Wet/Dry Cycling System User Guide

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Contents

1 Introduction

This user guide provides step-by-step instructions for operating the Wet/Dry Cycling System. The system simulates hydrothermal environments via programmable cycles of heating, rehydration, gas exposure, mixing, and sample extraction. A web-based interface allows researchers to interact with the device in real-time.

2 System Overview

The device includes the following subsystems:

- Thermal Control (Silicone Heating Pad)
- Fluid Delivery (Syringe Pump with 13-Port Manifold)
- Gas Delivery (CO_2 Manifold)
- Mixing System (DC Magnetic Stirring)
- Sample Extraction System (Stepper-driven movement)
- Embedded Control and Web Interface (ESP32-S3)
- Power Distribution and PCB

3 Setup Instructions

3.1 Powering the System

1. Connect the 12V DC power supply to a wall outlet (ensure it can source 25A) using the power plug shown in Figure 16.
2. Ensure the proper wiring to the 12V DC power supply based on the wiring diagram shown in Figure 1.
3. Verify all subsystems are connected to the correct terminals on the PCB based on the wiring diagram shown in Figure 1.

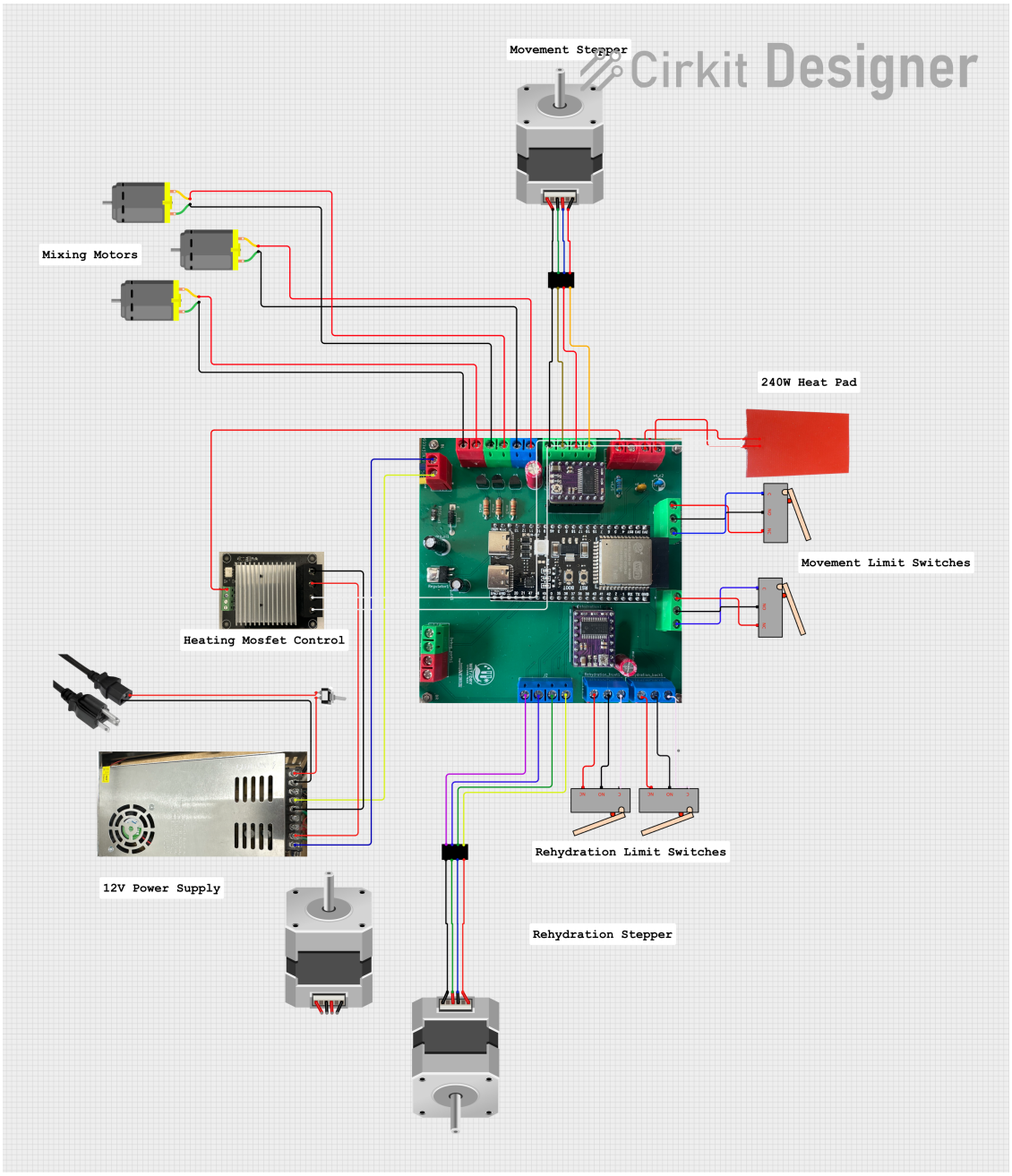

Figure 1: Wiring diagram of the Wet/Dry Cycling System. The wire colors shown in the diagram reflect the actual color coding used in the physical build. However, the spatial arrangement and scale of the components are not accurate.

3.2 Network Configuration

1. Clone or download the project repository from `https://github.com/UserIsMissing/Wet-Dry-Cycler.git`.

2. Open the `cycletron_esp_frontend` folder and launch the appropriate startup script:

- On Windows: double-click `start_full_auto.bat`
- On macOS: double-click `start_mac_dev_env.command`

If the server fails to launch or connect, refer to the Debugging section for troubleshooting steps.

