EML 4905 Senior Design Project

A B.S. THESIS
PREPARED IN PARTIAL FULFILLMENT OF THE
REQUIREMENT FOR THE DEGREE OF
BACHELOR OF SCIENCE
IN
MECHANICAL ENGINEERING

INSPECTION DEVICE FOR DEPARTMENT OF ENERGY HANFORD SITE UNDERGROUND TANKS
25% Report

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Ethics Statement and Signatures

The work submitted in this B.S. thesis is solely prepared by a team consisting of JENNIFER ARNIELLA, DANIEL GIRALDO, and GABRIELA VAZQUEZ and it is original. Excerpts from others' work have been clearly identified, their work acknowledged within the text and listed in the list of references. All of the engineering drawings, computer programs, formulations, design work, prototype development and testing reported in this document are also original and prepared by the same team of students.

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Abstract

The first retrieval of radioactive material at the Department of Energy Hanford Site began in 1944. The AY tanks are the oldest double shell tanks at the site that hold high level waste. In August of 2012, it was determined that waste had leaked into the annulus between the primary and secondary walls of AY-102 tank. It is believed that the high level radioactive waste leaked from the tank bottom flowed through the cooling channels of the refractory pad to the annulus. Breaking Under Ground (BUG) is a student-driven senior design group that has built a robotic inspection device that travels through the refractory pad cooling channels to gain further knowledge of the condition of the primary tank and the source of leakage. The body for the tool has overall dimensions of 1.2 in by 1.21 in and has a height of 1.15 in. The device consists of a small tank type frame with a magnetized plate on the top surface that houses a camera and two motors and that body is connected to a tank tread. The camera housed in the body of the inspection tool includes a fiber optic line to provide live visual feedback and power for the two motors. Using LabView, the device will be remote controlled to navigate through the pathway. With the magnetized plate on the top surface, the device runs upside down along the bottom of the carbon steel tank to avoid existing debris and potentially damaging the refractory pad in which it travels through. This design project is sponsored by the Department of Energy Environmental Management Office as well as the Applied Research Center's DOE-FIU Science and Technology Workforce Development Program.

1. Introduction

1.1 Problem Statement

The first retrieval of radioactive material at the Hanford Site began in 1944. This process recovered radioactive material from spent fuel and produced vast quantities of high level waste. There are 28 double-shell tanks arranged in six underground tank farms each holding close to one million gallons of high level waste. [14] Each one consists of a primary tank and a secondary liner tank. As seen in Figure 1, the primary steel tank is supported by the insulating refractory pad that rests on the secondary liner; an annular space of 2.6 ft. is formed between the primary tank and secondary liner. Figure 2 shows a photo taken within the annulus of the double shell tank prior to any leakage during its initial installation. [4]

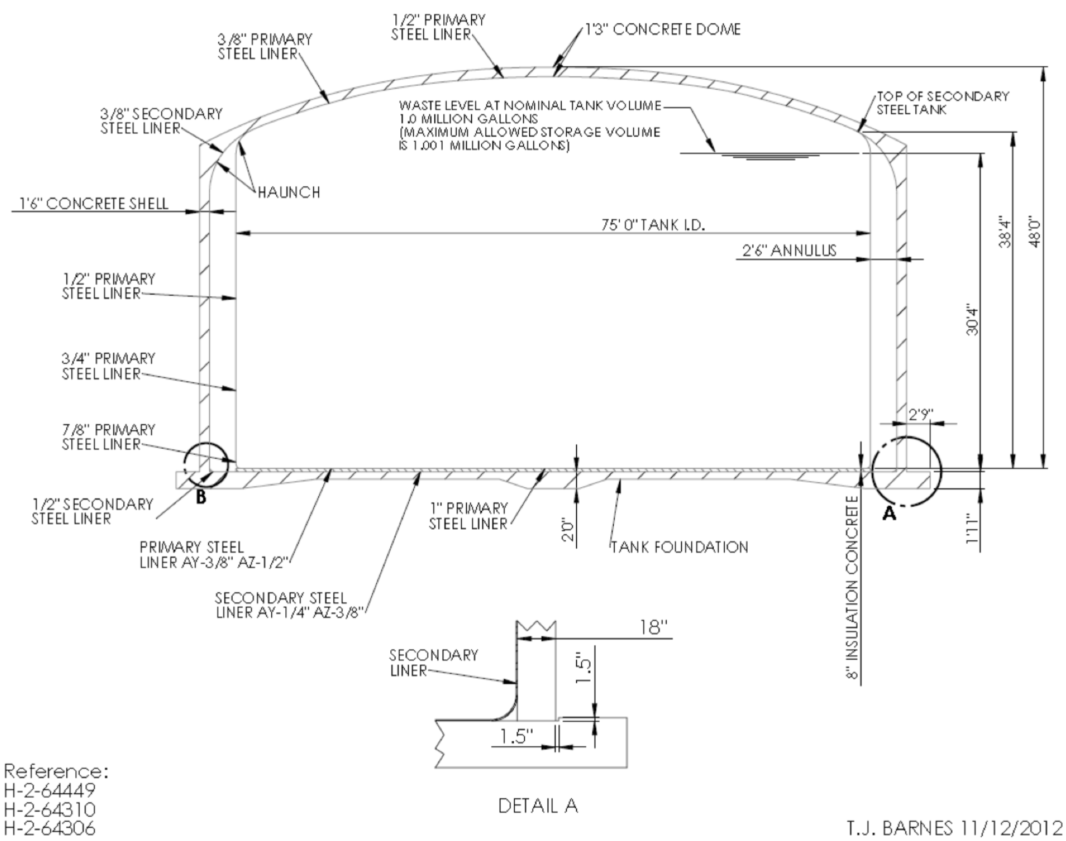

Figure 1. Double Shell Tank Cross Section

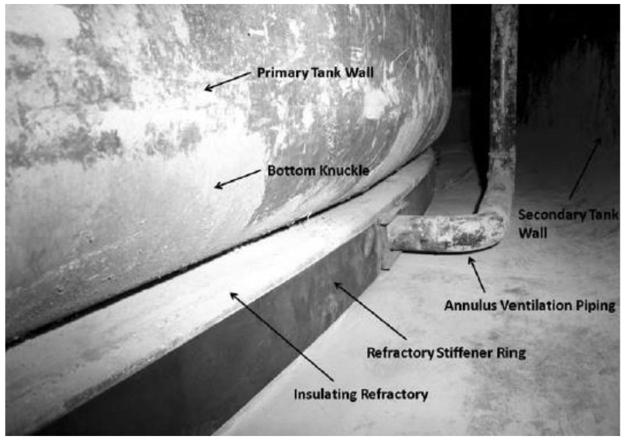

Figure 2. Annulus Detail

As mentioned previously, the primary tank rests on the refractory pad. Air distribution slots are cast into the top surface of the pad. Air supplied to the central air distribution chamber cools the primary tanks as it is drawn through the slots and exhausted from the annulus. The slot pattern and slot cross section vary by tank farm. The slot distribution seen in Figure 3 is the pattern most generally used. The slots emanate in a staggered radial pattern from two concentric air distribution circles surrounding the central air distribution chamber. Slot cross sections seen in Figure 4 vary from 1.5 in by 1.5 in square to a 2.5 in by 2 in and finally 2.5 in by 3 in . [18]

