

# Sampling Tool for High-Risk Nuclear Environments

CNL x uOttawa Design Challenge Report

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## Abstract

This report describes the design and development of a modular sampling tool for Canadian Nuclear Laboratories. The tool is expected to extract precise samples of metals from tubes under a high-radiation environment, within strict bounds of safety and operational protocols. The approach in the design shall be customer-oriented, with emphasis on easy mobility, reliability, and operator safety. Most of the challenges in the process involve environmental factors, material compatibility, and feedback mechanisms. The proposed design will conform to the necessary standards of industry regulation and requirements of operation and presents an innovative solution for fail-safe operation.

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# 1. Introduction

## 1.1 Background

Canadian Nuclear Laboratories is home to Canada's largest nuclear research facilities, working in the areas of clean energy, environmental remediation, and medical isotopes. Among its core objectives is the development of specialized tools to enhance operational safety and efficiency in high-risk environments.

## 1.2 Objective

The objective of the CNL x uOttawa Design Challenge is to design a device capable of retrieving a metal sample from the interior of a 4.572 m (15 ft) long tube with an internal diameter of 101.6 mm (4 inches). The tube can be oriented either horizontally or vertically.

# 2. Client Needs and Problem Statement

## 2.1 Identified Needs

Ranking: Least-Most Important (1-5)	Needs	Explanation
3	The tube must be modular and be taken apart with no user contact to sample.	It is important that all the parts be able to be taken apart easily, but it is not the most important as long as the sample can be easily taken from the machine. The other parts don't have to be as modular.
4	The tool must give the operator feedback and be able to verify sample sizes.	We think this is very important because the operator must know what they are doing while taking the sample. The tool needs to be precise and for that it needs to give precise feedback to the operator.
4	The tool should be retrievable in the event of breaking apart	This is an important feature because the environment in which this tool will be used has high radiation and therefore the tool must have a way for the operator to retrieve it easily in the event of failure.
2	Tool must work in	This is not as important because we are the

	both vertical and horizontal orientations and account for small bends in the pipes.	tool is designed for a CANDU reactor which is in the horizontal orientation. If we can make it work in both orientations that would be great, but if it works horizontally, that is what is important. Also, the bends in the pipes are minimal so they do not pose a major concern to the product.
5	The sample must be between 30 and 80 mg	This requirement is the most important as too big of a sample could cause damage to the pipe and too small of a sample would not be enough to perform testing within the lab
3	The tool should be quick and simple to use so that it can be easily demonstrated	The assumption is made that the operator has experience with these kinds of tools and the speed factor is more for its presentability when showing how it works to the clients.
2	The tool should accommodate for bends in the tube	The client specified that over time some pipes sag so having a tool that can work around slight curves would be ideal, but it is not the top priority as the tubes are also assumed to be in a clean condition.
5	The container for the sample must be detachable	This is an important criterion as it is unrealistic to send the entire tool to the lab for testing.
5	No contact can occur between the operator and the sample	For safety reasons this criterion is very important to the design as the sample collected could be radioactive.

## 2.2 Problem Statement

Design a modular, fail-safe samplings tool for CNL that can extract metal samples from pipelines under high radiation conditions while keeping the operator safe with industry regulation accuracy. Offer moderate feedback to confirm the operation of the tool and process status.

## 3. Design Constraints and Challenges

### 3.1 Constraints

The product must be able to reach 15 ft (4.572 m) into a tube). The tube is only 4 in (101.6 mm)

in diameter. There can be no physical contact between the user and the sample being collected. The product must be modular and can be broken down into man portable sizes. The sample collected must be between 30-80mg in mass.

## 3.2 Challenges

Challenges include the product being able to reach 15ft accurately while still being able to be controlled easily. It also needs to be able to break apart and be carried by one person can make it harder to stay strong when put together. There cannot be and sag which can cause it to perform poorly. Another challenge is being able to collect an accurate sample size from the inside of the tube. We don't want to take off too much which could damage the tube, and we don't want to take too little sample that it is unusable. The product needs to be able to send the user feedback on what is happening while obtaining the sample, which could be difficult because it needs to be operated from far away. The product must be operated from far away to keep the user away from the harmful radioactive material.

## 4. Proposed Design Solutions

### 4.1 Core Design Features

1. One of the core design features is that the device must be portable, capable of breaking down into components that can be transported manually.
2. Another design feature is giving the operator feedback upon retrieval of the necessary sample size.
3. The tool must be maneuverable in vertical and horizontal tubes while also being capable of accommodating slight bends in the structure of the tubes. Therefore, the joints of the design should be able to bend slightly.
4. The device will be fitted with a visual feedback mechanism where the operating status can be reflected precisely through the brightness of LED indicator lights: green stands for normal, yellow stands for possible adjustments, and red stands for faults or abnormalities. In this case, the staff can obtain information in time.
5. The design will incorporate light weigh materials such as aluminum (alloys) to reduce the overall weight which can helpful
6. If the solid skeleton of the tool is broken, then some sort of cord, rope, or chain should run through whole tool.

## 4.2 Prototyping and Testing

To design a prototype, initially we use similar products as a baseline for the prototype's performance. We would use the users' feedback on the available existing solutions and integrate them into our prototype.

The evaluation of existing tools such as Kinectrics CWEST will provide valuable insights into the features of similar products. The Circumferential Wet Scrape Tool (CWEST) is a specialized device designed for sampling pressure tubes in CANDU reactors. It is a custom tool used to monitor deuterium uptake in pressure tubes (PTs) of nuclear reactors. This system is designed to collect samples of material from the PTs under shutdown conditions to analyze deuterium content, which is critical for assessing the structural integrity and safe operation of ageing reactors.

The core structure uses the newly developed antimagnetic alloy material, excellent in dealing with the radiation environment, featuring high resistance to corrosion and temperature, stable in structure while ensuring long and stable operation for the equipment.

## 5. Conclusion and Recommendations

This sampling tool, by marrying the precision of a tool with the accuracy of a sampling tool, will meet both design needs and limitations, enhancing predictability. Priority design combines transportation with maintenance while accuracy ensures that the results of sampling are reliable and meet the strict requirements. Besides, the on-board visual feedback system allows the operator to monitor in real time the status of tools, hence enabling efficient adjustment of operations. The tool also focuses on convenience and intuitiveness, making it suitable for professional operations, demonstrations, and training.

## 6. References

Read. *CNL x uOttawa Design Challenge*. BrightSpace, 2025,

[Link to Client Meeting I Presentation Slides \(pdf\) - GNG1103F \(Winter 2025\) Engineering Design 20251](#)

*Custom circumferential wet scrape tool (CWEST) Design & Supply*. Kinectrics. (n.d.).

<https://www.kinectrics.com/projects/updated-design-supply-of-a-custom-circumferential-wet-scrape-tool>