Design Criteria

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GNG 1103 - Introduction to Engineering Design

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Sunday, February 2nd, 2025

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Introduction

The aim of this report is to present the detailed design criteria for the project. As outlined in previous reports, the goal is to design a tool that will be used by the EMED team at Canadian Nuclear Laboratories to safely collect a 30-80 gram sample of metal from inside a fuel channel that supplies uranium fuel to a CANDU reactor.

In the previous report, the project needs were identified and categorized based on their importance. In this report, a design criterion has been established for each project need, along with the corresponding metrics and target specifications. Additionally, the benchmarking process for the project has been completed. The benchmarking presented in this report includes two types: user benchmarking and technical benchmarking.

User benchmarking involves gathering insights from user perspectives on similar products available in the market, identifying areas where improvement is necessary. On the other hand, technical benchmarking focuses on identifying existing products that meet one or more of the interpreted needs. The information obtained from technical benchmarking provided the team with valuable insights into the features already available in certain products, as well as their costs. This has helped to identify areas where costs can be reduced.

All of this information will be used in the next stages of the project to ensure the design meets the necessary requirements.

Identified Needs and Design Criteria

The following table (Table 1) presents a list of needs identified in the previous report, along with the corresponding design criteria.

Table 1: Needs identified by the client and the corresponding design criteria.

Number	Need	Design criteria
1.	The part used to collect the sample must be made of a material harder than the material of the tube. This is necessary to ensure that the collection process is smooth and to prevent the part from breaking while inside the tube.	The part must be made of hard metals, such as steel or aluminum, as these materials are less likely to break. **Note:** During the client meeting, it was revealed that the tube is made of zirconium, a very hard metal that is also expensive. As a result, using a metal harder than zirconium would not be feasible due to cost constraints. However, the client has approved the use of either steel or aluminum for this part.
2.	The part used to collect the sample must not emit any sparks during the collection process.	The emission of sparks occurs due to the heat generated by the friction between the part and the surface of the tube. To

		prevent the generation of sparks, it is essential to use a metal that effectively absorbs the heat. Of the two metals specified as design criteria for need number 1—steel and aluminum—aluminum has a higher thermal conductivity. This means aluminum is more efficient at transferring heat and is less likely to cause sparks during the collection process. Therefore, to minimize the risk of sparks, the part must be made of aluminum.
3.	The device must be capable of extracting a metal sample from the interior of a tube that is 4.572 meters long, with a diameter of 101.6 millimeters and a wall thickness of 4.1 millimeters.	The tool must have the following dimensions: It must be capable of reaching a minimum length of 4.572 meters, which is the full length of the tube. However, it is important to note that while the tool needs to be as long as the tube, the sample will be collected at a point

		located exactly halfway along the tube, at a length of 2.286 meters. Regarding width, the device must have a maximum width of 91.6 mm, which is 10 mm less than the diameter of the tube. This extra space has been allocated to enhance the maneuverability of the tool within the tube.
4.	The device must be fail-safe, such that it can be removed from the tube in the event of failure.	The device must include a mechanism that moves the collection tool in and out of the tube. This mechanism should be placed outside the tube to ensure ease of operation and to prevent any contact between the radioactive material inside the tube and the operator. It is also important to note that if the mechanism is powered by a motor, it must have the capability to be operated manually in the event that the motor or its

		power supply fails. This ensures that the device remains functional even in the case of power loss. Furthermore, all moving parts of the device must be properly lubricated to prevent any jamming. This will avoid any mechanical issues that could prevent the parts from functioning properly.
5.	The device must be usable in a tube that is oriented vertically as well as horizontally.	When oriented vertically, the driving mechanism of the device must be able to support the weight of the parts placed above it. This can be ensured by using strong materials, such as stainless steel, for the mechanism's construction. Additionally, if a motor is used, it must be powerful enough to lift the device with ease. To achieve this, a servo motor with a power output between 2 and 4 kW should be used. This power range

