GNG1103

Design Project User and Product Manual:

The Sample Subway

Submitted by:

Sample Snatchers – F16

Tiam B Morrow-Rogers, 300427610

Radhe Pandey, 300442108

Eden Irwin, 300291076

Isaac Pinarski, 300414541

April 4th, 2025

University of Ottawa

List of Acronyms

Table 1. Acronyms

Acronym	Definition
BMS	Battery Management System
PETG	Polyethylene terephthalate glycol (3D Printer Filament)
PLA	Polylactic Acid (3D Printer Filament)
TPU	Thermoplastic Polyurethane (3D Printer Filament)
UI	User Interface
UX	User Experience

Names to change: End cap, head cover

1 Introduction

This User and Product Manual (UPM) provides the information necessary for operators to effectively use and maintain the Sample Subway, while articulating the prototype documentation for reproducibility.

The Sample Subway is a product used in nuclear reactors to obtain a metal sample from the interior of the fuel channel to be tested for hydrogen embrittlement, evaluating the integrity of the pipe composition. The development of this device assumes operating conditions in a neutral environment, rather than nuclear constraints of radiation, pressure, and temperature impacting the design constraints beyond the requirements provided in the scope of the project.

The document serves as instructions illustrating
The contents of the manual are organized as follows:

- Overview of Project & Product – details the project objectives,
- System Walkthrough
- System Functions
- Troubleshooting & Support
- Product Documentation

This document includes the appropriate documentation to reproduce
The scope of activities demonstrated through the manual highlights the step-by-step procedure for operating the product provided the physical system and the

2 Overview

2.1 Scope of the Project & Project

The goal of the project was to design a device for Canadian Nuclear Laboratories (CNL) to retrieve a metal sample that weighs 30-80 mg from inside a 15-foot-long tube, oriented either horizontally or vertically, with a 4-inch internal diameter. The collected sample will be transported to a laboratory to test for hydrogen embrittlement. The fundamental user requirements for the device include a containment method to remove direct contact between the tool operator and the sample, an adjustable sample retrieval process, a feedback control system to detail process status, a fail-safe design in the event of equipment failure, and a modular design capable of being broken down into man-portable sizes.

Based on the general project requirements, the team developed the following problem statement to focus our objectives throughout the development of the device: *"Operators who service nuclear reactors need a device to collect metal samples from pressure tubes while minimizing exposure to contaminated material. The solution should be compact and completely removable from the pressure tube, and it should also be able to report the stage of operation within a limited time."*

The Sample Subway is a device capable of retrieving a precise metal sample from a nuclear fuel channel including traction wheels for horizontal movement to the sampling location, a powerful scraper to retrieve the necessary sample mass, a winch for vertical movement and fail-safe, along with a self-sealing containment system to keep the sample protected and isolated from direct contact with the operator.

Figure 5-1 -

The design's originality focuses on the user needs and proposed fully automated system for the horizontal configuration and a containment system that prevents any contact with the sampled material. Additionally, the device consists of removable and interchangeable components such as the battery pack, which provides more than enough voltage and amperage to power the sampling tool, a carbide lathe bit that serves longevity and less maintenance. The Sample Subway also does work effectively in both horizontal and vertical configurations putting it ahead of competitors working on the project and in industry.

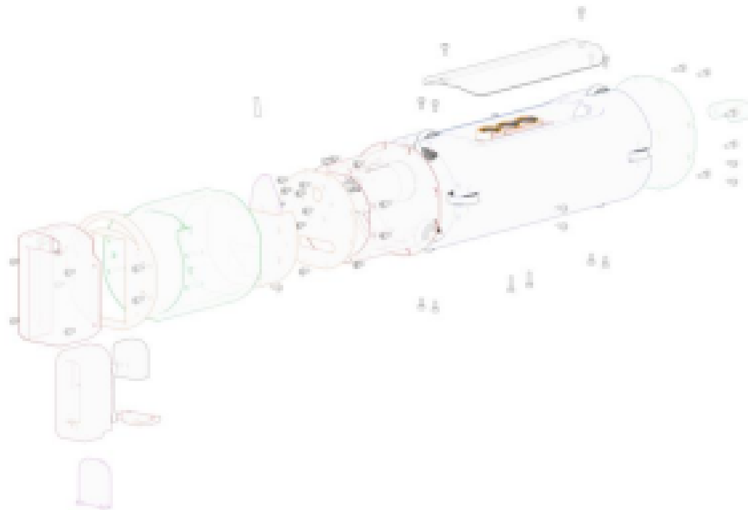

Figure 5-2

In terms of operation, the device is placed in the inlet of the tube, travels via motorized wheels or a manual winch to approximately 14.5 ft, scrapes the circumferential inner diameter of the tube estimating a sample collection of 65 ± 9.5 mg sealed inside a removable container where it will travel back to the operator once a desired sample is achieved. In terms of construction, the device can be categorized into various systems: power, scraping, movement, containment, fail-safe, and control. These systems components are specified as follows, respectively: a custom battery pack, a lathe bit, two movement motors and bearings, load cell, a custom winch, and a microcontroller. The system's chassis is made of 3D printed filament consisting of PTEG and PLA. The construction of the device utilizes numerous screws and a screwdriver. Further details outline the construction and composition of the device is illustrated throughout.

2.2 Conventions

Command Syntax Conventions – Explains how user actions are indicated, for example:

- **Action** – When the user needs to perform a specific step.
- **Note** – Highlights important information.

• **Warning** – Alerts the user to potential issues or critical steps.
• **Example** – Provides sample commands or scenarios.

2.3Cautions & Warnings

The battery and BMS assembly must be handled with extreme caution. Failure to exercise due diligence can result in serious harm to yourself and others. If you are unsure about proper handling practices, it is advisable to find an alternative power source for the device. There are many 3S1P batteries available on the market for hobby race cars and drones that can serve as substitutes. However, these alternatives may be significantly more expensive and come with their own risks. If the battery ignites all persons should immediately vacate the area, and emergency services should be notified.

The scraping tool bit can become stuck in the pipe. This component will need to be iteratively remodeled and adjusted since it is designed for a precise tube diameter. The current prototype was designed to scrape a 4.05-inch diameter pipe. A break line should be included in the design to allow the tool bit to break off if it becomes lodged in the pipe. Furthermore, scraping tests with the device should be conducted using the pass-through section at the front of the device. This setup allows for easier shutdown in case of a critical failure.

During operation of the device, the serial monitor in the Arduino IDE should be closely monitored so that any emergent issues can be handled. In the event of power loss, the device will have to be forcibly moved, using the same method as above. The application only acts as a demo and does not directly interface with the device. All controls will be through the serial monitor.

Getting started

Below a general walkthrough of the system will be provided. This will cover the setup and deployment of the Sample Subway, as well as the cleanup and storage of the device. How to configure and navigate the system will also be detailed.

