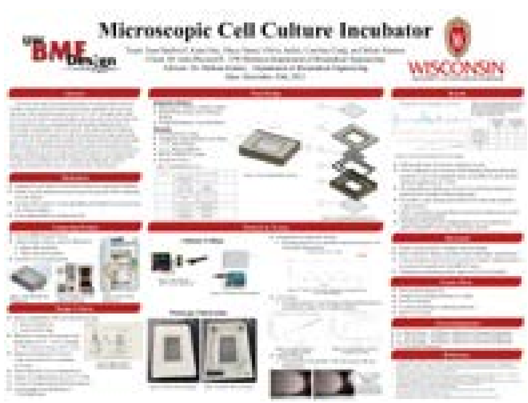
Content:

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

[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

Problem Statement:

Brief Team Update

Summary of Weekly Team Member Design Accomplishments:

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

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

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

[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

Problem Statement:

Brief Status Update

Summary of Weekly Team Member Design Accomplishments:

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

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

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

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

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

Download

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

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

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

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

Download

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

Problem Statement:

Brief Status Update

Summary of Weekly Team Member Design Accomplishments:

Download

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

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

Download

cell_incubator-progress_report-12.docx (12.6 kB)

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
    - CO_2 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?
- CO_2 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 CO_2
    - 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 CO_2 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

Download

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.

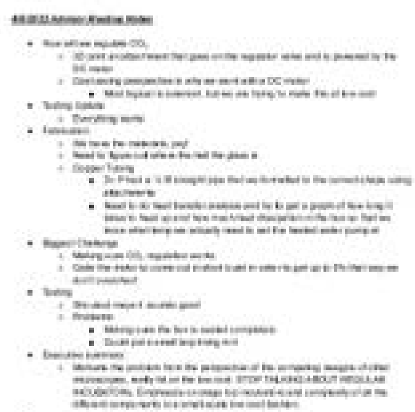
Content:

See Attached File.

Conclusions/action items:

See highlighted portions of attached file.

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



Download

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

Download

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:

- CO_2 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, CO_2, 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

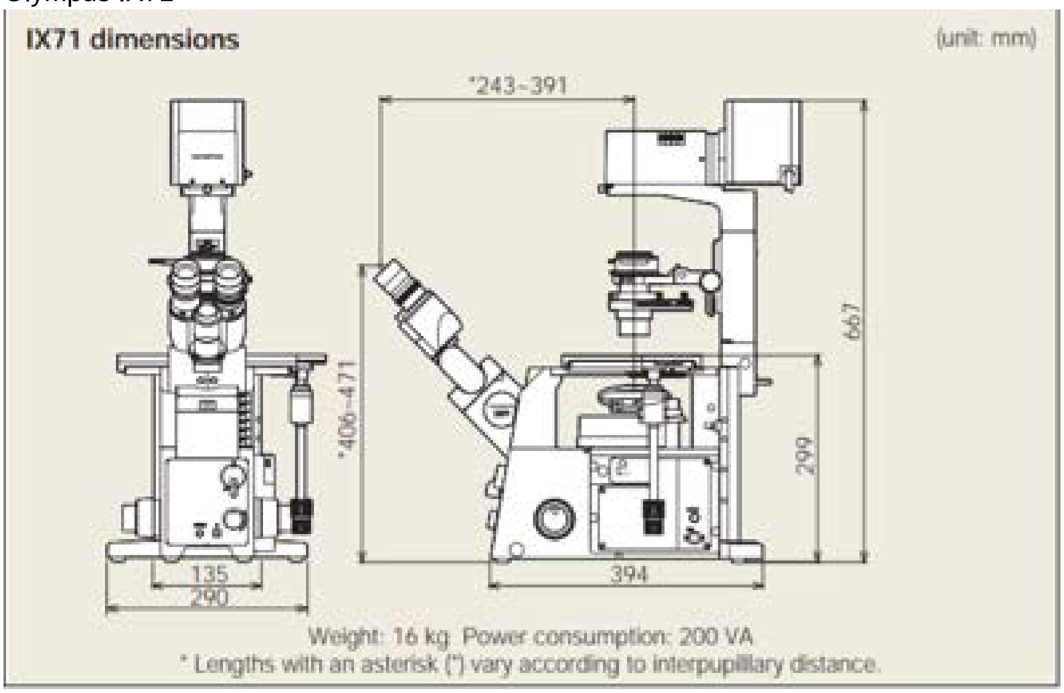
Date: 9/28/21

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 CO2 gas line? Or, will an external CO2 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.

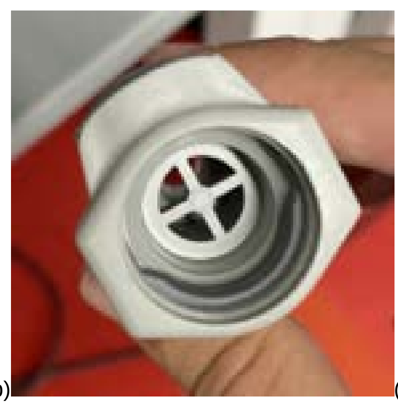
(a)(b)(c)

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

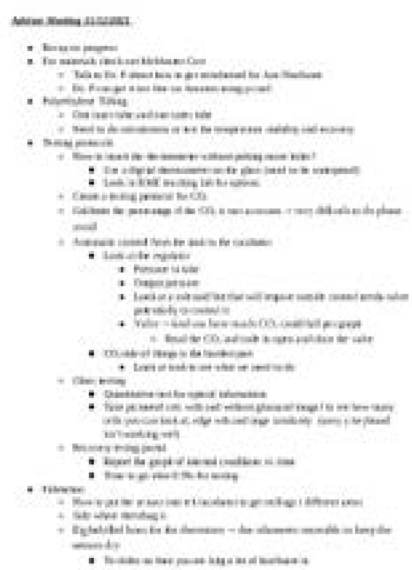
Goals: To document notes and conversation from our sixth advisor meeting with Dr. Kinney

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



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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

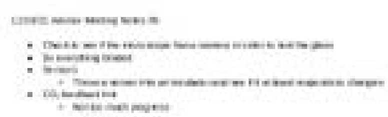
Goals: To document advice given by Dr. Kinney at our weekly meeting

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



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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

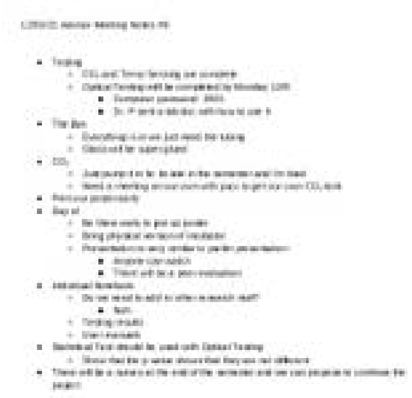
Goals: To document advice given by Dr. Kinney at our weekly meeting

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



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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

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.

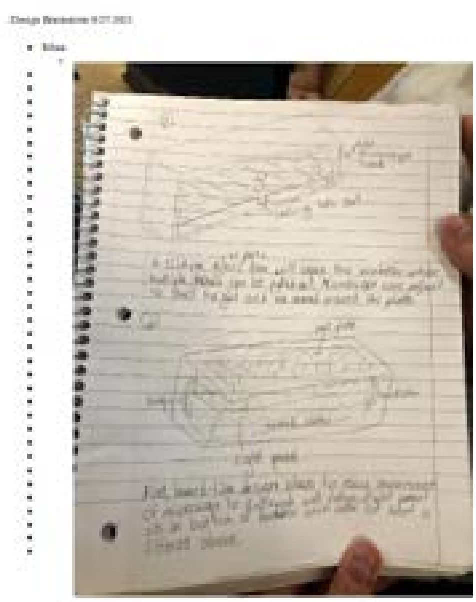
Content:

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



Download

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

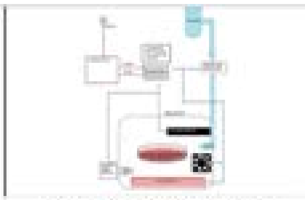
Date: 10/04/2021

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

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

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

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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

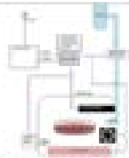
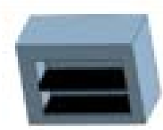
Date: 9/28/2021

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

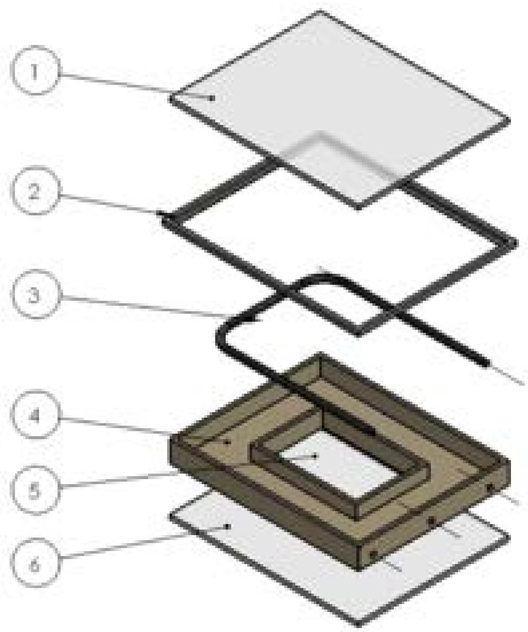


Figure 1: Exploded view of the Solidworks drawing showing the part names and descriptions.

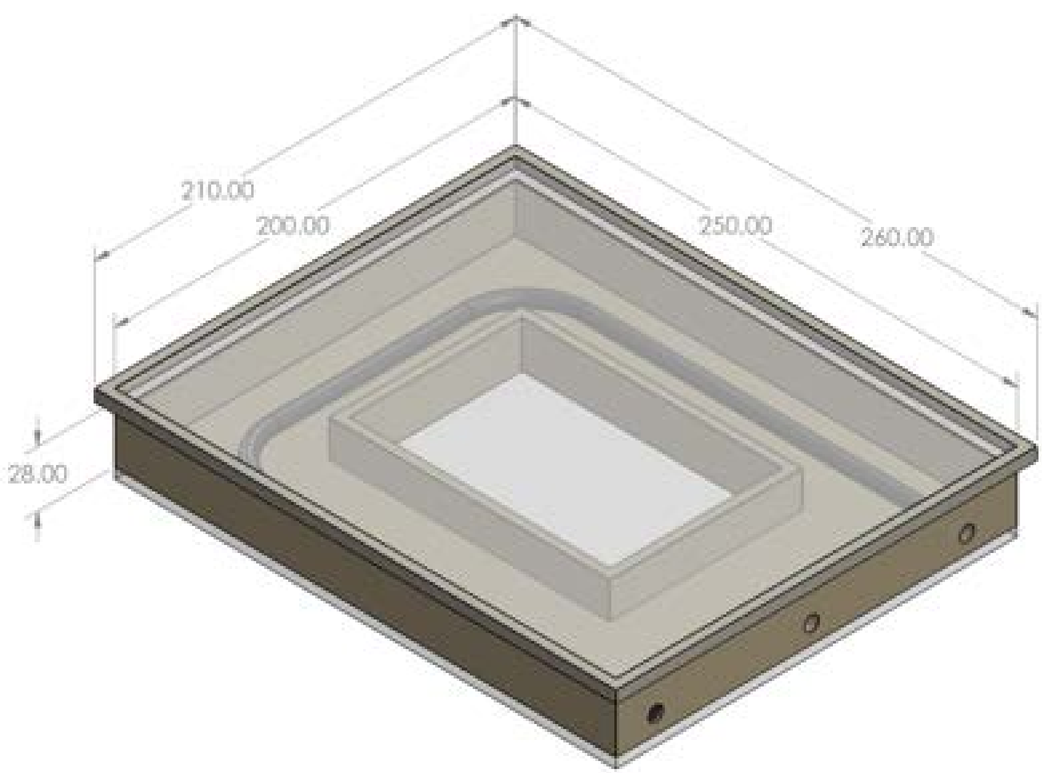


Figure 2: Collapsed view of incubator with dimensions of the box.

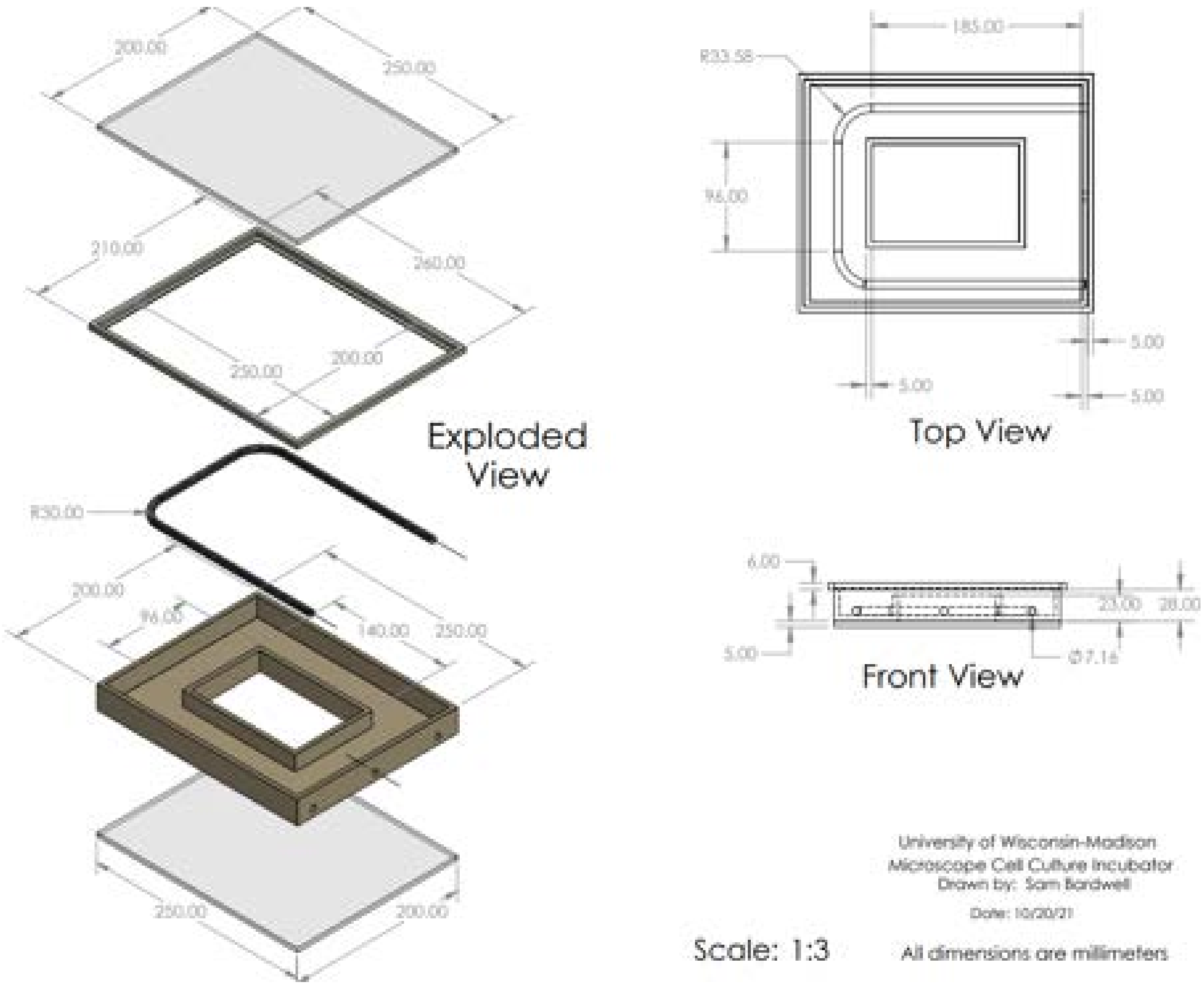
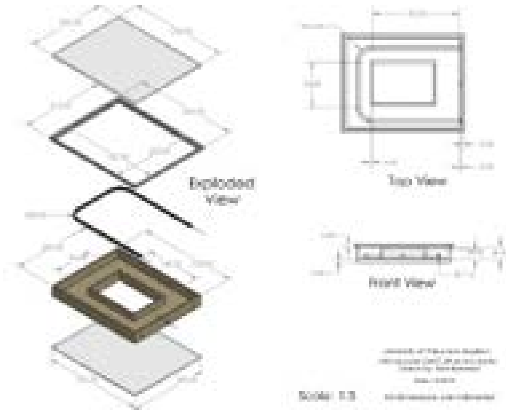


