GNG1103

Design Project User and Product Manual

Radial Telescoping Sampling System (RTSS)

Submitted by:

Radiant Designs, Team 2

Sydney McLean, 300421613

Sylvain Joanis, 300441551

Hodan Said, 300405555

Connor Cole, 300427950

Meltem Selin Cetin, 300435547

April 4, 2025

University of Ottawa

Table of Contents

Table of Contents ii

List of Figures iv

List of Acronyms and Glossary vi

1 Introduction 1

2 Overview 2

2.1 Conventions 5

2.2 Cautions & Warnings 6

3 Getting started 7

3.1 Configuration Considerations 7

3.2 User Access Considerations 7

3.3 Accessing/setting up the System 7

3.4 System Organization & Navigation 10

3.5 Exiting the System 10

4 Using the System 11

4.1 Sample Collection Subsystem (Scraper) 11

4.2 Movement Subsystem (Rod) 11

4.3 Sample Containment Subsystem (Container) 11

4.4 Code Example 12

5 Troubleshooting & Support 13

5.1 Error Messages or Behaviors 13

Special Considerations 14
5.2 Maintenance 14
5.3 Support 15
6 Product Documentation 16
6.1 Movement Subsystem 16
6.1.1 BOM (Bill of Materials) 16
6.1.2 Equipment list 16
6.1.3 Instructions 16
6.2 Sample Collection Subsystem 17
6.2.1 BOM (Bill of Materials) 17
6.2.2 Equipment list 17
6.2.3 Instructions 17
6.3 Sample Containment Subsystem 18
6.3.1 BOM (Bill of Materials) 18
6.3.2 Equipment list 18
6.3.3 Instructions 18
6.4 Testing & Validation 18
7 Conclusions and Recommendations for Future Work 20
8 Bibliography 21
APPENDICES 22
9 APPENDIX I: Design Files (sylvain) 22

List of Figures

Figure 1: Overall view of the motor and gear box, and scraper arm 3

Figure 2: Fish-eye view inside the motor and gear box 3

Figure 3: Back side of motor and gear box 4

Figure 4: Overall view of scraper arm and blade 5

Figure 5: One section of telescoping rod 5

Figure 6: Arduino code 9

Figure 7: Movement subsystem 11

List of Tables

Table 1. Acronyms vi

Table 2. Glossary vi

Table 3. Referenced Documents 22

List of Acronyms and Glossary

Table 1. Acronyms

Acronym	Definition
CANDU Reactor	Canada Deuterium Uranium Reactor
PLA	Polylactic Acid
RTSS	Radial Telescoping Scraper System
UPM	User Product Manual

Table 2. Glossary

Term	Definition
Motor and gear box	Part of RTSS that links the rod to the scraper assembly, and contains motor and gears
Scraper assembly	Most important moving part of RTSS, contains blade and container. This is the part that takes a scrape of the pipe.
Worm gear	Gear with threads instead of teeth, similar to guitar tuning screws

1 Introduction

This UPM provides the information necessary for users, including employees tasked with testing and maintaining the fuel channels in a CANDU reactor to effectively use the RTSS and for prototype documentation. This document outlines the steps taken to develop this design. In order to assist in the maintenance of the CANDU reactors, we were tasked to create a device that had the ability to travel 15ft into a pipe with a 4" diameter and remove a 30-80mg sample. This sample had to be placed in a container that would eliminate all contact between the operator and the radioactive sample obtained by the device as well as have the ability to be removed from the main body of the device. This container holding the sample will be taken to a lab to test Hydrogen levels within the pipe.

This document outlines each aspect of the design and any safety precautions that should be taken by the user. It goes through the materials and parts required to construct our device along with the overall operation of the device. The manual includes an overview of the system, an outline of the system operations, troubleshooting and support resources, documentation created during the design of the device, as well as lessons learned throughout the process and recommendations for future work.

2 Overview

At the core of the CANDU nuclear reactor, there is a very powerful reaction involving uranium and deuterium. This reaction occurs at very high pressure, which is contained inside the pressure tubes of the reactor. An average reactor has a few hundred such tubes.

These pressure tubes cannot be allowed to fail. If they do, the entire reactor will melt down, leading to a huge catastrophe. Unfortunately, as they get used, the metal of the tubes becomes contaminated with deuterium, and once a certain concentration of deuterium is reached, the tube is no longer safe to use, and must be replaced. The challenge we are faced with is the following: How will we know when that threshold is reached? The only known way to determine the deuterium concentration of the metal is to take a sample of that metal to a specific lab, where it can be tested. So, the problem we are looking to solve is that we need to collect a sample of the metal, 15 feet down the pipe, without removing or damaging the pipe. That pipe could be either vertical or horizontal, and is highly radioactive.

