# A Design and Development of a Metal Sampling Device for Nuclear Pressure Tubes


Wade Stanley, Jacob Thom, Samuel Cadotte, Ethan Zhang, Ramya Patel


January 26th, 2025


University of Ottawa

**Abstract**

*Efficiently maintaining nuclear reactors is crucial to ensuring optimal performance and safety in the nuclear power industry. This project involves designing a tool that will be used to collect metal samples from fuel channels in CANDU reactors. This tool must be able to extract samples from deep within 4 inch wide horizontal or vertical tubes while ensuring minimal user exposure to radiation and no direct contact with the samples. This document explores different user needs, benchmarks similar existing designs, and proposes some design solutions to meet the client's demands.*

# Table of Contents



Table of Contents, List of Figures, List of Tables: All tables and figures should be important enough to be referenced in the text of the document, otherwise they should be excluded. Microsoft Word has features to automatically generate tables of contents, lists of figures, and lists of tables. Citations should be provided where appropriate and properly linked to the bibliography. Again, Microsoft Word has a feature for this, but standalone systems such as Zotero or Mendeley work well too.

# 1 Introduction

The integrity of pressure tubes within nuclear reactors are essential to ensure that there are no catastrophic failures. Over time, these tubes degrade due to hydrogen build up from the “heavy water” used within the reactors. Our problem/task is to design a device that safely extracts metal samples from said tubes to allow them to be tested for hydrogen build up. There are existing solutions but CNL is looking for a more efficient and easy to use device. By benchmarking current designs and possibly innovating new improvements, our solution will ensure easy extraction of samples to raise safety within nuclear power plants.

# 2 Research and Analysis

## 2.1 User Needs and Requirements

For this project the primary customer is Scott Read who is an engineer currently working for CNL (Canadian Nuclear Laboratories). The customer requires us to design a device to obtain a metal sample from the inside of a tube 4.572 m (15 ft) from the tube inlet. The tube has an inside diameter of 101.6 mm (4 inches) and the tube could be positioned either horizontally or vertically. Diving into the specifics of the users requirements our device must have a suitable container to hold the sample and ensure that the operator doesn't have to make direct contact with the sample. The retrieved sample must also fall into the requirement of being between 30 and 80 mg in weight meaning our device has to have some sort of way to measure this out. The tool has to give feedback to the operator to confirm when the process is achieved, and the tool has to be fail safe designed meaning all the equipment can be removed from the tube if an emergency occurs. For this design challenge in particular there is no problem with leaving the tube damaged, however the designed tool must be reusable.

## 2.2 Problem Statement

A statement of the problem and any required justification for that problem statement.
The problem in this challenge is that companies in the nuclear sector encounter many different roadblocks when attempting to obtain samples of metal from reactor tubes for analysis. Without a purpose-built device to retrieve samples from the reactor tube, current sampling methods would require a disassembly of the tubes and are highly reactive which cause severe safety risks and incur longer downtimes for maintenance. Another important factor in this problem is reliability of the samples collected which can be varied when a technician does this task since they would wear protective gear causing reduced mobility and precision. A solution which allows the technician to be in a safe area and manipulate a machine would provide more accurate assessments of the reactor tubes, and thus, the reactor itself. Having accurate data on the reactor improves the overall safety of the system as well.

# 3 Design Solution

## 3.1 Dual Component System

Our first design solution we generated is the dual component system. This is a complex system relying on various parts including a “Plug” for the end  of the tube, as well as a “vehicle” that will be responsible for traveling in and along the tube. The vehicle will have wheels or some form of sliding mechanism in many orientations which will allow for full mobility within the tube itself, and allow for the vehicle to stay centered while it's moving. The core purpose of the plug will be to connect to the vehicle with a wire, which is ideal as it removes the need for a battery in the vehicle and not having radio signals since the tube is made of metal. On top of this purpose, the plug will also be used as a fail mechanism as if in the unfortunate event the vehicle/tool breaks down the plug wire can be used to pull the vehicle back and make sure it gets out of the tube. This design will allow for two vehicles to be plugged in to the end of the wire for either vertical or horizontal configuration. In terms of some form of monitoring system for what's going on inside the tube is to add a camera with light to the vehicle so that the operator can see inside of the tube while the process is being carried through.

### 3.2 Heat and Light Detection System

Our second design solution involves a heat and/or light detection system. This system is designed to detect changes in temperature of light levels to confirm if a sample has been collected by the tool. This would involve incorporating a heat and light sensor into the sampling component of the design. Should the sample be obtained by scraping, this system will detect any heat or light generated by sparks during the collection process. This detection system will provide real-time feedback to the operator, and can be combined with other feedback systems to help confirm the presence of a sample.

### 3.3 Design Criteria

| Design Criteria | Description | Priority |
|---|---|---|
| Sampling Distance | Ability to obtain samples inside a tube 15 feet from the inlet | 5 |
| Tube Diameter | Designed to fit within specification of 4 inch diameter tube and can account for variability due to buildup of material | 5 |
| Tube Orientation | Design should work in both vertical and horizontal placement of tube | 5 |
| Sample Size | Design is able to collect consistent sample of between 30-80mg | 5 |
| Fail-Safe System | Incorporates retrieval of design without disassembly of tube in case of critical failure | 4 |
| Real-Time Updates | Design can communicate status of sample collection process to operator | 4 |
| Modular/Portable System | Design can easily be broken down for | 3 |

| | | |
|---|---|---|
| | repair/transport | |
| Ease of use | Can be operated with little knowledge of intricate details of design | 2 |
| Containment of Sample | Design seals or contains samples so that the operator does not have to interact with the sample | 3 |
| Power system | Design integrates its own power system to not require external power (120v) during operation | 2 |
| Durability | Design can account for environment and sustain operation for many cycles before maintenance is required | 2 |

### 3.4 Selected Design Solutions and Justifications

After analyzing the requirements and constraints of the project, we carefully evaluated both considered design solutions: the Dual Component System and the Heat and Light Detection System. Each solution was assessed based on its ability to meet the design criteria consisting of sampling distance, tube orientation, reliable functionality, and ease of use. The Dual Component System offers a powerful and flexible approach with its vehicle and plug mechanism. It ensures reliable operation in both horizontal and vertical orientations while providing a fail-safe retrieval mechanism through the wired connection. Moreover, this system allows real-time monitoring via a camera and light, enabling the operator to observe the sampling process and ensure precision. The Heat and Light Detection System offers an innovative feedback mechanism to detect the presence of a sample by monitoring heat or light changes during the process. This solution emphasizes real-time operator feedback, which enhances the system's reliability and error reduction. However, both designs have strengths, but our decision would depend on further detailed research to validate their effectiveness under different circumstances.

## 4 Conclusions and Recommendations

Initially, during the process of developing these design solutions, we identified the key challenges involved in creating a safe and efficient sampling device. Both solutions address the critical need for accurate sample collection while minimizing safety risks for operators. Both the systems meet the project's key requirements such as operator safety, Precision and reliability. However, in future our focus should be on improving the designs to enhance durability and adaptability to different tube orientations. Additionally, exploring the integration of features from both the systems. For example combining the fail-safe wired retrieval mechanism with heat and light detection feedback. This can lead to a more effective solution. By prioritizing these improvements, the final design can ensure safety, reliability, and efficiency, hence meeting the standards in the nuclear industry.

# 5 Bibliography

Bibliography: We benchmarked off other solutions like the kinectrics CWEST (Custom Circumferential Wet Scrape Tool (CWEST) Design &… | Kinectrics) solution and also gained much information from Scott Read (scott.read@cnl.ca) during his presentation.