Configuration Considerations

The considerations for the system's configuration are dependent on the orientation of the fuel channel being tested, either vertical or horizontal. The changes in configuration affect the positioning of the containment system, requiring an additional head cover for vertical pipe sampling.

In a horizontal orientation, the container is inserted into the allocated slot in parallel with the whole device underneath the scraping bit, while the lid catches on a segment of the device to open the container, as seen below:

Figure 6-1

In a vertical orientation, an additional head cover is required to orient the container perpendicular to the device, as illustrated below. In a similar manner, upon insertion of the container, the lid contacts a segment of the device, seen as the arced component on the flat plate in Figure X to open the container underneath the scraping tool.

Figure 6-2

User Access Considerations

The users for the sample subway device include the operators, the maintenance team and the disposal team for a CANDU reactor. Each user/group will only handle the device in the way it was intended for them specifically. Operators will handle the operation of the device, sending the sample subway into and out of a tube to extract a sample. The maintenance team would ensure that the device is in proper working order (both the hardware and software) and ensure parts of the device are replaced in a regular and timely manner. The disposal team will deal with the proper disposal of various parts (as they will be exposed to radiation over time). Suppose a user/group faces issues with the device outside their qualifications for handling the device. In that case, they should consult with other users/groups qualified to handle that issue.

Accessing/setting up the System

Startup of the Sample Subway begins with determining whether the device will be sampling in the vertical or horizontal orientation. If the horizontal orientation is chosen, the operator must set the "Containment System" into place by pushing it into the hole located at the bottom of the devices' tooling head. If the vertical orientation is chosen, the operator must first attach the "End Cap" onto the end of the device by screwing it into place using M3 bolts. The operator can then insert the "Containment System" by pushing the Containment System into the hole located at the bottom of the End Cap.

Figure 6-3

Once the containment system has been inserted into the device, the device must be attached to the failsafe system spool. The operator must do this by tying the loose end of the rope attached to the spool, to the "hook", located at the back end of the device.

Figure 6-4

Following the attachment of the failsafe system to the primary device, the device may be placed into the desired fuel channel.

6.1.1 User Interface

Startup of the Sample Subway begins with the operator calibrating the device's user interface. To begin, the operator must enter their username and password into the login page of the application.

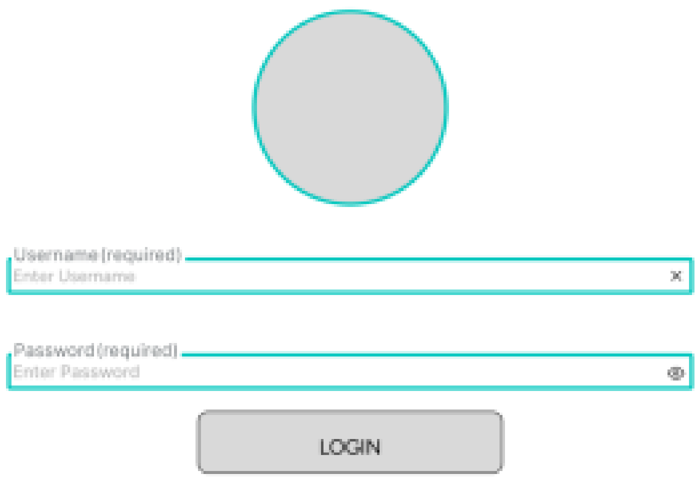

Figure 6-5 - User Interface Login

Once the operator has entered their credentials, they are then directed to the application's home page, wherein the operator can view the connected devices, pair a new device, view the saved devices, and review previous test results. For the purpose of this explanation the operator will select "Connected Devices" and then select "The Sample Subway".

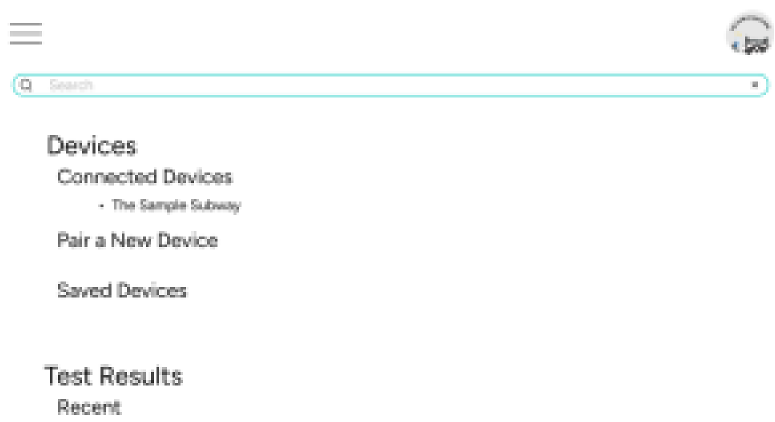

Figure 6-6 - User Interface Home Page

After selecting the relevant device, the operator is taken to the "Review Page". Here, the operator can choose to start a new sample test, view previous sample test results, and review the user manual. For this explanation, the user will select "Start a New Sample Test".

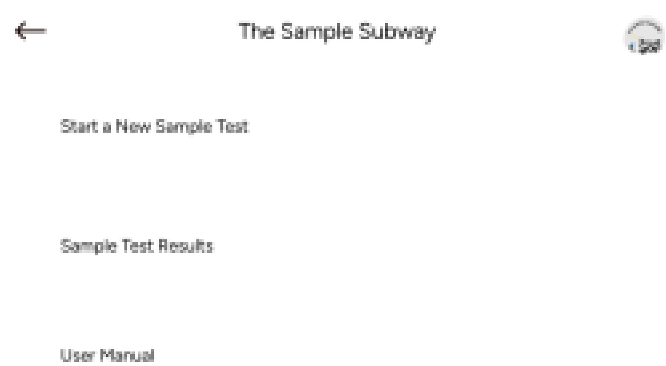

Figure 6-7 – User Interface R

The operator will then be directed to the settings page of the user interface. On this page, the operator will enter the following information; the name of the sample test, the fuel channel location the test will take place in, the orientation the device will sample in (horizontal or vertical), the distance to the sampling site, and the desired mass of sample that will be collected.