In order to safely get a good sample, the user needs a device that is easily portable and fail safe, that will take a sample from 15 feet down the pipe and place it into a removable container that will isolate it from the user. The client has also requested that the device be reusable, and that it not require any external power sources other than a standard 120V power outlet.

Our product allows users to collect a sample, 30 to 80 mg is size, of the pipe, at a depth of 15 feet. It takes a radial scrape, ensuring an even sample collection, and provides live feedback to the user, since it is fully manual. Our tool, when collapsed, can be stored and carried in a small backpack, and costs under $50 to produce. It is also very versatile: if a different size of pipe is to be scraped, the length of the scraper arm can be adjusted; if a different material is to be sampled, the blade can be changed; if a different sample size is to be collected, the number of revolutions of the scraper arm can be changed in the Arduino code; etc.

The device consists of a 15-foot collapsible rod, at the end of which is a 3D printed motor and gear box. Attached to the gear box is the scraper arm, which has a blade at the end of it. The arm has a wheel at the back of it, which puts pressure on the blade, ensuring we get a good scrape. The motor is controlled by an Arduino board which is connected to a computer, at the outlet of the pipe. A 15-foot cable connects the Arduino to the motor, and a 15-foot rope gives the user a backup retrieval system in case the rod fails. To better visualise this, see the pictures on the next few pages.