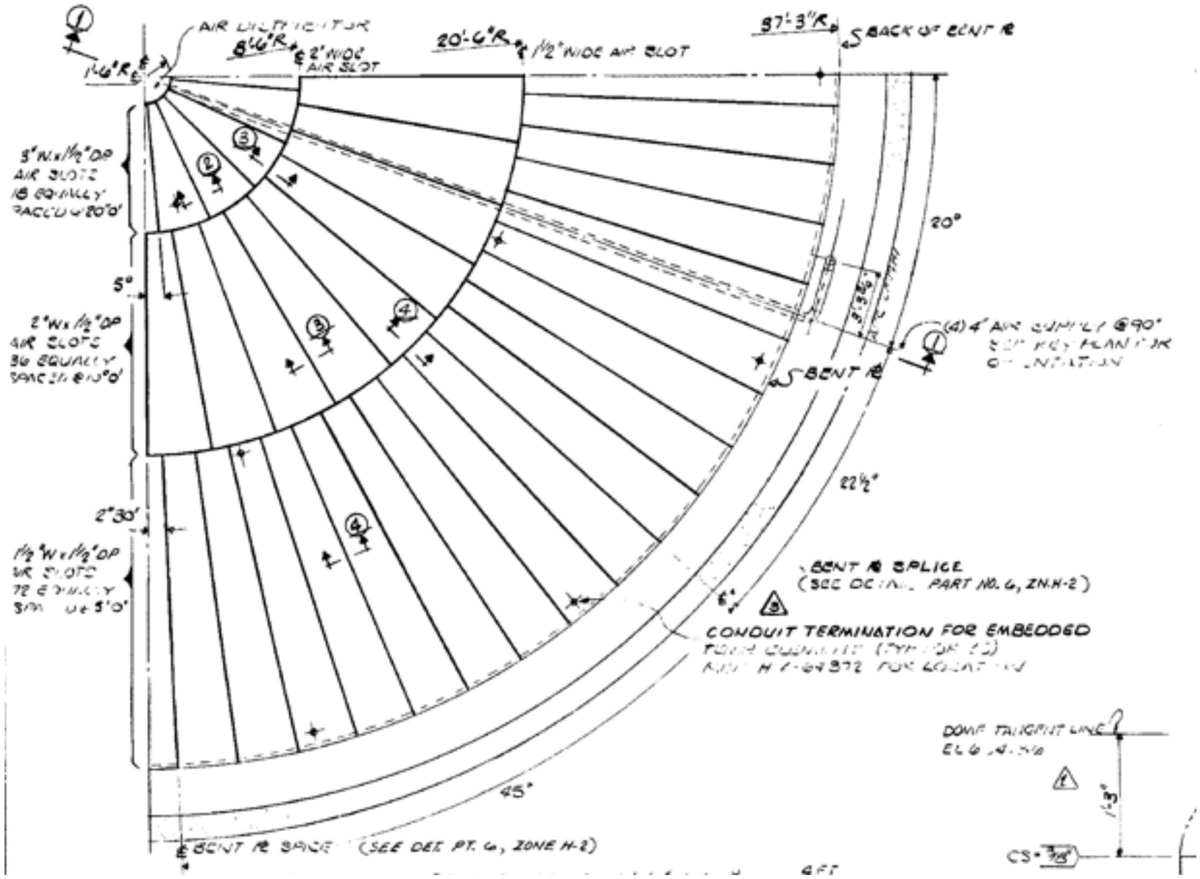

Figure 3. Air Distribution Slot Pattern

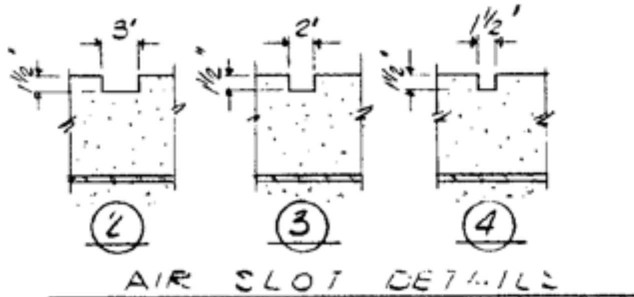

Figure 4. Square Slot Cross Section

The AY tanks are the oldest type of double shell tanks and the AY-102 tank was the first double-shell radioactive waste storage tank constructed at Hanford. The use life of the tanks was approximately 40 years and the tanks are currently at 45 years of use. In August of 2012, an accumulation of material was discovered at two locations on the floor of the annulus that separates the primary tank from the secondary line as seen in Figure 5. The origin is believed to be a break in the bottom of the primary tank. This material has since been removed partially through evaporation as well as physical removal. [2][5]