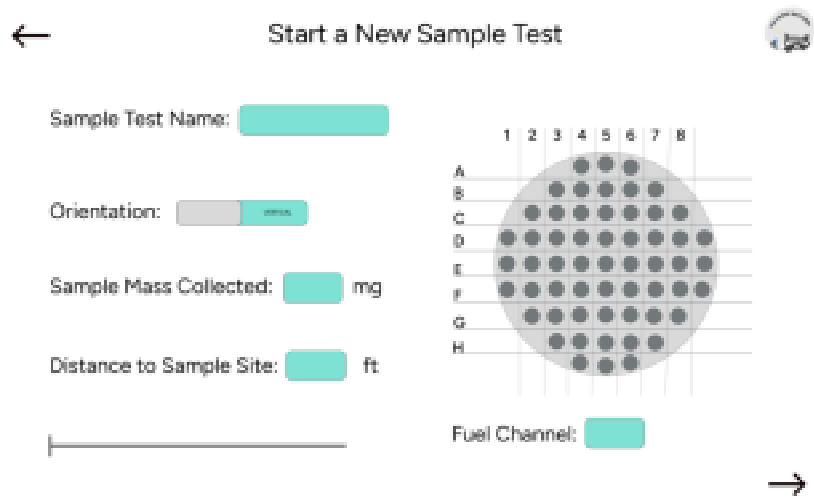

Figure 6-8 - User Interface Settings Page

Once the desired settings have been entered into the interface, the operator will then be directed to the status page. On this page, the parameters entered in the “Settings Page” will be displayed, as well as information pertaining to the status of the test. The information displayed is as follows; the current stage of the test (start, at sample site, sample obtained, returned), the distance the device has travelled, the mass of the sample collected, and battery life percentage the device has. From this page, the operator can also manually start and stop the test, as well as observe any alerts.

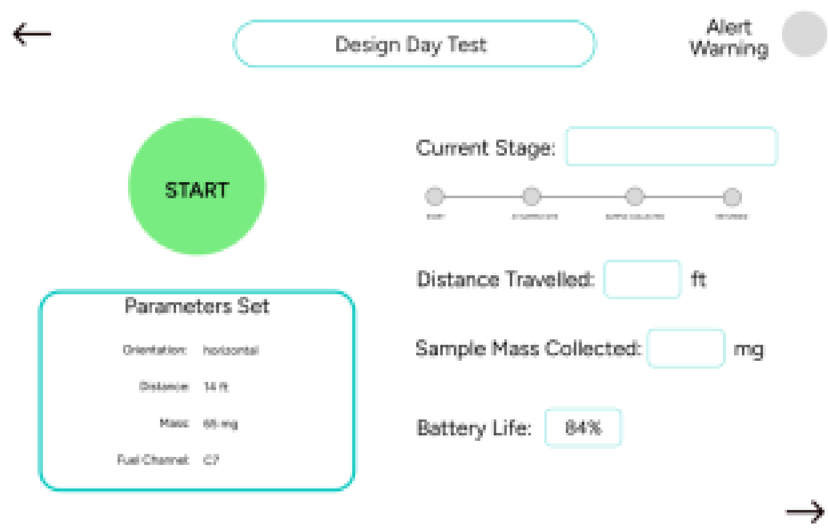

Figure 6-9 - User Interface Status Page

Once the device has completed the sample test, the operator will be directed to the final page of the user interface, the results page. On this page, the operator will be able to view the date the test took place, the operator who performed the test, the fuel channel where the test took place, and the amount of sample the test collected. The operator can then return to the "Home Page" where they can review the results or begin a new test.

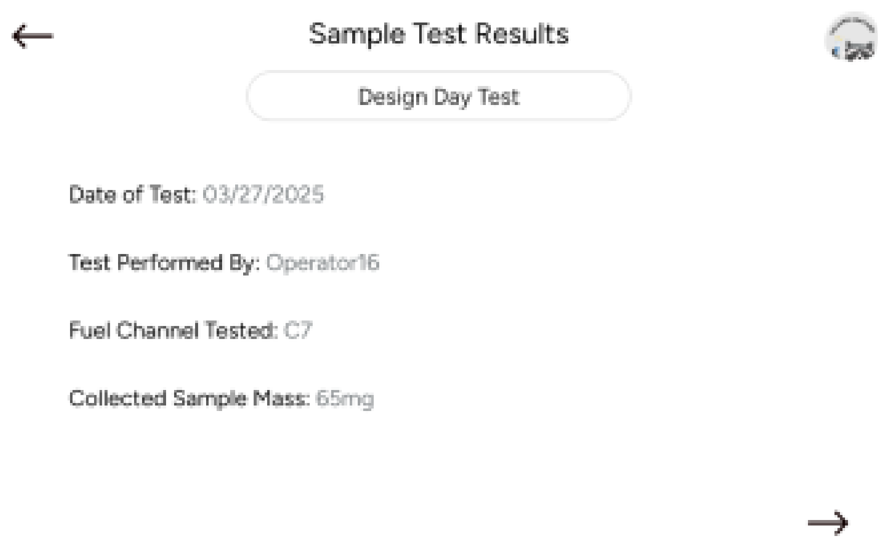

Figure 6-10 - User Interface Results Page

System Organization & Navigation

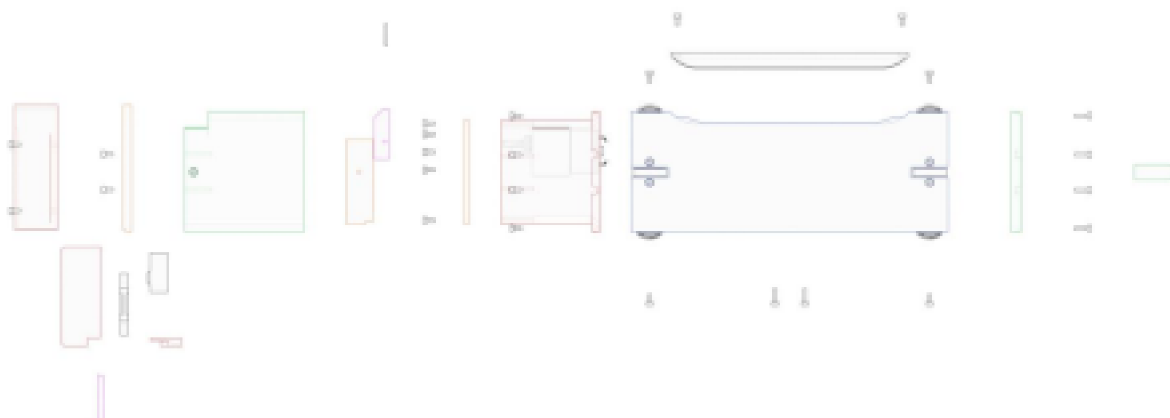

Figure 6-11

The Sample Subway is physically comprised of four main sections. The tool head, container, chassis, and failsafe. Each section is connected to another, and the order in which the system is assembled does matter. As such, this document will go in order of the assembly.

6.1.2 Chassis Organization

The chassis houses the battery and the BMS underneath the side panel. It also contains all 8 of the bearings and their respective mounts. All components for the chassis are mounted using M3 x 6mm bolts. It is advisable to use bolts up to 12mm in length for the battery holder. The wheels are slid onto the bearings, which are respectively slid onto the bearing mounts. These are then placed on the inner side of the chassis, then allowing the bolts to come through the chassis mating the components together.