3. Once the server starts, it should automatically open in your browser. Make note of the IP address shown at the top of the page. It will follow the format: `(xxx.xxx.xxx.xxx):5174`. Record the IP address **without the port number**.
   Example: `10.0.0.30:5174` → `10.0.0.30`

4. Connect the ESP32 device via the USB-C port located on the side of the enclosure shown in Figure 17.

5. To connect the device to your Wi-Fi network, open the `Main.cpp` file in the `Cycletron` folder. Update the following lines to match your network credentials and server IP:

```
const char *ssid = "YourWiFiName";
const char *password = "YourPassword";
#define ServerIP "10.0.0.30" // Replace with your actual IP
```

6. Make sure both the ESP32 device and the computer hosting the server are connected to the same Wi-Fi network.

3.3 Rehydration and Syringe Pump Setup

- Move the sample platform into the sample manipulation zone beneath the rehydration system. This prevents accidental water exposure to sensitive motors and electronics.
- Ensure that the manifold and all connected tubing are fully pre-filled with water and free of air bubbles.
- Inspect the syringe and verify it is completely filled and free of air bubbles.
- Securely position and mount the syringe in the pump carriage as shown in figure Figure 10. Confirm that it is aligned properly and firmly held in place before operation.
- Attach the syringe to the manifold using the Luer lock valve. Prime the valve thoroughly to prevent air from entering the distribution lines.
- Open the valve shown in figure Figure 11 to allow water to flow from the syringe into the manifold and toward the output tubing.

4 Using the Web Interface

4.1 First Startup

When starting a fresh experiment, you will be presented with the following webpage:

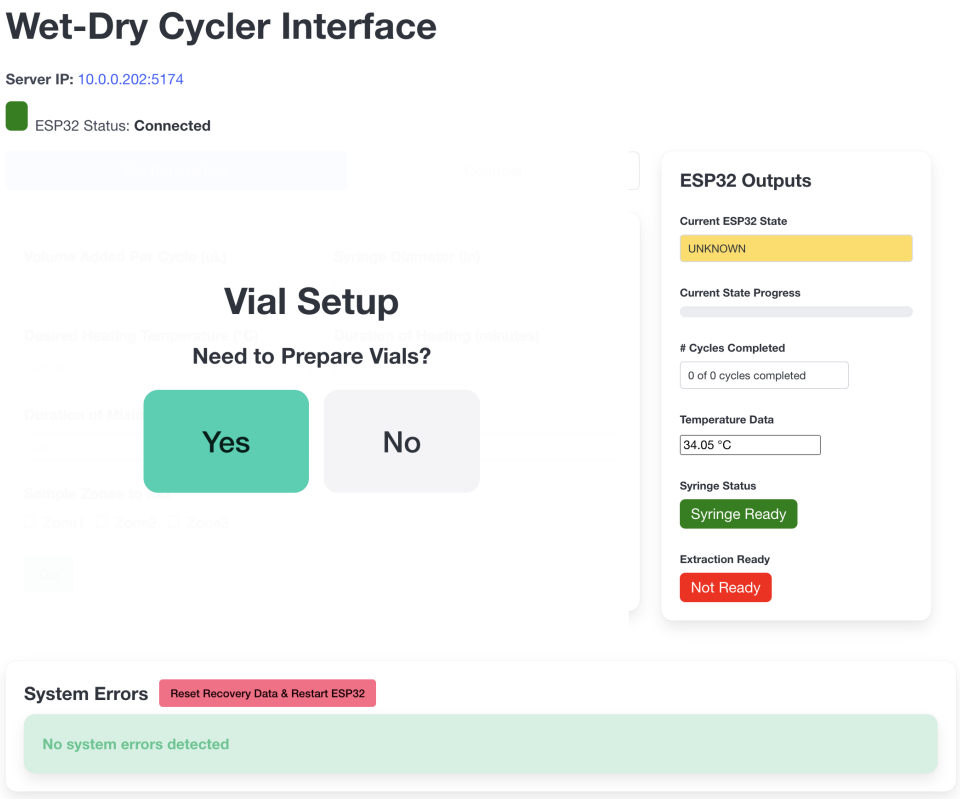

Figure 2: Initial Webpage Presented to the User

This page is asking if you want to make any changes to the vials before the experiment begins. If you press 'Yes', then the platform will begin moving the vials over to the extraction zone. If you pressed 'No', you are ready to set you experimental parameters.

4.2 Vial Setup: Yes

If you pressed 'Yes' on the Vial Setup page, please wait for the 'Extraction Ready' status light to turn green. This indicates that the platform is in the correct position and the vials are available for manipulation.

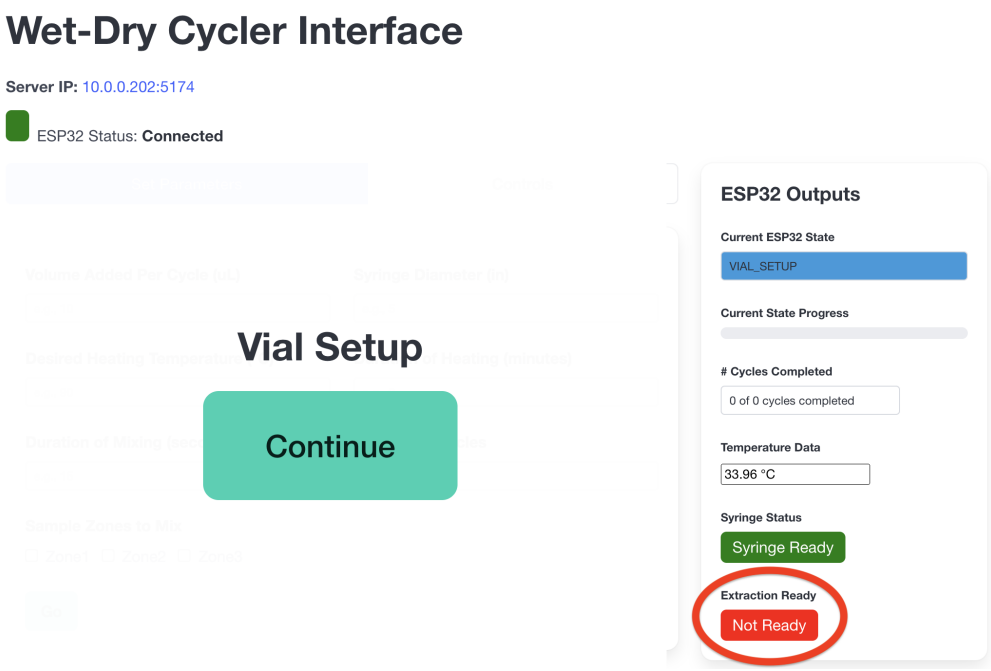

Figure 3: Initial Webpage Presented to the User

After you have placed the vials back in their correct positions and placed the lid back on the box, please press the 'Continue' button as shown above.