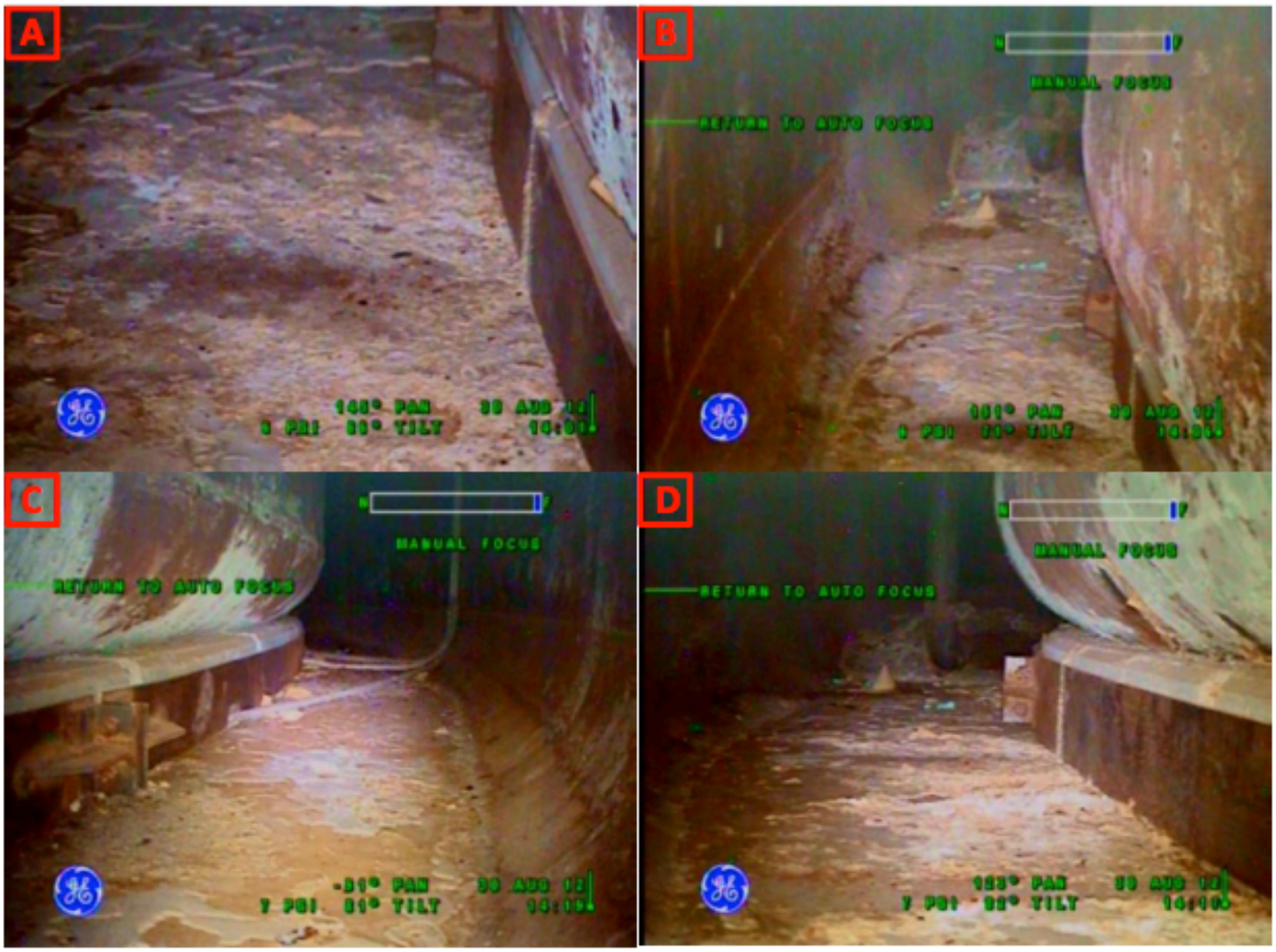

Figure 5. High Level Waste on Annulus Floor

1.2 Motivation

Leakage of the radioactive material into the subsurface soil is of a major concern and so the environmental impact is the foremost motivation. The largest waterway in the Pacific Northwest, the Columbia River is about 5 miles from the Hanford site where the tanks are located. [3] It is extremely important to avoid contamination of such a major body of water that can affect not only its ecosystem but also the communities downstream that use that water as a source. Currently there is no leakage from the secondary tank but before waste continues to build up into the annulus and potentially deplete the reliability of the secondary liner it is important to identify the leakage source for repair. [17][5] An inspection tool is thus required to travel through the refractory cooling channels as seen in Figure 6 to provide video feedback to site engineers of the primary tank conditions. [19]

Figure 6. Refractory Pad Cooling Channel (Air Slot)

A secondary motivation is the challenge the task presents. Site engineers originally contracted 4 different vendors to propose technologies but due to different limitations none of the proposed technologies are in current use. [11] The challenge comes with the small size of the channels with the sharp 90° turns, the long distance that the tool must travel, the multiple entry points, the friable refractory pad, the high temperatures the tool must withstand, and the potentially radioactive conditions it may come into contact with. [15] The channels are arranged in 3 sections: (1) 17 feet of 1.5 in by 1.5 in square slots (2) 12 feet 1.5 in by 2 in square slots (3) 7 feet of 1.5 in by 3in square slots therefore the inspection device must be less than 1.4 in already presenting a major design challenge because all components will be on a miniature scale and potentially not commercially available. [18] The tool must also provide live video feedback and a failsafe tether in case of malfunction, thus an already minute device must be able to carry its component weight as well as a tether weight. Finally the refractory pad has low yield strength of approximately 200psi and so the device must also avoid damaging the refractory pad as it travels through and as it drags the tether along through the 90° turns. [15]

1.3 Literature Survey

There are few robots specifically designed to be able to handle harsh conditions such as chemical disasters, much less in a micro scale. Not until the 2011 disaster of Fukushima did people start paying serious attention to the development of robots to be able to handle such conditions. According to an article published by the bulletin of the atomic scientist, “ Robot to the Rescue”, DARPA launched a robotics challenge to start producing robots capable of operating in dangerous, degraded environments.[12]

This brought about the development of robots that slither according to Science news. Howie Choset is a roboticist who used the snake as reference to build a robot that can slither, roll, swim, and climb. The robot has been successful as an inspection tool and is being tested to do search and rescue. The biggest problem that has been raised with the development of our robot is its ability to be able to make turns as sharp as 90 degrees however the research done by roboticist Howie Choset and biologist Robert Full show that by mimicking the anatomy of versatile animals this can be achieved. [8] [10]

Figure 7. Slither Robot

An article published by Edge of Technology uses as inspiration the agama lizard that can stick to walls and walk upside down giving us the vision for the inspection device to run upside down along the tank wall to avoid creating debris while running on the refractory pad. [12]

Research by MIT has developed magnets for robots that allow them to anchor themselves to pipe or ship hulls, they originally created this to assist underwater robots when they have to grip onto something when they need to turn, however it can be implemented on our design because it requires very little electrical energy to get the magnets activated. The way it works is that the magnets are initially aligned parallel to each other however when an pulse is sent through the weaker magnet's coil, its north and south pole switch, making the overall module a strong electromagnet which can be used for the robot to walk on the metal walls. [6]

1.4 Project Objectives

For this research and design task, our objective is to meet the design challenges and effectively create an inspection device that can travel at least the first 17 feet and make an initial 90° turn. If the inspection device is able to successfully navigate thus far it will have already covered 47% of the total travel distance, providing Hanford Site engineers with an initial comprehension of channel conditions.

As a senior design group, this task is providing us the perfect opportunity to work as a team to solve a real world application challenge. This task not only requires the application of our technical skills but also functions as a professional development opportunity. It is our goal to work as a cohesive unit and responsible members of the team by meeting deadlines and completing original work. As engineers we are to act professionally and as faithful trustees, it our goal to respect the intellectual property of others thus throughout the design process and compilation of the report we ensured to work as our own team using our own ideas, submitting our own work and referencing any resources that were used. It is also our ethical responsibility to complete jobs in the areas of our competence so team responsibilities were delegated based on each individual's strengths. Our aim is for every member to be in constant communication with others to ensure timely completion of the design and report.

Finally, it is our responsibility to hold paramount the safety, health and welfare of the public in the performance of our professional duties. BUG's ultimate objective is to consider the environmental implications of high level waste leakage into the subsurface soil and fully comprehend the importance of our inspection device tank to function as a preventive measure to find leaks so that they can be repaired to keep our environment and communities safe.

2. Design

2.1 Conceptual Designs

Contractors at Hanford identified four vendors to develop or utilize off-the-shelf technologies that can maneuver through the pathway and provide visual feedback of the refractory pad conditions. Vendors demonstrated the approaches to be used; however, for different reasons the contractors did not provide continued support to the effort.