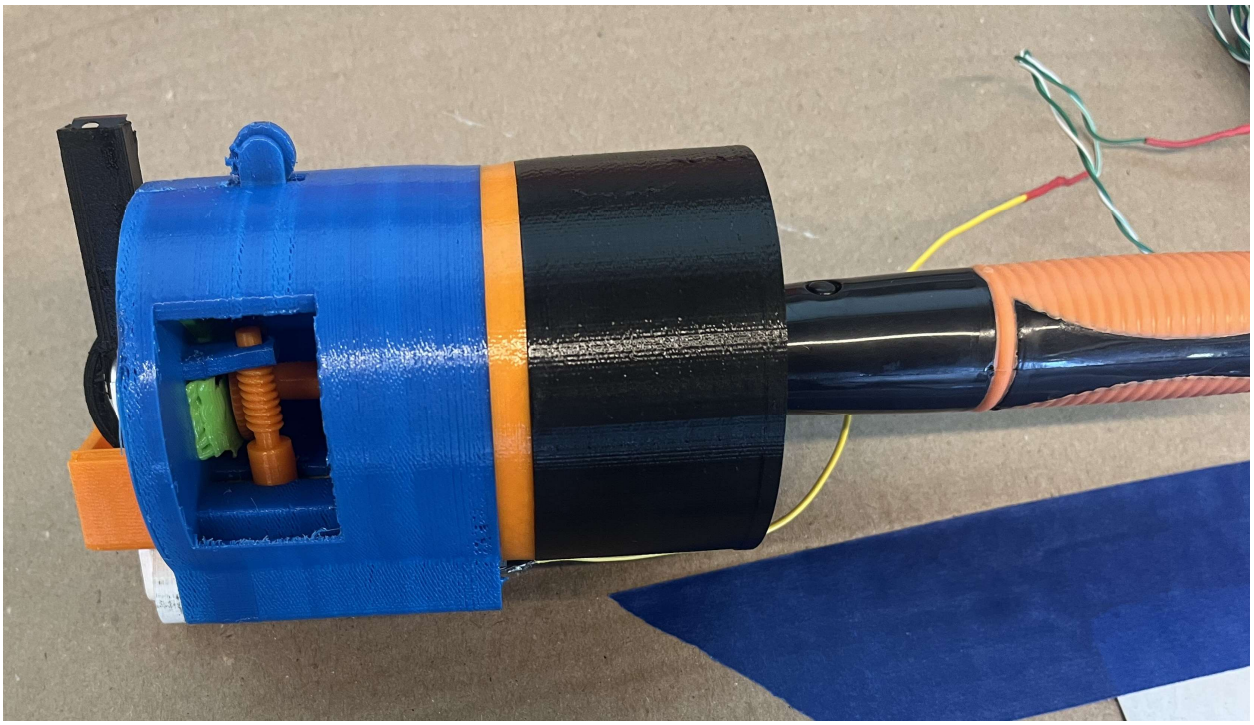

Figure 1: Overall view of the motor and gear box, and scraper arm

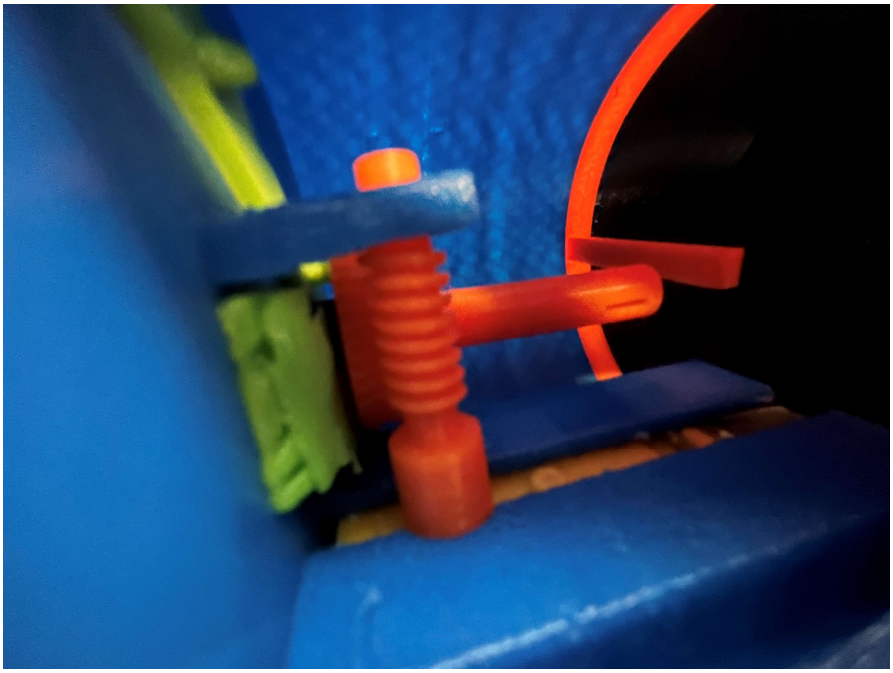

Figure 2: Fish-eye view inside the motor and gear box

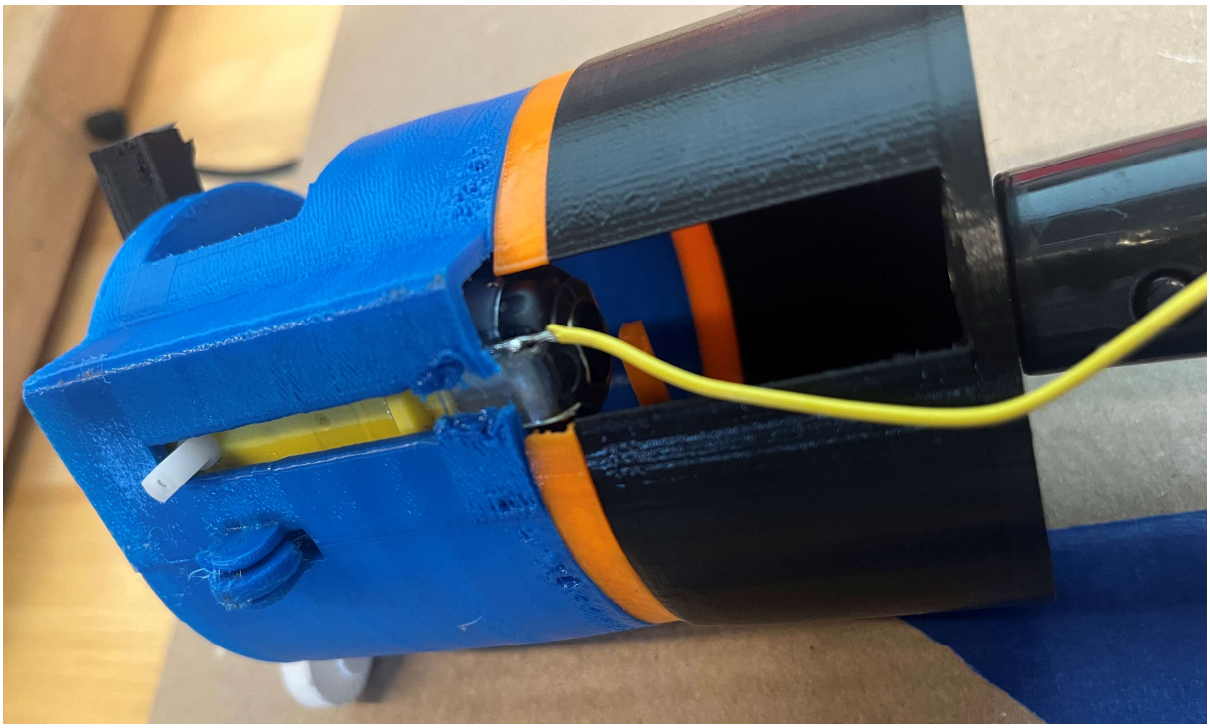

Figure 3: Back side of motor and gear box

Figure 4: Overall view of scraper arm and blade

Figure 5: One section of telescoping rod

To operate the device, a user must simply run the Arduino code and follow the onscreen instructions. The first step will be to insert the gearbox into the pipe with one section of the rod attached, and then push it in, adding more sections of rod until they are all in the pipe. At that point, the user must confirm to the software that the device is inserted, and the motor will be started to collect a sample and close the container. Once this is complete, the user will be prompted to remove the device from the pipe, and the sampling is complete.