Figure 3: Solidworks drawing showing more detailed dimensions of all the parts in the incubator.

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

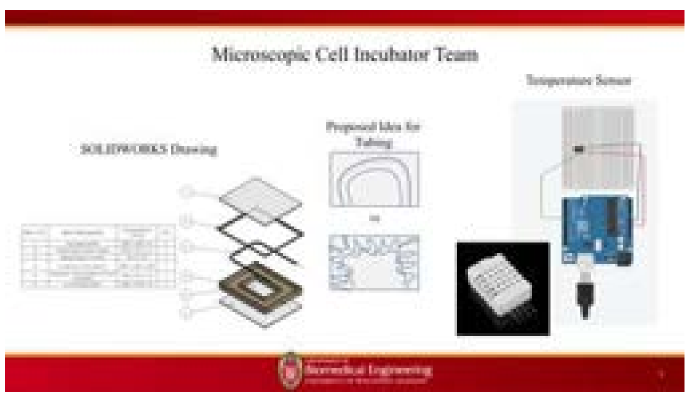
Goals: To document work done to prepare for show and tell

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 Gener
Arduino SD card logging shield		VELLEMAN	WPI304		1	$4.01	$4.01	SD card logging shield VN
						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	5ZMH1	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:

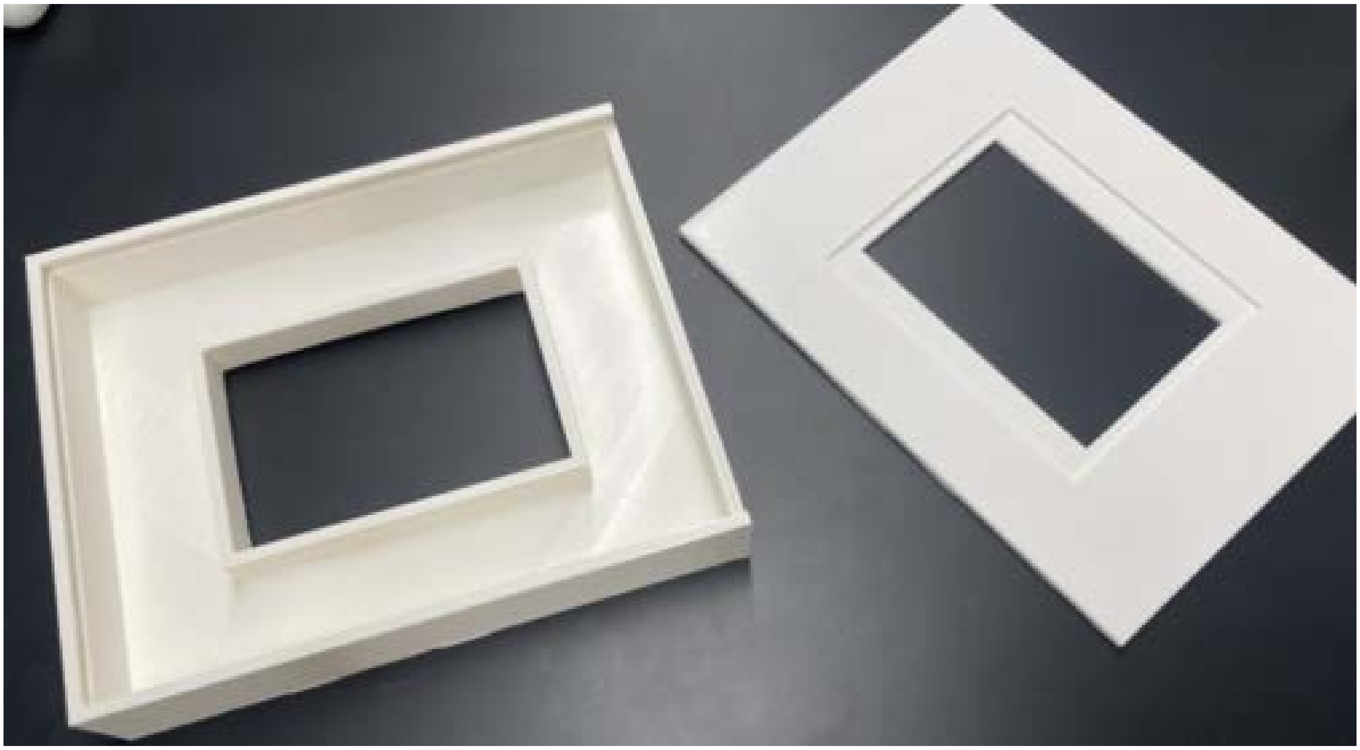


Figure 1: Top view of incubator box and crown 3D prints

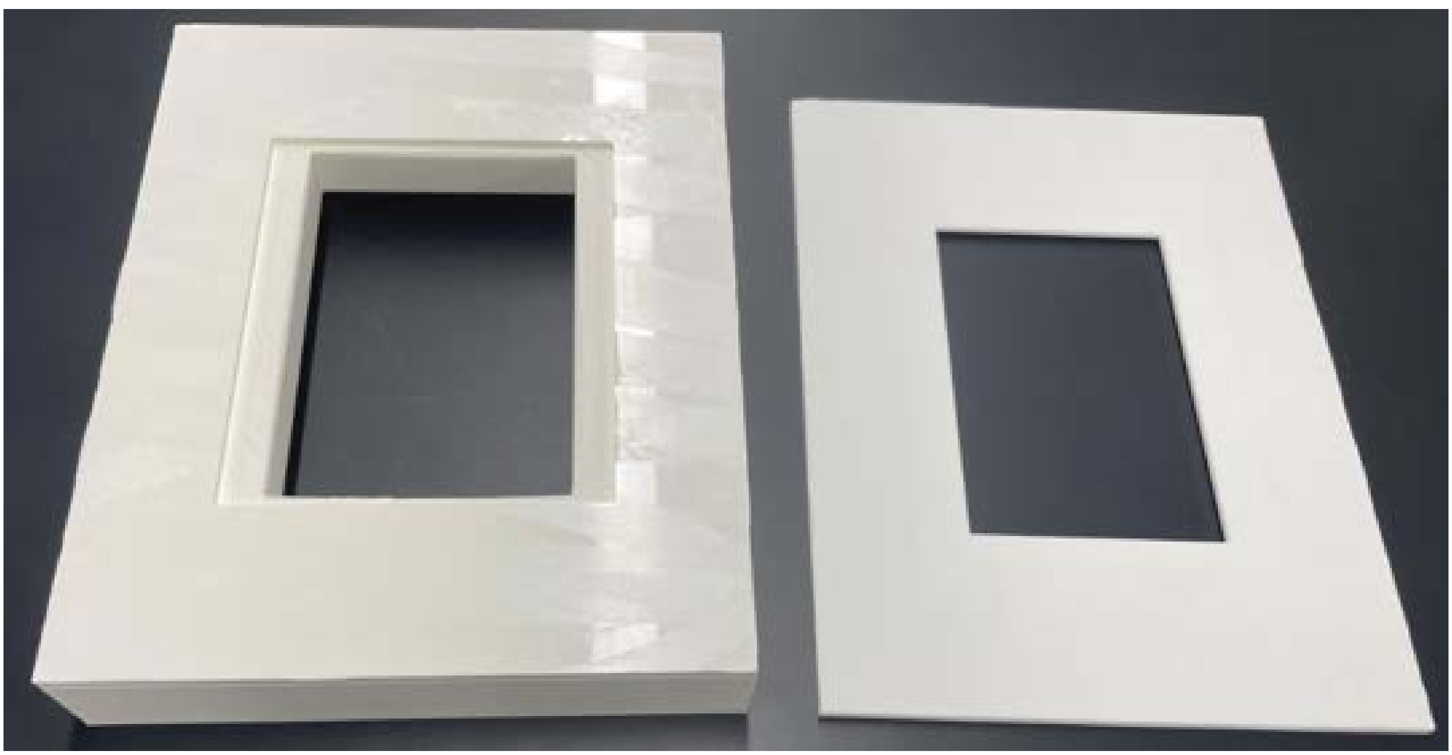


Figure 2: Bottom view of incubator box and crown 3D prints

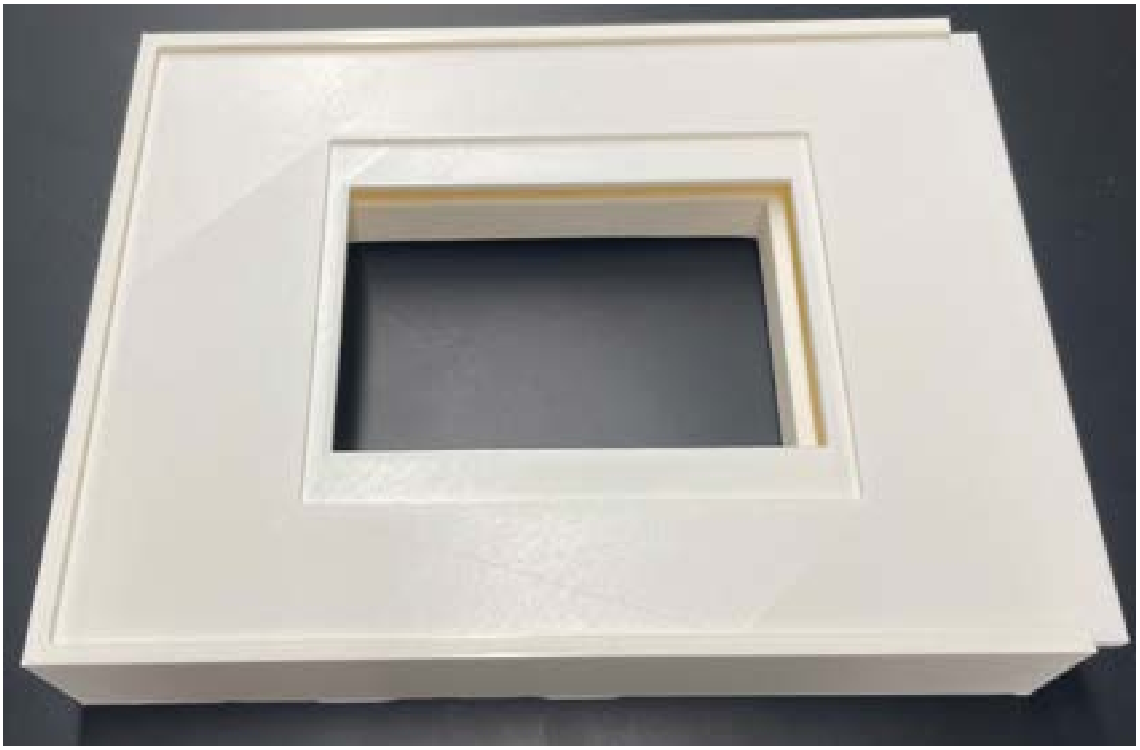


Figure 3: Assembled 3D printed incubator box.