2.2 Design Alternate 1

The first proposed alternative was presented by AREVA. AREVA prides itself in its expertise in engineering solution for double shell tank inspections, it's knowledge and experience of the double shell tank environment and the understanding of constraints particular to the AY-102 inspection. After consulting with robotic and inspection experts in France to utilize global experience, AREVA proposed a rigid SeeSnake MicroReel as seen in Figure 8. The Seesnake is a semi-rigid video probe that allows for quick inspection and the ability to push past debris. The crawler is used to position the probe and the pusher mounted on the crawler is to push the probe into the slots. The cons associated with the proposed design is that it requires manual or mechanical assist from the surface, the push probe is not proven to navigate through a number of bends and there is no articulation on the camera. The total cost was approximately $1,000,000: $260,000 for materials cost and $730,000 labor costs.

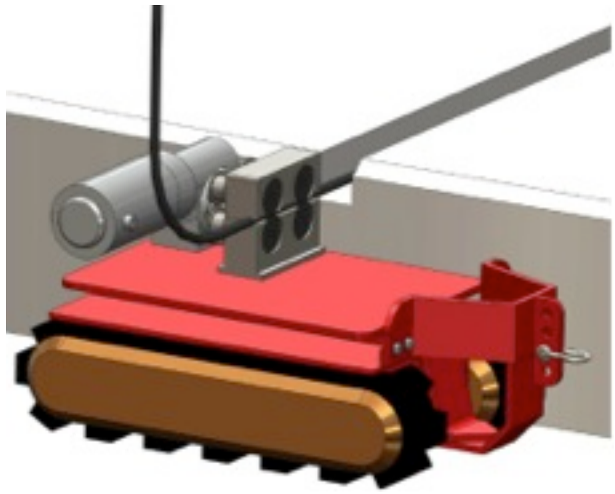

Figure 8. SeeSnake MircroReel

AREVA had a very high confidence level that the push probe would be able to navigate through the first 17 ft of the refractory pad but had a moderate confidence level that the push probe would be able to navigate through the first elbow and continue through the second and third sections of the refractory pad. The board chose not to continue with this design. [1][11]

2.3 Design Alternate 2

The second proposed design is a similar concept to the previously mentioned but presented by Vista Engineering Technologies is a crawler-mounted rolatube with a camera as seen in Figure 9. The rolatube has functioned for previous nuclear inspections and includes a repair capability with resin application which is one of the benefits of the design. The downfall of the design presented is the crawler has yet to be designed. The crawler design is expected to be compact with a self-contained drive and axle with a tipping plow that ensures the crawler will land on its feet when sent down the annulus riser into the annulus.

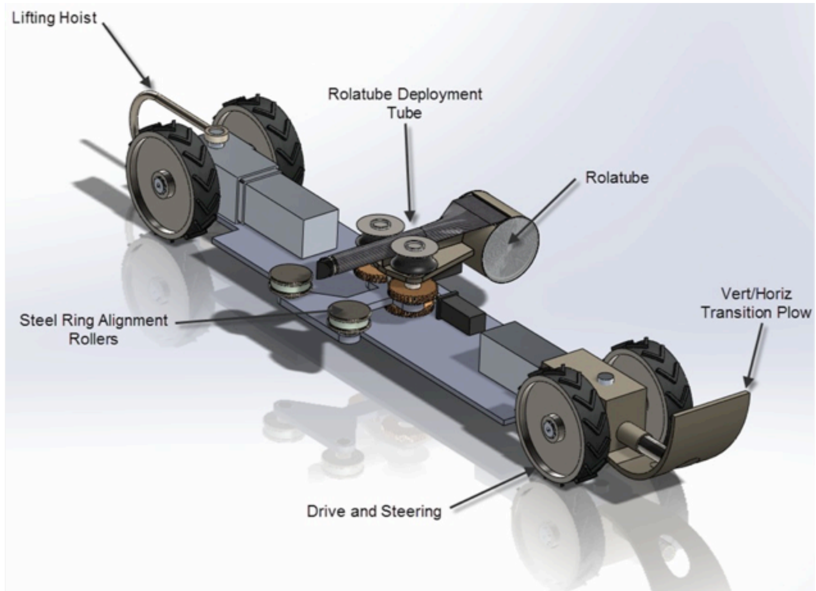

Figure 9. Rolatube Mounted on Crawler

The details of the rolatube as seen in Figure 10 demonstrates how the rolatube works. The rolatube extends through a friction drive as the magnetic guides position it. The rolatube also allows for a back drive if recovery is required in case of failure unit. The camera seen in Figure 11 is a small radiation tolerant camera with a light. The camera comes with a rotating special split viewing mirror too see the walls and middle slot exit. [11][16]