4.3 Setting your parameters before the experiment

When you are presented with the page seen below, please fill out every text box before pressing 'Go'.

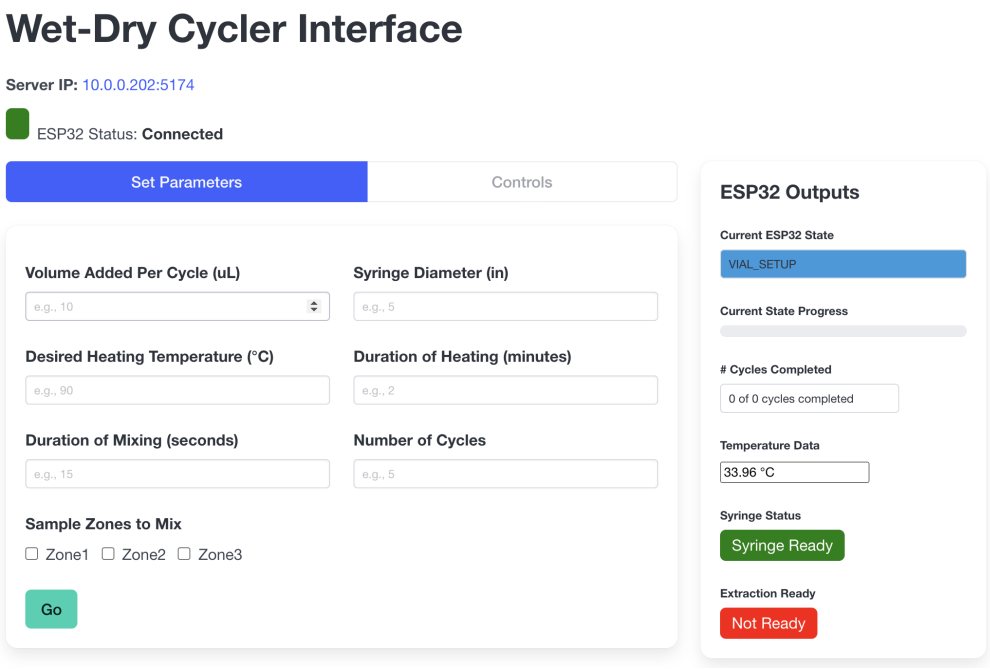

Figure 4

- Volume Added Per Cycle - the volume of water added to each vial, every cycle
- Syringe Diameter - in inches
- Desired Heating Temperature - in °C
- Duration of Heating - in minutes - Note: It takes approximately 5 minutes for the heating pad to go from room temperature to 90 °C
- Duration of Mixing - in seconds
- Number of Cycles
- Sample Zones to Mix - you are able to control which of the 3 zones you want to mix for the duration of each experiment

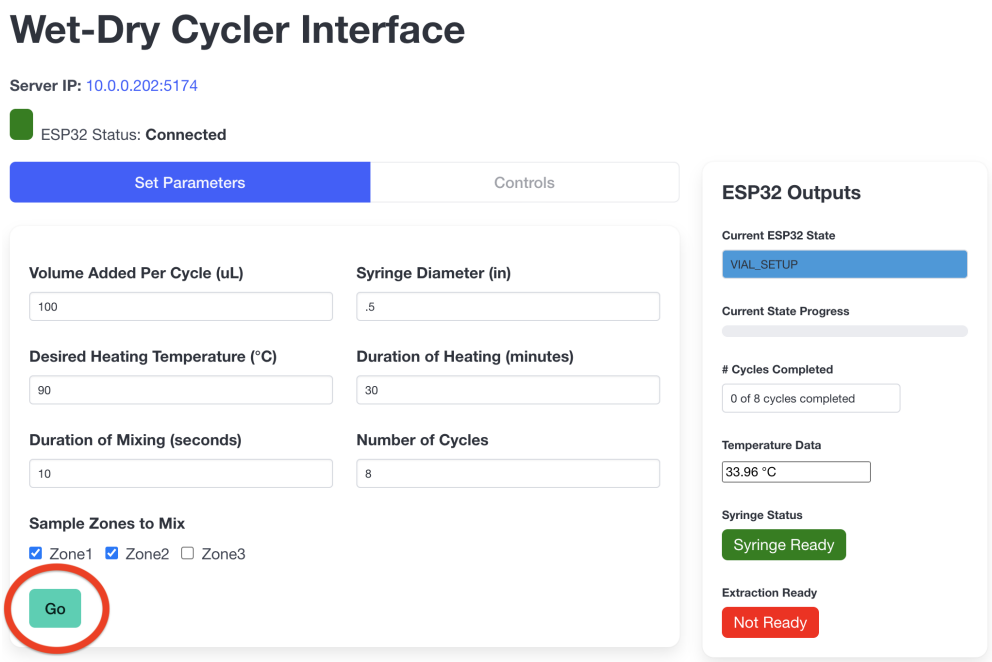

Figure 5

Once you press 'Go' as shown above, you will not be able to change your experimental parameters again unless you end the experiment by pressing 'End Cycle' or 'Reset Recovery Data & Restart ESP32' (located at the bottom of the page).

4.4 Start Experiment

Now that you have set your parameters for the experiment, please make sure the syringe is full of water, the vials are in their correct placement, the platform has returned to the correct position, and everything is in it's correct and secure position.

Once you have visually confirmed this, the button 'Start Cycle' will begin the experiment and it will not stop until all cycles have been completed.