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

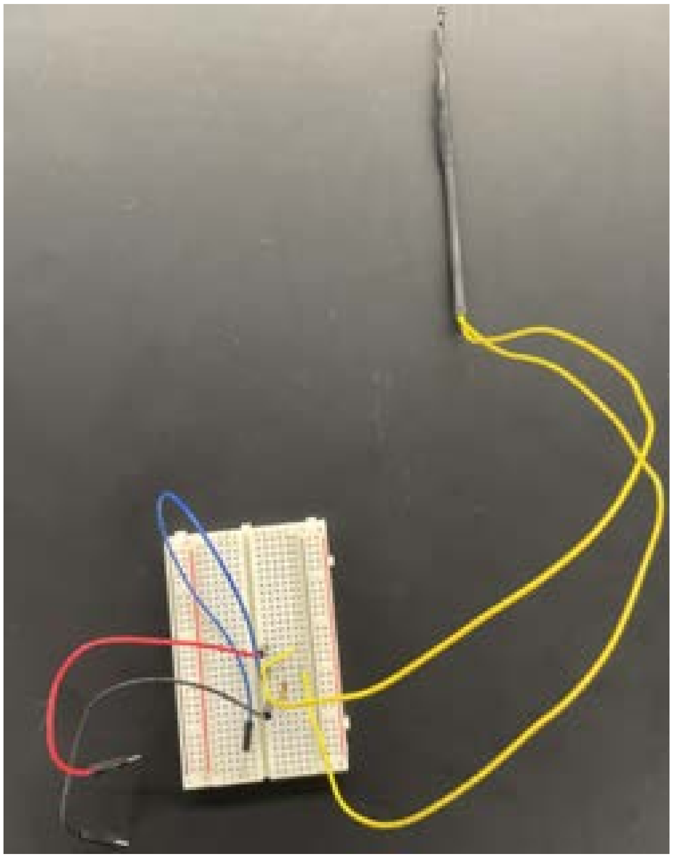
SAMUEL BARDWELL - Dec 09, 2021, 1:26 PM CST

Title: Hardware Setups

Date: 11/29/21

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

Content:



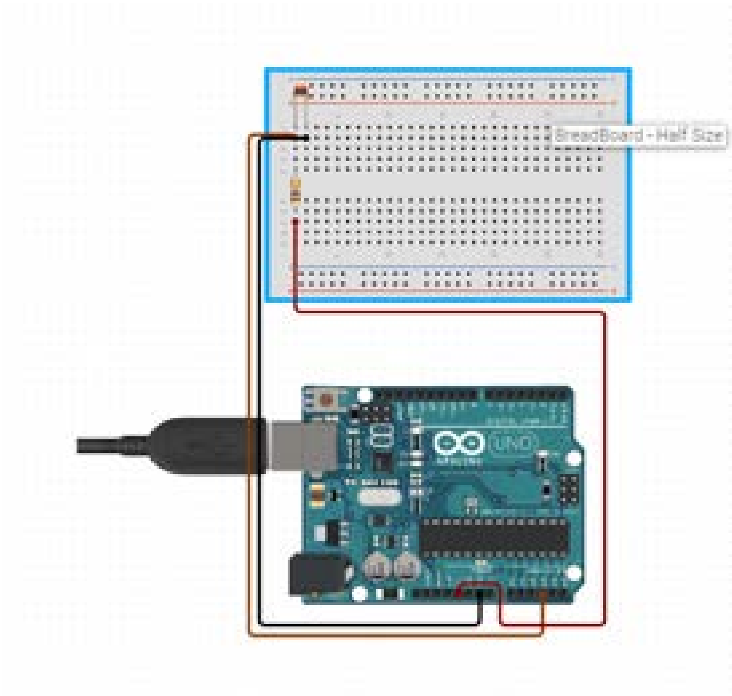


Figure 1: Thermistor hardware set up.

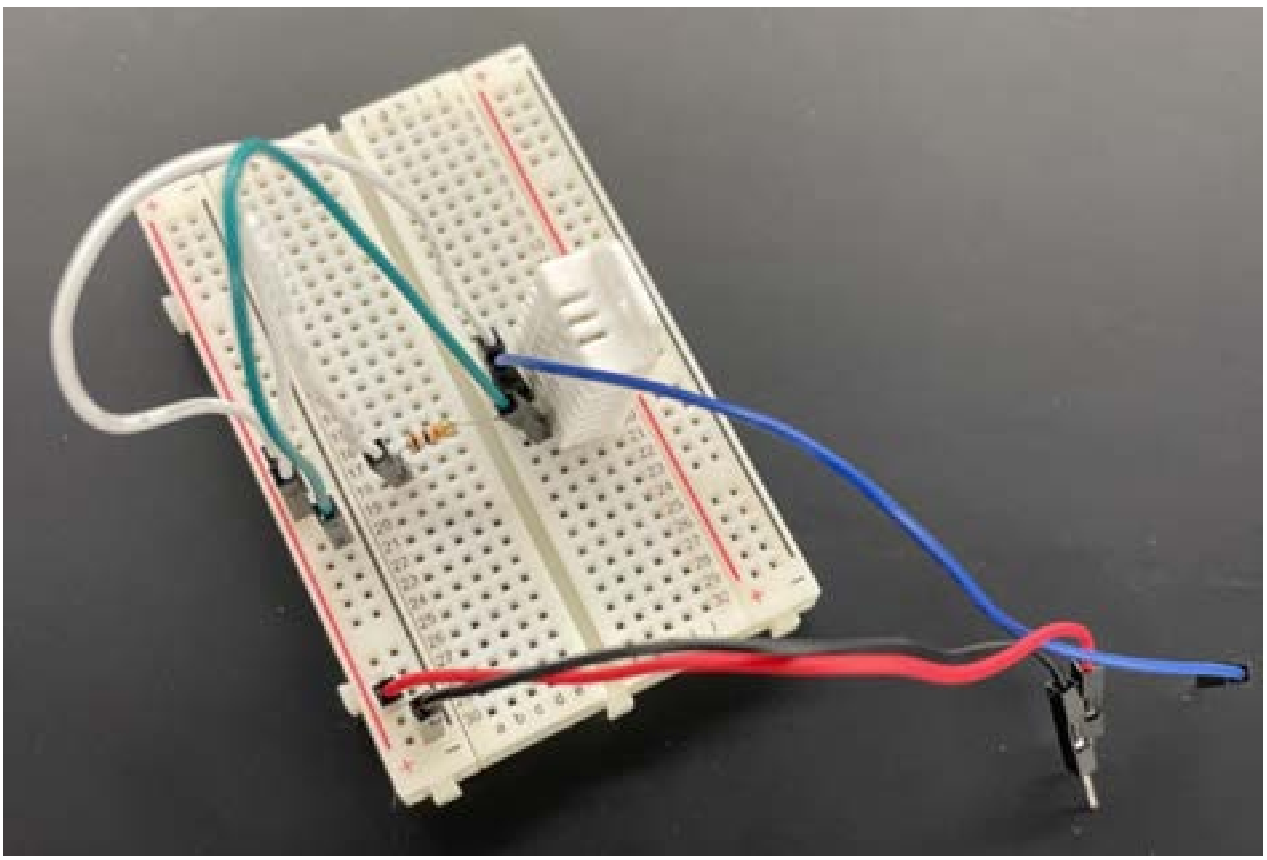


Figure 2: DHT22 sensor hardware set up

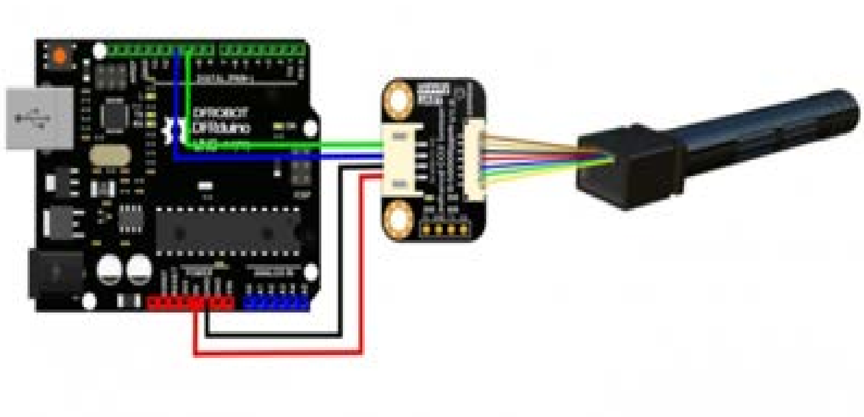


Figure 3: CO2 sensor hardware set up

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.

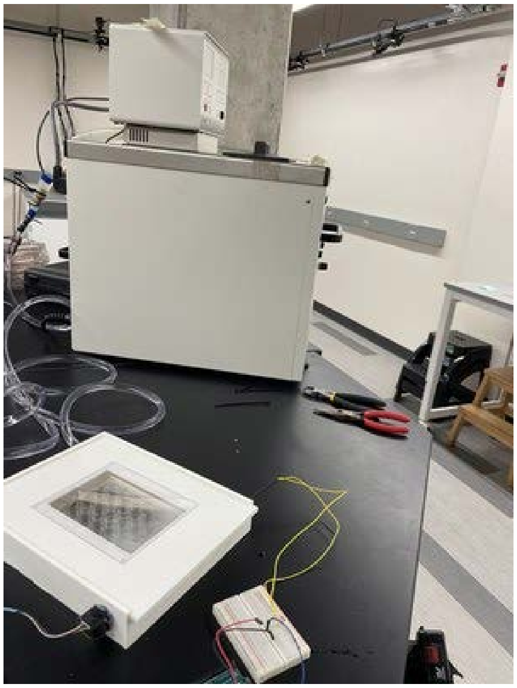
Content:

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 CO_2 sensor to fit in. The CO_2 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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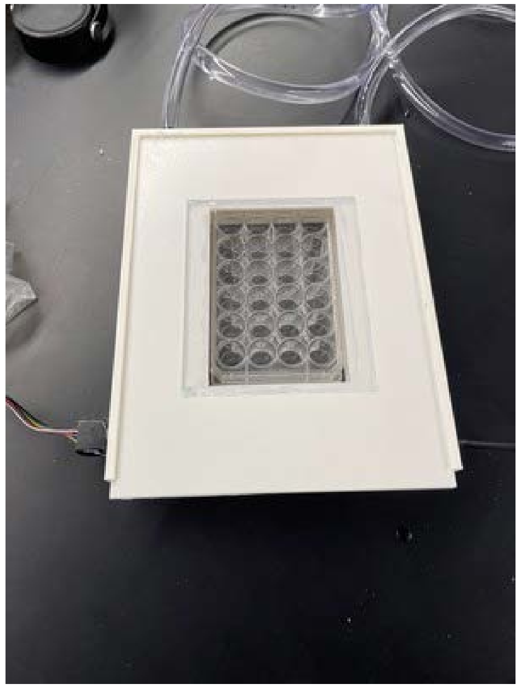
Katie Day - Dec 07, 2021, 8:04 PM CST



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

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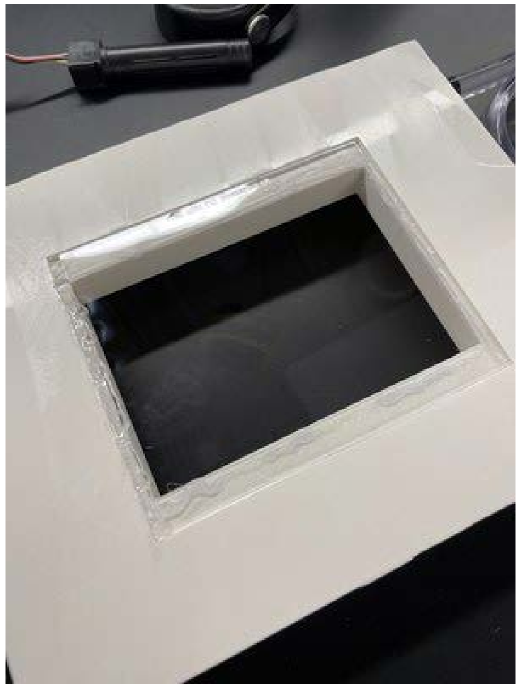
Katie Day - Dec 07, 2021, 8:04 PM CST



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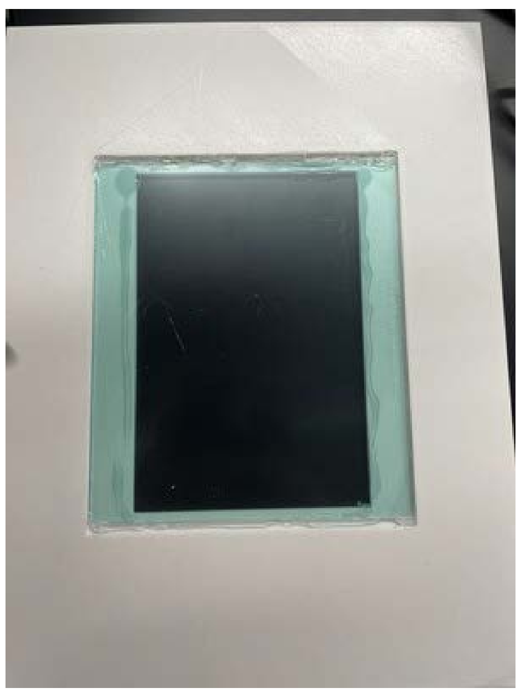
Katie Day - Dec 07, 2021, 8:04 PM CST



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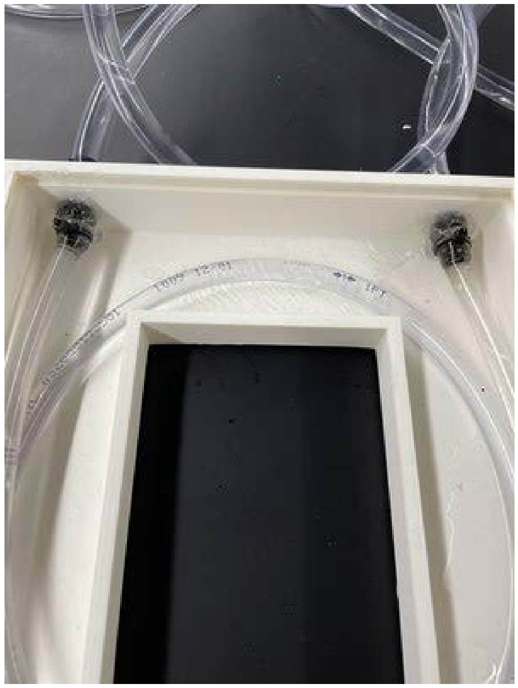
Katie Day - Dec 07, 2021, 8:04 PM CST



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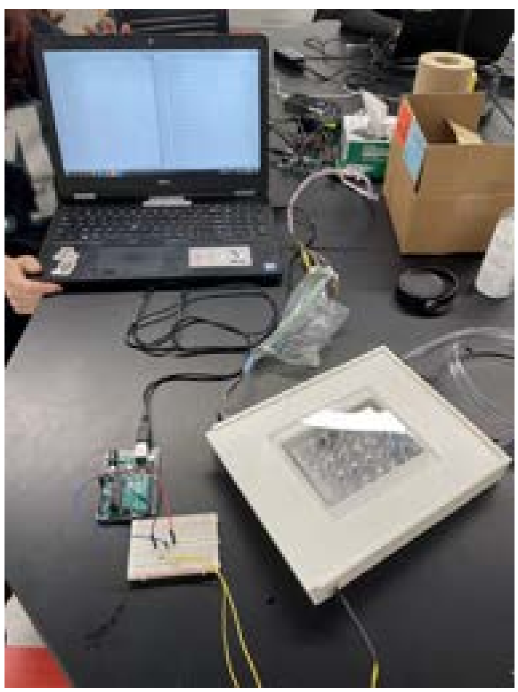
Katie Day - Dec 07, 2021, 8:04 PM CST



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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

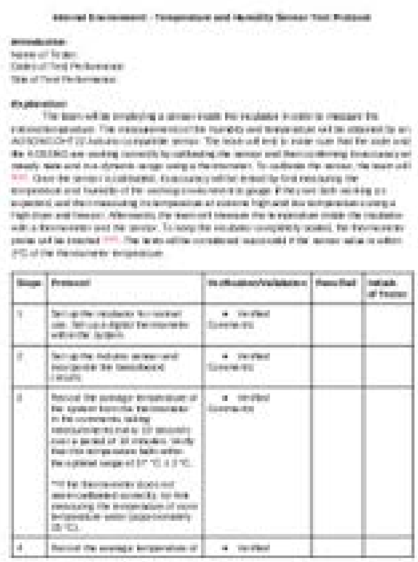
Goals: To document the initial draft of test protocols that were sent to Dr. Kinney for review/approval

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



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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:

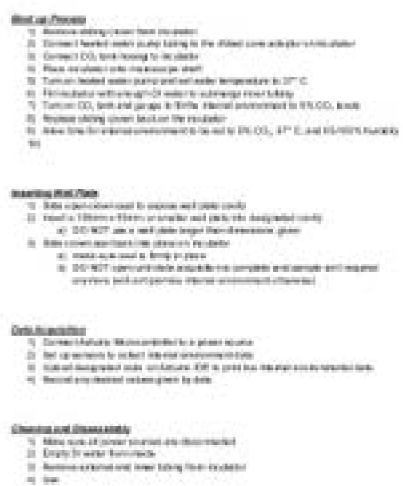
Goals: To establish a user manual to determine how to use the incubator once printed.