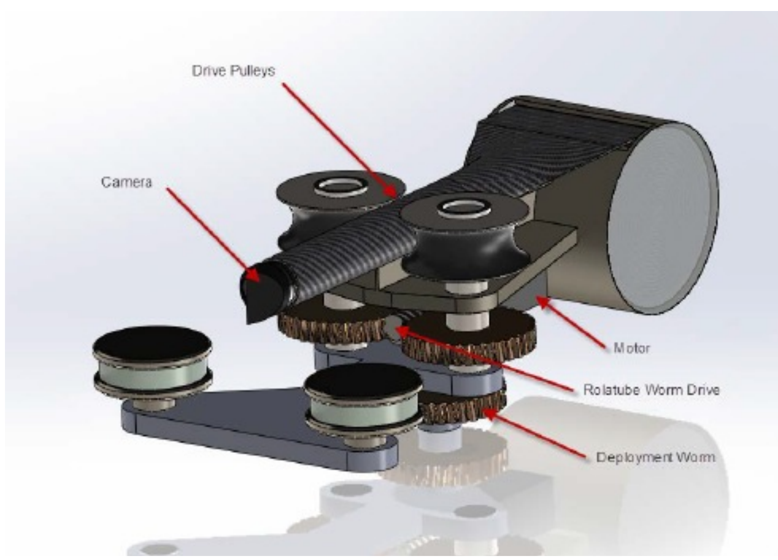

Figure 10. Detail of Rolatube

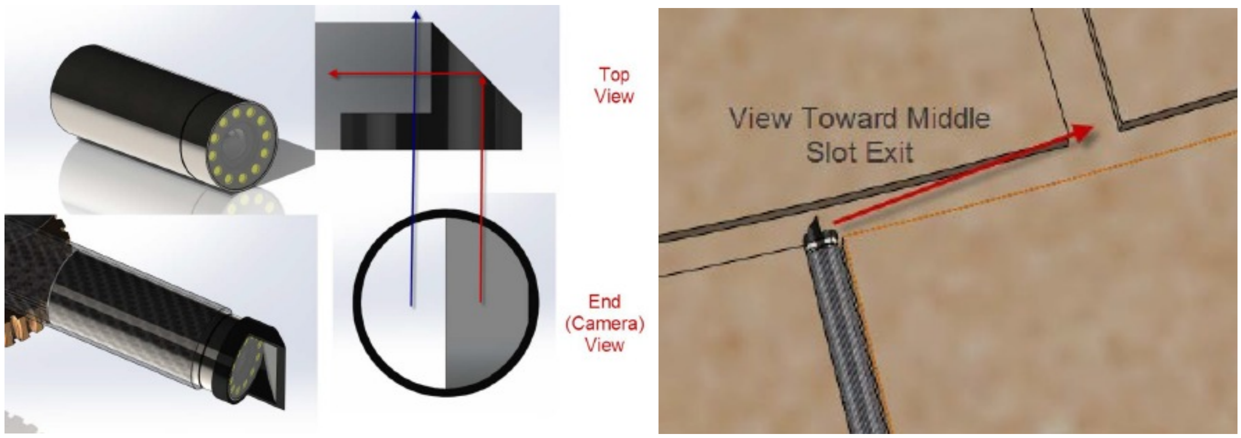

Figure 11. Rolatube Camera

2.4 Design Alternate 3

IHI Southwest Technologies proposed a small remote camera that had been used to inspect a portion of the slots in some tanks. It was expected to be a four-wheeled micro robot with a separate delivery crawler that would deliver the inspection robot into the annulus. The cons of the tool was there was not a set device to deliver the inspection tool but the pros outweighed this factor in that IHI had prior nuclear experience, they delivered a competitive cost and schedule and the device had prior use underwater so the inspection tool was promising.

This device was the only device selected by the board for use. Once deployed, the photos revealed spalling on the slot walls, and accumulated debris on the floors as seen in Figure 12. The camera was not equipped to record travel distance; and its forward and backward motion were limited to rapid jerks making its actual location in the slot uncertain and the video trace of marginal value. The total cost was estimated at $75,300: $41,600 for the controller, $17,300 for the refractory air slots robot and then an additional $16,400 for the pan/tilt camera. The robot design, manufacture, mockups, testing, and administrative duties such as design documentation, onsite training and final reports were all taken into account for the price of each component. [7][11]

Figure 12. Debris Inside Refractory Slot

2.5 Proposed Design

The objective of the design tool is to provide a means for Hanford engineers to inspect the primary tank bottom of AY-102 by navigating the device through the air slots in the refractory pad. Specific requirements for the design include:

1) Deploy at annulus base through riser (42 inch diameter) into a refractory slot opening
2) Navigate up to 38 feet to the center of the tank through slots that have a 1-inch height and vary in width from 1.5, 2 and 3 inches in width
3) Navigate through four 90° turns
4) Minimize damage to the refractory pad
5) Provide visual feedback of the tank bottom and refractory slots
6) In the event of a malfunction of the inspection tool, it should have a means for removal
7) Capable of exposure to elevated temperature and radiation levels (170 ºF, 85 Rad/hr)

The design consists of a small tank type body that can house a camera and motors and this body is connected to “tank tread” wheels. To avoid existing debris in the air slots and potentially damaging the refractory pad, the design has a magnetized plate sitting on the top surface of the frame so that it can run upside down along the bottom of the carbon steel tank.

Through discussion with Washington River Protection Solution engineers, an important aspect of the inspection tool is the live video stream so that distance traveled can be easily correlated with the video, and any obstructions at those distances can be repaired. It was also concluded that a tether was needed for the inspection tool as a full proof method to retrieve the tool in the event of malfunction. For this inspection tool, the tether will consist of a camera fiber optic line and a control/power feed for steering and navigation. Figure 13 shows a 3D rendering of the proposed inspection tool as it would be oriented upside down along the tank bottom.

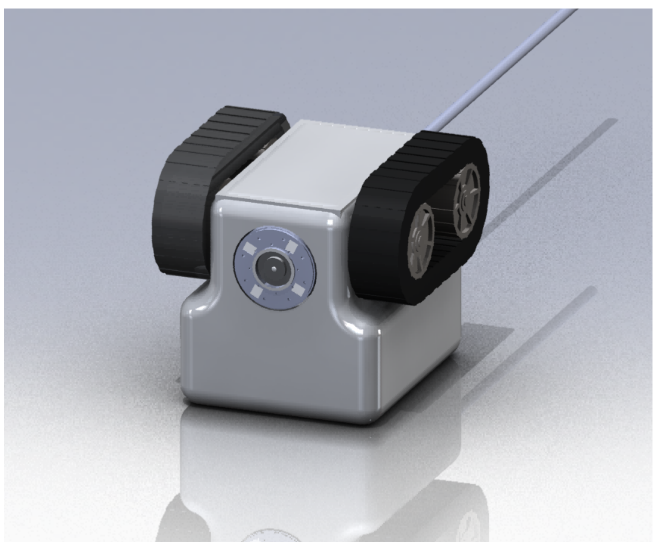

Figure 13. Rendering of Proposed Design

Figure 14 and Figure 15 shows additional views with the internal components exposed. The components have been sized using information from commercially available products. The body for the proposed tool is 1.2 in by 1.21 in and has a height of 1.15 in. Motors contained in the body are attached to one wheel on each side and drive the opposite wheels via a rubberized track. Having two motors will allow each side of the tool to operate independently and provide the means to navigate around turns in the refractory slots as shown in Figure 16. Gears have also been included to increase the torque from the motors, which will be needed to overcome the axial magnetic force and drag from the tether. The figures also show the camera, tether line, motors, and circuit board.