2.1 Conventions

When the user must perform an action, it is indicated by a line beginning with the word ‘Action’.

When the system will give feedback to the user, it is indicated by a line beginning with the word ‘Output’.

When the system prompts the user to do an action, it is indicated by a line beginning with the word ‘Prompt’.

When additional information relevant to the subsection of the document is provided, it is indicated by ‘*Note’.

2.2 Cautions & Warnings

This device contains a sharp blade that is able to scrape a metal pipe. When manipulating the tool, always beware of this to avoid cutting yourself or anyone else around.

Anytime the rod is extended and not inside the pipe, it is also a hazard. Never be careless or play with the rod, as it could hit someone, causing an injury.

3 Getting started

This section provides a general walkthrough of the system from setup through exit. The steps are organized in a logical order to guide the user through the full sampling process and flow of the system. The use of images ensures that anyone can easily follow these instructions.

3.1 Configuration Considerations

For the physical prototype: The device should be used in a dry environment, on a stable and secure surface, like a table at room temperature. The main components include the 15-foot rod, motor and gearbox, cable, scraper arm, and the sample collection container. In terms of connections, the 3D printed motor and gear box are connected to the end of the 15-foot rod. Refer to ***Figure 1*** for the overall view of the motor and gear box connection to the rod. No external power source is required, as the device is powered through the 120 V outlet from the computer connection.

For the software: Like the physical prototype, the device should be used in a dry environment, on a stable and secure surface, like a table at room temperature. The main components include the Arduino IDE software, Arduino board and a computer. In terms of connections, the Arduino board is connected to a computer at the outlet of the pipe and the 15-foot cable connects the Arduino to the motor. Additionally, the user will need to install the Arduino IDE software on their computer. It is compatible with both Windows and Mac.

3.2 User Access Considerations

The primary user group consists of the operator of the device. The user will be the one to physically operate the system, by inserting and retracting the scraper arm into the pipe and controlling the motor using the Arduino. This specific group requires some restrictions regarding age, knowledge, and health. The operator needs to be trained or familiar in the safe operation of the device in case of high-radiation environments. If the device is operated in these conditions, then they must also wear proper safety gear, like protective gloves and suits. The user must also be familiar with the functions of the device to safely operate the system. Finally, the user must be at least 17+, seeing that there are components, like the blade, that should not be handled by younger individuals.

3.3 Accessing/setting up the System

For the physical prototype: To set up the system, gather each component of the main subsystems. Make sure that they are all in good condition. Start by connecting the individual sections of the rod until it reaches 15 ft. Refer to ***Figure 5*** to see the section of rod. Next, put the gear box into the pipe, and push it down until the entire rod is in the pipe. Once this step is

completed, you will need to run the Arduino code. The system will seek confirmation that the device has been inserted and then will start scraping and collecting the sample.

For the software: To set up the system, you will need to download and install the Arduino IDE app on your computer. Then, launch the application and connect the Arduino board to your computer using a USB cable. You will need to select the Arduino Uno as the board. Finally, you will need to upload the code shown below to start the system.

```
#include "AFMotor.h"

AF_DCMotor motor(3);


String userInput = "";
bool pipeInserted = false;
bool motorRunning = false;
bool retractionPhase = false;
int motorDirection = FORWARD;

void setup() {
  Serial.begin(9600);
  Serial.println("Insert the pipe and type 'yes' to continue.");
}

void loop() {
  if (Serial.available()) {
    userInput = Serial.readStringUntil('\n');
    userInput.trim();
    userInput.toLowerCase();


    if (!pipeInserted) {
      if (userInput == "yes") {
        pipeInserted = true;
        Serial.println("Pipe detected. Type 'yes' to run motors or 'no' to skip.");
      } else {
        Serial.println("Waiting for pipe to be inserted. Type 'yes' when ready.");
      }
    }


    else if (pipeInserted && !motorRunning && !retractionPhase) {
      if (userInput == "yes") {
        motorRunning = true;
        Serial.println("Motors running. Type 'forward' or 'backward' to control direction, 'stop' or 'no' to stop.");
        motor.setSpeed(200);
        motorDirection = FORWARD;
        motor.run(motorDirection);
      } else if (userInput == "no") {
        Serial.println("Motors skipped. Type 'yes' to start retraction.");
        retractionPhase = true;
      } else {
        Serial.println("Please type 'yes' to run motors or 'no' to skip.");
      }
    }


    else if (pipeInserted && (motorRunning || retractionPhase)) {
      if (userInput == "yes") {
        motorRunning = true;
        motor.run(motorDirection);
        Serial.println("Motors running.");
      }

      else if (userInput == "no" || userInput == "stop") {
        motorRunning = false;
        motor.run(RELEASE);
        Serial.println("Motors stopped. Type 'yes' to start again or 'forward/backward' to change direction.");
        retractionPhase = true;
      }

      else if (userInput == "forward") {
        motorDirection = FORWARD;
        if (motorRunning) {
          motor.run(FORWARD);
        }
        Serial.println("Direction set to forward.");
      }

      else if (userInput == "backward") {
        motorDirection = BACKWARD;
        if (motorRunning) {
          motor.run(BACKWARD);
        }
        Serial.println("Direction set to backward.");
      }

      else if (userInput == "done") {
        motorRunning = false;
        motor.run(RELEASE);
        Serial.println("Container is closed. Take the sample and the scraper.");
      }

      else {
        Serial.println("Unknown command. Use 'yes', 'no', 'forward', 'backward', or 'done'.");
      }
    }

    else {
      Serial.println("Invalid input or process already completed.");
    }

    userInput = "";
}
  }
```