Content:

See attached user manual.

Conclusions/action items:

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



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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

Download

Testing_Protocols_Template_1_.docx (599 kB)

12/03/2021 CO_2

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

Title: CO_2 Testing

Date: 12/3/2021

Content by: Katie, Olivia, Maya, and Caroline

Present: Katie and Olivia

Goals: To test the CO_2 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 CO_2 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

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

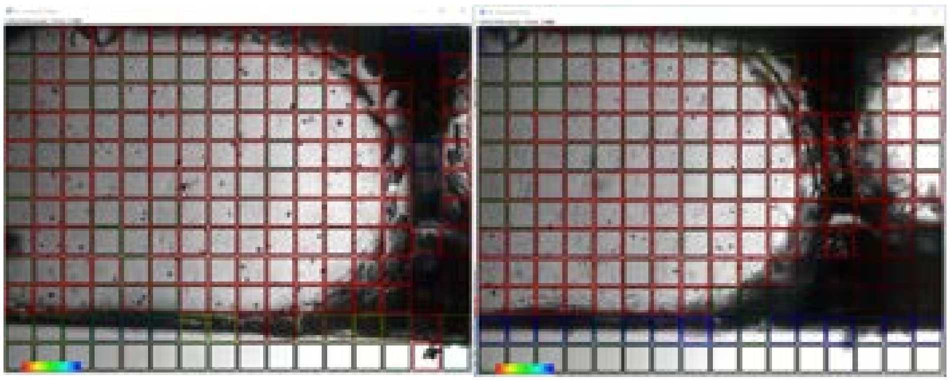


Figure 13: Optical analysis from ImageJ of microscopic cells with glass (left) and without glass (right)

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:

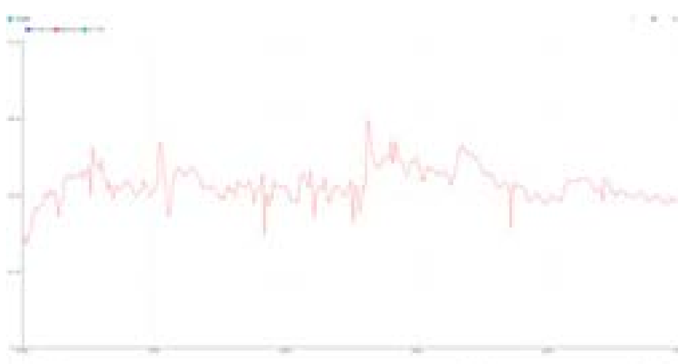
1. Polyethelene tubing acted more as an insulator than a conductor and would not heat up the water bath to the desired temperature. Need to use a metal tube.
2. PLA box was leaking slightly. It is unclear where or how it is leaking as it has been sealed via hot glue and zipties.
3. Glass did fog up after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

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.

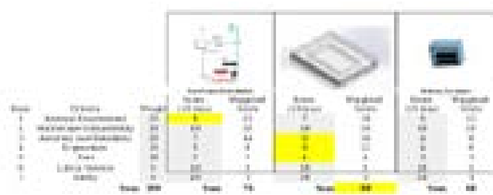
Content:

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



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.

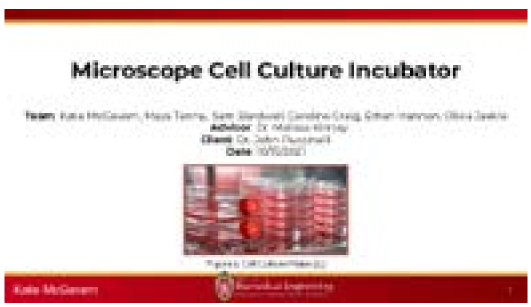
Content:

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

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.

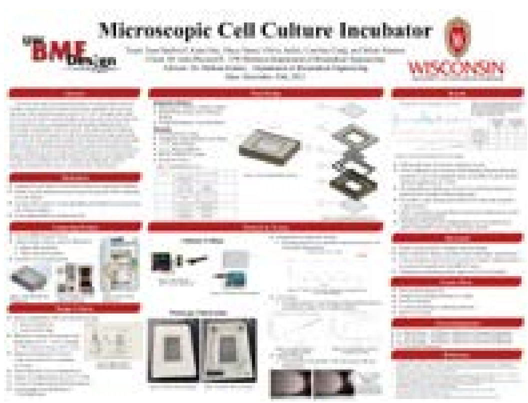
Content:

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

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

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

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

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

[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

Problem Statement:

Brief Status Update

Summary of Weekly Team Member Design Accomplishments:

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

Problem Statement:

Brief Status Update:

Summary of Weekly Team Member Design Accomplishments:

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

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

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

[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

Download

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

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

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

[Download](#)

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

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

Download

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

Problem Statement:

Brief Status Update

Summary of Weekly Team Member Design Accomplishments:

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.

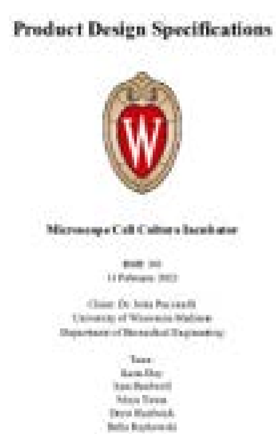
Content:

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

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 CO_2 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 CO_2 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 CO_2 input. The winning incubator box design is the hinge top incubator. Prototype fabrication will begin as soon as possible. The winning CO_2 input design is the 100% CO_2 input. The input sensor and coding will be a little more complicated than the 5% CO_2 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:

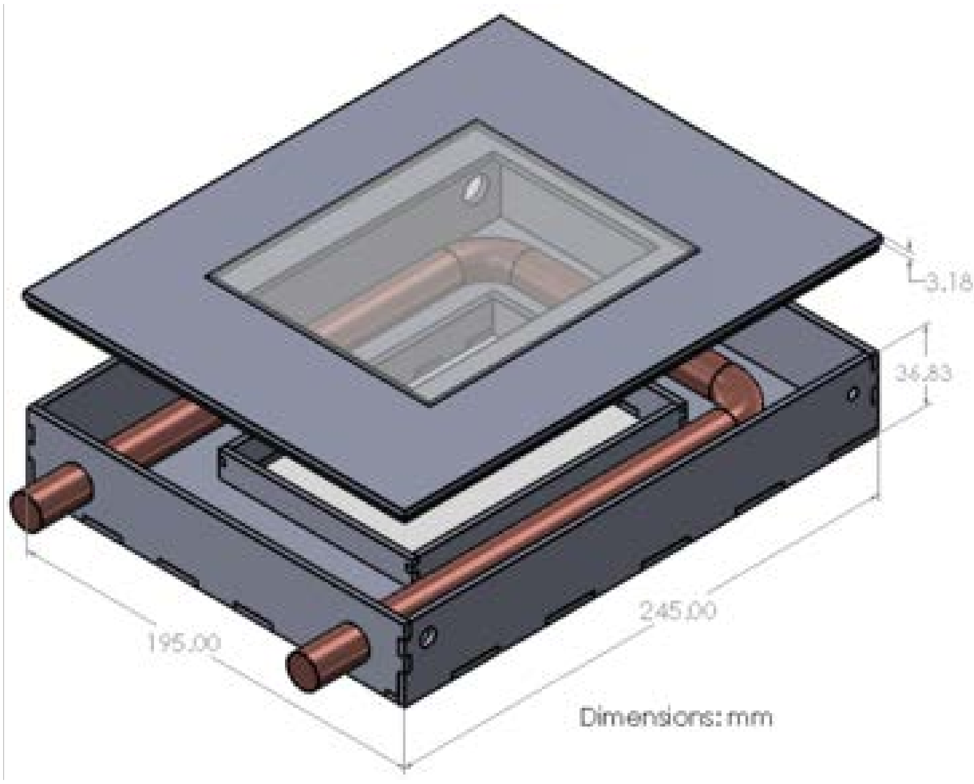
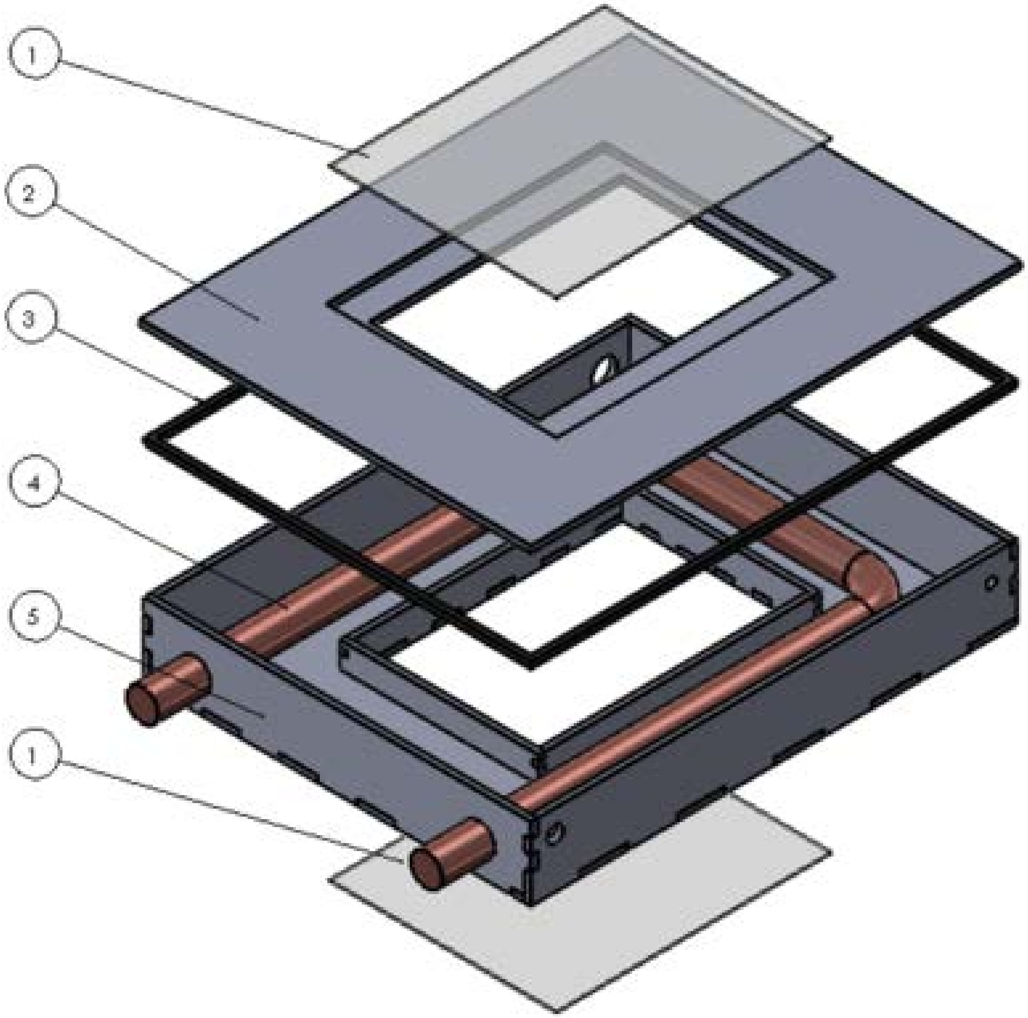