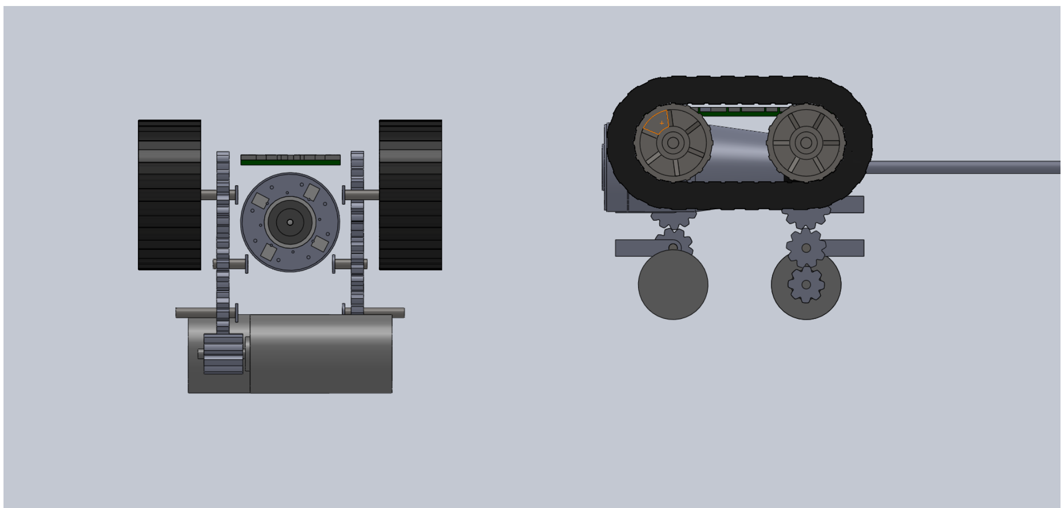

Figure 14. Front and Side View of Internal Components

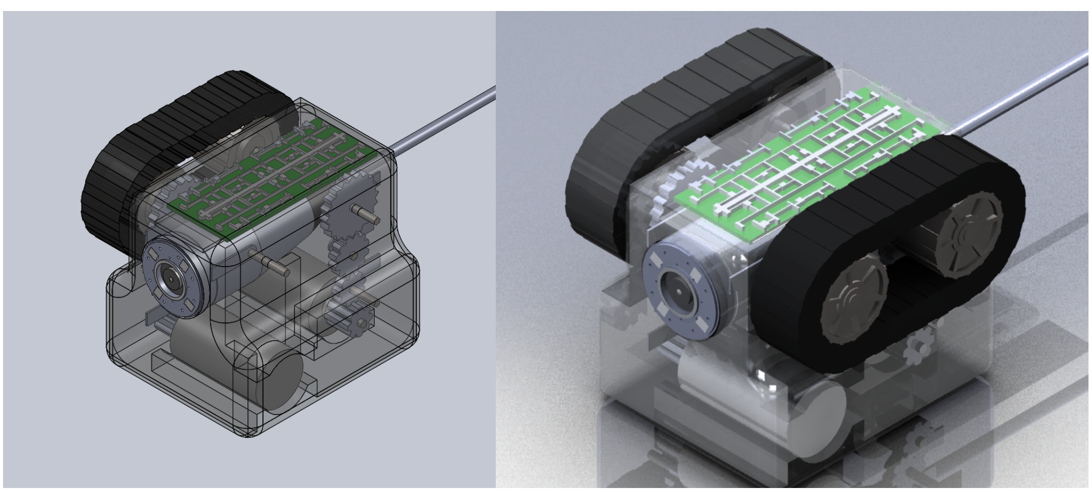

Figure 15. Rendering with Transparent Housing of Components

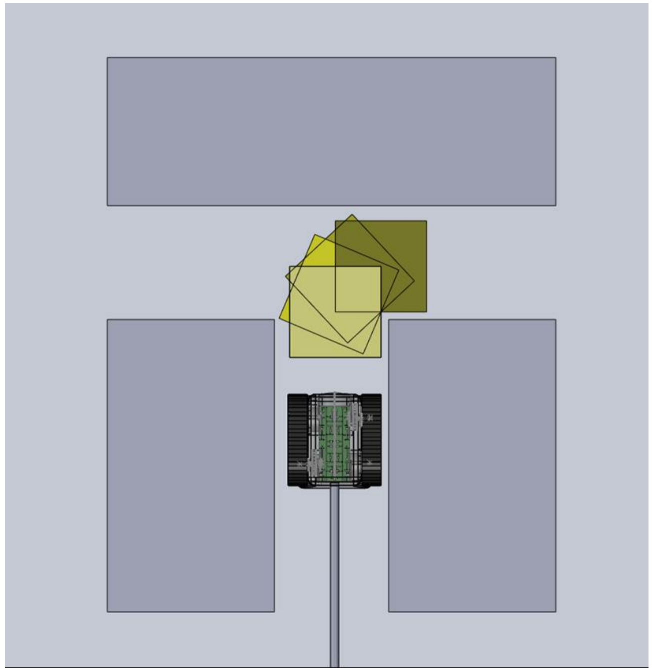

Figure 16. Schematic of Path through a 90 ° turn

3. Project Management

3.1 Organization of Work and Timeline

The Gantt chart for the project timeline is shown in Table 1. The major milestones are listed as well as the month and week when the task were completed. For example, starting in first week of January, the literature review began and it was completed by the end of the month. This chart served as a guideline of the ideal schedule of the project and enabled the team to complete the project in a timely and efficient manner. When the schedule was delayed or advanced, this chart was updated accordingly.

Table 1. Project Timeline

Category General	**Activity**	**Month**											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Project Formulation	Literature Survey	**X**											
	Conceptual Designs		**X**										
	Finalized Design			**X**									
	Cost Analysis				**X**								
Proof of Concept	FEA Analysis				**X**								
	Material Gathering					**X**							
	Concept Testing					**X**							
Prototype Development	System Integration						**X**						
	Prototype Construction							**X**	**X**				
	Prototype Testing									**X**	**X**		
Final Presentation to IAB and MME	Poster Formulation											**X**	
	Presentation												**X**

3.2 Breakdown of Responsibilities Among Team Members

The general tasks this project comprises of, as well as the team member(s) responsible to complete them, are listed in Table 2. In order to balance the workload the majority of the tasks were given to two members of the group. More complex tasks were divided among three members while tasks that required less effort/time were assigned to a single member. Nevertheless, team members assisted each other in all aspects of the project.

Table 2. Breakdown of Responsibilities Among Team Members

Breakdown of Responsibilities			
	Jennifer Arniella	**Daniel Giraldo**	**Gabriela Vazquez**
Global Learning		**X**	**X**
Solidworks Modeling	**X**		**X**
FEA Analysis	**X**	**X**	
Literature Review Research		**X**	**X**
Material and Component Selection	**X**		**X**
Record Keeping	**X**		
Testing Apparatus	**X**	**X**	**X**

4. Engineering Design and Analysis

4.1 Analytical Analysis

4.1.1. Kinematic Analysis

Crawler:

Based on the laws of kinematics we can determine the type of magnet needed in order to maintain the crawler elevated as well as producing a large enough normal force in order to generate the proper amount of friction to propel the crawler forward

$$\sum F = m * a \tag{1}$$

Where:

$$\sum F_y = F_{Magnetic\ Force} - F_{Crawler\ Weight} + F_{Normal} \tag{2}$$

$$\sum F_x = F_{Friction} - F_{Tether} \tag{3}$$

Gears:

In order calculate the amount of horsepower for the motor to be able to propel the crawler forward we need to calculate the torque and forces being implemented on each gear. The following equations are being used.

$$W_t = F_{21} \tag{4}$$

$$T = W_t * \frac{d}{2} \tag{5}$$

$$V = \omega * \frac{d}{2} \tag{6}$$

$$H = \frac{W_t * V}{33000} \tag{7}$$

Where:

W_t = Transmitted Load

T = Torque

V = Tangential Speed in ft/min= $\frac{\pi * d * \omega}{12}$

H = Power in HP

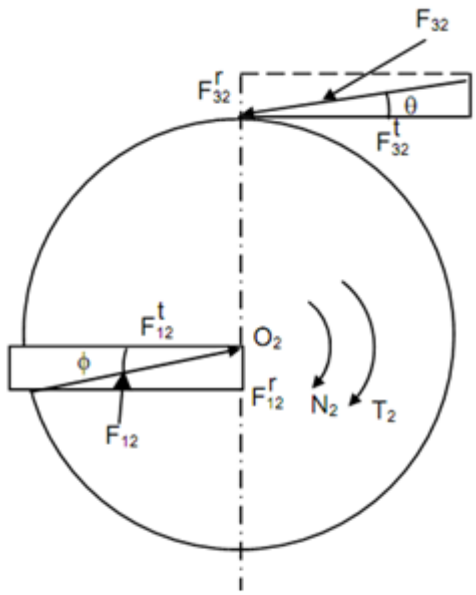

Figure 17. Free Body Diagram

4.1.2. Force Analysis

Gears:

The gears being used are stainless steel. In order calculate bending strength and durability of the gears the following equations are being used.

$$\sigma = \frac{W^{t} * P}{F * Y} \tag{8}$$

Where:

$P = \frac{\pi}{p}$ = diametral pitch

F = Facewidth

Y = Lewis Form Factor

Shaft:

The shafts on our design are used to transmit the loads from the motor to the gears and from the gears to the tracks. In order to be able to transfer the torque the shafts were analyzed with the following formulas

$$\sigma = \frac{M*c}{I} \qquad (9)$$

$$\tau_{max} = \frac{T*c}{J} \qquad (10)$$

Where:

σ = *Allowable bending stress*

c = radius of the shaft

I = moment of inertia

J = Polar moment of inertia

T = Torque

4.2 Major Components

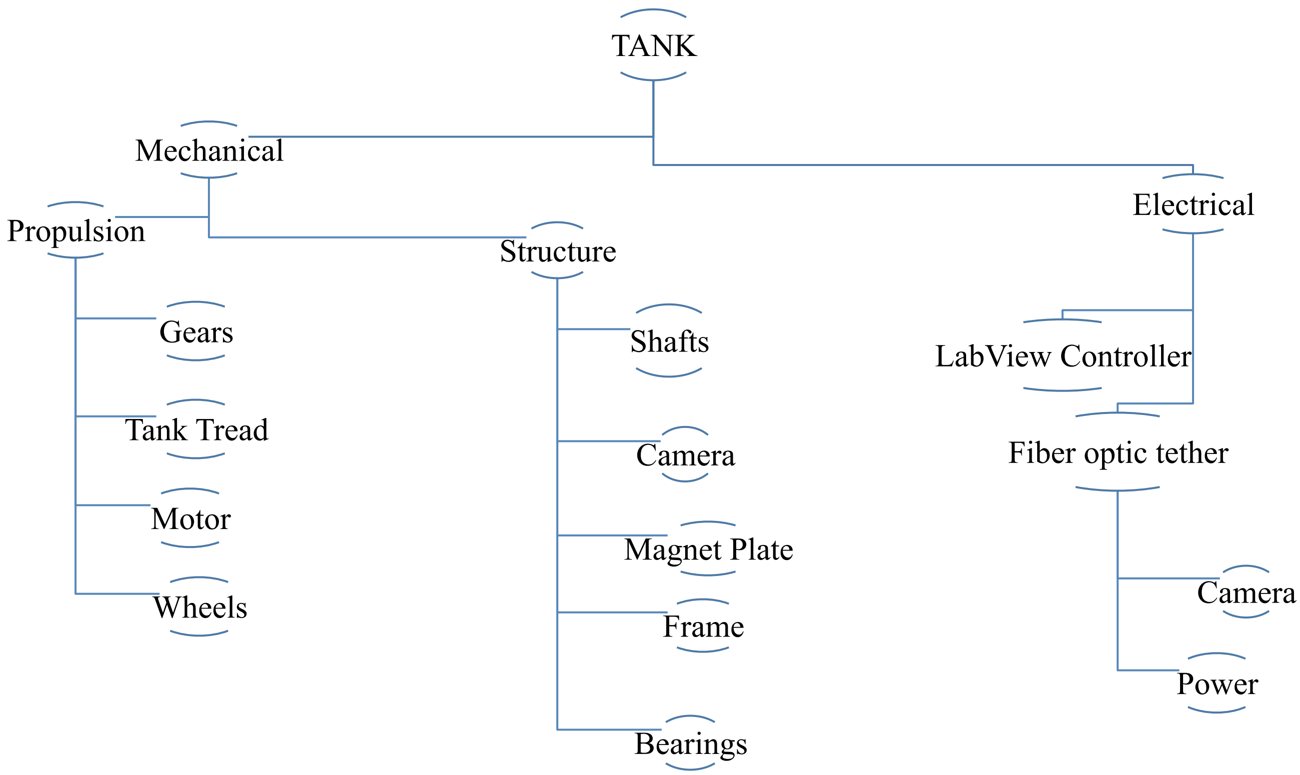

Figure 18. Major Components

The components that will be used in the inspection device are listed in Table 3. The components that are crucial in this design include the frame, magnetic plate, motors, track tread, and camera. Determining the frame dimensions is an essential part of this project since our frame needs to accommodate multiple components in a micro space, while at the same time, allowing the components to interact well with each other. The magnetic plate needs to be strong enough to attach the inspection device to the carbon steel tank while at the same time meet the available space between the inspection device and tank. The motors were carefully selected in order to fit in the constrained dimensions while providing enough power for the wheels to roll. Moreover, the tank treads need to be made with a material that can withstand high temperatures without significant deformation. The camera is the most important component because it is what will provide video feedback to show engineers the underground tank conditions. This camera needs to be very small and radiation hardened and therefore is the component of highest cost.

Table 3. Components list with main specifications and manufacturer.

Component	Specifications	Manufacturer
Magnet Plate	Dimensions: 1 in x ¾ in x 1/8 in thick Material: NdFeB, Grade N42 Weight: 0.407 oz. (11.52 g) Pull Force: 12.36 lbs Max Operating Temp: 176ºF (80ºC) Part Number: BX0C2	KJ Magnetics
Motor	Diameter: Body 0.315 in Length: Shaft and Bearing 0.413 in Torque: Starting (oz-in / mNm) 0.07 / 0.5 Weight: 0.006 lb (2.72g) RPM: 16364 RPM Part Number: PNN7RE09PD	NMBTC
Shafts	Length: 11.81 in Diammeter: 0.0393 in Material: Through-Hardened 17-4 PH Stainless Steel Part Number: 1174K12	McMaster
Frame (Body)	Material: 303 Stainless Steel Width: 1.2 in Length: 1.2 in Height: 1.15 in	Schenke Tool Co.
Wheels	Diameter: 0.350 in Bore Diameter: 0.0397 in Face Width: 0.25 in	Schenke Tool Co.
Track Tread	Temperature Resistance: < 230 F Material: High Temperature Elastic Urethane Diameter: 1 in	DuraBelt
Camera	Name: Mini Crystal Cam Diameter: 0.875 in Length: 2 in Radiation Hardened	Inuktun
Bearings	Bore Size: 0.0469 in Outside Dia: 0.1562 in Overall Width: 0.063 in Dynamic Load 16 lbs Static Load 5 lbs Part Number: A 7Y55-F1504	SDP-SI