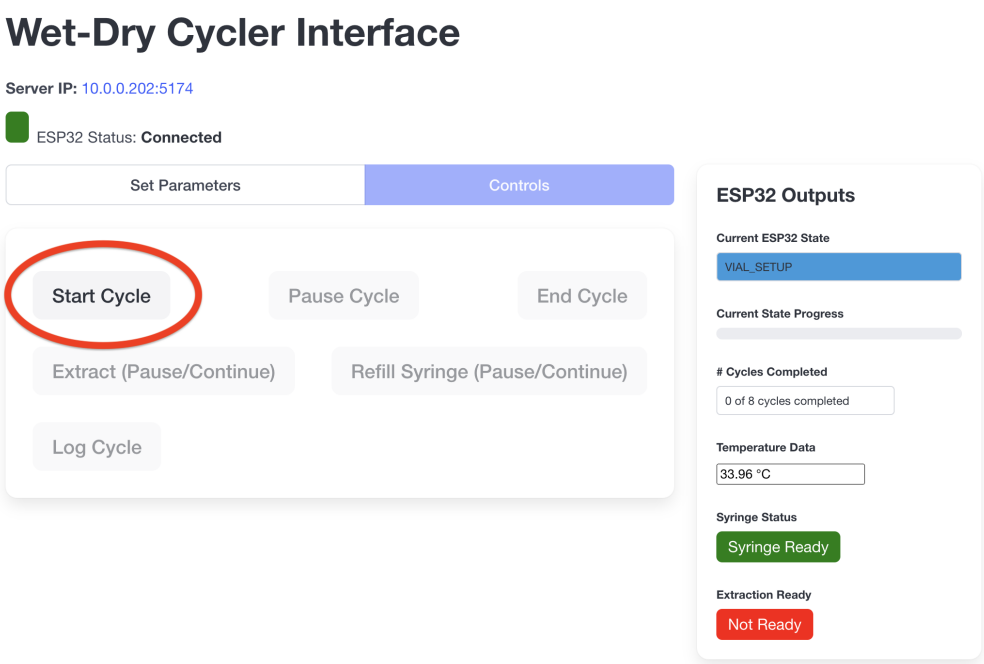

Figure 6

4.5 Typical Experimental Page

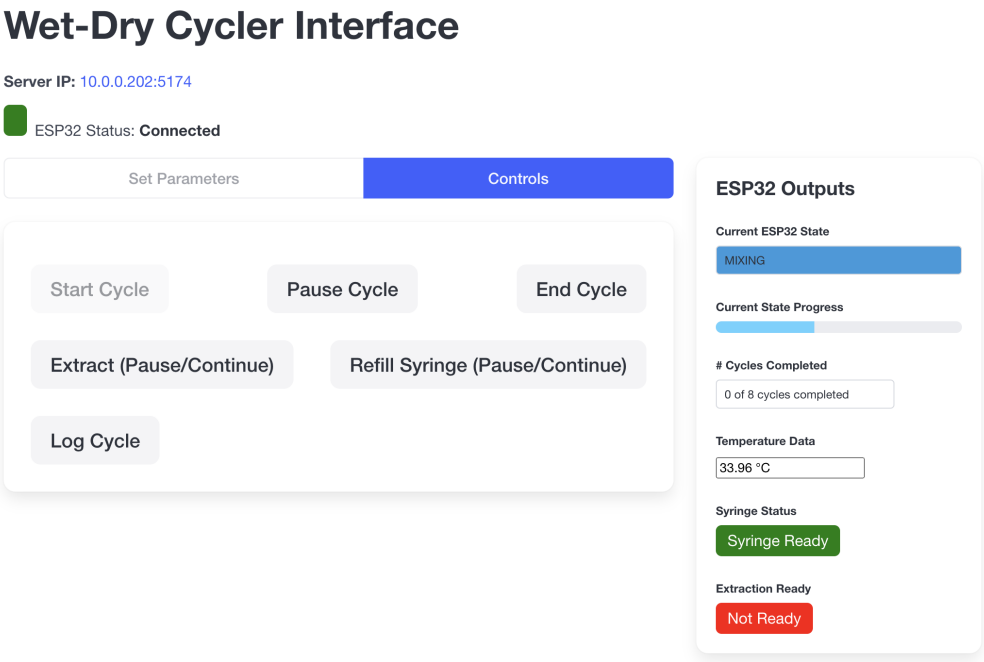

Figure 7

This page is what a typical experiment will look like. The right hand side of the page shows status indicators about what the microcontroller is sending to the server. This includes

information such as current state, state progress, and current temperature. At the bottom of that section are two status lights. The first one indicates if the syringe needs to be refilled. It will change to a red button and say "SYRINGE EMPTY" when it is time to be refilled (however it is best to refill the syringe before this occurs - and at the beginning of a heating stage - so the correct amount of water can be dispensed every time).

The other status light is for the vial extraction zone. When extracting from the vials, please do not open or reach your hands inside the box until this light turns green.

Experimental Control Buttons

In the 'Controls' tab, there are several buttons available to you while the experiment is running.

- Pause Cycle - This allows you to pause the current experiment and stop all subsystems.
- End Cycle - This will completely end the experiment, download a log of the initial parameters from the setup, and take you back to the initial startup page. You can end the experiment at any time. If the experiment completes on it's own, you must press 'End Cycle' to go back to the starting page.
- Extract - This will pause the experiment and move the vial platform to the extraction zone where you can take samples as needed. If you press this button again, the platform will return the the experimental zone and continue running the experiment.
- Refill Syringe - A popup will appear , shown in Figure 8, explaining the steps for how to refill the syringe when it is low or empty. Once you press 'Yes' on the popup, the experiment will pause and then you can begin the steps from the popup. After placing a full syringe back in it's place, press the green 'Refill Syringe' button again to continue with the current experiment.
- Log Cycle - This will download a file containing info on the parameters set at the beginning of the experiment, as well as the current cycle progress at the moment of logging that cycle. (This is the same info as pressing 'End Cycle' however 'Log Cycle' will not interrupt the current experiment).