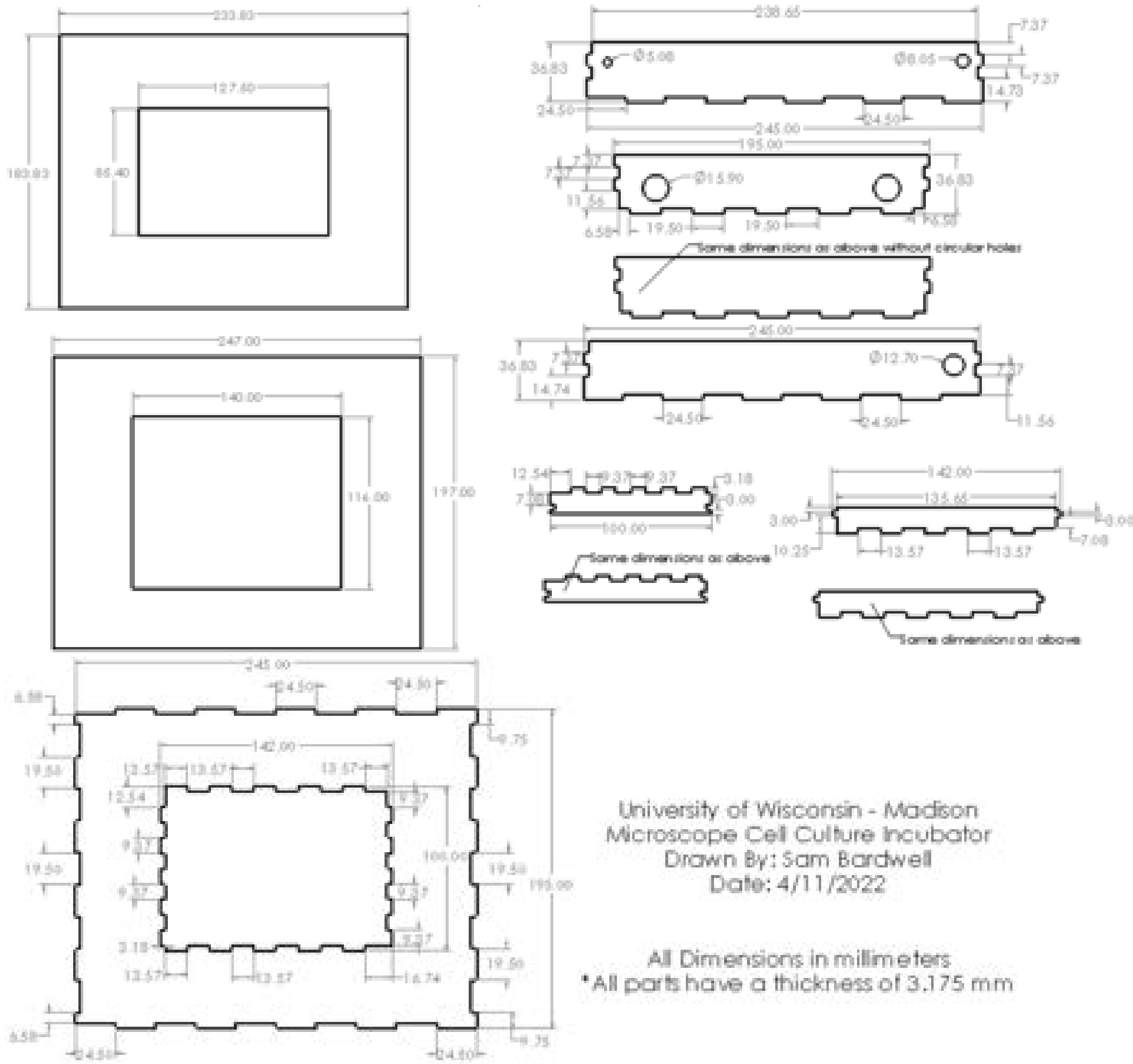
Figure 1: Final SOLIDWORKS drawing of the final design in mm



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

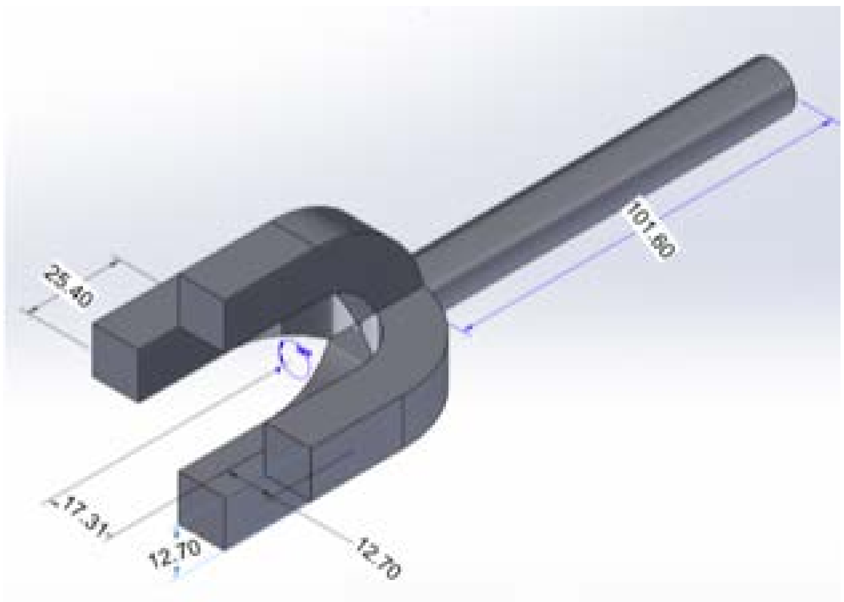


Figure 1: SOLIDWORKS DC Motor Attachment with dimensions shown in mm

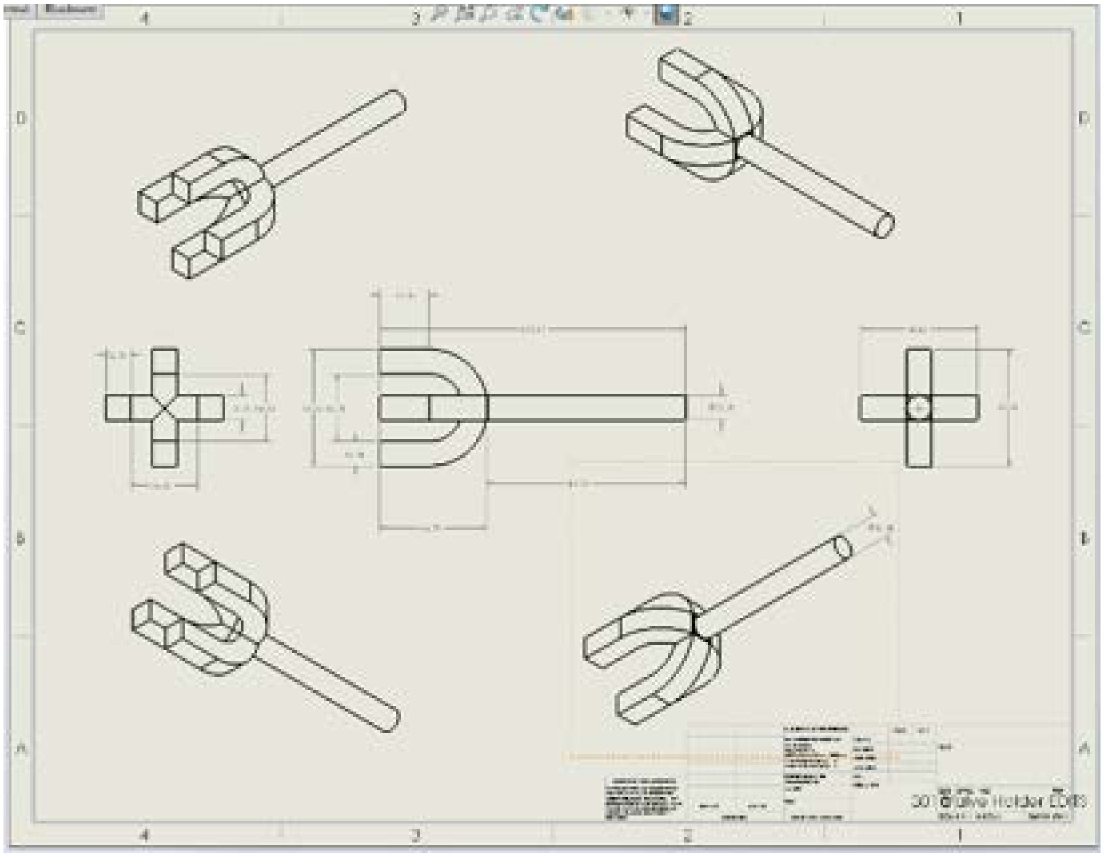


Figure 2: SOLIDWORKS Drawing of DC Motor Attachment with dimensions shown in mm

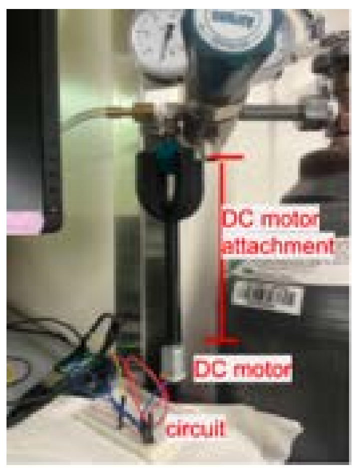


Figure 3: Testing setup with motor, valve holder, and circuits all attached to the CO_2 tank

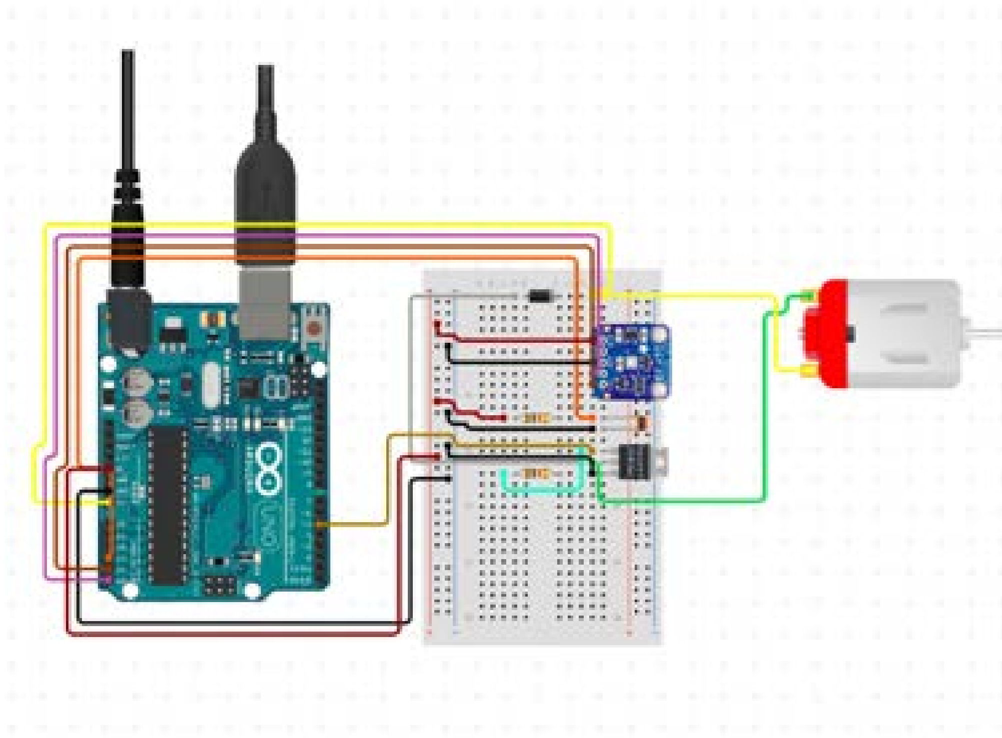


Figure 4: Complete Incubator Circuit Design

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

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:

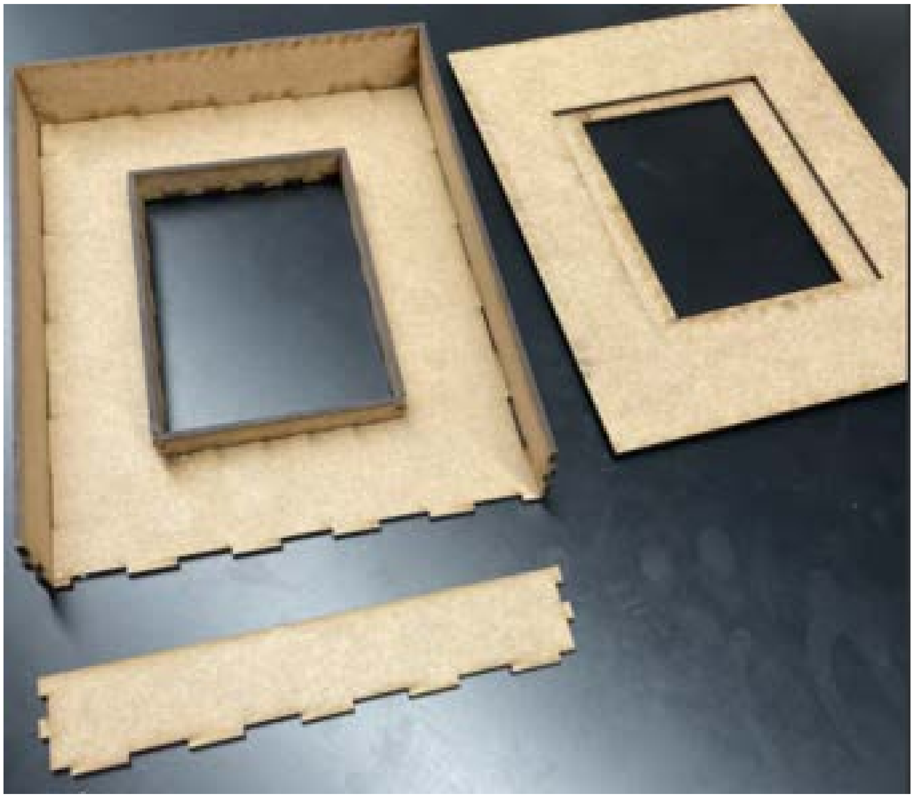


Figure 1: Photo of the laser cut HDF showing the parts being not completely assembled

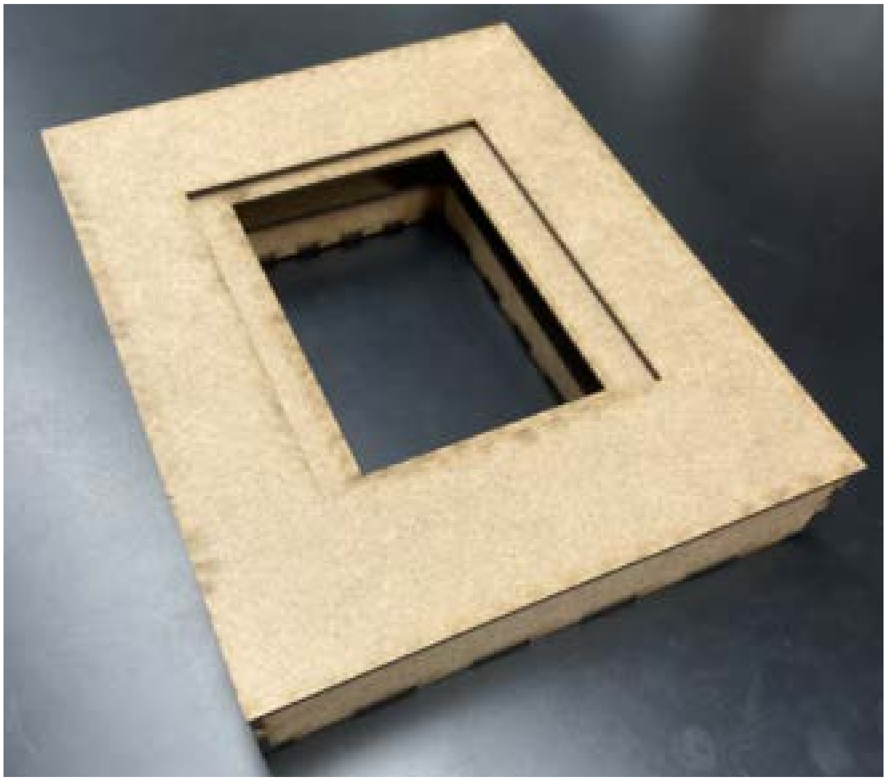


Figure 2: Photo of the laser cut HDF prototype with all the pieces assembled together.

