Request for Proposal #1

The Barrel Inspector Machine

Need

A nuclear power plant needs to frequently check for its inventory of used heavy water autonomously, which is kept in barrels in a protected area.

Goal

Design and manufacture the scale-down, proof-of-concept prototype of a mobile platform that can travel along a row of barrels of various types and identify whether each barrel is full, half-full or empty.

Specifications

The machine is expected to check the level of liquid in a number of barrels, unspecified *a priori* but at least 3 and not more than 7, which are placed on a flat ground in a row with no extra attachments. Each barrel can be considered as a tapered cylindrical container in black colour, with a diameter of $19.5^{\pm 0.5}$ cm at the bottom and $23^{\pm 0.5}$ cm at the top. Each barrel is equipped with a liquid level indicator mounted on its external surface. The level indicator can be emulated in the prototype by a vertical line made of white duct tape with a width of $7^{\pm 0.5}$ cm stretched up from the bottom of the barrel. There are two types of barrels, tall with a height of $35.5^{\pm 0.5}$ cm and short with a height of $25^{\pm 0.5}$ cm. Each empty barrel weighs 445 g (tall) or 320 g (short) with a ±5 g tolerance. Samples are available from the client. Barrels are positioned on a line with ±1 cm variance. The minimum distance between the centrelines of two adjacent barrels is 45 cm. There is also one round column in black colour with a diameter of $9^{\pm 0.5}$ cm and indefinite height positioned somewhere, unknown *a priori*, between the barrels along the row. The distance between the centrelines of the column and a barrel is not less than 35 cm. The orientation of each barrel in the row is such that its level indicator is either at the closest distance with the machine when it passes by, or $180^{\pm 10}$ degrees opposite side. Each barrel is considered as full when the length of the indicator is more than two-third of the barrel's height, empty when it is less than one-third of the barrel's height, and half-full when it is between one- and two-third of the barrel's height. For the operation, a Start Line is specified not closer than 20 cm but not farther than 40 cm from the centreline of the first barrel. The machine shall begin the operation from a location so that its front end is at or behind Start Line, and travel along the row of barrels to detect them and identify their liquid level. The machine can travel only on one side of the barrels during the operation. Parts of the machine can be in contact with the barrels or column, but cannot move, shake, mark, or scratch the barrels or column. Methods of inspection are up to the design, but must not require moving or relocating any barrel or column at any time. In each operation, the machine shall start through a keypad, perform the inspection autonomously until it reaches the last barrel or the end of the inspection line that is not longer than 400 cm from Start Line, then return and stop at Start Line in the standby mode displaying a completion or termination message on the LCD and ready to communicate with the operator the inspection information. The entire operation shall take no longer than 3 minutes. The information to be retrieved from the machine after each operation shall include: operation time, total number of barrels for each type, the type of each detected barrel, its location with reference to Start Line and level of liquid in it. The client requires that the machine be portable with no need for installations in the field, and as such there are constraints on weight and dimensions. Also, for safety purposes, the machine must have an easily-accessible emergency off switch that stops all the mechanical moving parts immediately. The machine must use an on-board power supply.

Operation

The machine is initially positioned at Start Line in a standby mode. The operation starts by pressing a <*start*> button on the keypad. The machine then travels along the barrels, detects each barrel and identifies and records the liquid level in it. The machine can travel only on one side of the barrels during the operation. When the machine reaches the last barrel or the end of the inspection range it returns and stops at Start Line. The entire inspection process must be done autonomously and must take no longer than 3 minutes. Upon completion of the operation, the machine must display a completion or termination message on the LCD and be ready to communicate with the operator the inspection information, including operation time, total number of barrels for each type, the type of each detected barrel, its location with reference to Start Line and level of liquid in it.

Machine performance will be evaluated depending on the operation time and the accuracy of the retrieved information, as detailed in the sequel.

Performance Evaluation

The prototype will run two separate but consecutive operations, and the total time and accuracy of these operations are measured. Reward and Penalty points will be given to the prototype performance according to the following scheme. Each operation is qualified if the machine detects at least 3 barrels and attempts to identify their liquid level, does not move, shake, mark, scratch the barrels or column, and stops and displays the completion/ termination message at the end of its operation and prompts for the inspection information.

➢ Each "qualified" operation	+500
➢ Each correctly "detected" barrel	+100
➢ Each falsely "detected" barrel	- 200
➢ Each detected barrel whose type is identified correctly	+300
➢ Each detected barrel whose type is identified incorrectly	- 200
➢ Each detected barrel whose liquid level is identified "correctly"	+300
➢ Each detected barrel whose liquid level is identified "incorrectly"	- 200
➢ Each detected barrel whose location is recorded "correctly"`	+300
➢ Each detected barrel whose location is recorded "incorrectly"`	- 200
➢ The total number of short barrels is correct	+300
➢ The total number of tall barrels is correct	+300
➢ The operation time recorded on the display is "correct"	+500
➢ The operation time recorded on the display is "incorrect"	- 300
➢ Machine "returns to" Start Line	+1000
➢ Time penalty	- 10 per second of operation
➢ Each disqualified run	- 0

Bonus Points for Extra Design Features:

➢ Robustness and Durability	0 to +300
➢ Operability and Sustainability	0 to +300

➢ Elegance and Safety	0 to +300
➢ Extendibility	0 to +300
➢ Accuracy	0 to +300
➢ Dexterity	0 to +300
➢ Compactness and Portability	+ 500
➢ Real-time Date/Time Display	+ 300
➢ Permanent Logs	+ 500
➢ PC Interface	+ 300
➢ Remote Operation	+ 200

Constraints

a. The entire prototype shall completely fit within a 55× 55×55 cm^3 envelope at all operation times.
b. The weight of the machine shall not exceed 10 kg.
c. The total prototype costs shall not exceed $230CDN.
d. The machine must use its own on-board power supply during the operation.
e. The machine must be fully autonomous, and no interaction with an external PC or remote control is permitted during the operation. The operation must start by hitting a *<start>* button on the keypad.
f. The machine must have an emergency STOP button that stops all the mechanical moving parts immediately.
g. The operator must be able to set up the machine for the operation and take it away afterward conveniently (to the referee's discretion) with no need for moving or relocating the barrels or column at any time. No instrumentation is allowed in addition to what is devised within the machine.
h. Parts of the machine can be in contact with the barrels or column, but cannot move, shake, mark, or scratch them at any time.
i. At the end of each run, the machine display must be on prompt to show the following information per user's request: the operation time, total number of barrels for each type, the type of each detected barrel, its location with reference to Start Line and level of liquid in it.
j. The machine user interface for both the operation and information retrieval shall be self-explanatory and provide easy navigation for users of various skill levels.
k. Each barrel is considered "detected" only if the machine clearly signals its detection (e.g., light, sound, etc.)
l. The liquid level in each barrel is measured "correctly" if the machine identifies whether the barrel is full, half-full, or empty according to the specifications; otherwise, it is "incorrect."
m. The location of each barrel is recorded "correctly" if the displayed distance with reference to Start Line is within ±10 cm of the real distance (to the barrel centerline); otherwise, it is "incorrect."
n. The machine is considered to have "returned to" Start Line if, at the end of operation, the machine stops where its entire body is behind Start Line.
o. The operation time is the duration between when the *<start>* button on the keypad is pressed and when the machine stops and displays a completion/termination message on the LCD. The recorded operation time is considered "correct" if it equals the time measured by the referee ± 5%. Otherwise, it is assumed "incorrect."
p. Each run is "qualified" for scoring if the machine detects at least 3 barrels and attempts to measure their liquid level, does not move, shake, mark, scratch the barrels or column, and stops and displays the completion/ termination message at the end of its operation and prompts for the inspection information.

q. Each run is "disqualified" if the machine structurally collapses, falls over, hangs or jams unpredictably (for more than 3 minutes), or moves, shakes, marks, or scratches a barrel or column, or terminates the operation before detecting 3 barrels, or does not display the termination/completion message on the LCD at the end of operation, or the team declares the termination. If any of the above happens to the first run, the team will have 3 minutes to fix the system and run for the next time, should they wish.

r. Each team will have a period of maximum 3 minutes to set up the machine before each run. If the preparation time exceeds 3 minutes, the run is "disqualified."

s. There will be no control on the conditions of the contest environment. Hardwood or Vinyl tile flooring with bright colour can be assumed (SF4102-3).

t. No railways or tracks are allowed.

u. The machine must pose no hazard to the operator, and shall not be perceived as hazardous (e.g., too much vibration or noise or frequent spike during the operation is perceived as dangerous.)

Extra Design Features

The following features would enhance the machine performance, and increase the Bonus Points:

- **Robustness and Durability:** Machine is durably constructed and functions consistently with a small failure frequency and under different indoor and outdoor conditions, including various types of terrain.
- **Operability and Sustainability:** Little time/effort is needed to set up and calibrate the machine in the field, and the machine is modular so that parts can be replaced or repaired easily.
- **Elegance and Safety:** Machine looks elegant, and operates quietly and smoothly with little or no sensible noise or vibration.
- **Extendibility:** Machine can inspect barrels with different heights and diameters with little or no need for modifications.
- **Accuracy:** Machine can measure the liquid level more precisely.
- **Dexterity:** Machine is capable of inspecting barrels that are not arranged along a line.
- **Compactness and Portability:** The entire prototype weighs not more than half of the maximum weight permitted, and in the beginning of its operation it completely fits within an envelope that is less than 25% of the volume of the maximum envelope allowed.
- **Real-time Date/Time Display:** Date and time of each inspection are displayed on the LCD in standby mode.
- **Permanent Logs:** Machine stores log information in permanent (EEPROM) memory.
- **PC Interface:** The operation information can be readily downloaded on a PC.
- **Remote Operation:** Machine can start and (emergency) stop the operation by a remote controller.

Expected Outcomes

Design and Construction Process: The team must follow a logical and systematic process in accomplishing their tasks of design, analysis, and construction. Conceptual design and system analysis are important steps of this project where the team has to compromise speed, accuracy, and cost. The detailed process must be reflected in the final report submitted by the team.

Proposal: Each team must work together to generate a proposal documentation on the design. The design proposal should reflect the conceptual design phase, team and project management with the scheduling, the steps to be taken for the detailed design and prototype fabrication, and the methods of manufacturing, integration and debugging to be followed in building the prototype.

Final Report: This report details the entire process of design, analysis, fabrication, and evaluation.

Final Prototype: The final prototype developed by the team should reflect the work presented in the proposal. Any significant changes in the design of the prototype must be justified in the final report. The quality of the