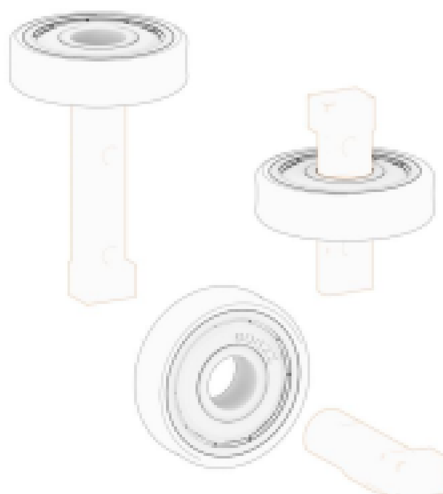

Figure 6-12

6.1.3 Toolhead Organization

The toolhead is comprised of 6 main components; the sample plate, head cover, container mount, tool bit holder, tooling head cover, white tube and motor plate. The sample plate's purpose is to allow for the mounting of the head cover to the tooling head. Additionally, the plate acts as a guide that allows the collected sample to fall into the containment system when the device is in the vertical orientation. The head covers purpose is to allow for sampling collection to take place in the vertical orientation, as the containment system can be inserted vertically into the container mount when the head cover is attached. The container mount allows for the insertion of the containment system into the tooling head. A notch located on the bottom of the container mount allows for the containment system to remain open while sampling is taking place. The tool bit holders' purpose is to allow for the sampling bit to be attached to the motor, allowing for efficient sampling to take place. The tooling head covers purpose is to contain all of the components located within the tooling head, as well as protect the sample from exposure while sampling takes place. The white tube's purpose is to allow for the mounting of the motor plate, as well as the mounting of the tooling head cover. The final component, the motor plate, allows for the sampling motor to be mounted. This allows for the motor shaft to be used in the tooling head, allowing for sampling to occur.

6.1.4 Failsafe Organization

The failsafe consists of two main components: an end cap which is attached to the chassis, and the winch which is tethered to the end cap using a paracord rope.

6.1.5 Container Organization

6.1.6 Software Organization

Sample Subway uses an app for operation. This app allows the user to operate the device (control its movement and sampling), know its current state of operation and obtain results. The app begins with a login page for the user to sign in. This opens the menu where previous results can be reviewed, and sample devices can be connected to. When a user connects to a device they can begin a new sample collection, in this page, settings for the device's location, orientation and mass collection can be toggled. Once the desired settings are confirmed, the user is brought to another page to begin sample collection. The page informs the user on the sample collection progress including its stage of operation and the amount of sample collected. Finally, after device operation is completed, the user is brought to a final page where sample collection results are displayed.

Exiting the System

If in the horizontal orientation, the device should return automatically after collecting an appropriate sample size. If it is unsuccessful a "return” command can be issued to the device through the Arduino IDE. This will instruct the device to put the tool bit in the safe position, allowing the device to move back to the operator. Motor failure can occur, and if it does, then a “stop” command will completely halt all operation on the device. Then the device can be pulled back utilizing the winch mechanism. After the device has fully left the pressure tube, the container can be safely removed.

In the vertical orientation, after sampling the device will prompt the operator to use the winch. After the operator uses the winch to pull the device back up, the container can be moved from the front. The same “stop” command is available in the event of an emergency.

It is advised to disconnect the battery before storing the device. A stand exists to prevent the device from rolling around on flat surfaces. The container can now be used independently and taken to the sample analysis lab.

Steps for exiting the system:

1. Type “return” into the serial monitor.

2. Remove Sample Subway from the pipe.

3. Remove container from Sample Subway.

4. Remove panel cover revealing the battery.

6. Disconnect the battery from the XT60 connector.

7. Remove battery from Sample Subway.

8. Place Battery and Sample Subway in a safe location, hand off container to lab.

7 Using the System

The following subsections provide detailed, step-by-step instructions on how to use the various functions or features of the Sample Subway.

Functions and Features

The Sample Subway’s features consist of 4 subsystems: movement, sampling, containment, and failsafe. The respective functions and features of each individual subsystem will be detailed, while also making remarks about the entire operation provided in the order of subsystems presented. Before operating the device, it is crucial to determine the orientation of the pressure tube sampled, which can be horizontal or vertical.

7.1.1 Movement

The orientation of the pressure tube dictates the respective subsystem used for movement. In a horizontal orientation, the device is manually placed in the inlet of the pipe with the tool head orienting facing the sample site. Theoretically, this system would include two motors that would actuate the bearings by using the ESP32 microcontroller, commanded by the operator to commence and specify movement to the sample site. Unfortunately, the horizontal movement features were not tested, provided the team was assigned to a vertical testing demonstration on Design Day.

Figure 7-1

For a vertical orientation, the movement of the device is manually operated using a custom winch, the failsafe system, with measurement points indicated at every half foot to determine the distance of the device inside the pressure tube. That being said, the bearings remain to provide guidance and fit along the inner pipe walls. To set up the operation, clamp down the winch to a nearby fixed structure (i.e. table). Carefully extend the paracord up to the inlet of the top of the pressure tube, while placing the device parallelly inside the inlet with the tool head facing the ground. The pressure tube plate, connected to the winch prevents excessive damage and friction against the tube, while centering the controlled downwards movement and resting on the top of the pressure tube. The device is meticulously guided down the tube, acknowledging the depth achieved based on the half foot measurements on the paracord. Once the device reaches the desired sample site depth, it must be held in place by the operator as sampling begins, as any movement will interfere with the sample extraction process.

7.1.2 Sampling

The sampling system functions for both horizontal and vertical testing, however, the control system procedure to commence the sampling changes. For horizontal testing, the control system is automated provided the detailed code articulating the command to start the motor to sample once the sample site depth is reached. For vertical testing, once the operator reaches the desired depth with the winch, the motor mechanism for scraping is commanded through use of the application or the ESP32 control system. As the containment system calculates the collected mass, the microcontroller will stop the motor once the tool bit holder reaches an offset position (i.e. not extruded from device), allowing for an easy and controlled retrieval of the device.

7.1.3 Container

The containment system itself can be defined as an isolated spring-loaded mechanism; the principle that self-seals the sample inside the container by a lid that slides open, compressing the springs upon contact to a segment of the device. As the sample is collected, a load cell is incorporated to display the collected mass through the application, providing an accuracy of ±The container remains in this position (open) until the device is completely extracted from the pressure tube. Without direct contact with the device, the operator can manually extract the container which removes the compression on the springs, allowing for the lid to self-seal, isolating the sample and reduce exposure to the operator. The configuration considerations for the two orientations have been previ

7.1.4 Failsafe

The fail-safe system has dual purposes, achieving vertical movement for the device, while also capable of removing the device from the pressure tube in emergent circumstances acting as a fail-safe mechanism (i.e. equipment failure). As the device travels inside of the tube, paracord is directly connected to the device, allowing the operator to manipulate the device from the outside using the custom winch without any direct contact with any contaminated material.