- 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

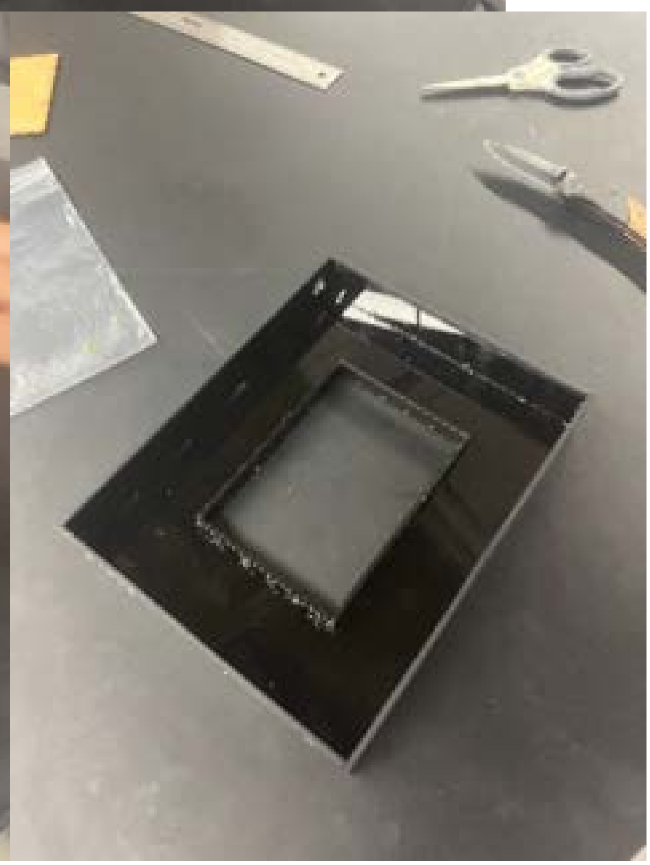
Content by: Katie Day and Sam Bardwell

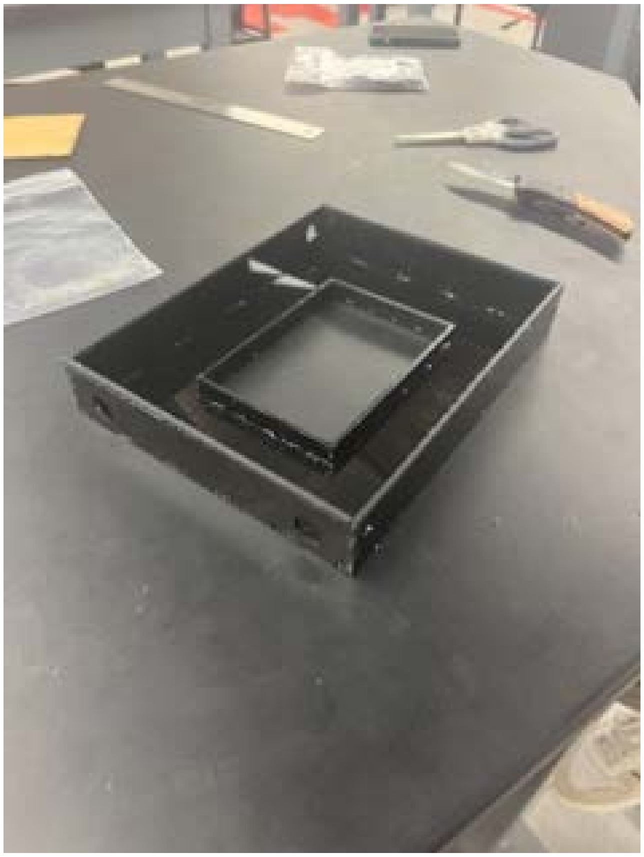
Present:

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.

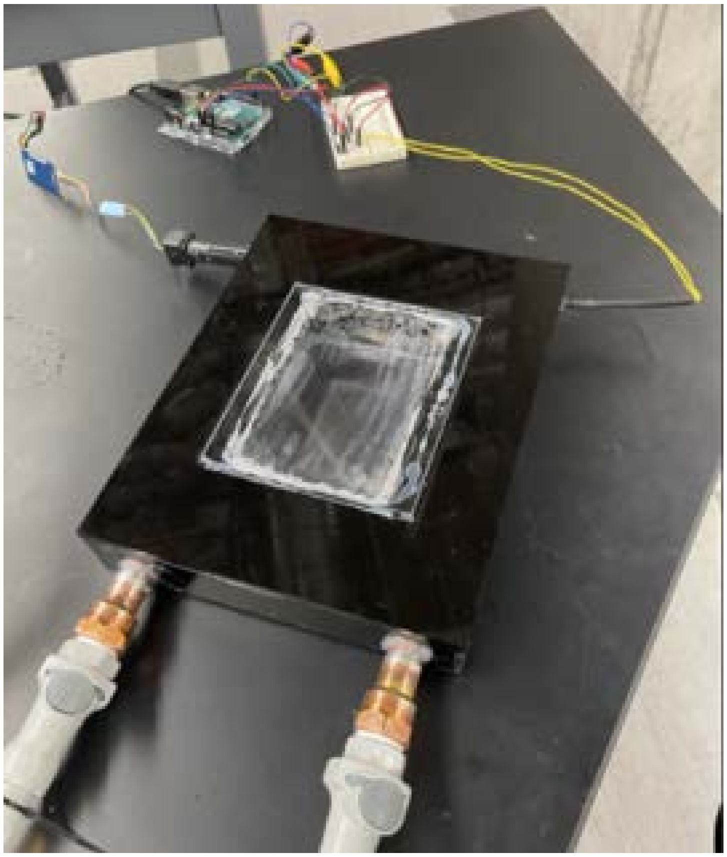


Figure 2: Final design fabrication with an closed lid.

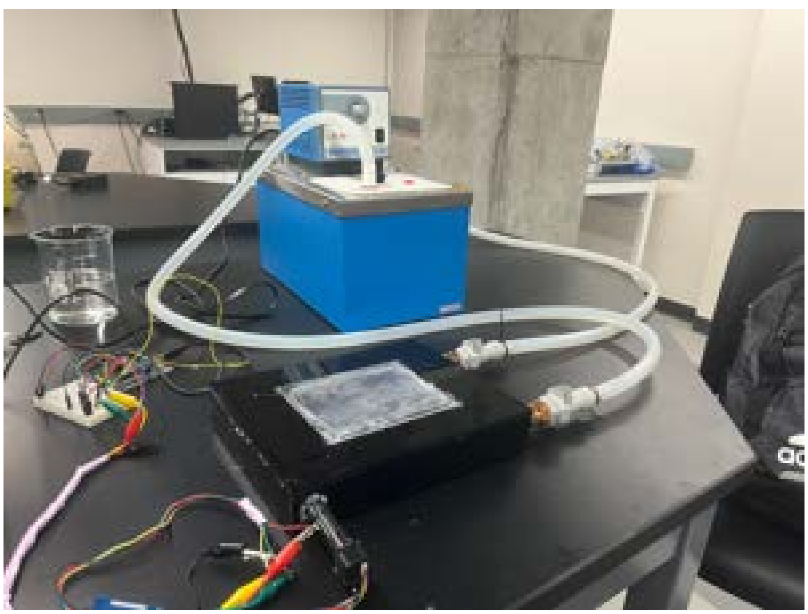


Figure 3: Whole Incubation Set-up

- 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.

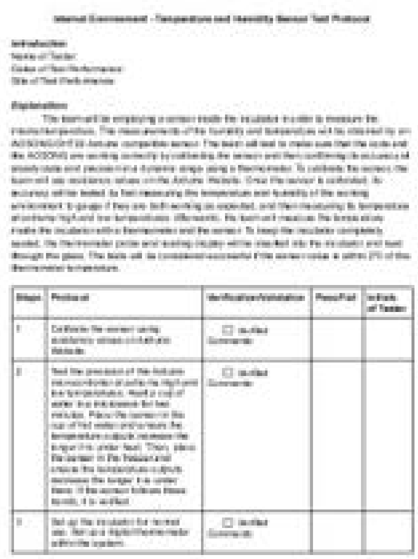
Content:

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



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

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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.

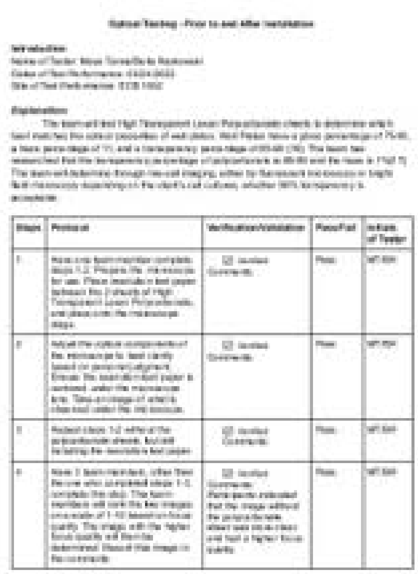
Content:

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



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% CO2 coming out of the CO2 tank at 14.7 psi.

Content:

Time to fill balloon with CO2 = 3s

Initial Water Volume = 2050mL

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

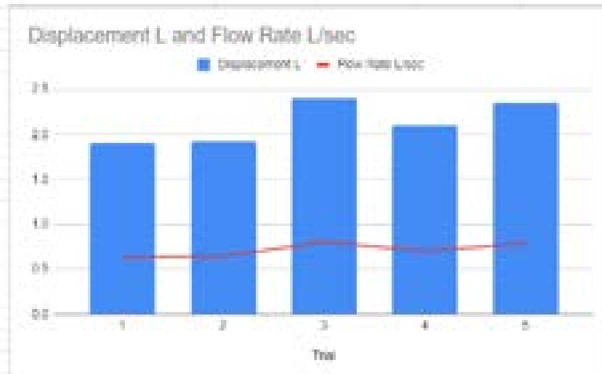


Figure 1: Photo of the flow rate data and graph showing the average flow rate at 14.7 psi.

- 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 CO2 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% CO2.

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

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

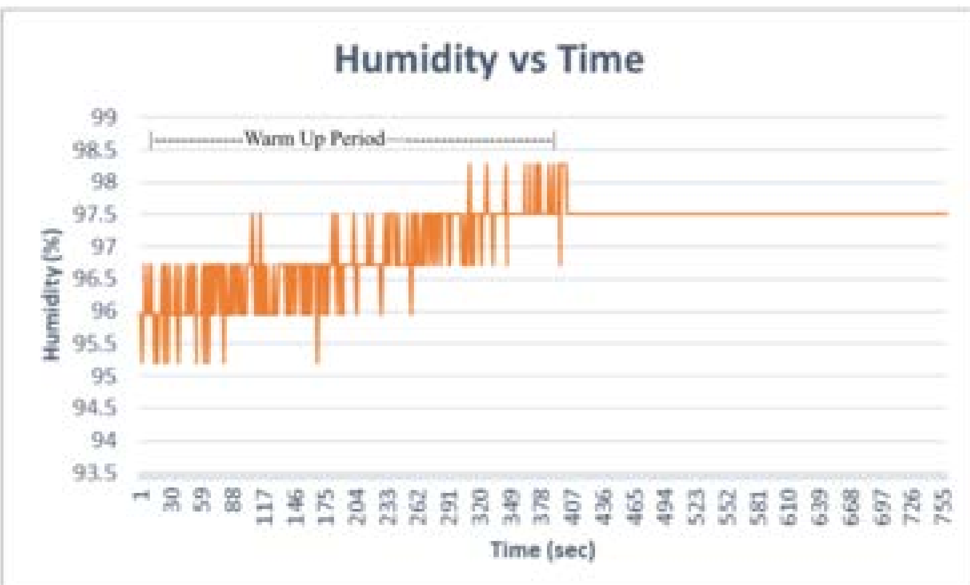
Content by: Katie Day, Maya Tanna, Bella Raykowski, Drew Hardwick, and Sam Bardwell

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.



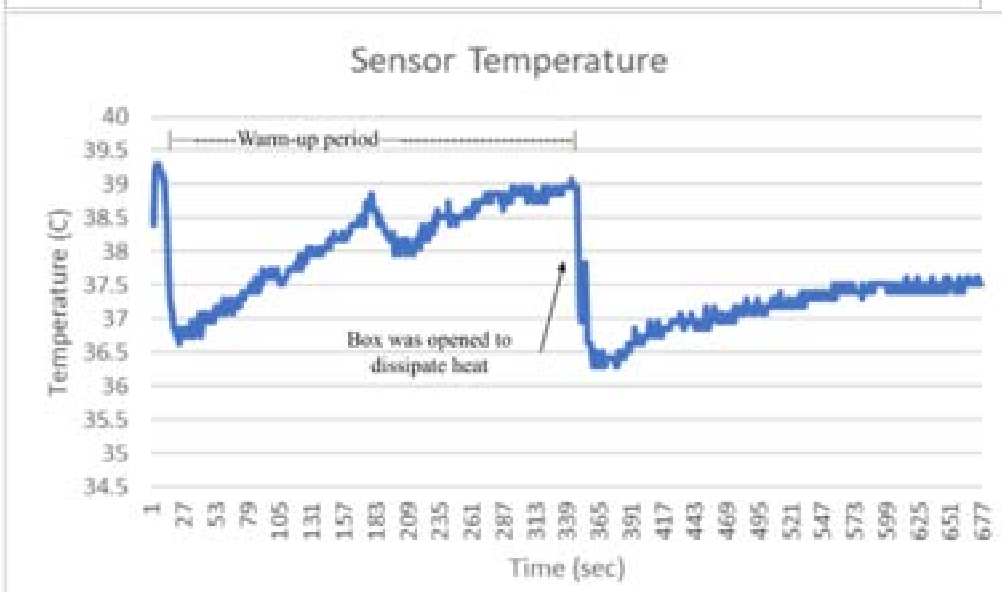


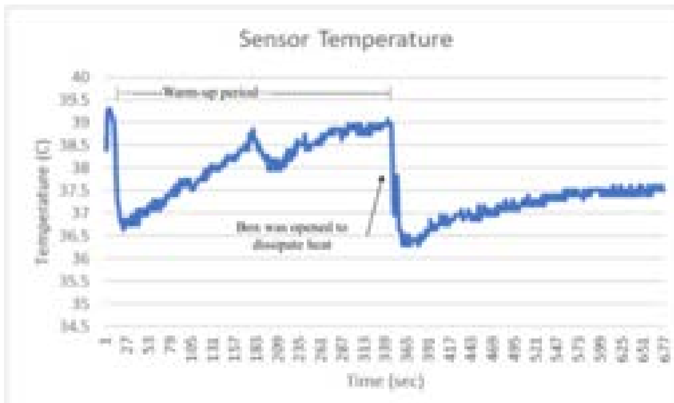
Figure 1: Sensor Humidity Results *Figure 2: Sensor Temperature Results*

See attached for raw data

Conclusions/action items:

Complete recovery testing.