Figure 6: Arduino code

3.4 System Organization & Navigation

For the physical prototype: The device is made of three main subsystems. The first is the movement system, which consists of a 15-foot collapsible rod. At the end of the rod, there is a 3D printed motor and gear box. The second subsystem is the sample collection. It contains a scraper arm that is connected to the gear box, along with a blade at the end of it. On the arm is a wheel, which is used to ensure that pressure is applied to the blade to achieve a 30 to 80 mg sample of metal. Refer to ***Figure 4*** for the overall view of the scraper arm and blade. Included is a motor that is controlled by an Arduino board, that is connected to a computer. Additionally, a 15-foot cable allows the connection of the Arduino to the motor. The last subsystem is the containment of the sample. Once the sample has been collected, the 3D printed container will rotate closed with the help of the motor. During the whole process, the Arduino will run a code which will provide instructions and status updates to the user throughout the collection. Once the process is complete, the user will remove the device from the pipe and obtain the sample.

For the software: The code will be displayed when the software is opened. The code will direct the user to insert the pipe. When they have completed the task, they must type ‘yes’ to continue. The system will print confirmation that the pipe was inserted and ask the user to reply ‘yes’ to run the motors. The motor will not run if the system does not receive confirmation that the pipe has been inserted. A message will appear that the motors are running. The system will then ask the user to type either ‘forward’ or ‘backward’ to control the direction of rotation. The blade will scrape the pipe and collect a sample. The sample will fall into the container and will rotate closed. The user will be prompted to type ‘stop’ or ‘no’ to stop the motors from running. A message will print that the motors have stopped running. Once the sample is collected, the system will print a message that the container has been closed. After obtaining a scrape of the metal, the system will ask the user if they would like to start retracting the pipe along with the sample. The user will need to type ‘yes’ to start the retraction. Refer to ***Figure 6*** for a visual representation of the code.

3.5 Exiting the System

For the physical prototype: Once the sample has been collected, carefully retract the rod by removing the connected sections of rod out of the pipe. Collapse the rod into its smaller, individual sections. Ensure the scraper arm and motor are properly secured to avoid any potential damage. If needed, clean the scraper arm to ensure that it is free of any loose sample or contamination. Store the device for future use.

For the software prototype: Close the software to end the process. Disconnect the Arduino from the computer and remove the USB cable. Store the Arduino board for future use.

4 Using the System

The following sections provide detailed step-by-step instructions on how to use the various functions and features of the RTSS.

4.1 Sample Collection Subsystem (Scraper)

The scraper mechanism is driven by a motor, which is controlled by an Arduino microcontroller. The Arduino is connected to a computer, which serves both as the interface for running the control code and as the power source via a USB connection. The operation process is user-friendly and guided entirely through serial prompts in the Arduino software.

Upon initiating the system, the code prompts the user to confirm whether the scraper has been inserted into the pipe. The user must type “yes” to proceed. Following confirmation, the program will ask whether the user would like to start the motor; a second “yes” will activate the scraper. The system then prompts the user to choose the motor direction by entering either “forward” or “backward”. Depending on the input, the scraper will start turning in the specified direction.

While the scraper turns, the blade at the end of the scraper will start cutting the interior surface of the pipe, collecting a radial metal sample. To stop the motor, the user simply types “no” or “stop” when prompted, at which point the motor ceases operation.

4.2 Movement Subsystem (Rod)

The movement subsystem is based on a telescoping rod composed of multiple connected segments. These segments thread together, enabling the device to extend up to 15 feet. In order to add one of the segments to the next, the user must put the ends together and turn them until they fit together. When the first two pieces are connected, it is safe to add the others until the desired length is reached. Ensure the rod segments are fully aligned before tightening; misalignment might cause some damage that will impact the overall function of the device. This modular design ensures the system remains compact, lightweight, and easily portable.