		will ensure that the motor can effectively handle the weight and provide sufficient force to lift the device.
6.	The sample retrieved from the tube must be stored in a suitable container, and must not come in direct contact with the device operator.	The collection tool must be designed to transfer the collected sample directly into a container. This container must be capable of sealing itself when detached from the tool. The self-sealing feature is essential to prevent the tool operator from coming into contact with the radioactive sample, ensuring safety during the collection process.
7.	Power sources required for the functioning of the device must be specified in the design.	If the mechanism is powered by a motor, the specifications of both the motor and the battery that powers it must be included in the design plan. These specifications should cover details such as voltage, electricity consumption, and the power produced by the

		motor. However, if the device is operated manually, no such specifications need to be provided in the design plan.
8.	The device must be reusable.	All parts of the device must be made from durable materials, such as strong metals and high-quality plastics, to ensure the longevity of the main components. For critical parts such as motors and sensors, only high-quality components should be used to ensure reliability. The reliability of these parts can be verified by consulting product reviews on reputable e-commerce websites, such as Amazon. Additionally, the battery powering the device must have a long lifespan, with a minimum duration of 24 hours. This will ensure the device can be used multiple

		times throughout the day without the need for frequent recharging.
9.	The device must have some method of providing feedback to the user to confirm the status of the collection process.	The distance traveled by the tool can be determined using a rotary encoder, which is a device that converts rotational motion into an electrical signal. It counts the number of rotations or partial rotations of a shaft. By knowing the number of encoder counts and the distance the shaft moves per count (based on the encoder's resolution), the total distance traveled can be calculated. Note: The rotary encoder will function regardless of whether the shaft is driven by a motor or manually. However, the tool must be moved into or out of the tube using the rotational motion of a shaft, which, in turn, drives the movement of the device.

10.	The device must include a method for adjusting the sample retrieval process to ensure that the sample obtained weighs between 30 and 80 grams.	A load cell is a device that converts a load, such as the weight of an object, into an electrical signal. This signal can then be measured and used to control the operation of a collection tool. For example, if the mass measured by the load cell is less than 30 grams, the electrical signal will be sent to the collection tool, allowing it to continue collecting the sample. However, if the mass exceeds 80 grams, the electrical signal will trigger the shutdown of the collection tool by cutting off the power supply, thereby stopping the sample collection process. This functionality of the load cell can be used to meet the design requirements for controlling the amount of sample collected.
11.	All parts of the device must	The container holding the

	have the capability to be broken down to man-portable sizes.	collected sample must be detachable without the need for any hand tools. This design feature allows for easy removal of the container, facilitating the transport of the sample to the lab for analysis. Additionally, all other parts of the device must be easily detachable for general maintenance. These parts should be designed to be removed using common hand tools, such as screwdrivers and spanners, ensuring ease of maintenance.
12.	The device must be able to pass through a tube that may not be straight.	The device needs to be flexible enough to bend along with the tube. To achieve this, it must have movable joints placed at regular intervals along its length. These joints will allow the device to maintain flexibility while adapting to the tube's curvature, ensuring it can move and function properly as the tube bends.

Note: Points 1 and 2 are new developments in the project and were not included in the previous report. It is important to highlight that the importance of these needs is categorized as critical, as they are essential to the proper functioning of the tool.

Benchmarking

Technical benchmarking

There are unfortunately not many similar products available in the market that could be considered. However, one product that was considered was Kinetrics's CWEST. This is a device that uses a rotating cutting head driven by an electric motor. Hydraulic clamps center the tool in the pressure tube, while a hydraulic cutter actuator mechanism radially extends the cutters. During the cut process, light water is injected around the cutters to prevent deuterium contamination of the sample. Pressure tube samples are collected in an 8-compartment tray within the tool head. Upon completion of sampling the tool head is removed by the delivery machine and moved to a maintenance cart for sample retrieval.

Possible restrictions with current designs:

- The tool requires precise operation and handling which requires special training to use safely and effectively
- The design does not have full radiation exposure shielding as manual handling during tool retrieval is still prevalent

User Benchmarking

Unfortunately, there are no user reviews available on e-commerce websites or forums. However, the client has mentioned that the device is currently being used in the CNL lab, and they are quite satisfied with its performance. Based on the client's testimony, it is clear that the product designed by this team does not need to address any missing features in the existing product. However, focusing on the restrictions mentioned above would be beneficial. The primary goal should be to ensure that the new product meets the same standards as the one currently in use.