8 Troubleshooting & Support

This section will detail error messages, and how a user may use them to identify issues. Appropriate actions to the identified errors will be provided and maintenance instructions to prevent other potential errors.

Error Messages or Behaviors

Error Message	Reason	Action
Load Cell Unavailable	Faulty connection, HX711 communication error.	Disconnect and reconnect the load cell. Can be tested with another Arduino to verify communication protocols.
Collection Failure	The scraping mechanism was unable to collect a sample within the given timeframe.	Enter the “Return” command in the serial monitor to instruct the device to return to the operator.
		Check scraping bit integrity. The cutting depth is either not deep enough, or the cutting bit has dulled and needs to be replaced.
Lost Communication	Power Failure / Faulty Mainboard	The failsafe mechanism must be utilized. If the machine was in scraping position the tool bit should

		snap off.

Special Considerations

Variation in the collected mass is to be expected. There is a fair amount of noise affecting the precision and accuracy of the load cell. There are functions that were used to improve accuracy; however, the data can still fluctuate due to a variety of reasons, and it's likely not worthwhile trying to debug these issues with the prototype. With a properly shielded container manufactured out of aluminum, these conditions would be significantly more stable. This problem is simply a money barrier.

25
26

Maintenance

Part	Maintenance Required	Frequency
MOVMENT		
Rubber Tread	Replacement	1-2 years
Wheel Motors	Oil	1-2 years
Wheel	Replacement	3-4 years
Spool Rope	Replacement	1-2 years

SAMPLING		
Bit Head	Replacement	N/A
Sampling Motor	Oil	3-4 years
Bit Mount	Replacement	0.5-1 year
POWER		
Batteries	Replacement	1-2 years
Wires	Replacement	10-15 years
Battery Charge	Charge	3-6 months
ESP32-WROOM C3	Replacement	8-10 years
MEASURMENT		
Load Cell	Replacement	8-10 years
XT60	Replacement	6-7 years

Support

In the event of an emergency that involves the battery, and the failsafe mechanism doesn't function as expected, the operator should step away and contact emergency services. Below is a list of contacts you can reach out to and various support that they would be able to provide.

Name	Reason	Contact Info
Tiam B Morrow-Rogers	General Inquiries	tiambennett@gmail.com
Emergency Services	Fire/Explosion/Significant Harm	911

Non-Emergency Fire Service	Risk of fire, concerns of battery integrity	311

9 Product Documentation

The final physical prototype was constructed utilizing the main chassis shell as the basis for all other components. Only components in the orange tool head require a specific assembly order. All other components can be assembled in nearly every order. Any assembly conflicts will be mentioned in their respective categories in section 6.1.3. All structural components were 3D printed using either PLA or PETG. It is worth noting that a fully functional model would be made from aluminum to improve the longevity of the device and improve resistance to the elements. Metal was outside the budget and scope of the project but would be the next step in the development of the Sample Subway.

A digital prototype was also made, using Figma as the prototyping platform. This prototype was made to give a generally sense as to how the user flow would function, and test for any UX concerns.

9.1.1 BOM (Bill of Materials)

Battery and Power Delivery (PDXX)					
Item #	**Part**	**Vendor**	**Description**	**Qty**	**Cost**
PD01	22 awg Wire	Amazon	Wires for connecting components to circuit	1	CA$0.80
PD02	XT60 Connectors	Aliexpress	Connectors for battery pack	1	CA$1.60
PD03	16 awg Wire	Amazon	Wires for 12v components	1	CA$0.80

PD04	P42A Molicel Battery 21700	18650 Battery	For battery pack assembly	3	CA$15.00

PD05	3S Battery Management System	Aliexpress	For safety	1	CA$2.94
PD07	LM2596	Aliexpress	Step down buck converter, 36V/24V/12V/5V/3V	1	CA$0.45
Control and Logic (CLXX)					
Item #	**Part**	**Vendor**	**Description**	**Qty**	**Cost**
CL01	ESP32-WROOM-C3	Elegoo	Controller w/ Wifi + BT	1	CA$9.99
CL02	H-Bridge Motor Driver BTS7960	Aliexpress	Driving 12V motor for scraping	1	CA$7.41
CL03	HX711 Sensor	Aliexpress	Strain gauge for mass analysis	1	CA$1.80
Measurement (MXX)					
Item #	**Part**	**Vendor**	**Description**	**Qty**	**Cost**
M01	100g Load Cell	Aliexpress	Strain gauge to measure mass	1	CA$4.93
Structural Components (SCXX)					
Item #	**Part**	**Vendor**	**Description**	**Qty**	**Cost**
SC01	PLA - ~0.70 KG	Bambu	Filament for chassis	1	CA$16.99
SC02	M3 Female Threaded Insert	Aliexpress	Heat set threaded inserts for chassis	1	CA$0.80
SC03	M3/M4 Machine Screws	Aliexpress	Various length M3 Machine Screws	24	CA$1.00

Sampling Tooling Components (STXX)					
Item #	**Part**	**Vendor**	**Description**	**Qty**	**Cost**
ST01	Lathe Bit	Aliexpress	Lathe Bit and armature	1	CA$3.25

ST02	JGB37-520 7rpm 12v Motor	Aliexpress	For moving the armature with lathe bit	1	CA$11.28

Movement (MVXX)					
Item #	**Part**	**Vendor**	**Description**	**Qty**	**Cost**
MV01	Bearings	Aliexpress	For reducing friction and precise movement	8	CA$4.69
MV02	N20 12V 200RPM	Aliexpress	Moves the device through the pipe	2	CA$10.78
MV03	Rubber Bands	Amazon	Increases Friction of wheels, prevents slippage	8	CA$1.68
				Total:	CA$96.19

9.1.2 Equipment/Software List

Equipment	
Soldering Iron Used to connect electrical components together	
Bambu Lab A1 3D Printer	Fused deposition modelling tool for additive manufacturing of chassis
Heat Gun	Used for shrinking heat shrink
Fume Extractor	Removes dangerous fumes created from soldering
Screwdriver	Connecting and disconnecting basic hardware

Breadboards	Useful for prototyping components, may be used in final design, cost will not be accounted
Multimeter	Helpful for testing the circuits and their connections
USB-C Chargers	Charges the devices used

USB-C Cables Transfers data and power from charges and laptops to devices, used to flash microcontroller	
Computer	For rendering and visualization
Spot Welder	For rendering and visualization
Software	
Keyshot For rendering and visualization	
Onshape	CAD Modeling software with collaborative tools and version control
Arduino IDE	Programming environment with useful integrated libraries for compilation
Google Sheets	For creating tables, BOMs, and logging data
KiCAD	For creating custom circuitry and PCB designs
Python	Used for making scripts to read and file incoming serial data

9.1.3 Assembly Instructions

The first component to assemble most easily are the sets of bearing mounted wheels. The process for assembling a bearing unit happens in 4 steps as depicted in the following images.