Figure 7: Movement subsystem

4.3 Sample Containment Subsystem (Container)

After the sample is collected by the scraper, the system prompts the user to initiate the containment process. This involves the motor again, controlled via the Arduino, which activates the container’s closing mechanism. The user will again be prompted to type “yes” to activate the

motor and “no” or “stop” to terminate the process once the container has securely sealed the sample. At the end, the user types “done” to make sure the code is finished with their feedback, the code will give the output that the sample is in the container and the container is closed so we can take the sample. This ensures the safe isolation of the radioactive material from the operator and the environment.

4.4 Code Example

Here is an example on how the code works and in which way the user should give input:
Prompt:

```
Insert the pipe and type 'yes' to continue
```

Action: yes
Prompt:

```
Pipe detected. Type 'yes' to run motors or 'no' to skip.
```

Action: yes

```
"Motors running. Type 'forward' or 'backward' to control direction, 'stop' or 'no' to stop."
```

(The motor won’t start running until the user types forward or backward)
Action: forward

Output:

```
Direction set to forward
Motor running
```

Action: No (in order to stop the motors)
Prompt:

```
Motors stopped. Type 'yes' to start again or 'forward/backward' to change direction.
```

Action: done (ending the code)

```
Container is closed. Take the sample and the scraper.
```

5 Troubleshooting & Support

This section covers when the device encounters an error and diagnosing the issue the device may have. This will rank the steps we recommend you follow when the device is not working to the best of its ability or when it isn't working at all.

1. The first step is to check the Arduino power supply, as sometimes wires may become loose or connections may not be made as intended. Ensure that the motor and wires attached are all connected and in the correct ports. Also check your computer to see if you have the correct Arduino libraries installed and if it has enough power to run the motor.
2. If that doesn't seem to work you can reset the Arduino by unplugging the power cable for 10 seconds and plugging it back in. Sometimes the Arduino board has trouble receiving the code from the computer so a simple reset and recompilation of the code may resolve the problem.
3. Check to see if all the rod segments are secure and stable. When assembling the pieces of rod you shouldn't have to jam them together as they slide in nicely then you screw them on. Make sure the rod is fully inserted and that it hasn't gotten stuck.

These are the basic fixes to the most common issues, but we will go into further detail of these and list more if you still cannot figure out why the device isn't working

5.1 Error Messages or Behaviors

Issue 1: The blade on the end of the rod to scrape sample isn't spinning at all or is not spinning fast enough. This can happen for many reasons, but common ones are faulty wiring, motor failure, and Arduino-related issues.

1. Check the motor connections to the Arduino, make sure the cables aren't twisted in the pipe.
2. Confirm that the command you are inputting into the Arduino does exist in that Arduino library.
3. In your Arduino code, make sure you have max power, ensuring the blade spins at the ideal torque setting.
4. If the problem persists, restart your device as well as the Arduino

Issue 2: The blade is working properly but the sample isn't falling in container. This can happen for many reasons but the most common are dull blades, containers not aligned with the chute, jammed containers, and debris blocking the sample.

1. Ensure that the container is aligned under the scraper, so that the sample you are collecting falls into it.
2. Check for debris or any parts that may seem broken

3. The container can get jammed which leads it to being stuck shut and no sample. If that occurs look into the container and see what's stuck on and apply WD-40 so it helps ease the rotation of the container.

Issue 3: The rod extensions aren't staying together or are getting stuck in the pipe. This can happen because of debris in the pipe, a scraper arm malfunction, or broken rod attachments

1. Check for debris in the pipe and between sections of the rod, foreign objects can make the attachments less secure.
2. Remove the device from the pipe, take apart the rod and carefully put it back together, ensuring proper attachment.
3. Check the scraper assembly to make sure the spring is compressing properly and the wheels are turning smoothly.
4. If the device gets stuck, change the angle of force. You may just be caught on a screw. If anything ever feels unsafe, pull on the rope. It is the fail-safe, and is designed to remove the device in case of failure.
5. If the rod still can't be assembled, you may be dealing with a mechanical failure. Consult the bill of materials to find a replacement part, and replace the faulty rod segments.

Special Considerations

When troubleshooting this device, there are a few important things to consider before you start. The first is that you are working in a high radiation environment. Ensure you are wearing proper protective equipment at all times.

If you need to repair the motor and gear box, you will need a heat gun to separate the parts. Simply heat the joint where they were assembled, and they should come apart easily. Avoid doing this too often, since there is a limited number of times you can do this before losing integrity of the materials.

When repairing the device, do it in a controlled, radiation free environment. When testing, use a pipe that is not radioactive, to avoid unneeded exposure to radiation.

If the device ever gets stuck, never reach your hand into the pipe. If needed, use the rope to pull it out safely and slowly.