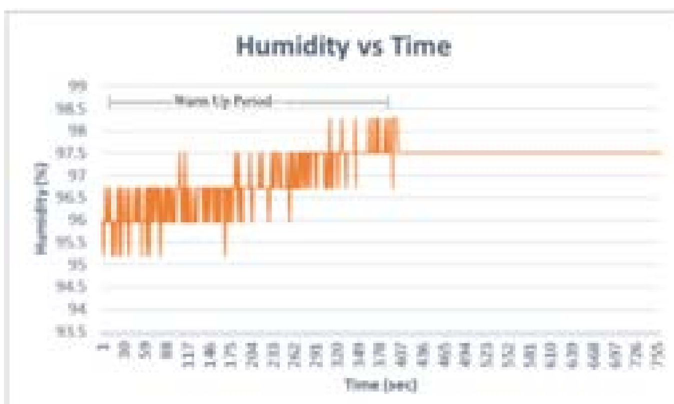
Katie Day - Apr 21, 2022, 12:37 PM CDT



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

Download

Incubator_temp_testing.csv (20.1 kB)

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

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

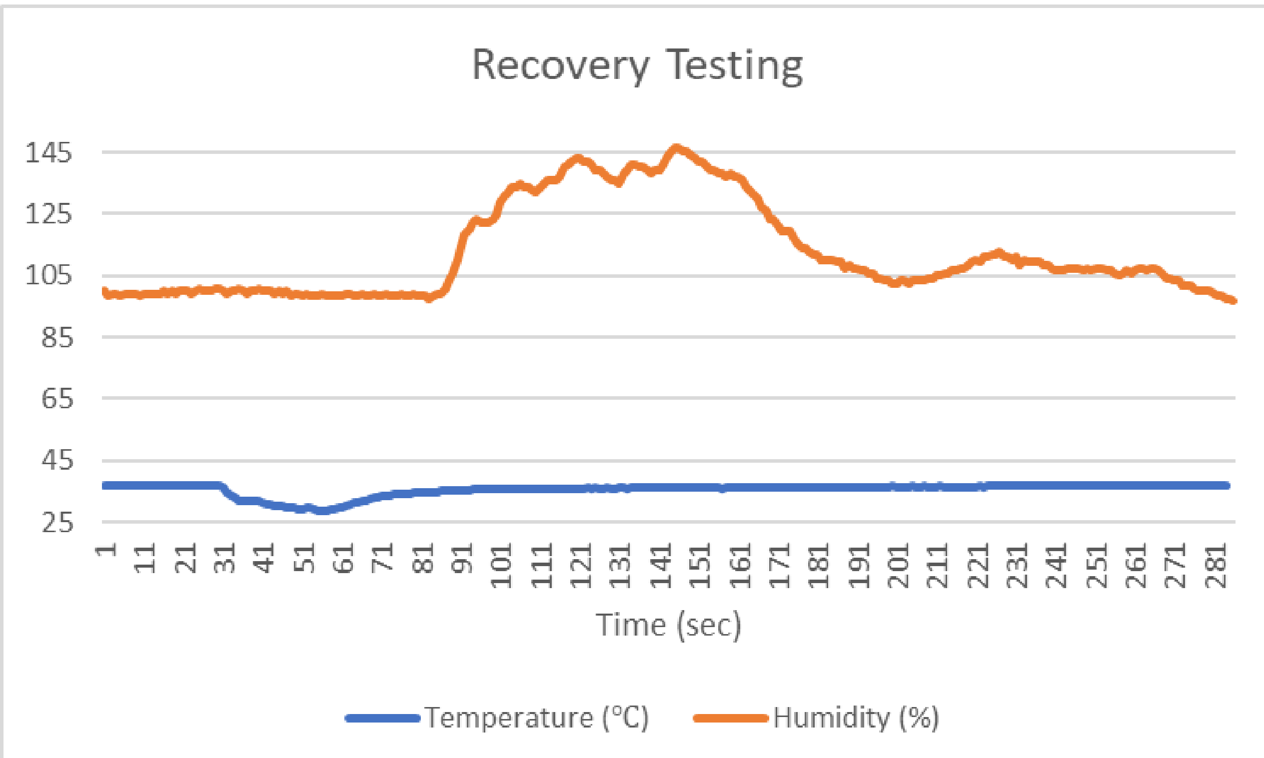
Content by: Katie Day, Maya Tanna, and Bella Raykowski

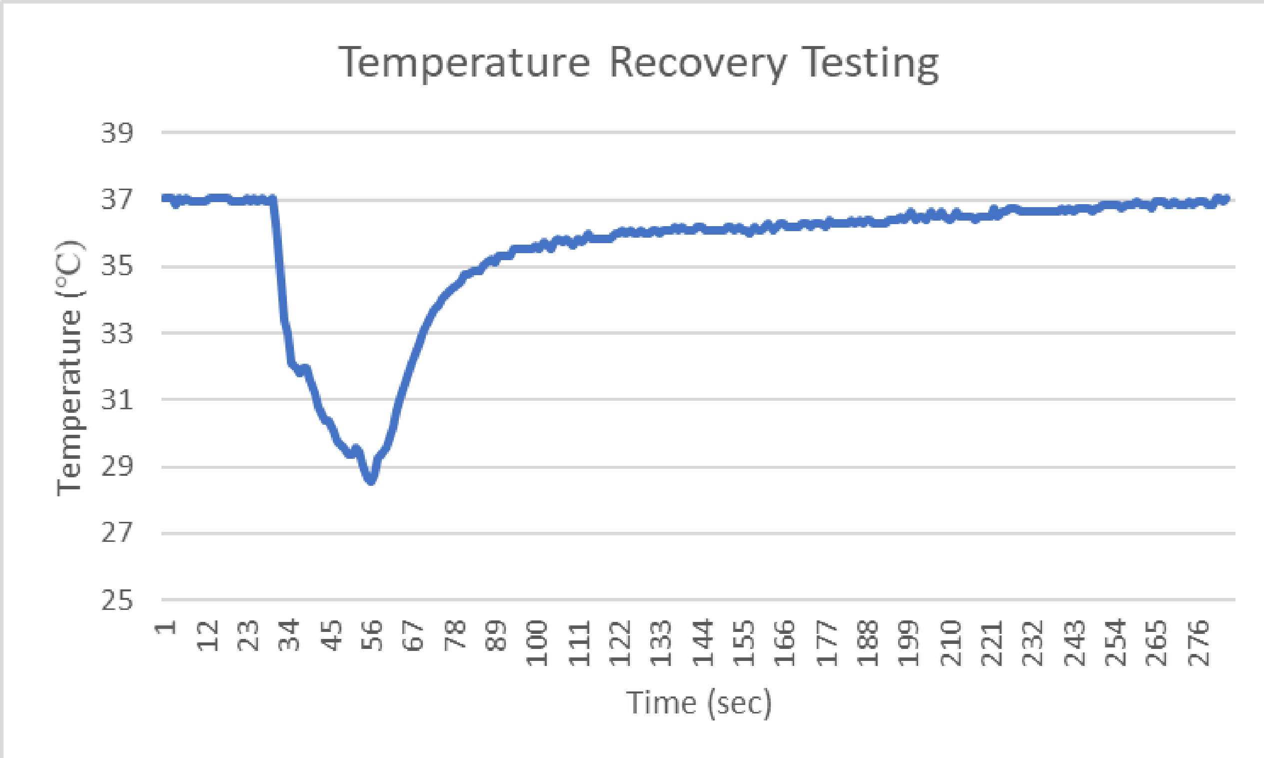
Present: Whole Group

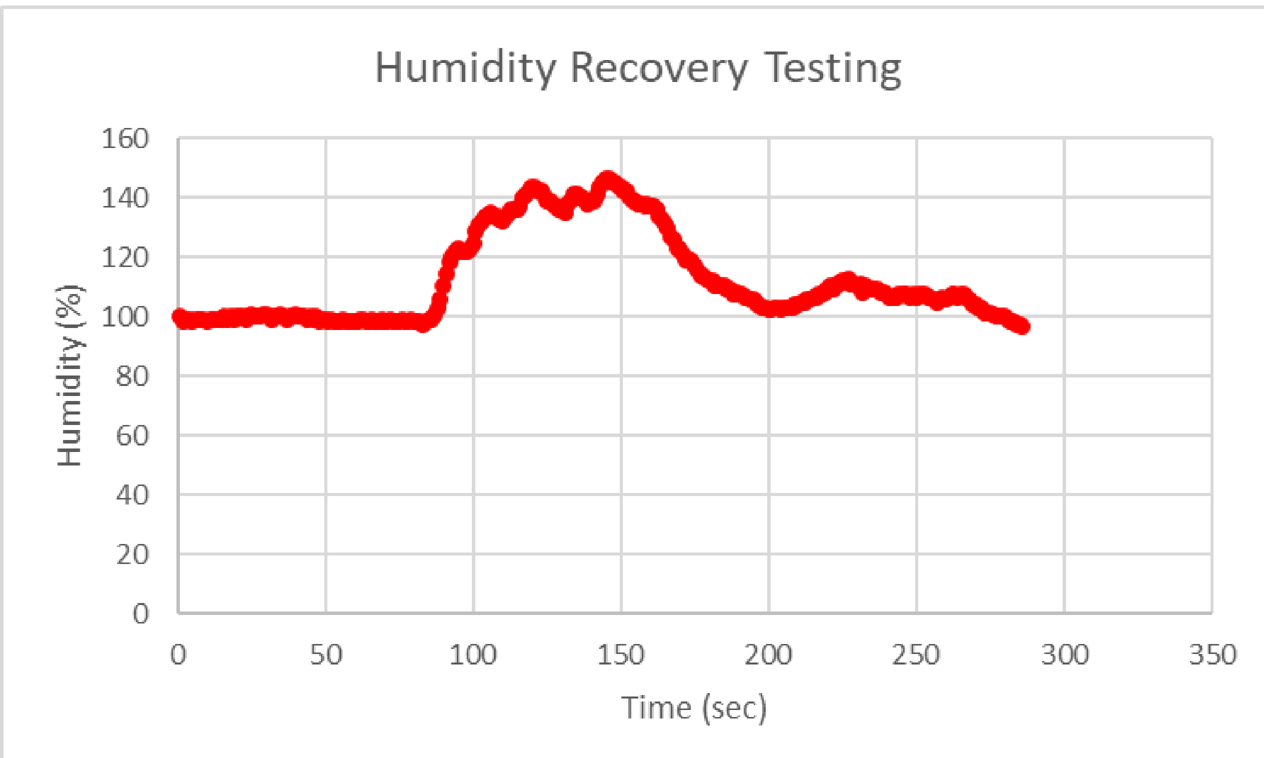
Goals: To determine the amount of time it takes the incubator to return to standard temperature and humidity after opening the box for a short amount of time.

Content:

See attached files.



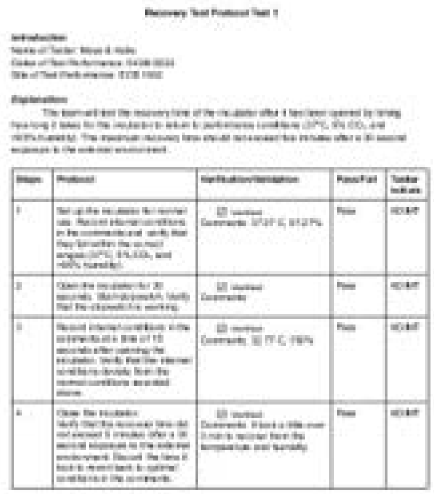




Conclusions/action items:

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

Explanation

Steps	Protocol	Verification/Validation	Pass/Fail	Tester Initials
1	[illegible]	[illegible]	Pass	[illegible]
2	[illegible]	[illegible]	Pass	[illegible]
3	[illegible]	[illegible]	Pass	[illegible]
4	[illegible]	[illegible]	Pass	[illegible]

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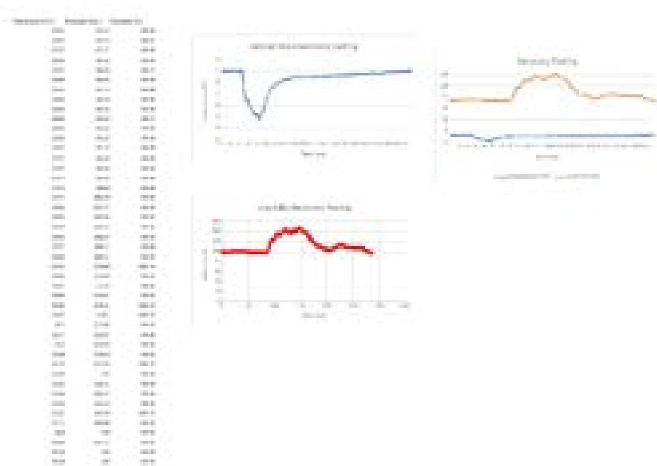
Maya_Katie_Bella_Recovery_Testing.pdf (66.7 kB)

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



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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.

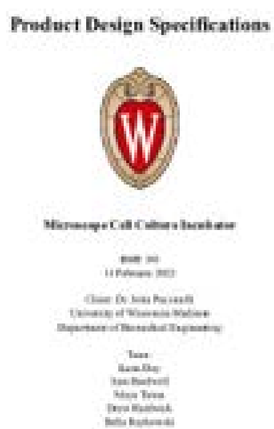
Content:

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

Download

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.