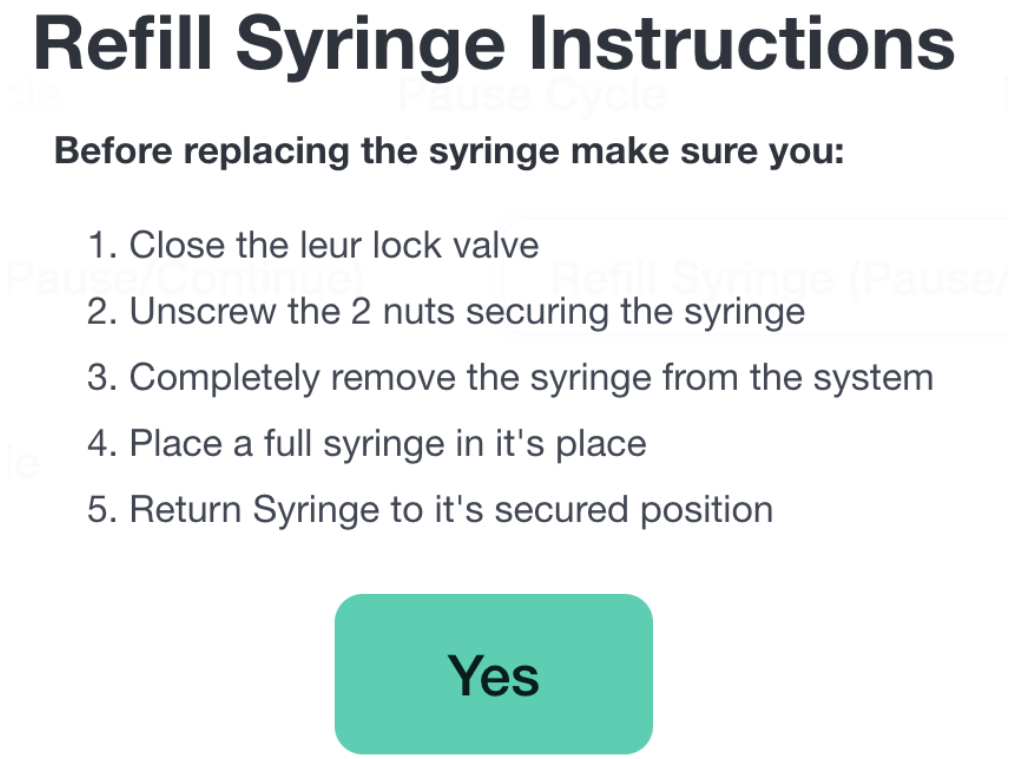

Figure 8: Refill Syringe Instructions popup

5 Subsystem Operation Details

5.1 Heating System

The system uses a 12V silicone heating pad paired with a thermistor for temperature sensing. Temperature is regulated using bang-bang control within a tolerance of ± 2°C.

5.2 Rehydration

Water is delivered through a syringe pump connected to a manifold. A typical volume dispensed is 100µL per sample.

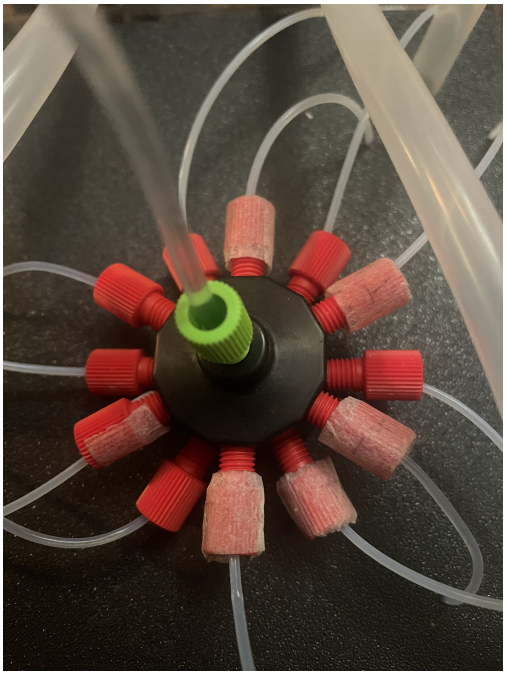

Figure 9: Manifold used to split flow from syringe pump into the 12 vials

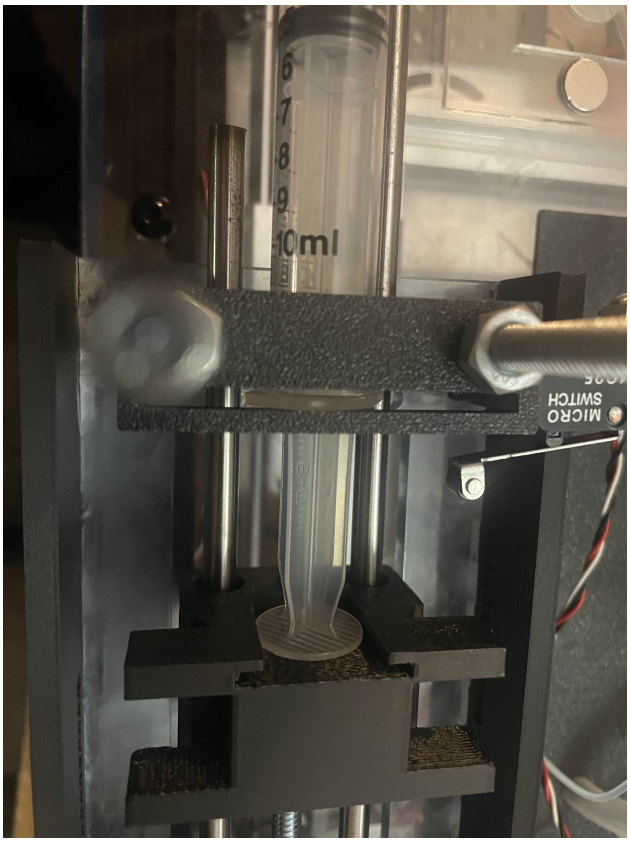

Figure 10: Syringe properly locked into the pump, note the edge of the syringe in the clamp and the plunger extended and clipped into the pump

Figure 11: Syringe leur lock valve in the open position

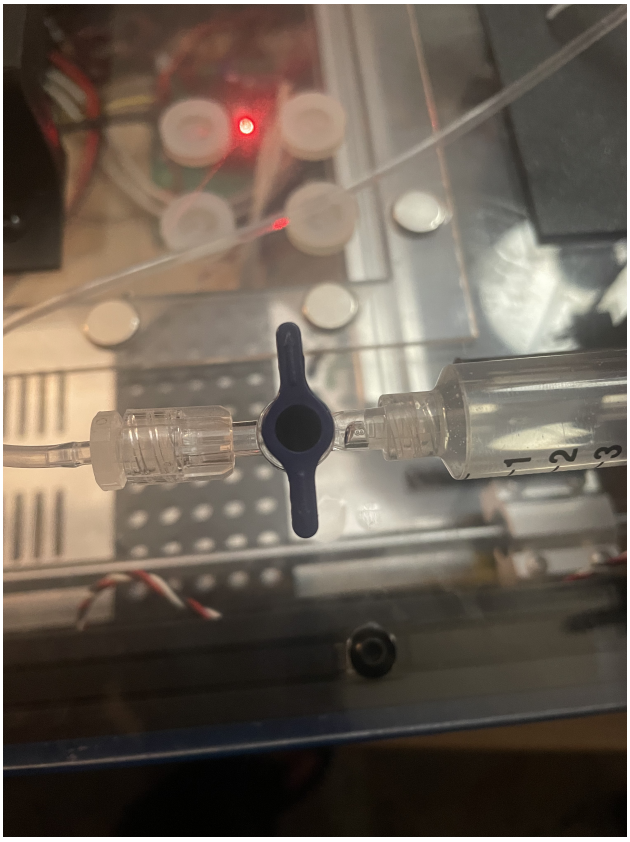

Figure 12: Syringe leur lock valve in the closed position

5.2.1 Refilling the Syringe and Priming the Line

To refill the syringe, begin by moving the syringe pump to the back position using the "Refill Syringe" button, as shown in Figure 7. Once the pump is fully retracted, insert the newly filled syringe and secure it firmly, as demonstrated in Figure 10. Before attaching the Leur lock, ensure there are no air bubbles inside it. It is recommended to use a pipetman to completely fill the Leur lock before reattaching it to the syringe. After the Leur lock is attached (Figure 12), twist the valve to the open position (Figure 11) and press "Continue" on the website. Be sure to close the valve before replacing the syringe to avoid depressurization and water spillage.

5.3 Gas Delivery

A CO_2 or nitrogen tank is connected to the gas manifold shown in Figure 13. The manifold provides manual control over gas flow to each of the three sample zones. Before starting the device, ensure that the appropriate valves are opened, as illustrated in Figure 14.

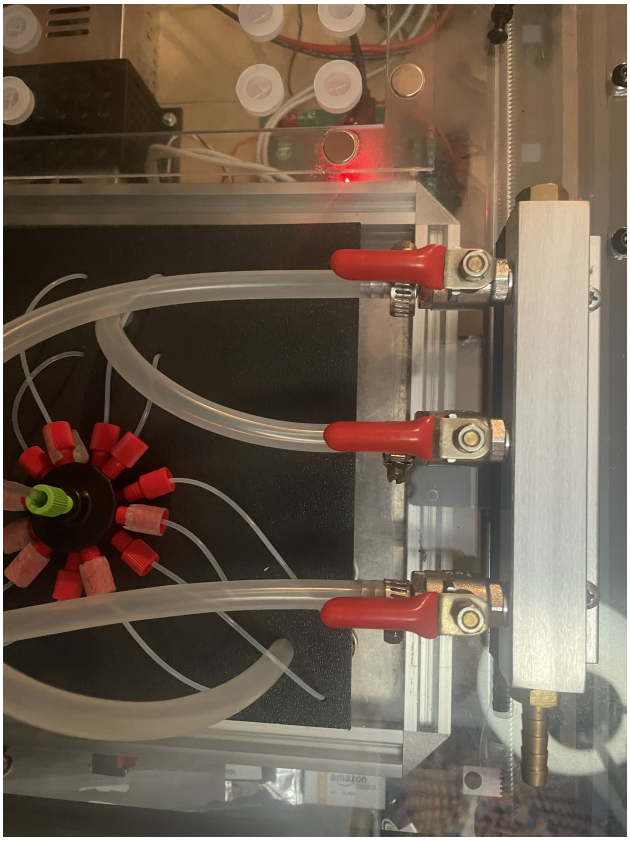

Figure 13: CO2 manifold, all outputs set in the closed position

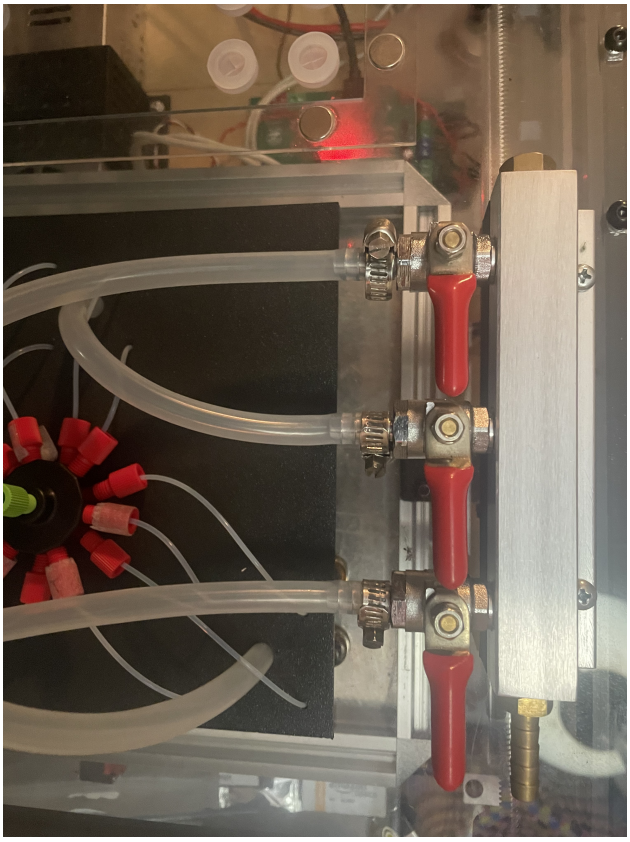

Figure 14: CO2 manifold, all outputs set in the open position

5.4 Mixing

Magnetic stirring is achieved using DC motors in three vial zones. Each motor is controlled by an ESP32 and MOSFET driver circuit. Mixing behavior is configured through the webpage using the "Mixing Zones" and "Mixing Time" parameters, as shown in Figure 4. The zones are numbered for reference in Figure 15.

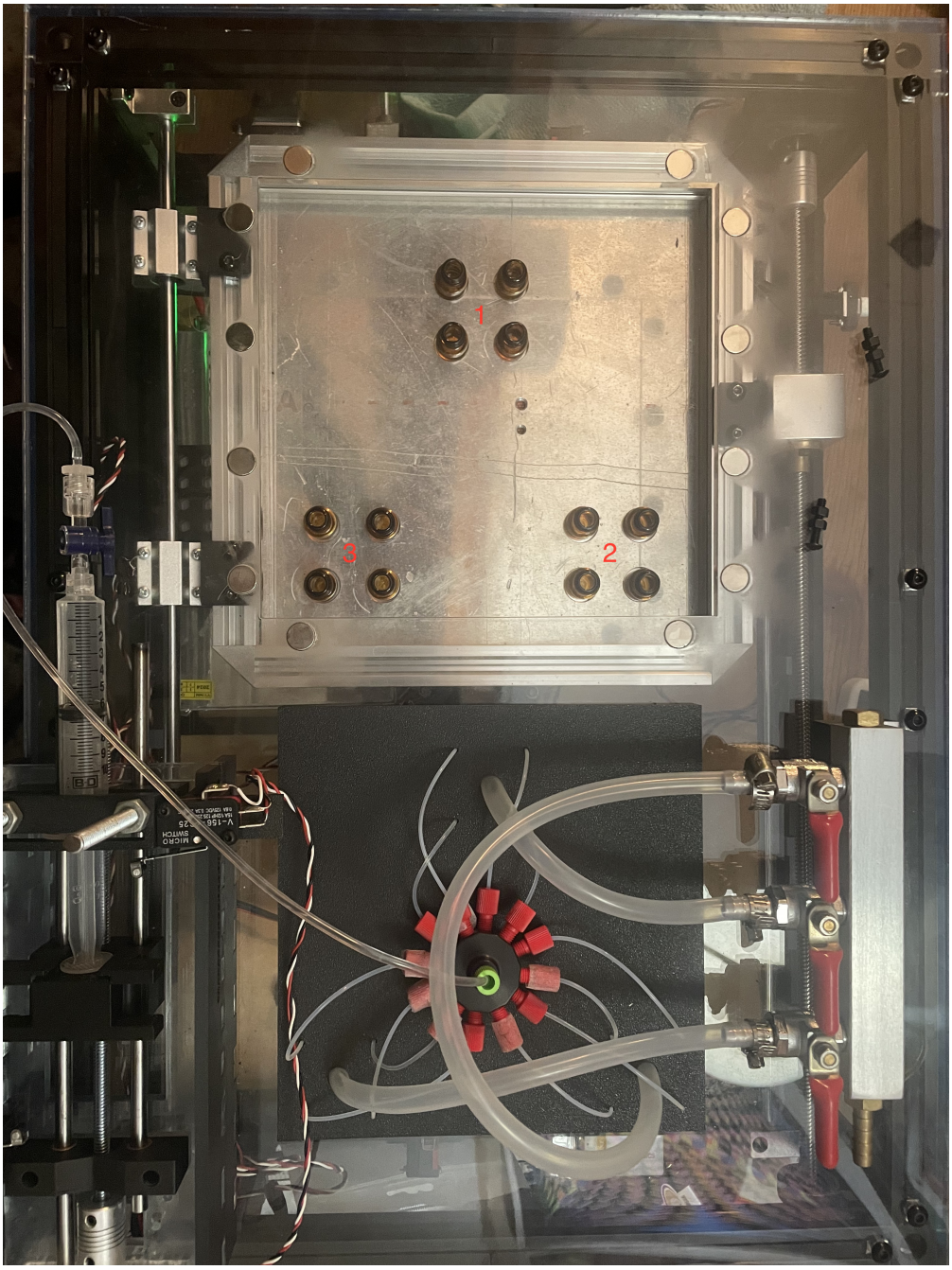

Figure 15: Sample vial zones numbered for reference.

5.5 Sample Extraction

Sample extraction is automated using a stepper motor that moves the aluminum platform holding the sample vials. Once the "Extraction Ready" message appears (Figure 3), users can insert a pipetman into the silicone cutouts to retrieve fluid without allowing CO_2 to escape.

6 Repair

6.1 Debugging the PCB and Rewiring

- Pay close attention to the color coding of all wiring. Note that the silkscreen labels on the PCB are not fully accurate—wire color should take priority during debugging and rewiring.
- The black adapter boxes connected to the stepper motors convert the female connectors (typically provided with the motors) into male headers compatible with the PCB. The wire colors in these adapters are accurate, and orientation is critical. Reversing the motor connection will result in malfunction or potentially cause permanent damage to the system.
- For the bumper (limit switch) connections, the silkscreen markings for polarity are reversed. The red wire should be connected to the terminal labeled as negative, and the black wire should be connected to the terminal labeled as positive. This correction is illustrated in Figure 1.

7 Error Handling and Safety

7.1 Frontend Alerts

Errors are reported through the web interface:

- Overheating
- Stepper Driver Fault
- Limit Switch Timeout
- Communication Loss

8 Appendices

A. Default Parameters

- Volume: 100 µL
- Heating: 90°C for 25 min
- Mixing: 10 seconds
- Co2: Constant Flow
- Rehydration: 1.2 mL total via 13-port manifold

B. Troubleshooting Tips

- If no fluid dispenses: check stepper driver, syringe limit switches, manifold tubing.
- If heating fails: check MOSFET LED, thermistor wiring, and power rail.

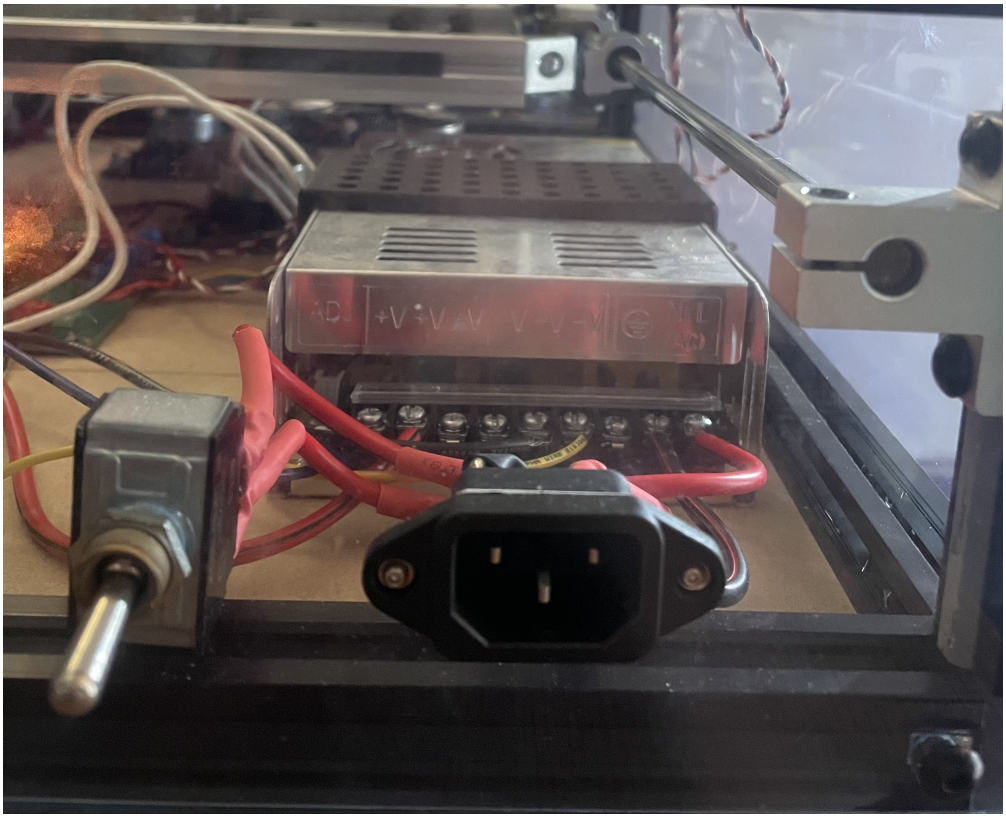

Figure 16: IEC C16 power plug that connects the device to 120V AC

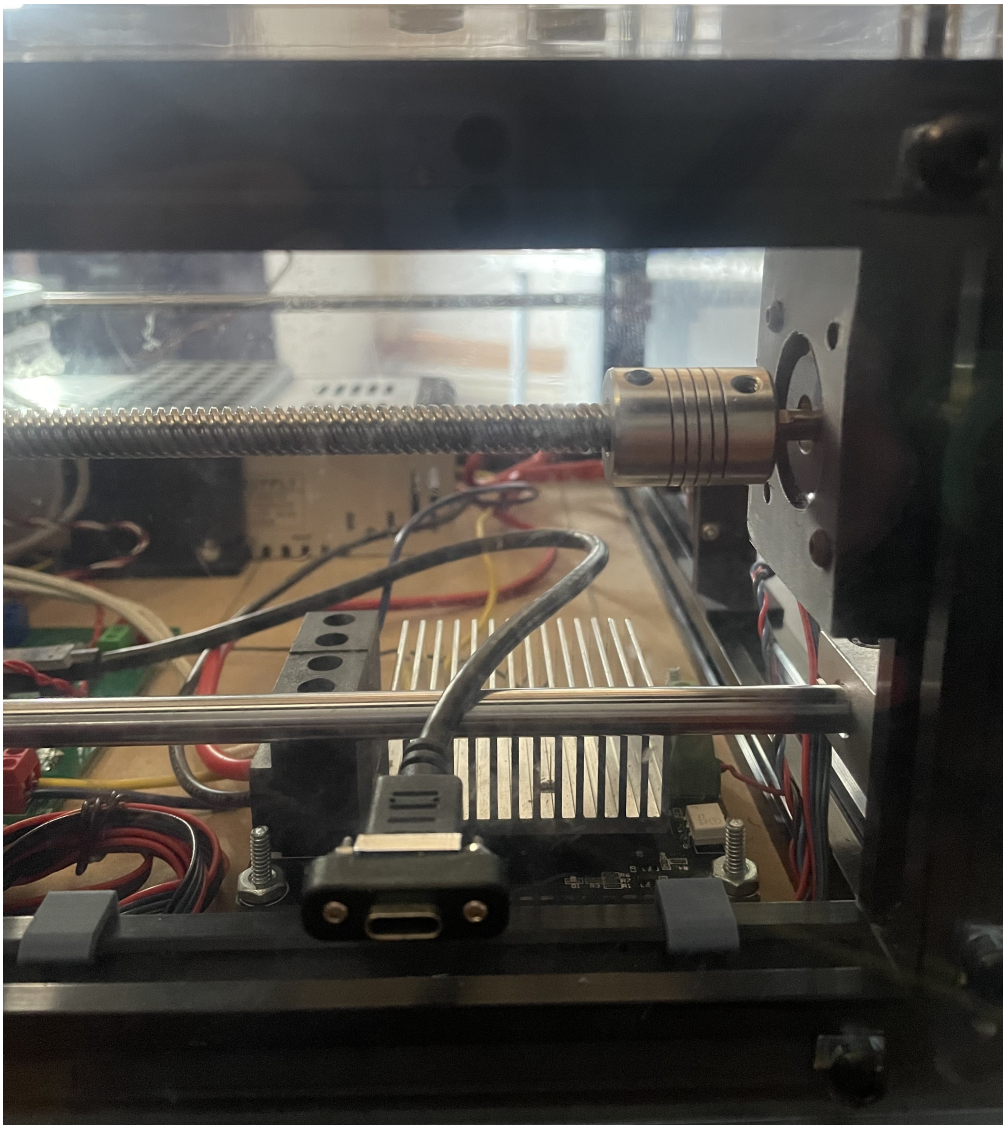

Figure 17: USB-C port used to plug the microcontroller into a serial monitor for debugging.