5.2 Maintenance

Performing regular maintenance on this device is crucial as it will guarantee it functions optimally for years to come. Without maintenance, issues will be much more common, and the lifespan of the device will be significantly reduced. To guarantee optimal function, follow these checklists before and after use, and every month the device is used.

Before Use:

- Make sure each wire to the Arduino is connected and that the wire isn't tangled
- Ensure the blade is sharp and secure
- Secure each extension so that it is snug
- Check for debris that could block any function of the device

After Use:

- Clean the blade and wheels, and remove any debris in the device
- Put pieces of rod in a secure place
- Ensure the container is properly sealed

Monthly maintenance:

- Change the blade if needed
- Ensure the motor runs at full speed
- Inspect the rod for any broken attachments or other issues

5.3 Support

If you require additional help or emergency assistance, contact any of the following people:

Sylvain Joanis (sjoan056@uottawa.ca)– Physics and Electrical Engineering student
Sydney Mclean (smcle018@uottawa.ca)– Civil Engineering student
Hodan Said (hsaid060@uottawa.ca)– Civil Engineering student
Connor Cole (ccole055@uottawa.ca)– Electrical Engineering student
Meltem Selin Cetin (mceti052@uottawa.ca)– Physics and Electrical Engineering student

Emergency/Security Handling:

- If you feel you have been in direct contact with radiation, seek help from medical staff
- Only allow certified operators to use, failure to do so may result in serious injuries
- If electronics fail while the device is inside, manually use the failsafe to safely remove the rod

For troubleshooting errors, refer to 5.1 for handling.

6 Product Documentation

This section contains a detailed description of the final prototype's construction, underlining critical design considerations and material choices. It is divided into the device's three subsystems: movement, sample collection, and containment. This section includes the materials used and the cost of each subsystem, as well as the tests conducted and testing results. Additionally, instructions and relevant information of the construction of the system has been included.

6.1 Movement Subsystem

6.1.1 BOM (Bill of Materials)

Material	Cost	Amount	Total	Location	Link
Extendable Rod	$25.99	1	$29.37	Amazon	Extendable Rod
Arduino Microcontroller	$15.25	1	$15.25	MakerRepo	Arduino Microcontroller
TOTAL	$44.62				

6.1.2 Equipment list

- Computer (Or any device that can access and run the code)
- Code
- Screwdriver
- Soldering iron

6.1.3 Instructions

1. Purchase extendable rod from Amazon.
2. Attach individual parts together to reach a distance of 15 ft.
3. Attach the 3D printed motor and gear box, following the dimensions of the CAD model, at the end of the rod.
4. Connect the 15-foot cable from the Arduino to the motor.
5. Download the code from MakerRepo to confirm the insertion of the rod using the Arduino IDE.
6. Connect the Arduino to the computer, click on the compile and upload button in the Arduino IDE.
7. Run the code to confirm that the rod has been detected in the pipe.

6.2 Sample Collection Subsystem

6.2.1 BOM (Bill of Materials)

Material	Cost	Amount	Total	Location	Link
PLA	$0.00	120 g	$0.00	MakerSpace	PLA
DC Motor	$0.00	1	$0.00	MakerLab	DC Motor
Exacto Blade	$2.50	1	$2.83	Dollarama	Exacto Blade
Cable	$5.00	1	$5.00	MakerRepo	Cable
Arduino Microcontroller	$15.25	1	$15.25	MakerRepo	Arduino Microcontroller
TOTAL	$23.08				

*Note: 120 g of PLA and one Arduino Microcontroller is needed for the entire prototype.

6.2.2 Equipment list

- Computer (Any device that can access and run the code)
- Code
- Soldering iron
- Screwdriver
- Heat gun

6.2.3 Instructions

1. 3D print the scraper arm by following the dimensions in the CAD model.
2. Place the blade in the designated opening of the scraper arm.
3. Connect the 15-foot cable from the Arduino to the motor.
4. Download the code from MakerRepo to rotate the motor using the Arduino IDE.
5. Connect the Arduino to the computer, click on the compile and upload button in the Arduino IDE.
6. Run the code to rotate the motor and obtain a sample of the pipe's metal.

6.3 Sample Containment Subsystem

6.3.1 BOM (Bill of Materials)

Material	Cost	Amount	Total	Location	Link
PLA	$0.00	120 g	$0.00	MakerSpace	PLA
DC Motor	$0.00	1	$0.00	MakerLab	DC Motor
Cable	$5.00	1	$5.00	MakerRepo	Cable
Arduino Microcontroller	$15.25	1	$15.25	MakerRepo	Arduino Microcontroller
TOTAL	$20.25				

6.3.2 Equipment list

- Computer (Any device that can access and run the code)
- Code
- Soldering iron
- Screwdriver

6.3.3 Instructions

1. 3D print the container by following the dimensions in the CAD model.
2. Insert the container at the bottom of the scraper arm.
3. Connect the 15-foot cable from the Arduino to the motor.
4. Download the code from MakerRepo to close the container using the Arduino IDE.
5. Connect the Arduino to the computer, click on the compile and upload button in the Arduino IDE.
6. Run the code to start the motor in order to close the container.