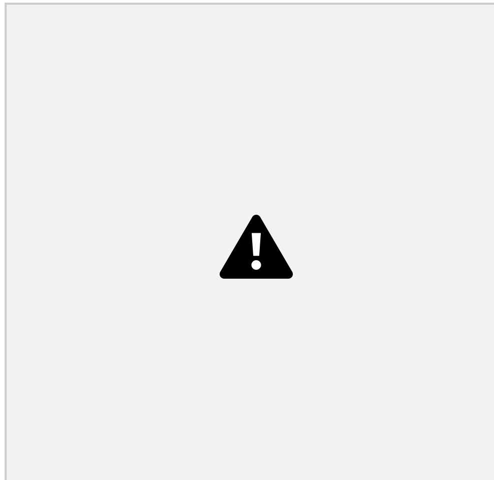

Figure 9-1

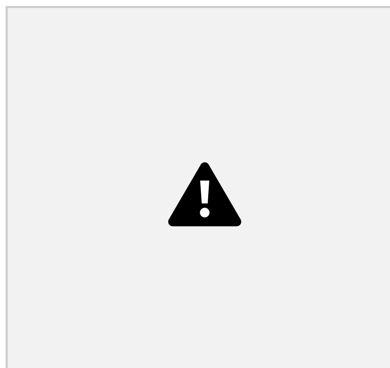

Figure 9-2

The wheel can slide onto the bearing and fit snuggly. The wheel will be prevented from slipping off by a groove on the inner diameter of the wheel, and the pressure of the pipe. For the prototype

we also wrapped an elastic band around the wheel, but utilizing a softer rubber would allow one to avoid this step altogether.

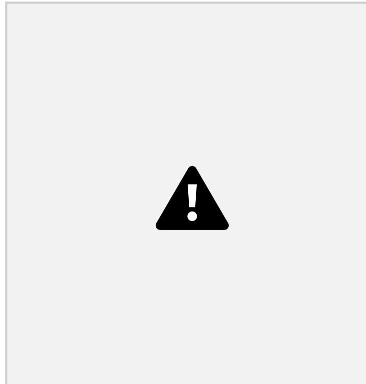

Figure 9-3

The wheel and bearing are then slid onto the mounting pin. This pin has a round and a flat side. In the center of the pin a bump is noticeable. This bump is what allows the bearing to press fit onto the mount, while also allowing the pin to sink into the chassis wall.

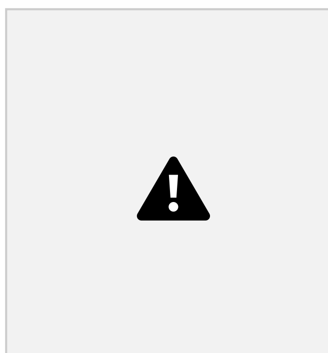

Figure 9-4

Once the wheel and bearing are positioned on the center of the pin, the pin can then be oriented with the slots located on the chassis frame.

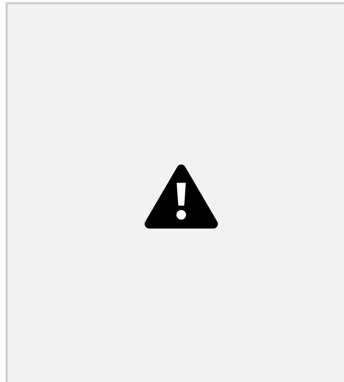

Figure 9-5

It is easier to install the wheels before any other components, however it is still possible to install the wheels through the panel cover on the top of the device. Holding the flat portion of the pin against the wall of the chassis allows the screw holes to line up. Then an M3 screw can be used to mate the components together.

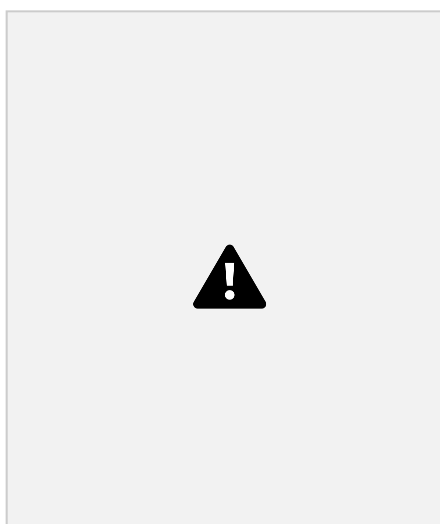

Figure 9-6

The chassis has an extra component necessary so that the length of the screws required for assembly were not excessive. The white tube component below uses 8 screws to directly mate the white tube to the main chassis shell.

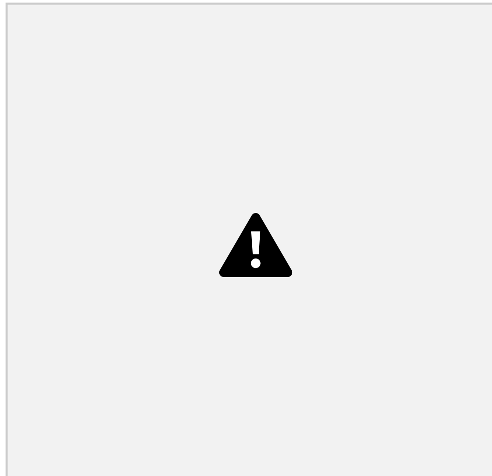

Figure 9-7

Afterwards the motor can be mounted to the motor plate. These components are assembled separately, as adjusting the motor after assembly is quite difficult.

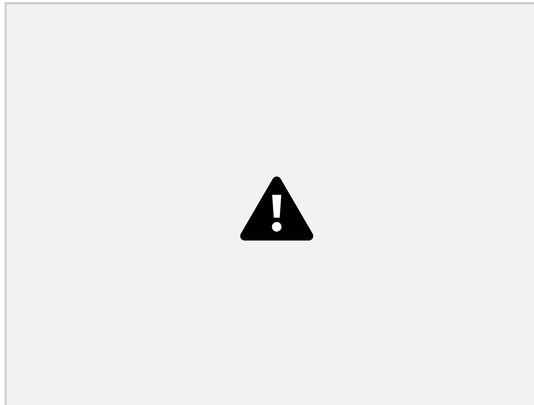

Figure 9-8

The motor plate can be connected to the white tube. Use only the top and bottom holes. A passthrough window will be aligned on the bottom of the plate. If you are assembling to test the scraping bit, it is advisable to pass the cables for power through this window.