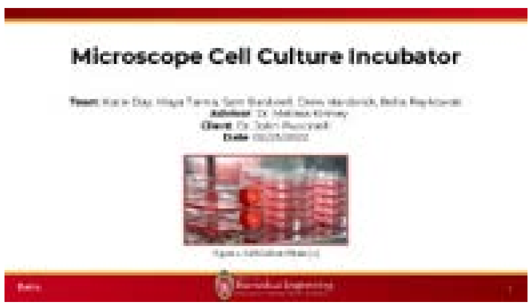
Content:

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



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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

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

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.

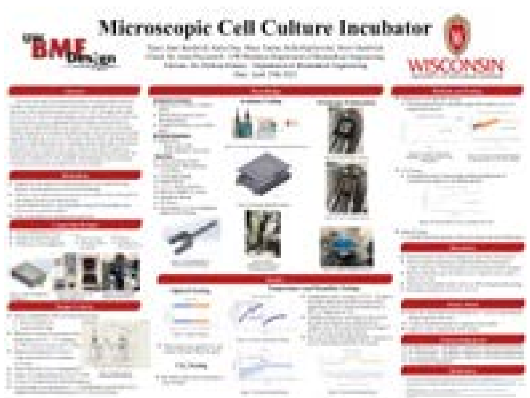
Content:

See attached file.

Conclusions/action items:

Continue the project next semester focusing on CO_2 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

Download

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.

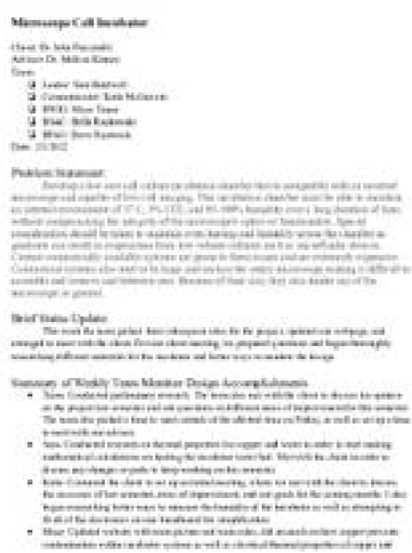
Content:

See attached file.

Conclusions/action items:

See attached file.

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



Microscope Cell Incubator

Problem Statement

Brief Status Update

Download

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

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

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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.

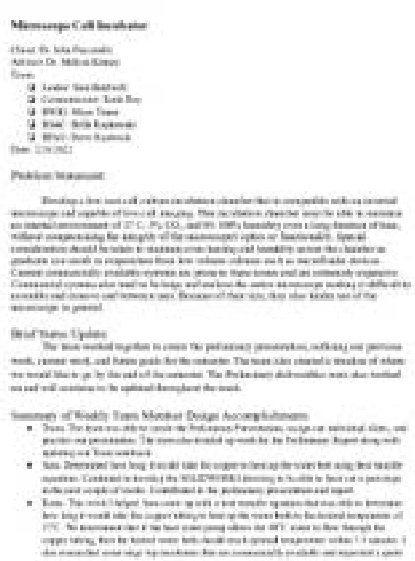
Content:

See attached file.

Conclusions/action items:

See attached file.

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



Microscope Cell Incubator

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

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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.

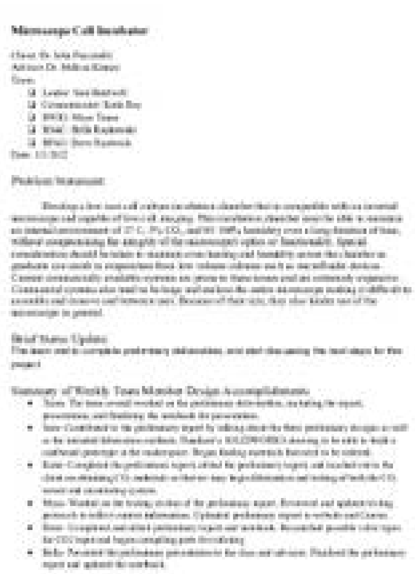
Content:

See attached file.

Conclusions/action items:

See attached file.

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



Microscope Cell Incubator

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

Download

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.

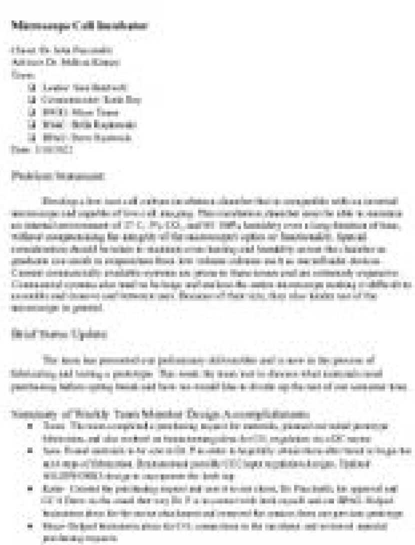
Content:

See attached file.

Conclusions/action items:

See attached file.

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


Microscope Cell Incubator

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

Download

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.

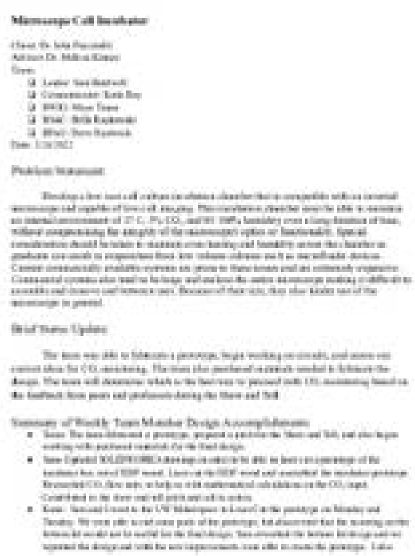
Content:

See attached file.

Conclusions/action items:

See attached file.

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



Download

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

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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.

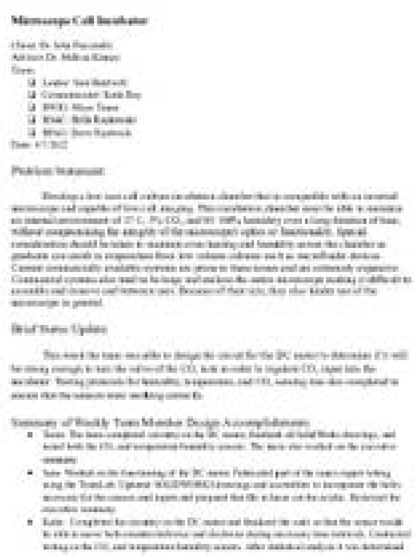
Content:

See attached file.

Conclusions/action items:

See attached file.

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



Microscope Cell Incubator

Problem Statement

Brief Status Update

Summary of Weekly Team Member Design Accomplishments

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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

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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.

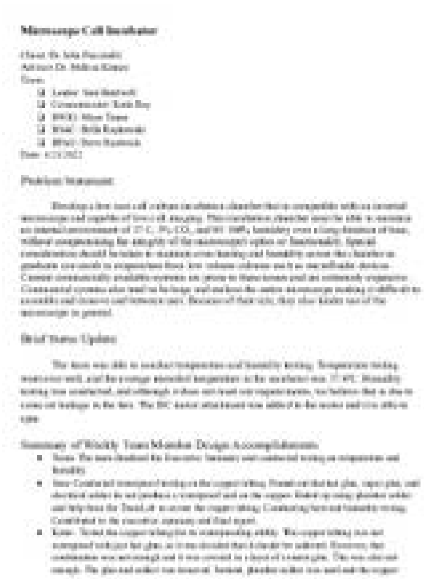
Content:

See attached file.

Conclusions/action items:

See attached file.

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



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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.

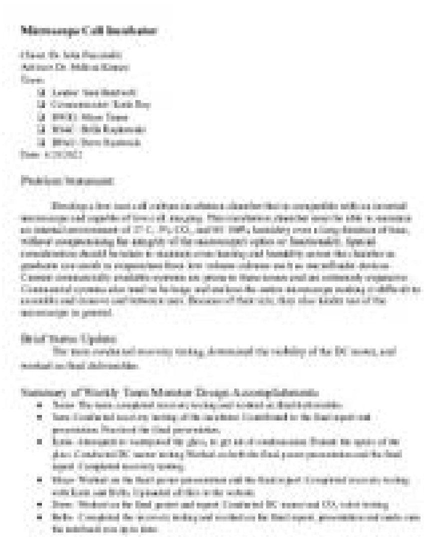
Content:

See attached file.

Conclusions/action items:

See attached file.

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


Microscope Cell Incubator

Problem Statement:

Brief Status Update:

Summary of Weekly Team Member Design Accomplishments:

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cell_incubator-progress_report_12_-_Google_Docs.pdf (98.3 kB)

9/10/2022 - Motivation

Drew Hardwick - Dec 13, 2022, 8:24 AM CST

Title: Project Motivation

Date: 9/10/22

Content by: Drew Hardwick

Present: N/A

Goals: Establish Project Significance

Motivation/Project Significance:

Cell culture is a commonly practiced laboratory method for the use of studying cell biology, replicating disease mechanisms, and investigating drug compounds. Due to the use of live cells during this process, incubators are necessary to keep the cells viable for the duration of the study. Onstage incubators allow for live cell growth because they maintain a highly regulated internal environment of 37 ℃, 5% CO_2, and 95% humidity, without compromising the integrity of the microscope. The COVID-19 pandemic has caused the CO_2 incubator market to increase by 7.69% with an estimated market growth acceleration of 8% over the next decade. Major disadvantages of current commercially available systems are that they tend to be large and bulky enclosing the entirety of the microscope making it difficult to assemble and remove between uses while hindering the use of the microscope in general, and they are often expensive; Fisher Scientific's Enviro-Genie cell incubator is priced at $6,510.68. This project will focus on developing a low-cost cell culture incubator that allows for interchangeable culture plates, compatibility with an inverted microscope, easy disinfection, and live cell imaging via maintenance of the internal environment needed for cell growth.

This project has the potential to make small scale, teaching laboratories much more efficient and cost effective. There is currently no product like this on the market that is anywhere near the $100 price tag our incubator will have. Successful design of this product would provide a cheap, easy, and effective way for professors and teachers across the country to teach students about cell growth and tissue engineering. The client envisions the final product being packaged and sold, marketed as a DIY imaging cell incubator setup, and hopes that other professors (and even high school teachers) across the country will purchase the product for use to inspire the next generation about the wonders of cell growth and tissue engineering.

9/23/2022 Preliminary Design Specifications

Drew Hardwick - Dec 12, 2022, 5:27 PM CST

Title: Preliminary Report

Date: 9/23/2022

Content by: Whole Team

Present:

Goals: To Establish our Product Design Specifications

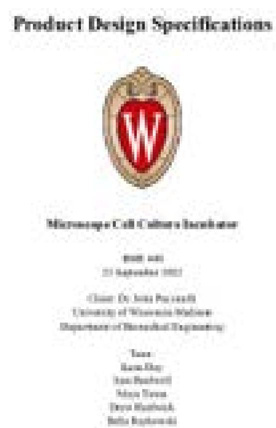
Content:

- **See attached file.**

Conclusions/action items:

Begin fabrication, testing, and purchasing.

Drew Hardwick - Dec 12, 2022, 5:28 PM CST


Product Design Specifications

Download

Product_Design_Specifications_Fall_2022.pdf (222 kB)

10/7/2022- Preliminary Presentation

Drew Hardwick - Dec 12, 2022, 5:32 PM CST

Title: Preliminary Presentation

Date: 10/7/2022

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

Present:

Goals: To present our preliminary findings with our advisor, client, and peers.

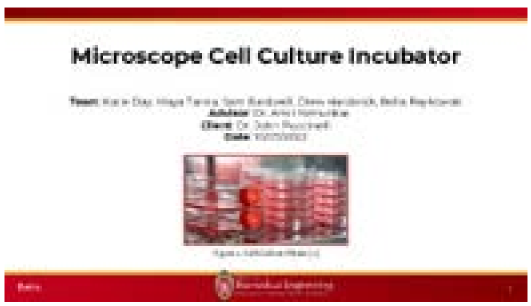
Content:

See attached file.

Conclusions/action items:

Begin ordering materials and prototyping.

Katie Day - Oct 07, 2022, 12:12 PM CDT



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Prelim_Presentation_Slides_Fall_2022_1_.pdf (2.22 MB)

10/12/2022 Preliminary Report

Katie Day - Oct 12, 2022, 11:00 AM CDT

Title: Preliminary Report

Date: 10/12/2022

Content by: Whole Team

Present:

Goals: To present our preliminary findings.

Content:

See attached file.

Conclusions/action items:

Begin fabrication and testing.

Katie Day - Oct 12, 2022, 11:01 AM CDT


Microscopic Cell Culture Incubator
Preliminary Report

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Prelim_Report_Fall_2022.pdf (4.58 MB)

12/9/2022 Final Presentation

Drew Hardwick - Dec 12, 2022, 5:33 PM CST

Title: Preliminary Presentation

Date: 12/12/2022

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

Present: All

Goals: To present our final findings to our advisor, client, and peers.

Content:

See attached file.

Conclusions/action items:

Finish Final Deliverables

Drew Hardwick - Dec 12, 2022, 5:33 PM CST

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Final_Poster_Cell_Incubator_Fall_2022.pdf (2.06 MB)

12/12/2022 Final Report

Katie Day - Dec 12, 2022, 5:31 PM CST

Title: Final Report

Date: 12/12/2022

Content by:

Present:

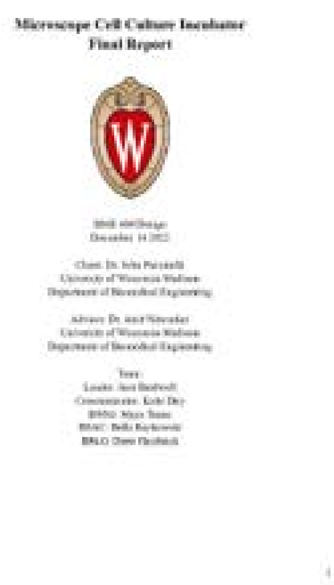
Goals: To finalize our work for the semester.

Content:

See attached file.

Conclusions/action items:

Katie Day - Dec 12, 2022, 5:31 PM CST



Microscope Cell Culture Incubator
Final Report

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Final_Report_Fall_2022.pdf (23.9 MB)

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: