Automated Percolation Tester

User Manual

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Automated Percolation Tester
User Manual

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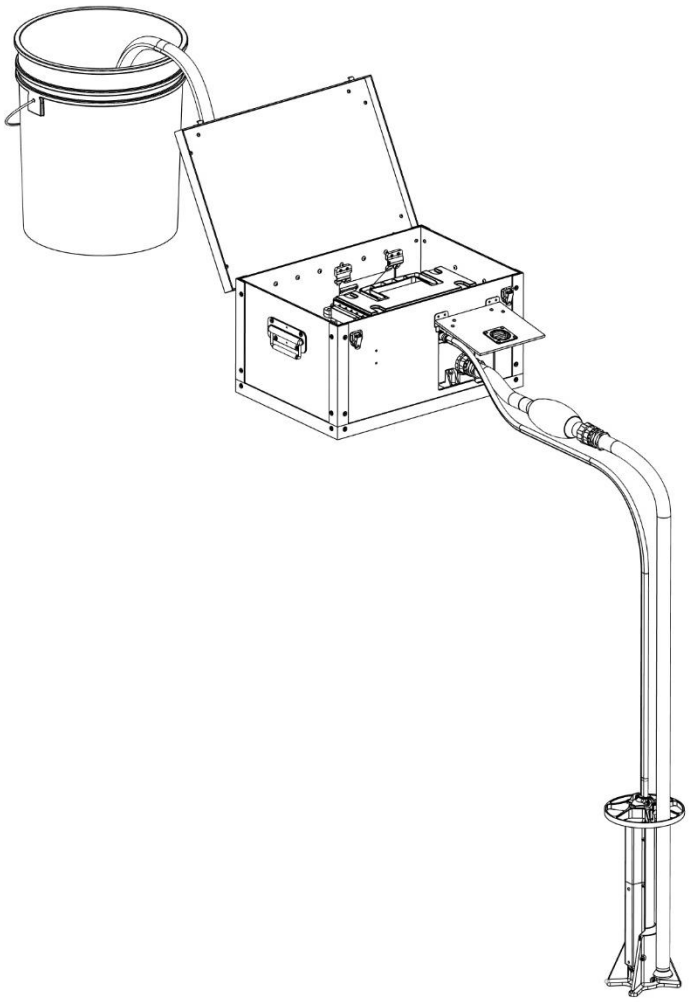

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1. Introduction

The automated percolation tester is used to perform a complete soil percolation test with high precision and minimal user interaction. The primary goal of the device is to ensure that all EMI percolation tests are performed to the standard specified in the EMI Civil Design Guide Section A3.3.1 as consistently as possible.

This document serves as the user manual for the device. As such, it does not include all of the design details for the device. Those details can be found in the EMI R&D document 5.01.01.003 Auto-Percolation Tester Design Manual.

2. System Overview

As shown in the schematic, the system consists of a water storage tank, a motorized valve to control flow of water into the test hole, and a depth sensor to measure water depth in the test hole. The system is monitored and controlled by a system running an ESP32-S3 microcontroller and auxiliary electronics. The electronic control system and motorized valve are all housed in the control box. The system runs through the standard EMI Percolation test protocol, using the depth sensor to determine when to open and close the valve to refill the hole with water. The control system records the depth of the water every second, as well as additional data that is useful for troubleshooting.

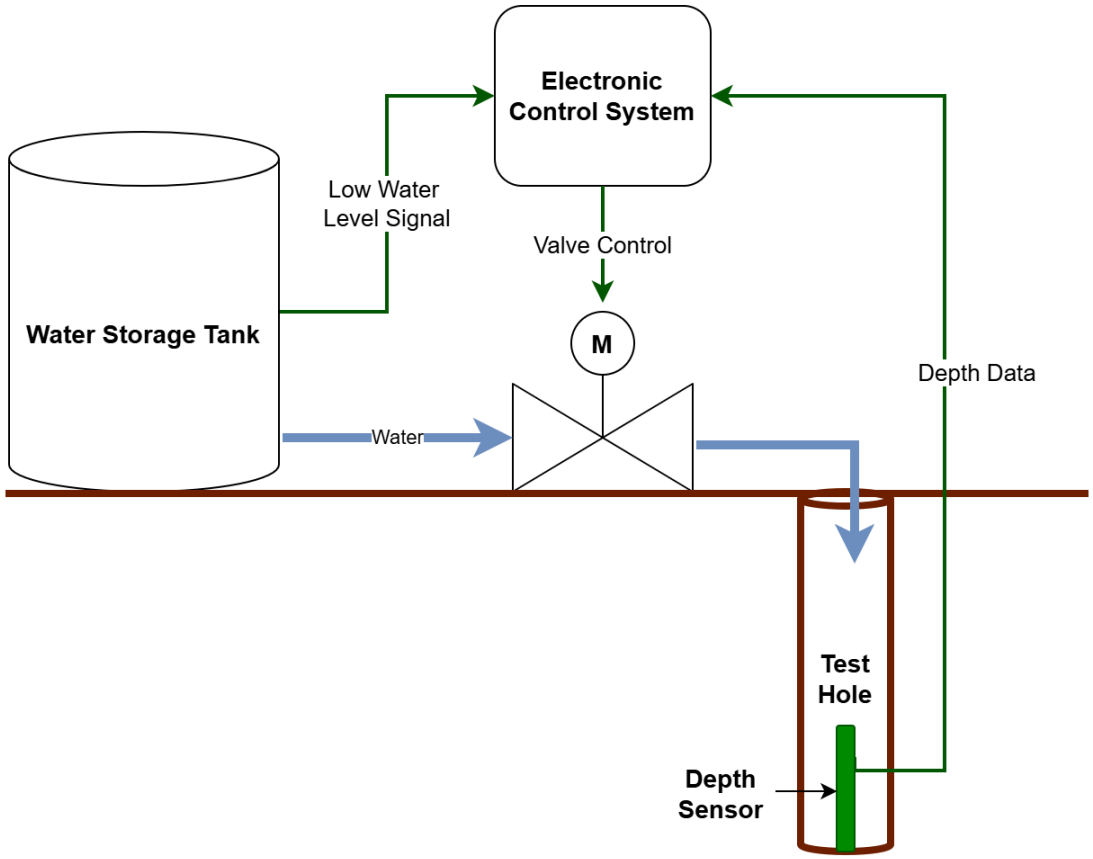

Figure 2-1 System Schematic

The device consists of 5 main assemblies:

Perc Tester Box: Aluminum box that includes the control box (with electronic control system, motorized valve, and battery) and also acts as a transport/storage box for the rest of the components.
Upstream Hose Assembly: Transfers water from the tank to the perc tester box. Includes sensors to detect when the tank water level is low.
Downstream Hose Assembly: Transfers water from the perc tester box to the test hole. Includes a siphon pump to create a siphon from the water tank.
Level Sensor Assembly: Measures the depth of water in the test hole.
Water Tank *(not provided):* Stores water to be used for the test. To simplify transport, this can be almost any water container that can be found near the test site.

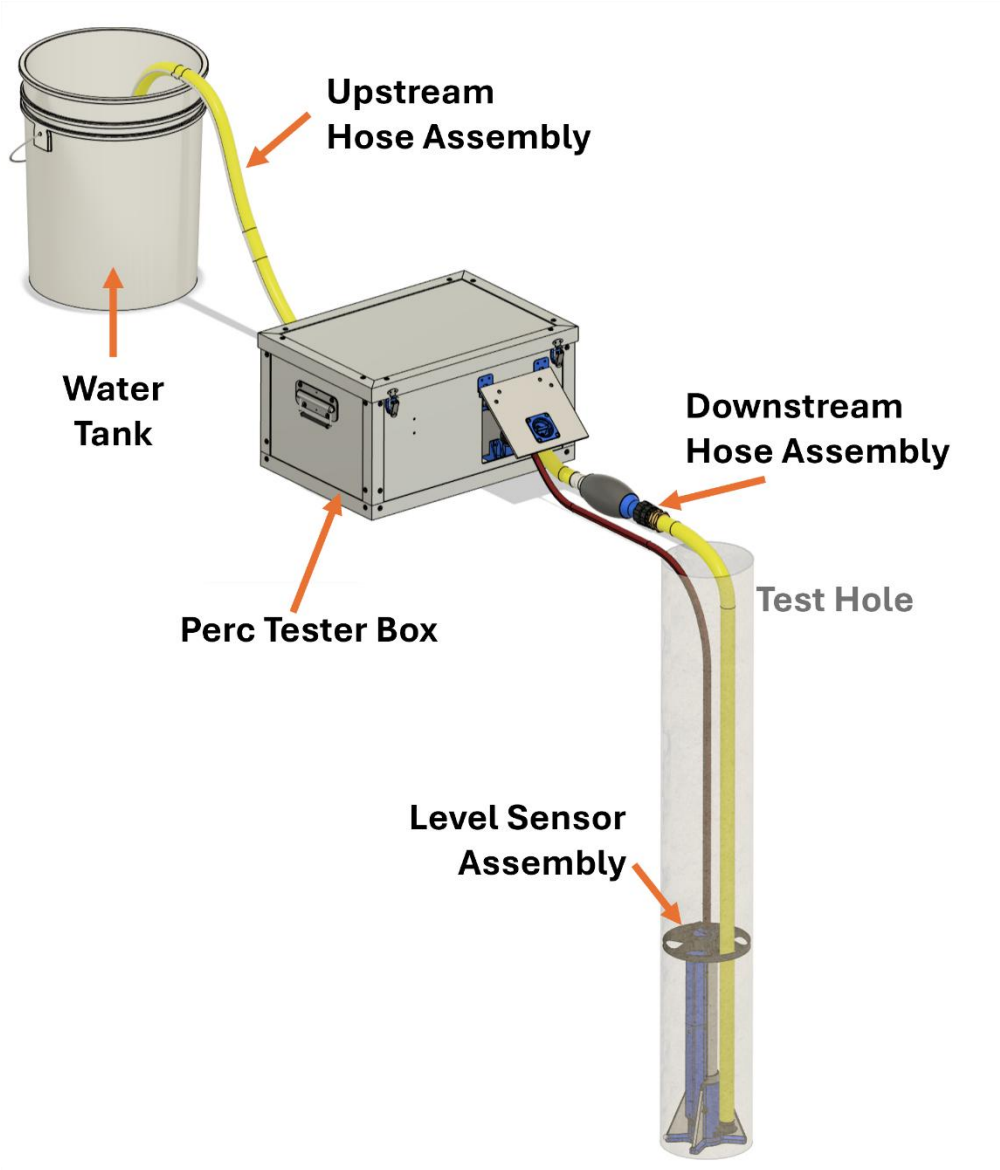

Figure 2-2 Annotated Assembly

2.1 Perc Tester Box

The perc tester box consists of an aluminum box that houses the control box. It also acts as a transport/storage box for the rest of the components. The primary purpose of the aluminum is to reflect solar radiative heat, keeping the electronics in the control box cool. It also acts as additional rain protection for those electronics. The box has 3 openings: the top lid and two side hatches to allow hoses and cables to be easily routed to the control box.

The control box is fastened to the aluminum box through brackets. It's designed to always stay in the box except for maintenance. The aluminum box also includes storage brackets for the depth sensor assembly, depth sensor stabilizer, and the water tank weight.

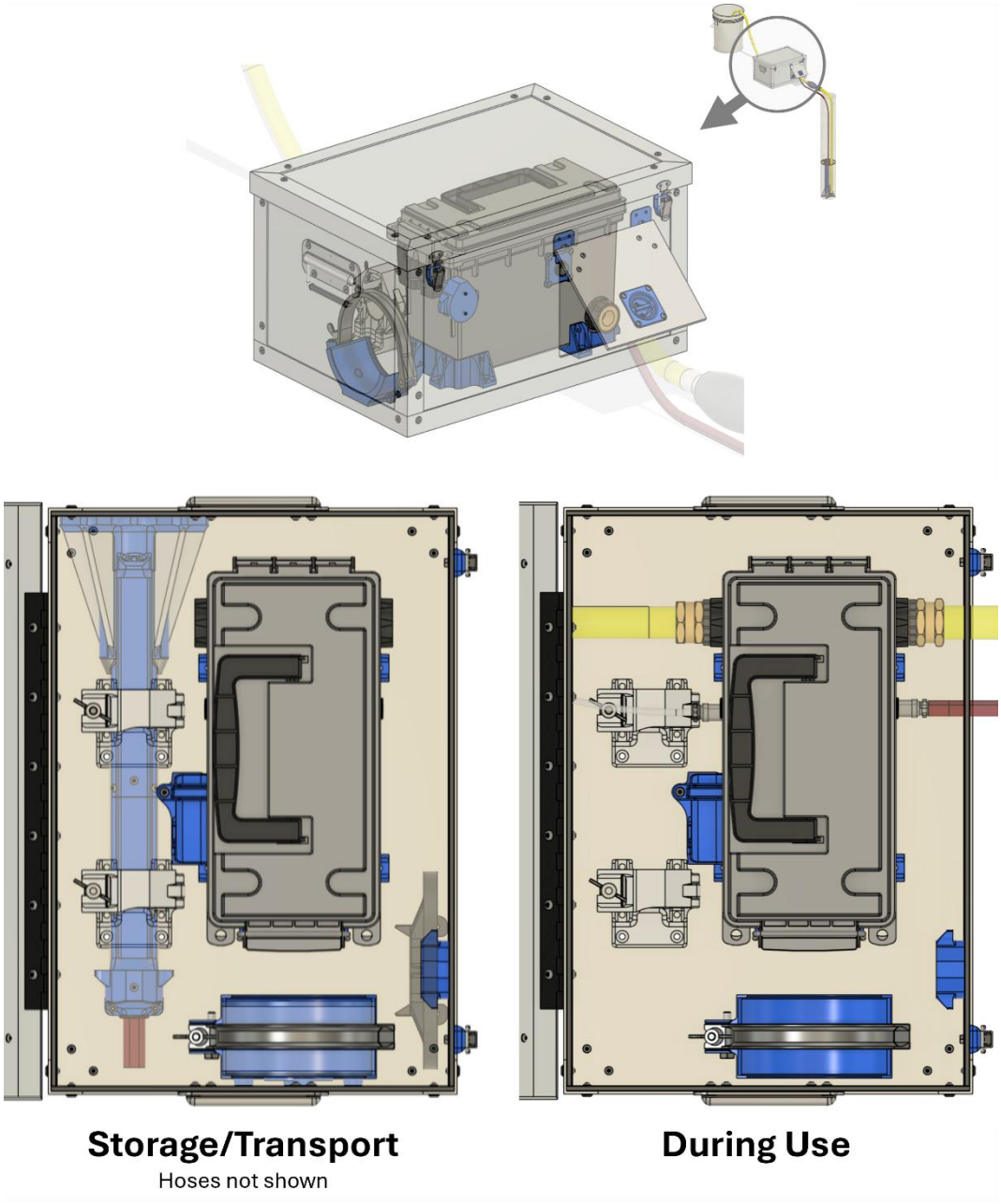

Figure 2-3 Percolation Tester Box Assembly

2.2 Control Box

The control box is the heart of the perc tester system. It houses the battery, motorized valve, and electronic control system. The plastic box acts as added transport protection and is fully waterproof in the event of the system being left in the rain, as long as the lid is properly closed. The box includes quick disconnect fittings to attach the hoses, and electrical connectors for level sensors.

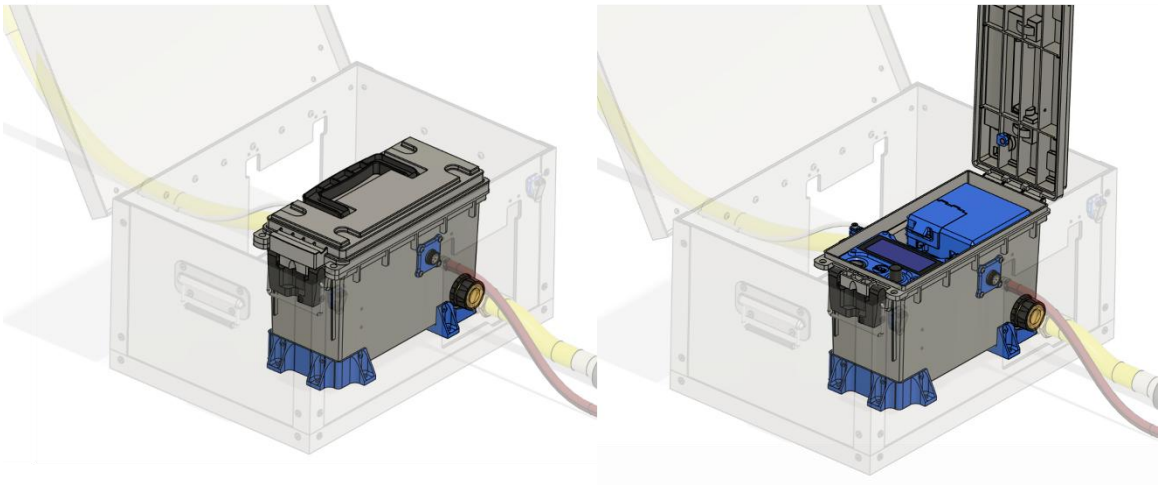

Figure 2-4 Control Box Installed

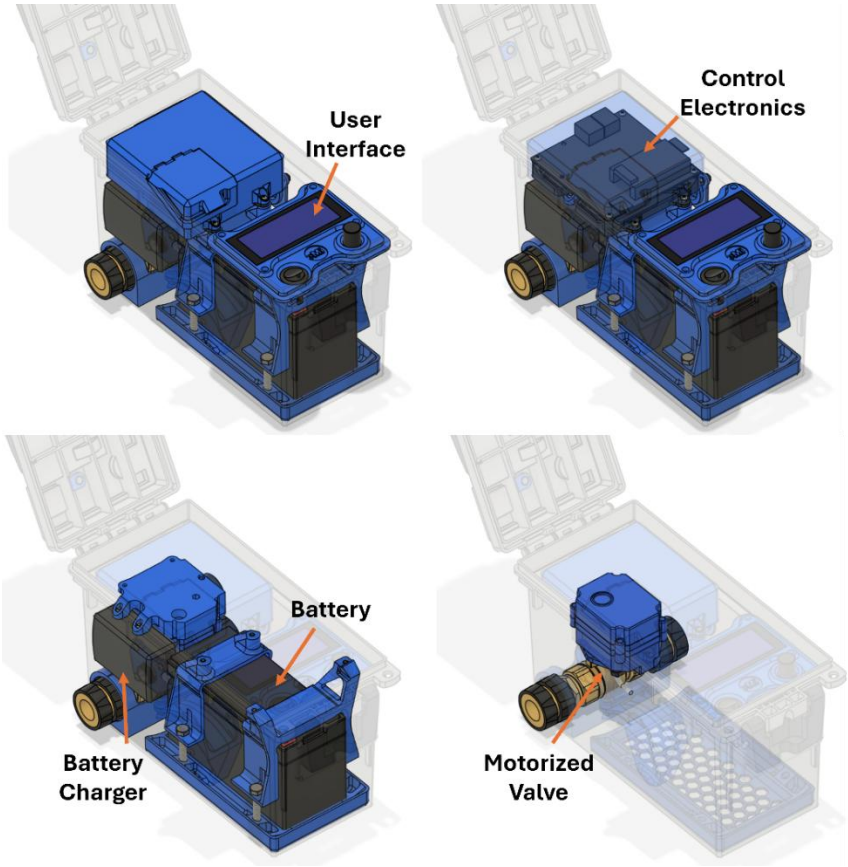

Figure 2-5 Control Box Components

2.3 Depth Sensor Assembly

The depth sensor assembly is used to measure the depth of the water in the test hole. It is comprised of a pressure sensor and 6 level switches, acting as redundant systems to determine the water depth. The system reports a calibrated depth, based on the pressure sensor data that is regularly recalibrated with the level switches. The level switches are located at 75mm, 100mm, 125mm, 150mm, 250mm, and 300mm above the bottom of the hole. They provide discrete values of water depth that are used to ensure that the pressure sensor maintains a reasonable calibration and updates the calibration if it falls outside of an acceptable range.

The assembly is sized to only fit in a hole with a minimum diameter of 150mm. This is to force the user to dig the correct diameter hole that meets the requirements specified in the EMI Civil Design Guide.

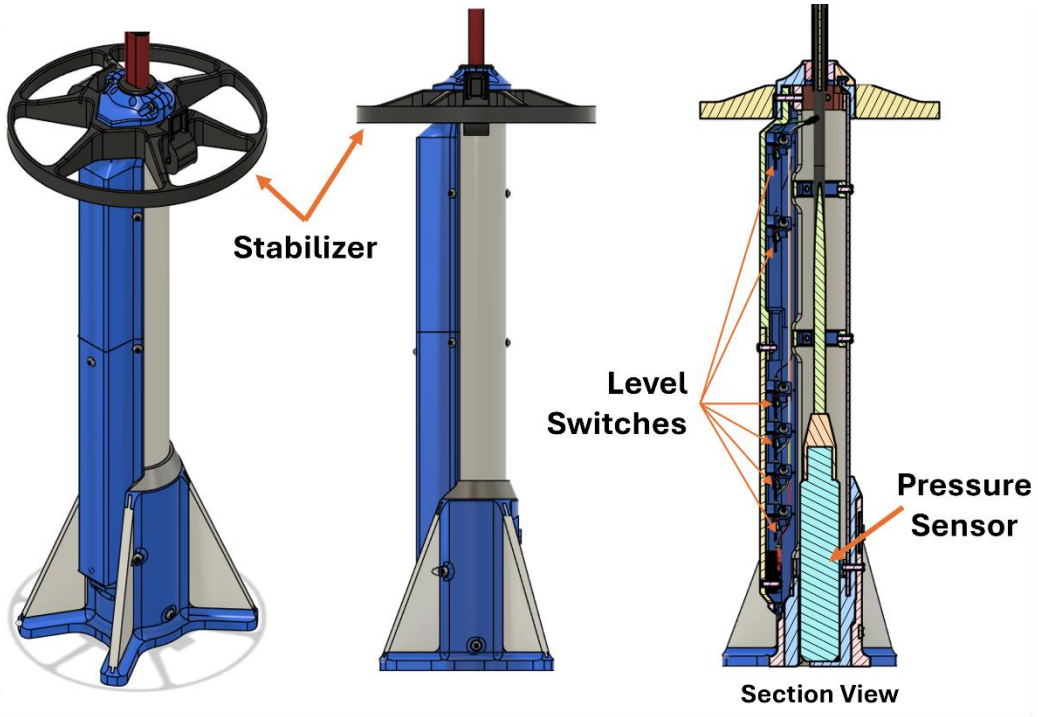

Figure 2-6 Level Sensor Details

2.4 Upstream Hose Assembly

The upstream hose assembly transfers water from the water tank to the control box. It is comprised of a hose with a level switch assembly on one end and a male quick disconnect fitting on the other end. The level switch assembly detects low tank water conditions at 2 levels to alert the user when the tank needs to be refilled.

There is also a tank weight included. This weight is to be used when a bucket or other type of tank is used that has a wide enough opening for the weight to fit. It ensures that the end of the hose is held at the bottom of the tank. The sensor assembly is simply inserted into the weight and twisted to lock in place with the locking groove. The level switch assembly is designed to fit in any opening over 34mm in diameter, which allows it to be used in a standard jerrycan.

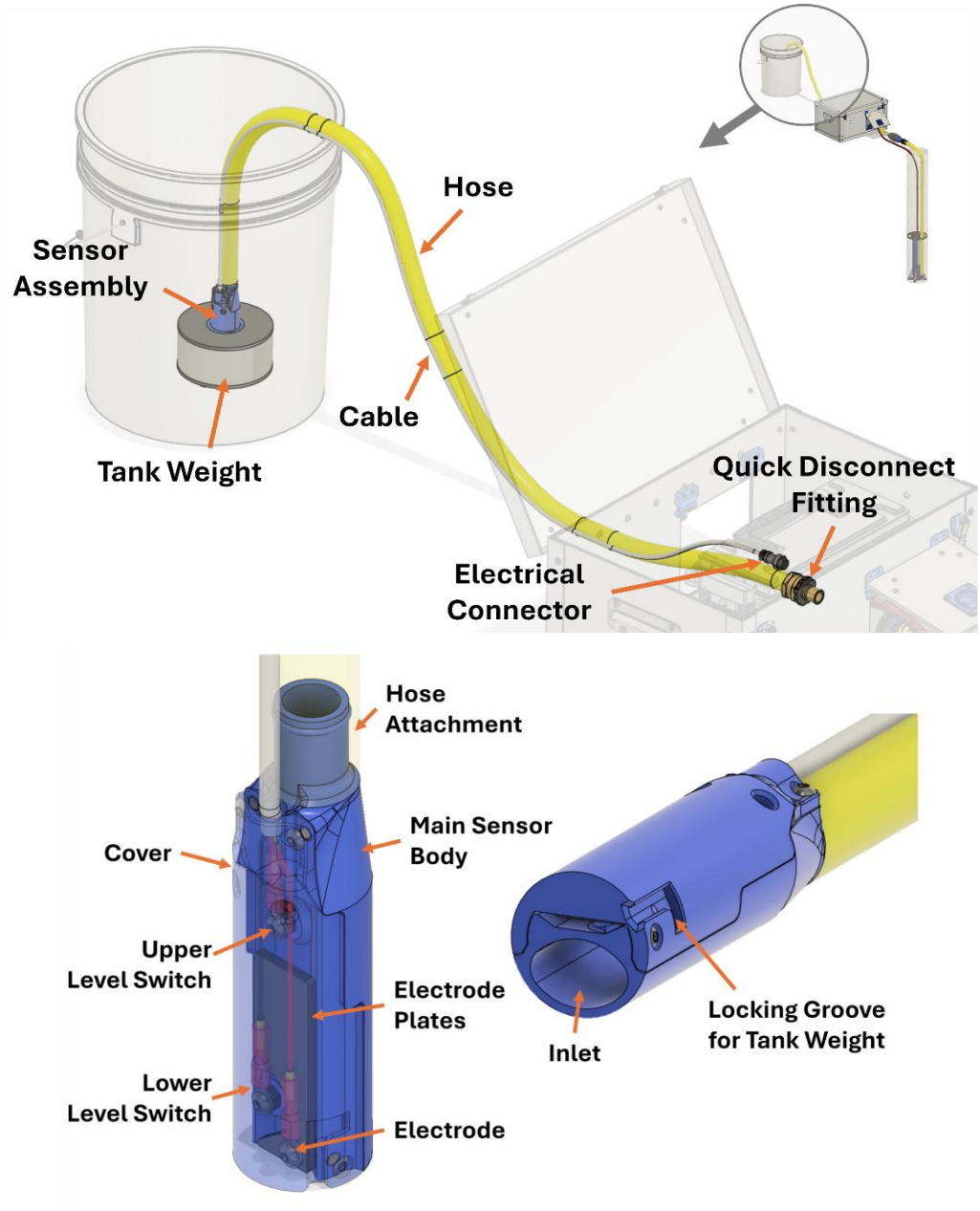

Figure 2-7 Upstream Hose Assembly

2.5 Downstream Hose Assembly

The downstream hose assembly transfers the water from the control box to the test hole. It includes a hand siphon pump which allows a siphon to be easily made between the water tank and control box. The pump is located on the downstream side as it minimizes the impact of any leaks that may occur in the pump itself.

The assembly is comprised of 2 sub-assemblies: the siphon pump assembly and the hose assembly. The two assemblies are connected with a quick disconnect fitting, allowing them to be quickly disassembled, which minimizes the strain on the siphon pump when stored in the box.

The end of the hose has a diffuser, which works to minimize any erosion of the test hole at the outlet of the hose.

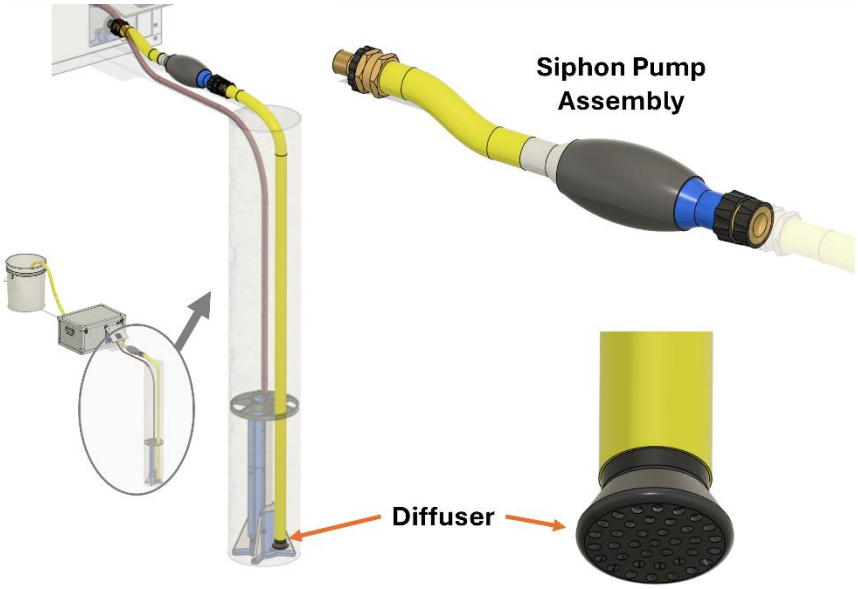

Figure 2-8 Downstream Hose Assembly

2.6 Other Components

There are a few other components that are critical to the percolation tester that have not yet been discussed:

1. **Augur:** A 150mm (6 inch) augur or post hole digger is critical for digging the test hole. This is not provided with the device; it needs to be sourced separately.
2. **Hole Scratcher:** This is a piece of wood with nails protruding from the head that is used to scratch the sides of the hole. This is done to ensure that the sides are not compacted from the augur/hole digger. There is not space for this to be held in the box; feel free to replace the provided hole scratcher with something better if desired.
3. **Gravel Bag:** There is a provided mesh bag that is used to hold gravel. The entire bag can be placed in the bottom of the hole and easily removed after the test to be used for future tests.

3. System Operation

3.1 Preparation Before Going to Site

Prior to going to the test site, the following preparation should be performed:

1. **Charge the device:** There is sufficient battery capacity for the device to run for over 48 hours. The system will report an estimate of battery percentage remaining, but it is far from perfectly accurate. It is good practice to fully charge the device prior to going to the test site. Plug the cord on the side of the control box into any electrical outlet (100-230VAC) and allow it to charge overnight (if possible). The charger has overcharge protection, so it does not need to be closely monitored.
2. **Find a water tank:** If you don't have a water tank with you, it is best to procure one before heading to site. A 20L (or larger) bucket is ideal, but a jerrycan can also work. It's best for the tank to have a large enough opening to allow water to be added without removing the hose.
3. **Plan for sufficient time:** A standard test will take at least 5 hours, but it can easily take 8-10 hours (sometimes even longer). *Plan to spend the full day at the test site*. The device does not allow shortcuts to be made to shorten the test, as those can have significant impacts on the test results.
4. **Ensure that you have everything:** Double check the box to ensure that all the components are present. It's especially critical to check the micro-SD slot to make sure that it was replaced after data was last downloaded. Also make sure that you have all the components that aren't housed in the box: the augur and the hole wall scratcher.

3.2 Setup

1. Choose a suitable location for the percolation test.
2. Use a 150mm (6-in) augur/post hole digger to drill a hole to the desired test depth. Ideally, this is the bottom of the proposed wastewater application infrastructure. It should be at least 1m (3.3ft) deep.
3. Use the included hole wall scratcher to scrape the walls of the hole.
4. Add 50mm (2in) of gravel to the bottom of the hole.
5. Remove the upstream hose (with tank sensor assembly) and downstream hose (with level sensor assembly) from the box.

Figure 3-1 Test Setup

6. Place the box and water tank relative to the test hole as shown in Figure 3-1.
7. Assemble the downstream hose assembly using the quick disconnect fitting between the siphon pump and the longer hose section.

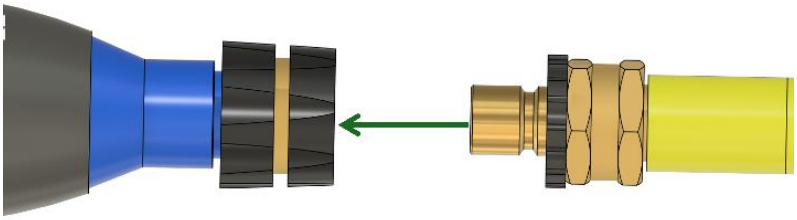

Figure 3-2 Downstream Hose Assembly Process

8. Connect the upstream and downstream hoses and electrical connectors according to the orientation shown in Figure 3-1.
    a. The quick release must be pushed in as shown, then the hose end can be inserted. Ensure that the quick release fitting pops back to its original location (see Figure 3-3).
        i. *Note:* It is possible to connect the hoses on the wrong side, but the electrical connectors have a different pin count, preventing incorrect installation.

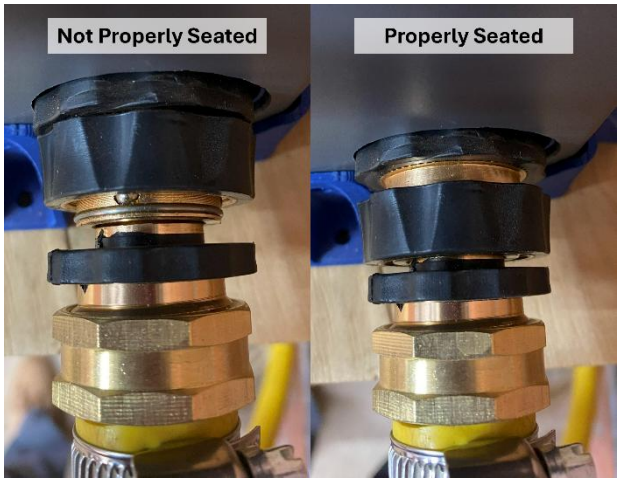

Figure 3-3 Quick Disconnect Seating

    b. The electrical connectors are just pushed into place (with the alignment guide facing up), and then locked with the nut.
9. Feed the depth sensor cable through the center of the stabilizer and clip the stabilizer onto the top of the depth sensor assembly. This keeps the sensor vertical, which is critical for accurate depth readings for the level switches. The stabilizer should just click into place when pushed onto the sensor cap.
10. Lower the depth sensor into the test hole.
11. Place the upstream hose into the water tank.
    a. If using the water tank weight, first insert the end of the upstream hose into the weight, ensuring to align the locking groove with the marking on the weight. Twist clockwise to lock in place.
12. Place the downstream hose into the test hole. Try to have it point as straight downward as possible.
13. Fill the water tank with water if not already full.

Throughout the test, it is important to close the aluminum box lid whenever possible. The lid helps keep everything cool by reflecting the majority of the solar radiative heat.

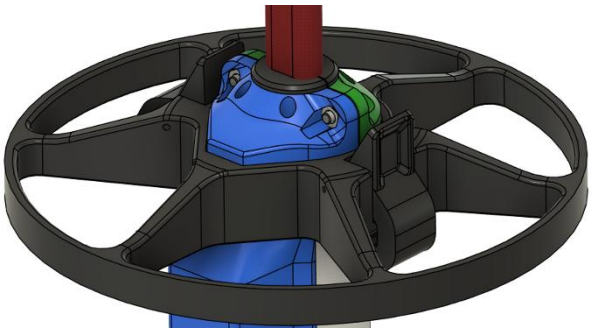

Figure 3-4 Installed Stabilizer

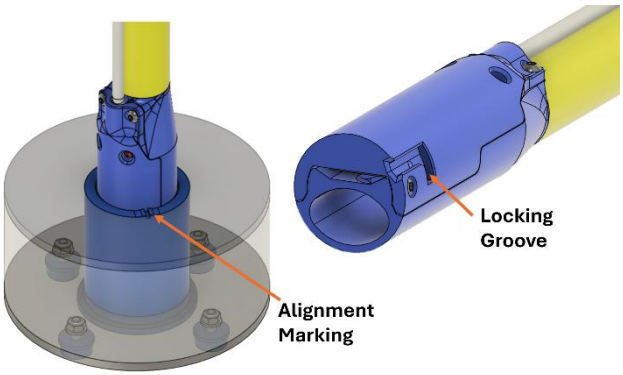

Figure 3-5 Installed Tank Weight

3.3 Home Screen

To start the system, toggle the power switch. The device will beep, and the LCD will turn on[1]. It will first load a splash screen with firmware and hardware information, then go to the home screen and wait for user input.[2]

The rotary encoder can be rotated in either direction for menu selection and pressed to make selections.

The home screen provides 2 options for the user:

1. **Press to start:** A short press of the rotary encoder will start a standard percolation test.
2. **Hold for settings:** A longer press of the rotary encoder will enter the settings menu.

The home screen will display if a micro-SD card is not detected by the system. Without an SD card the system cannot store any data, so it is critical to address this issue before starting a test. To access the micro-SD card slot, open the hatch of the control electronics cover as shown in Figure 3-9. The standard home screen should return after an SD card is inserted. If not, try power cycling the device. If the issue persists, there is likely a deeper issue with the PCB that needs to be addressed.

The home screen also shows the system date and time. Before starting the test, ensure that this is reasonably accurate. The data will include timestamps based on this clock, so it can be useful to have accurate timestamps to differentiate between different tests and troubleshoot any issues in the test data. See the Settings Menu section for more information on how to set the time and date.

Figure 3-6 User Interface Assembly

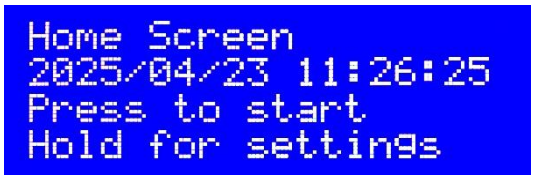

Figure 3-8 Standard Home Screen

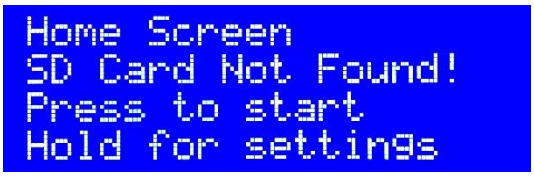

Figure 3-7 Home Screen showing SD Error

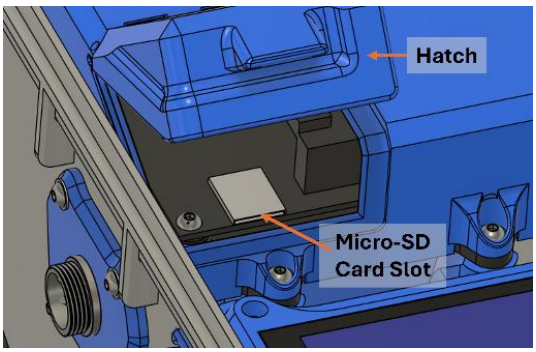

Figure 3-9 Micro-SD Card Slot Access

[1] There is currently a bug where the system fails at startup and the LCD will not turn on. When this happens, just turn the system off and back on again.

[2] During startup, the device also commands the valve to be closed if it was left open during the previous shutdown. This can be useful if the valve needs to close in an emergency: just turn the system off and back on again and the valve will automatically close. It should be noted that this will cancel whatever test was ongoing and a test will have to be started again from the beginning.

3.4 Test Operation

After the user initiates a test, the system will automatically run through a full percolation test with minimal user input. Throughout the test, the LCD will show the standard test screen shown in Figure 3-10.

Figure 3-10 Standard Test Screen

1. **Test Phase:** The top line shows the current test phase. In the event of an error or warning, this line will be replaced with a message to the user.
2. **Cycle Count:** Most of the phases go through multiple cycles. This shows the current cycle number of the current test phase.
3. **Drain Time Difference:** During each drain cycle, the total drain time is measured. This shows the percent difference between the last two drain cycles, if applicable. Otherwise, it shows 0%.
4. **Cycle Time:** Elapsed time of the current cycle.
5. **Depth:** Calibrated depth (in millimeters) of water in the test hole.
6. **Level Switch Status:** Current status of each of the level switches in the level sensor assembly, in order from bottom to top *(75mm, 100m, 125mm, 150mm, 250mm, 300mm).* If it shows 1, the switch is currently triggered (indicating that the water depth is above that switch). Figure 3-10 is indicating that all switches are triggered other than the 300mm switch, which aligns with the calibrated depth of 284mm.

Throughout the test, all data from that test will be saved if the user powers off the device. However, the user will have to start a new test from the start. There is currently no way to get the system to start in the middle of a test after the system has been powered off mid-test. This is to prevent users from skipping important parts of the test (mainly the saturation phase) due to time limitations. Bad test data (due to skipped test phases) is generally worse than no test data at all.

While the device is designed to be mostly automatic, it does require some user intervention from time to time. The most significant user input is to make sure the tank does not run out of water. There are two sensors embedded in the upstream hose assembly. When the top sensor is uncovered, the device will start flashing a TANK LOW warning, with a short, loud beep every 5 seconds. If the bottom sensor is uncovered the warning will change to TANK EMPTY and the beeps will become longer. This will not stop the test, but the test will be forced to pause if it ever takes too long for the hole to fill (Error: FILL TOO LONG), which is usually due to an empty tank. In general, it is a good idea to monitor the device shortly after starting the test to get a feeling for how rapidly the hole is draining and when it might be necessary to return to fill the tank.

Throughout the test, if the user would like to exit test mode, press and hold the rotary encoder until the system returns to the Home Screen. This cancels the current test, but all data will be saved.

3.5 Test Protocol

The automated percolation tester attempts to follow the percolation procedure laid out in the EMI Civil Engineering Design Guide as closely as possible. After initiating a test from the home screen, the device will run through the following test phases:

1. Initial Fill and Drain Phase

The hole is filled to 300mm and allowed to drain for 9 minutes. If the hole drains below 75mm in less than 9 minutes, the device will interpret this as a potential issue. It will re-run the initial fill and initial drain. If the second drain also takes less than 9 minutes to get from 300mm to 75mm, the device will enter the error state DRAIN TOO FAST. The percolation rate from this test indicates an unsuitable soil for wastewater application (rate < 1min/25mm). After 9 minutes, if the depth is still over 250mm, the hole is allowed to continue draining until it reaches 250mm. If it takes over 4 hours to reach 250mm, the system will enter the error state DRAIN TOO SLOW, indicating that the percolation rate is more than 120 minutes per 25mm. The user can choose to continue the test if desired. For more information regarding slow drain states, see Slow Drain Time Estimates on page 24.

Note: For all fill states, the valve will start to close before the target depth is reached. It will fully close after the corresponding level switch is triggered, indicating that the fill depth has been reached. Because the valve takes time to close, the depth will then be slightly above the target depth. After the valve is fully closed, there is a short settling period while the hole drains to the target depth. When the water has drained to target depth the drain cycle time will begin.

2. Saturation Phase

In this phase, the device will fill the test hole to 300mm and allow it to drain to 250mm. It will continue to do this for 4 hours, using as many cycles as it takes during that time. After 4 hours has elapsed, it will complete the current drain cycle and then move to the next phase.

3. Transition Phase

This phase allows the water level in the hole to drop from 250mm to 150mm, which is where the testing phase will start.

4. Testing Phase

During this phase, the device will fill the test hole to 150mm and then drain to 75mm repeatedly. It will do this until the variability in drain times of the last three drains are within 10% of each other. This is the phase that generates the data used in the determination of soil percolation rate. Only data from the last three drain cycles should be used to determine the rate.

5. Stability Phase

During this phase, the device will continue filling the test hole to 150mm and then drain to 75mm until five consecutive drain cycles have drain times that are within 10% of each other. If time and water allow, this phase can be useful to ensure that the hole was fully saturated. However, feel free to exit the test at any time if desired (by either turning off the device or holding the rotary encoder).

6. Idle State

Once this criterion has been reached, the device will enter an idle state until the user manually stops the test. Data will not be written to the SD card during this state, and the device will play a song to indicate that the test has been completed. The user is still required to hold the rotary encoder to end the test and return to the home screen or power off the device.

3.6 Manually Recorded Data

In addition to the data recorded by the device, the user should record the data in Table 3-1 during the test (or after the test if applicable). This data is required by the test report. It is important to ensure that you collect all data and pictures so that the test report is complete.

Table 3-1 Manually Recorded Data

Information	Notes
GPS coordinates	Use a phone or other GPS device to determine accurate coordinates.
Ambient Temperature	Just provide an estimate here. Could be useful in troubleshooting (device overheating, etc.)
Weather Characteristics	Rainy, sunny, etc. Could be useful in troubleshooting data.
Soil characteristics	Any observations from the user that might be pertinent – clay, sandy, loamy, etc. Will be used for future percolation test characterization.
Depth of hole	Typical depth is 1m, but should be dug to expected depth of the application infrastructure.
Diameter of hole	Critical to record if the hole isn't the standard 150mm – don't use a different diameter unless absolutely necessary.
Were the hole walls scratched?	The report will be flagged if this wasn't done, but the user needs to report it.
50mm (2-in) gravel added to the bottom of the hole?	The report will be flagged if this wasn't done, but the user needs to report it.
Pictures of the site and the test setup	Used to ensure that the location matches the GPS coordinates; also used to troubleshoot issues.
A satellite image of the test site with the test location clearly marked	Used to differentiate between tests on the same site. Can be retrieved from Google Maps using the GPS coordinates.
Any deviations from Setup/Test Procedure protocols	Check if the proper procedure was followed.

3.7 Settings Menu

The settings menu is accessible from the home screen with a long press of the rotary encoder. To go back to the home screen, just do another long press. To access any of the menu options, scroll to the desired setting and do a short press of the encoder.

Date/Time

This allows the user to set the date and time. When a portion of the displayed date/time is flashing, rotate the encoder to increase or decrease the value, and click to advance to the next portion. Advancing past the final segment will set the date/time to the new value; exiting the screen before doing this will discard all changes. The user should verify that the device's date and time match local time before using it.

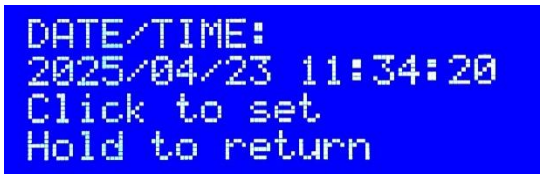

Figure 3-11 Date/Time Menu

Calibration Reset

This resets the saved pressure sensor calibration to the default values. Sometimes the device's stored calibration can be significantly wrong, causing the device to exhibit strange behavior. In this case, resetting the calibration might fix the problem.

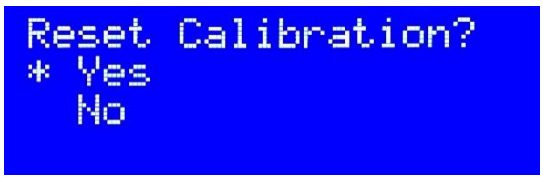

Figure 3-12 Calibration Reset Menu

Switch Ignore

This provides the user with an interface to designate specific level switches or tank switches as faulty. ***Only do this when a switch is causing persistent issues.*** Click the rotary encoder to enter the interface. When a switch is highlighted, turn the encoder clockwise to set the switch to active ("A") and counterclockwise to set the switch to inactive ("X"). The calibration code will ignore switches set to inactive. Switches to the left of the "/" are sensors in the hole, and switches to the right of the "/" are sensors in the tank. Switch settings persist even across power cycles.

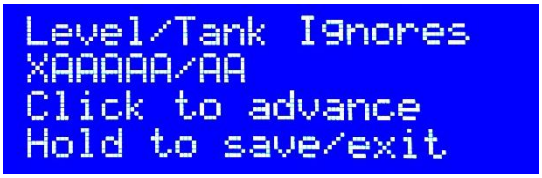

Figure 3-14 Switch Ignore Menu

Battery

This screen displays the battery voltage, along with a very rough estimate of the remaining charge.

Figure 3-13 Battery Menu

SD Card

If the device recognizes a SD card, this screen displays the size of the card.

Figure 3-15 SD Menu

Level Sensor Test: This screen displays the state of the level switches and the pressure sensor. The set of values on the left indicates the tank switches (note that 6 values are displayed even though only two switches are installed on the device). The set of values on the right indicates the six switches in the level sensor assembly. A value of "0" indicates that the switch has a low voltage, and therefore is not covered by water. A value of "1" indicates that the switch has a high voltage and therefore is covered by water. The third line displays the calibrated reading from the pressure sensor, followed by values that indicate the raw reading from the pressure sensor.

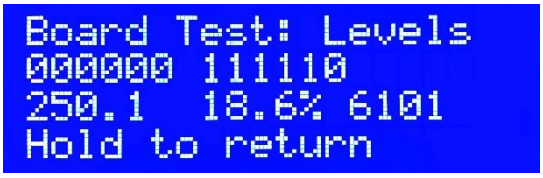

Figure 3-16 Level Sensor Test Menu

Valve Test

This allows the user to open and close the valve to a specified percentage of the full open position. The user might need to use this feature to check whether the valve is functional. It can also be used to fill the hole outside of a test mode. After selecting this screen, rotate the encoder to change the value next to “ENC”. Once this is at the desired percentage, click the encoder to send the instruction to the device; the value should then be displayed next to “CMD.” The valve will open to the specified position; the current valve position is given next to “POS.” To close the valve, rotate the encoder to set the value next to “ENC” to 0%, then press the encoder to send the command to the device. Note that there is a delay between CMD and POS, as the valve takes time to open and close.

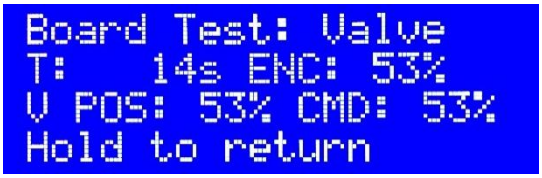

Figure 3-17 Level Sensor Test Menu

Calib Fill/Drain

This is used to force a calibration based on a fill/drain cycle. This might be required if the default value is substantially wrong, though the device should perform something similar under normal operation. This cycle operates like an abbreviated percolation test; selecting this menu item will start the test.

Figure 3-18 Calib Fill/Drain Menu

Perc Simulation

This allows the user to simulate a percolation test (purely in software). It is used for firmware testing.

Perc Test Repeated

This allows the user to run several percolation tests on repeat. After a test is complete, the system will automatically start another test. It is mainly used for system testing purposes.

Web Interface

This is under construction. Eventually it will allow the user to view the test data on a separate device over a Wi-Fi connection to the percolation tester.

Return to Home

Selecting this option will return the user to the home screen. Alternatively, doing a long press at any point of the top menu will return to the home screen.

4. System Storage and Maintenance

The most important aspect of maintenance is to ensure that all components are properly stored.

After a test is complete, it is important to rinse the level sensor as thoroughly as possible. This will help prevent components from corroding or getting clogged with mud. If there isn't sufficient clean water at the test site, be sure to clean the sensor when you get back to a location where that is possible.

All components should be put back in the box in the same way that they came, as specified below:

1. All connections to the control box (hoses and electrical connectors) should be disconnected. The control box should be closed and latched.
2. The level sensor, tank weight, and level sensor should be secured in their respective brackets. The level sensor and tank weight bracket wingnuts should be properly fastened.
3. The downstream hose components should be separated at the quick disconnect fittings. This is to prevent strain on the siphon pump connections.
4. Hoses are then coiled and placed in the box and the siphon pump placed on top, as shown in Figure 4-2.
5. Close and latch the box.

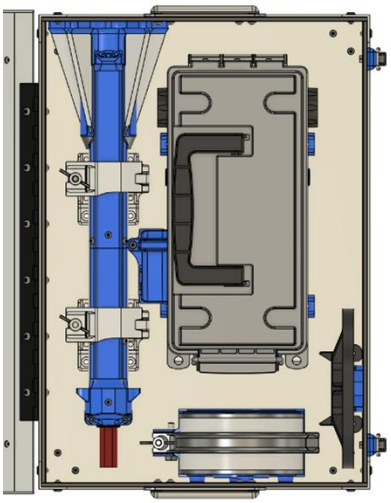

Figure 4-1 Level Sensor, Tank Weight, and Sensor Stabilizer Storage

It is important to get everything as dry as possible before long term storage. If wet components are put in the box, consider taking them out later to allow them to dry prior to long term storage.

4.1 Other Maintenance

Currently, the only required maintenance activity is charging the battery.

There have been issues with some of the siphon pumps starting to leak, especially at the joint between the white plastic fitting and the gray bulb. If this is causing significant issues, it can be fixed by pulling the parts apart, applying silicone sealant, and reassembling.

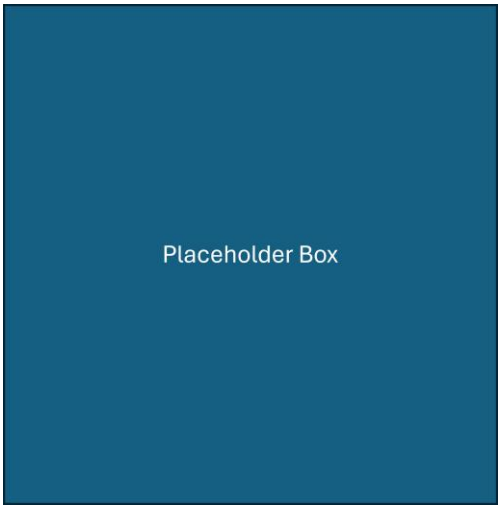

Figure 4-2 Hoses and Siphon Pump in Box

5. Data Analysis

All test data is recorded on the micro-SD card. To access the data, remove the SD card from the slot by opening the access hatch as shown in Figure 5-1.

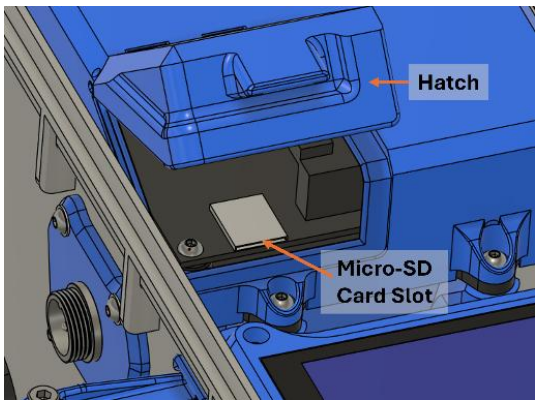

Figure 5-1 Micro-SD Card Slot Access

Each test creates a new data file, named by the time and date when the test was started. The data is saved in a .csv format, which allows for easy viewing in Excel if desired.

A data analysis tool is currently in work which will import the data file that the user specifies and automatically generate a test report. It will ask the user for the information specified in Table 3-1 on page 15. When all of the data has been entered, the tool will generate a Microsoft Word document with all pertinent data, graphs, pictures, etc. The final analysis and decisions will be left to the user, with places for the user to fill in that analysis. More details on the tool will be added to this document when the tool is complete.

6. Warnings and errors

While running the test, the device might give a warning or an error. A “warning” indicates that something is wrong but does not stop the test. In general, pressing the encoder will clear a warning, and also prevent future warnings of that type from appearing. An “error” stops the test, indicating that something has prevented the device from achieving proper test conditions. Some, but not all, errors may be bypassed by pressing the encoder. This will return the device to its previous state and disable future errors of that type.

When deciding to clear a warning or an error, please ensure that you are doing so after carefully considering the cause of the warning or error. Some errors might arise because of hardware malfunctions; in this case it is appropriate to clear them if, in the judgment of the user, the test can still be satisfactorily completed. Some hardware malfunctions critically impair the ability of the device to conduct the test; Clearing these errors might result in erroneous test data. Many errors are designed to give the user advance warning of unsuitable soil for long-term wastewater application, and clearing these errors might waste time on unnecessary testing. It may be more profitable to instead choose a different location and start a new test.

Table 6-1 outlines the warnings or errors a user might encounter, the conditions that lead to them, and what actions might be taken by the user to resolve the issue.

Table 6-1 *Alarm Codes*

Alarm Code	Display	Description of Issue	How to Resolve:
Tank Low	LCD Displays the message: "TANK LOW. FILL TANK! OR CONSULT MANUAL." Audio: Loud beep every 5 seconds	The top sensor in the upstream hose assembly is uncovered, indicating low water level in the tank	Ensure the water level in the tank covers the entire sensor assembly on the upstream hose. If this does not remove the warning, it is possible that the top sensor in the upstream hose assembly is malfunctioning. In this case the warning can be bypassed by pressing the rotary button. Note that this will disable all tank-related warnings for the duration of the test. If you do this, ensure that someone is monitoring the water level in the tank and refilling it as needed.
Tank Empty	LCD Displays the message: "TANK EMPTY! FILL TANK! OR CONSULT MANUAL." Audio: Loud beep every 5 seconds	The bottom sensor in the upstream hose assembly is uncovered, indicating very low water in the tank.	Follow the same steps as when dealing with the Tank Low warning, above.
Confused Tank Sensor	LCD Displays the message: "CONFUSED TANK SENSOR. CONSULT MANUAL." Audio: Loud beep every 5 seconds	The bottom sensor in the upstream hose assembly registers no water, but the upper sensor registers water. This indicates a malfunction with one or both sensors.	There is almost certainly a problem with the tank sensor, and it will not function properly. Press the rotary encoder to clear the warning and monitor the water level in the tank for the remainder of the test. Please contact EMI R&D for assistance with device repair.
Slow Drain	LCD Displays the message: "SLOW DRAIN. CONSULT MANUAL." Audio: Song indicating an issue of potential concern.	This warning indicates that the predicted percolation rate, based on the current drain time, is more than 60 minutes per 25mm.	The predicted rate results in the slowest possible long-term application rate (LTAR) according to the table used in the EMI Civil Engineering Design Guide (8 lpd/m2; table A3.3-28). You might want to consider if this is a good place for wastewater infrastructure, or if you should find a different location. It also indicates that the test is likely to take a long time. This warning can happen during any drain phase and so does not indicate that this will be the final percolation rate, but it does require the user to decide if the test is worth continuing. The user has the option to continue the test or end it (the test will continue to run in the background even without user input). Because the percolation rate is slow, it is likely that the test will take a long time. Consult Table 6-2 on page 24 to see the estimated time remaining for this percolation test.

Table 6-1 *Alarm Codes*

Alarm Code	Display	Description of Issue	How to Resolve:
Drain Too Slow	**Test is paused.** LCD Displays the message: “Drain Too Slow”. Audio: Loud beep once per second. Pushing the rotary encoder allows the user to recover from this error.	This error indicates that the predicted percolation rate, based on the current drain time, is more than 120 minutes per 25mm.	The predicted percolation rate indicates that the soil is unsuitable for wastewater application according to Table A 3.3-28 in the EMI Civil Engineering Design Guide. This error can be bypassed but note that the slow rate of percolation means the test will likely take a long time. Consult Table 6-2 on page 24 to see the estimated time remaining for this percolation test.
Drain Too Fast	**Test is paused.** LCD Displays the message: “Drain Too Fast”. Audio: Loud beep once per second. Pushing the rotary encoder allows the user to recover from this error.	The device drained from 300mm to 75mm in less than 8 minutes. Two subsequent drains that meet these criteria are required to activate this error.	Table A 3.3-28 in the EMI Civil Engineering Design Guide specifies the maximum percolation rate as 1 minute per 25mm. This error indicates that the drain rate exceeds this percolation rate. The user may recover from this error but should consider carefully whether the resulting test data will be useful.

Table 6-1 *Alarm Codes*

Alarm Code	Display	Description of Issue	How to Resolve:
Fill Too Long	**Test is paused.** LCD Displays the message: “Fill Too Long”. Audio: Loud beep once per second. Pushing the rotary encoder allows the user to recover from this error. Unlike other errors, this error may occur again after the user has bypassed it.	The device has not been able to fill the hole to the desired water level within 2 minutes	A fill normally continues until the top level switch is activated. This error exists to prevent a malfunctioning level switch from causing an infinite fill, which would submerge the level sensor, flood the hole, and empty the tank. The most likely cause of this error is that the tank ran out of water during a normal fill cycle. If there is evidence of flooding, it could be that the top level switch has failed, overfilling the hole. If the tank is not empty, it could be that the siphon was not established or that the valve has failed to open. Verify that the hoses are assembled correctly without any leaks, kinks, or blockages. Pressing to continue will restart the fill sequence (and the timer). Once restarted, squeeze the siphon pump several times to purge any entrained air within the water hoses. If the device still fails to fill the hole, the device may have insufficient battery to actuate the valve. There should be an audible noise (a whine lasting 2 or 3 seconds) that accompanies the movement of the valve, which should occur at the beginning and end of the fill sequence. You can check the ability of the device to actuate the valve with the “Valve Test” option in the settings menu. If available, the device can be connected to an electrical power source to supply power for the rest of the test. If the error occurs while a significant amount of water is entering the hole, then the hole drain rate may exceed the capacity of the device to fill it. In this case, the percolation rate is much too fast for the required applications. A different site should be selected for wastewater application.
Settle Too Long	LCD Displays the message: “Settle Too Long”. Audio: Loud beep once per second. Pushing the rotary encoder allows the user to recover from this error. This error should automatically recover if the water level drops beneath the fill level.	The device has not transitioned from the settle state to the drain state within 30 minutes.	This is likely an issue with the device overfilling the hole during the previous fill cycle and/or an insufficient hole drainage rate. Check the water level as indicated on the device display and compare with the target fill level as described in the Test Algorithm to determine whether the actual level is far above the target level. You can also verify that the measured water level on the display matches the actual water level in the hole (the sensor itself is just over 300mm tall and can be used as a reference).

Table 6-1 *Alarm Codes*

Alarm Code	Display	Description of Issue	How to Resolve:
Calib Switch Error	**Test is stopped.** LCD Displays the message: “Calib Switch Err”. Audio: Loud beep once per second. This error is not recoverable; the test must be re-started.	This error means that the level switches used for automatic calibration have been activated out of order.	This indicates that one or more of the digital level switches are broken. Since the device uses the level switches to calibrate the pressure sensor, it cannot function if they are broken. However, there is a menu option for the user to specify switches that do not function. To figure out which switch is causing the problem, you can look at the data on the SD card, or you can use the “Valve Test” menu option to fill the hole, and the “Level Sensor Test” menu option to see which switches are activated with a full hole. See section 5 for information on these menu options. Please contact EMI R&D for assistance with device repair.
Timeout	**Test is stopped.** LCD Displays the message: “Timeout”. Audio: Loud beep once per second. This error is not recoverable; the test must be re-started.	The device has remained in the same state for at least 24 hours	The test has been inactive for too long and must be restarted. This could happen if the device has been left in an error state for too long. It is meant to prevent the user from continuing a test that has been paused long enough to invalidate soil saturation.
Error	**Test is stopped.** LCD Displays the message: “Error”. Audio: Loud beep once per second.	The device has encountered a critical error and is unable to recover	The user should never see this message. If seen, power cycle the device and restart the test. Please contact EMI R&D with details of the issue.

6.1 Slow Drain Time Estimates

When a Slow Drain warning is encountered, use this table to estimate the minimum time remaining before the end of the percolation test. Read the column for either the Slow Drain Warning or the Drain Too Slow Error, and read the row based on the state the device is currently in (for warning) or recovers to (for error). Please note that these are *minimum* times; the actual time remaining may be much longer and depends on the actual percolation rate and the variability between cycles.

Table 6-2 Slow Drain Time Estimates

State	Cycle	Slow Drain Warning: Min. Time Remaining (hours)	Drain Too Slow Error: Min. Time Remaining (hours)
Init Drain	-	21	42
Sat Drain	1	19	38
Sat Drain	2	17	34
Sat Drain	3+	15	30
Transition	-	13	26
Test Drain	1	9	18
Test Drain	2	6	12
Test Drain	3+	3	6