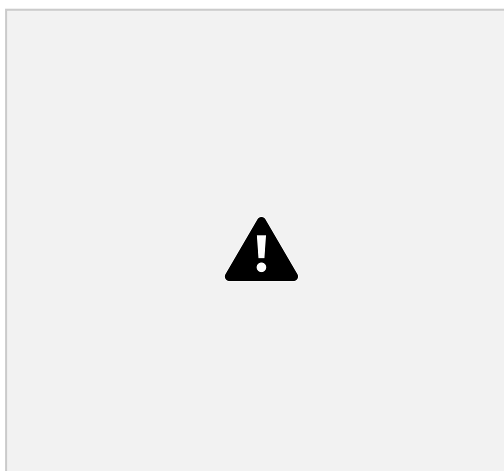

Figure 9-9

The scraping bit is then able to be attached to the motor mount. In the following image the motor is positioned with the blade in the scraping position. It is likely that the motor will have to be powered so that it moves the scraper to the recessed position. If this is not done, the next steps for assembly might be impossible as the extended scraping bit will obstruct the tool head cover from sliding over. Make sure to tighten the grub screws on the side of the scraping bit holder so that the system can endure the high torque forces.

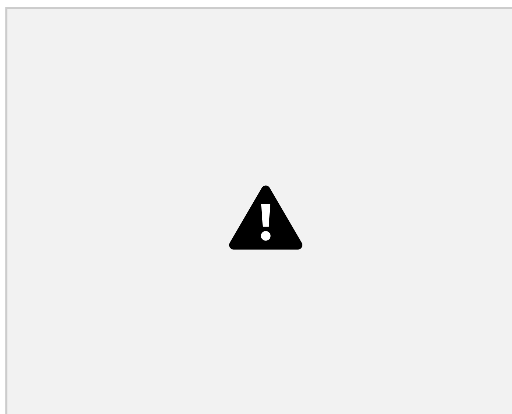

Figure 9-10

An orange tool head cover can be slid loosely over the white tube extension. Another mounting cover with a window for the sample container and 4 mounting holes can then be attached to the chassis by passing M3 x 16mm screws through the motor mount and into the chassis.

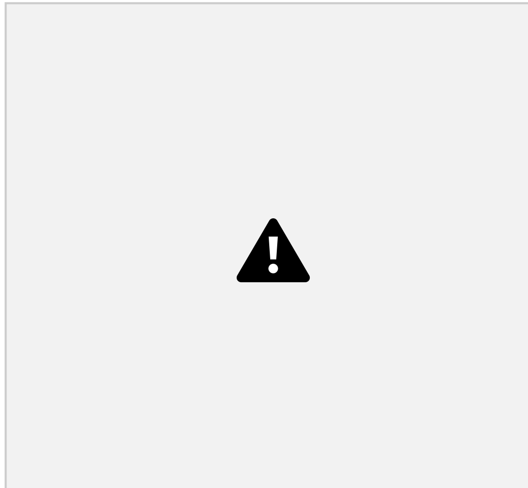

Figure 9-11

Two screws on either side of the tool head cover secure the cover to the tool head.

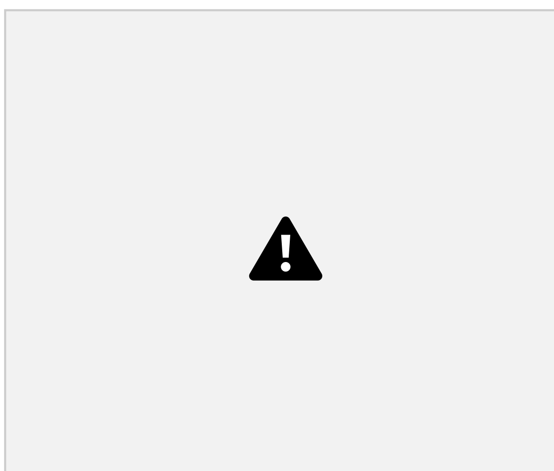

Figure 9-12

The front plate of the tool head is then able to be attached to the tool head cover using 4 more M3 bolts. This cover is responsible for guiding the collected sample to the container and allowing the container orientation to be adjustable.

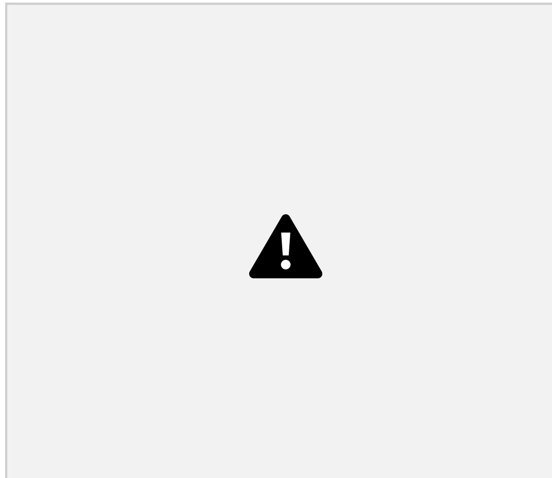

Figure 9-13

The container can now be mounted for sampling by inserting the device through the front.

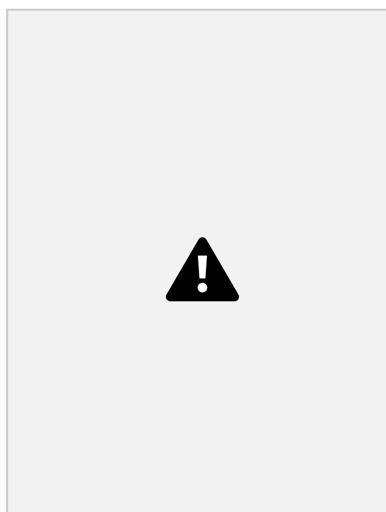

Figure 9-14

40

The cover to allow the container to be mounted for the vertical orientation can be added onto the front of this plate with 4 screws. The opening for the container should be located at the bottom, so that the front of the container is able to collect the falling sample.

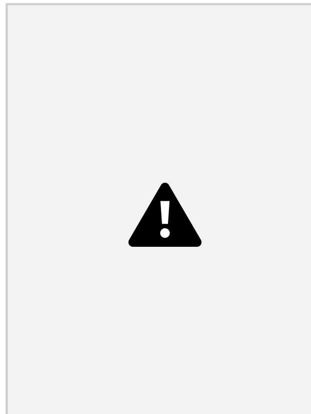

Figure 9-15

On the other side of the chassis the end cap with the failsafe hook can be attached using 8 x M3 bolts. The hook portion uses 2 x M3 bolts on the other side of the white plate to mate the two components.