Gear (8)	Diametral Pitch: 64 No. Of Teeth: 8 Material: Brass Face Width: 0.1563 in Pitch Dia: 0.125 in Part Number: A 1B 1-Y6400864	SDP-SI
Gear (9)	Diametral Pitch: 64 No. Of Teeth: 9 Material: Brass Face Width 0.1563 in Pitch Dia: 0.141 in Part Number: A 1B 1-Y64009	SDP-SI
Gear (12)	Diametral Pitch: 64 No. Of Teeth: 12 Material: Brass Face Width: 0.1563 in Pitch Dia: 0.188 in Part Number: A 1B 1-Y64012	SDP-SI
Gear (20)	Diametral Pitch: 64 No. Of Teeth: 20 Material: 303 Stainless Steel Face Width: 0.125 in Pitch Dia: 0.3125 in Part Number: S1164ZN064S020C	SDP-SI
Lab View Controller	A program that will enable the user to control the inspection device from outside of the slots through power lines	N/A
Fiber Optic Line	Think fiber optic line that gives power to the motors and camera.	N/A

4.3 Structural Design

The frame will be made from stainless steel. It will be optimized using Abaqus to make sure we use the least amount of material possible to reduce weight, material cost, and maintain a strong design. Its non-corrosive properties make it ideal to ensure a long lasting product with out affecting the reliability of the design. Stainless steel also works well in radioactive material by deflecting radioactive particles that can be destructive to the electronics inside the crawler. The stainless steel housing not only provides structural support to the crawler but also serves, as a protective shell that will ensure a reliable product.

4.4 Prototype System Description

The prototype system entails the tank body with its housing the motor, gears, shafts, and camera. The camera provides video feedback through a fiber optic line. The data collected will be recorded at the surface through a digital video recorder (DVR) that records video in MPEG-4 file format directly to a USB flash drive. The DVR allows for video recording, viewing live feeds, and play back recorded feed so that the real-time inspection can be easily stored on a convenient flash drive. The camera's fiber optic line is jacketed together with the power lines to the motors. The propulsion of the tank motor is controlled from the surface at a control unit. Programmed using Laboratory Virtual Instrument Engineering Workbench (LabVIEW), the forward and backward motion will be coordinated by switches on the controller.

4.5 Prototype Cost Analysis

In order to determine the final cost of the proposed design, a detailed cost analysis was conducted. As an engineer, it is our job to determine what is the lowest possible cost of our project and it is necessary to research competitive companies that will enable us to reach this goal. After doing research and carefully comparing the information obtained, the components were selected and the final cost is listed in Table 4. Also, the labor cost was calculated using the hours that each team member spends in the project for two semesters and a salary of $12/hour. By adding these two amounts, the total cost of the project is $ 10,530.24.

Table 4. Cost For Components and Labor Work

Component	Manufacturer	Price/Unit	Units	Total Price
Magnet Plate	KJ Magnetics	$3.20	1	$3.20
Motor	NMBTC	$4.07	2	$8.14
Shafts	McMaster	$28.74	1	$28.74
Frame (Body)	Schenke Tool Co.	$400.00	1	$400.00
Wheels	Schenke Tool Co.	$36.55	4	$146.20
Tank Tread	DuraBelt	$8.85	2	$17.70
Camera	Inuktun	$7,000.00	1	$7,000.00
Bearings	SDP-SI	$8.97	6	$53.82
Gear (8)	SDP-SI	$2.97	2	$5.94
Gear (9)	SDP-SI	$2.97	2	$5.94
Gear (12)	SDP-SI	$2.97	2	$5.94
Gear (20)	SDP-SI	$11.31	2	$22.62
			Total Component Cost	$7,698.24
Estimated Labor Cost (Spring, Summer and Fall Semester)	Salary	Hours/ Semester	Semesters	Total Labor Cost
	$ 12/hr	118	2	$2,832.00
			Total Project Cost	$10,530.24

To determine the labor cost, the time each member spent on the project is required. Throughout the project development, the time each team member spent on the project was tabulated. The total time spent in the project for one semester is listed in Figure 4 along with the specific dates the work was performed.

Table 5. Total Work Hours

Time Reporting							
Group Meetings		Gabriela Vazquez		Daniel Giraldo		Jennifer Arniella	
Date	Time (hrs)	Date	Time (hrs)	Date	Time (hrs)	Date	Time (hrs)
1/27/14	0.5	1/31/14	1.5	1/31/14	1	1/31/14	0.5
2/3/14	1.5	2/3/14	1.5	2/4/14	1.5	2/6/14	1.5
2/10/14	1.5	2/12/14	1	2/13/14	0.5	2/15/14	1
2/26/14	1.5	2/27/14	2	2/28/14	2	2/27/14	3
3/10/14	3	3/12/14	2	3/30/14	1	3/30/14	3
3/17/14	2	3/19/14	1.5	3/21/14	1	3/19/14	3
3/24/14	2	3/27/14	1.5	3/29/14	1.5	3/28/14	2
3/31/14	3	3/31/14	2	3/31/14	2	3/30/14	1.5
4/7/14	1	4/10/14	3	4/12/14	3	4/14/14	2
4/14/14	2	4/16/14	3	4/15/14	3	4/17/14	2
4/21/14	1.5	4/23/14	2	4/22/14	1.5	4/22/14	1
Total	19.5	Total	21	Total	18	Total	20.5
Total Hours	118						

4.6 Plans for Testing Prototype

To improve and validate the design, several tests will be conducted with the prototype. These tests include:

- The device behavior will be monitored in different level of corroded carbon steel plates.
- Magnets with different thickness will be purchased to test different magnetic strength on the device.
- Environments with temperature variations will be created to run the device.
- A model with the slots will be built to testing the device abilities to travel through 90-degree turns.

5. Conclusion

5.1 Conclusion and Discussion

Our main motivation to initiate this project has arisen from the need to avoid radioactive contamination into the subsurface soil. The Colombia River is located only 5 miles away from the tanks carrying the radioactive waste and if uncontrollable leakages were to occur the river could get contaminated. This river provides water to the city and could potentially pollute the environment and community in Washington State.

The Department of Energy is in need of specially designed equipment that can inspect underground tanks for leakages of high-level radioactive waste. The design developed consists of a magnetic tank that will travel upside down along the carbon steel tanks. This device will travel through air slots and will provide video feedback that will enable engineers to detect the position of the leakages and eventually repair the tanks. The design was validated using FEA analysis and motion analysis utilizing Abaqus and Solidworks software's.

In a global perspective radioactive waste management is an issue that all developed countries must address. In order to avoid environmental contamination that can affect the global ecosystem, it is important for us to be proactive in our research towards monitoring and managing waste storage. Our magnetic tank is applicable to all countries such as Sweden, Canada, Finland, and United Kingdom who store waste in a repository that requires periodic inspection to monitor leakage. Countries like France, whose nuclear industry is their main supplier of electricity, are working with research companies in a combined effort to develop radiation tolerant robotic devices. For example, devices such as France's AREVA's SeeSnake MicroReel are references for the development of our inspection tool. Using the lessons learned from this device came the development of housing the camera within an electronic tank that can travel through the slots instead of pushing a device manually.

In conclusion, to sustain a safe and dynamic environment in our world today and for future generations to come, there is an obligation to properly treat and store the legacy waste. B.U.G.'s Inspection Device for the Department of Energy's Hanford Site Underground Tanks in a combined effort with international corporations will have a hand to reach this goal.

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