6.4 Testing & Validation

Test	Objective	Test Method	Results
Cohesion of all parts of the prototype	To determine if all the parts fit together and if the subsystems function as expected	Assembling each part of the subsystem and seeing if they all fit together.	Each part is able to be connected and all the subsystems
Force applied to the blade	To determine the force needed for the blade to scrape the pipe without breaking or dulling	Scraping the inside of the pipe using different amounts of force applied to the blade	The blade needed a significant amount of force to obtain a sample

Sample size	To determine if the correct sample size is collected	Scraping the inside of the pipe and weighing the sample to see if it satisfies the 30 to 80 mg requirement	The correct sample size was obtained after a scrape using the Exacto blade
Rotation of the wheel	To determine if the wheel can freely rotate in its axle	Rotating the wheel in both directions and see if it is able to turn freely	The wheel was able to rotate in both directions and turns freely
Effectiveness of the code	To determine if the code is able to direct the motors and the provide user feedback effectively	Running the code and troubleshooting for any issues that might occur during the operation	The code was able to successfully direct the motors and give feedback to the user during the operation
Overall functionality	To determine if all the components are able to work together to follow the requirements.	Testing the entire design by running the code and attempting to retrieve a sample	The design was able to complete some parts of the requirements but not all, as the sample requirement was not fulfilled

7 Conclusions and Recommendations for Future Work

Throughout this project, we learned many lessons, both about the overall design process and how to effectively manage a project of this sort. The lessons learned throughout this project range from the importance of effective communication and time management to learning a number of new techniques to be used during 3D printing.

In the non-technical aspect of this project, we quickly discovered the importance of effective communication between team members. Without this constant flow, tasks face the risk if not being completed efficiently and effectively. In addition to this, remaining flexible throughout the project will contribute to a welcoming, inclusive, and productive atmosphere. This mindset allows all conflict to be dealt with in a constructive manner. After this project reached its completion and was reflected upon, we determined that beginning the prototyping stage of this process earlier would have been greatly beneficial and could have led to a more functional final prototype.

While developing the device and its design, we also learned many technical lessons ranging from how to create an effective 3D printed part to determining the best way to piece together a final prototype. Throughout the construction of all prototypes, we faced many issues. One issue we faced was using the correct motor. Initially, we planned on using a direct drive motor, however, this did not provide the required torque. This led us to the decision to use a geared motor instead. In addition to this, choosing the proper wires to power and connect the motor to the Arduino board is incredibly important. The wires that we chose to use had too much resistance and did not allow the motor to run at its full capacity. If this project were to be replicated, the use of higher gauge wires would be recommended. While generating designs and CAD renderings of the wheel component of the device, we quickly realized that there was a need to adjust its manufacturing process. We determined that in order for it to properly function, a smaller and more precise printer nozzle was needed and the proper supports needed to be inserted. Overall, we learned the importance of selecting the correct materials to ensure the overall strength and functionality of the device.

For future work to this project, we would recommend looking into more effective electrical materials to allow the device to operate at its full capacity. Specifically, determining the most effective wiring would greatly improve the operation of the sampling system. In addition to this, finding a better material for the blade would allow the device to consistently take a sample from the pipe. The design and construction process could also be improved upon by more thorough testing. These tests would allow all target specifications to be met.

8 Bibliography

Adafruit. (2018, December 20). *Adafruit Motor Shield Library.* Retrieved from Github: https://github.com/adafruit/Adafruit-Motor-Shield-library

Kinetrics. (n.d.). *Custom Circumferential Wet Scrape Tool (CWEST*) Design & Supply*. Retrieved from Kinetrics: https://www.kinectrics.com/projects/updated-design-supply-of-a-custom-circumferential-wet-scrape-tool

Read, S. (2025, January 22). Client Meeting 1. (D. Knox, Interviewer)

Read, S. (2025, January 25). *Client meeting 1 presentation.* Retrieved from uOttawa Brightspace: uottawa.brightspace.com

APPENDICES

9 APPENDIX I: Design Files

Table 3. Referenced Documents

Document Name	Description	Document Location and/or URL	Issuance Date
AFMotor.h	Arduino library used for the code	https://github.com/adafruit/Adafruit-Motor-Shield-library	2014-02-01
MotorAndGearBox.stl	CAD rendering of the motor and gear box, and scraper arm	Makerepo https://makerepo.com/smcle018/2435.gng1103fpipe-scraper	2025-04-04
ScraperCode.ino	Arduino code	https://makerepo.com/smcle018/2435.gng1103fpipe-scraper	2025-04-04