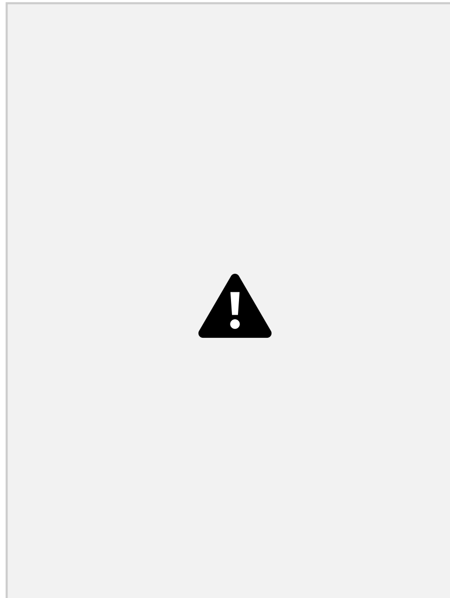

Figure 9-16

Testing & Validation

To validate the operation of the device, testing was conducted on focused and comprehensive LoFi/HiFi prototypes of the different subsystems and the system as a whole.

For the sampling subsystem, we tested sample collection through a sample weight test and a sample obtainment test. For the sample weight test, the load cell prototype (HiFi, focused) was conducted by

For the sample obtainment test, we tested whether the scraper prototype was able to remove material from inside the tube. This was tested by visually inspecting the material collected from the pipe and weighing it. After testing, the scraper bit prototype was able to remove material using light pressure, although the material scraped smaller flakes than anticipated. Since this test was conducted manually, this validated the application of motors as they would have more than enough torque to remove material. The containment system prototype test

Radhe

Explain the tests that were done on the prototype for validation of the final design. Present all of the applicable results that you obtained (i.e. data collected, performance graphs, etc.). List any issues or special requirements for sustained usage. Add pictures to help your explanation.

10 Conclusions and Recommendations for Future Work

If given an opportunity to redesign the device, it would likely be more strategic to design an inner frame rather than working with a shell. This would make it much easier to adjust component placement. This is like how cars are designed, where the frame generally gets engineered first, while the shell is iteratively designed by designers.

A critical failure with the scraping component caused the device to be inoperable on the testing day. The disaster could have been prevented two different ways. The device could have been externally powered, preventing the motor from straining the battery. The tool bit holder also could have been designed with a break point along the same direction as the pipe. It did not need structural reinforcement along this axis, and a break line would allow the failsafe mechanism to work much more effectively.

With a few more months to work on this project, the device would have had the main chassis redesigned to house the battery parallel to the device. The side panel would also open a larger section of the device, allowing easier access to the inner workings. Internal power rails would be integrated into the walls of the shell, making wiring the device significantly easier and not requiring complete disassembly every time it was worked on. The current design also has many unnecessary

components. Parts could be combined, such as the cap for the failsafe. This can be redesigned into one component, however for the initial design process the current solution was much more effective as it allowed for more prototypes to be tested.

The integration of the app was also a strongly desired feature that there was simply no time to develop. Having the device correctly interface with the ESP32 board would have been a very exciting exploration. With the time available the only functions of the ESP32 were to run the motors, measure the load cell, and report back to the operator via Bluetooth on the Arduino IDE.

It is suggested that any future team that takes up this project focuses on consolidating components, reducing screw count, integrating a functional application, and including a break line on the scraping bit holder. Although the BMS is what ultimately failed on the project, it did it’s intended job, and a future group could put time into making this better, but it won’t necessarily result in an improvement. The break line would have prevented the failure just as much as a more expensive BMS would have.

11 Bibliography

Custom circumferential wet scrape tool (CWEST) Design & Supply. (n.d.). *Kinectrics*. Retrieved February 4, 2025, from https://www.kinectrics.com/projects/updated-design-supply-of-a custom-circumferential-wet-scrape-tool

Fuel Channel Inspection & Maintenance. (n.d.). *Kinectrics*. Retrieved February 4th, 2025, from https://www.kinectrics.com/capabilities/products/nuclear-generation-products/fuel channel-inspection-maintenance

Pressure Tube Integrity. (n.d.). *Bruce Power*. Retrieved January 29, 2025, from https://www.brucepower.com/safety-first/pressure-tube-integrity/

Sampling assembly CSA420. (n.d.). *Endress+Hauser*. Retrieved April 4, 2025, from https://www.endress.com/en/field-instruments-overview/liquid-analysis-product overview/sampling-assembly-csa420?t.tabId=product-overview

20G x 1 1/4" BD Closed IV Catheter Nexiva™ Sliding Safety Needle - Each. (n.d.). *MedNeedles.ca.* Retrieved April 4, 2025, from https://medneedles.ca/products/20g-x-1-1-4-bd-closed-iv-catheter-nexiva%E2%84%A2-sliding-safety-needle

each?variant=41349381357761&country=CA&currency=CAD&utm_medium=product_s
y
nc&utm_source=google&utm_content=sag_organic&utm_campaign=sag_organic&gad_s
ource=1&gclid=Cj0KCQjwhr6_BhD4ARIsAH1YdjAYGbp6UG9bbIeggUDAL
v6D0sGTkQeIMNE0MUOjDXhzFLGnCSinGQaAg-bEALw_wcB

Amazon Basics Stainless Steel Drain Snake - Effectively Remove Hair and Debris in Bathroom, Sink, Shower - Each. (n.d.). *Amazon.ca*. Retrieved April 4, 2025, from
https://www.amazon.ca/Amazon-Basics-Stainless
EffectivelyBathroom/dp/B087PYM1HQ/ref=sr_1_1_ffob_sspadib=eyJ2IjoiMSJ9.wpC6xI
wyPhGzfCk75w_LVn6SG894lP6kCKdzeFPoUSEX0z_HLkaoYiNMxlqWhnlru1tRVkWf
i1RHGPtE2EHmK4wmnthLj4ldeEVxc1D2uPRHwenYrJDvdB17WGiIrFPmsVUaaKBB
3

jJIT5NBGKikjCeGpJoYfMo2AzNBTvvYD8g6pMQan_G97LgSj4F945ylgkI0ynaSC6Vpi

dtwOkoPXVLx38ByF4PqaaAfT3BzVRYYvJcrdiPAk8DrqEJrRkQ6NGMJ4gAcRRXq0Sj
xVT6WObYAa4oio4z4wvtObLY.Dz5XYAuzgx2nIw_9hGZMfpJDIeUqFOpVmGLUEr5
UW8&dib_tag=se&keywords=drain+snake&qid=1743810464&sr=8-1-
spons&sp_csd=d2lkZ2V0TmFtZT1zcF9hdGY&psc=1

Insert your list of references here.

APPENDICES

12 APPENDIX I: Design Files

Radhe

Summarize the relationship of this document to other relevant documents. Provide identifying information for all documents used to arrive at and/or referenced within this document (e.g., related and/or companion documents, prerequisite documents, relevant technical documentation, etc.).

Include all design files in MakerRepo.

Also provide the MakerRepo link to your project.

Table 2. Referenced Documents

Document Name	Document Location and/or URL	Issuance Date

13 APPENDIX II: Other Appendices

You can include other critical and important work here. Maybe they are not important in the structure of this document but need to be included.