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Improved Third Generation Peristaltic Crawler for Removal of High Level Waste Plugs at Hanford Site Pipelines

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to the U.S. Department of Energy
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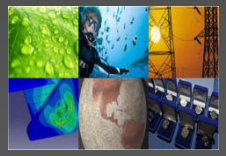
Worlds Ahead



Overview

- Background Information
- Problem Description and Objective
- Overview of Previous Research
- Research Progress for Current Semester
- Path Forward
- Acknowledgments

Background Information

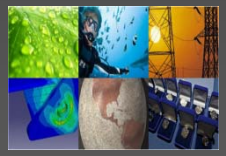
- The first retrieval of radioactive material at the Hanford Site began in 1944.
- High level waste at Hanford has many different chemical compositions and physical characteristics.
- The earliest tanks to hold the HLW were single-shell tanks (SSTs). These SSTs have outlived their useful life and it has resulted in leakage of waste into the surrounding soil.
- The later double-shell tanks (DSTs) consist of a first tank surrounded by a secondary containment tank. The external shell of the DST provides an additional barrier.

- It is estimated that up to 1.97 m^3 of radioactive waste might have leaked from the inner shell of a DSTs.
- Transfer not only from SSTs to DSTs but from older DSTs to the newer DSTs.

Problem Description

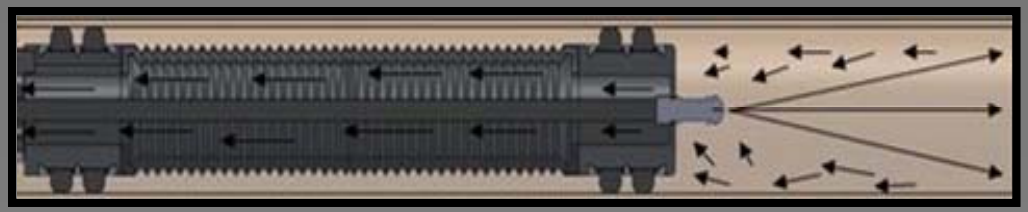
- Closure of the Hanford tanks is vital to surrounding environment protection.
- There is to be a complete transfer of this HLW from single shell tanks to secure double shell tanks by 2040.
- This transfer is done via pipelines.
- **Some of the pipelines have formed blockages due to particle settling, phase changes, or reactions accompanied by gel formation that occur during transport.**

Where the DREAM TEAM comes into play



Objective

To continue the transfer of waste through the pipelines, our goal is to create a peristaltic crawler as an unplugging tool/technology capable of pulling its own weight to accurately locate the blockages and remove plugs that exist in pipelines



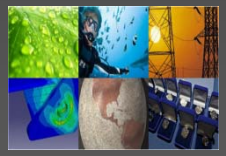
Design Metrics

Fit within 7.62 cm inner diameter pipes

Survive in a RADIOACTIVE environment

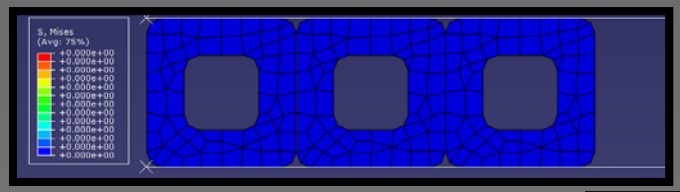
Operate below 2068 kPa

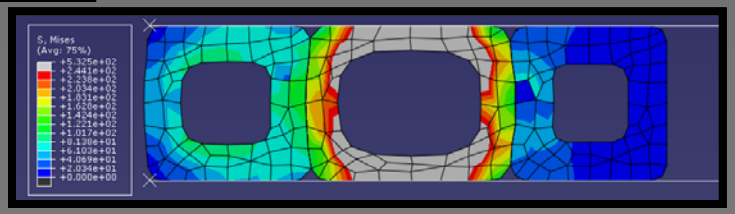
Maneuver through a 90º ELBOW with a 10.795 cm turning radii

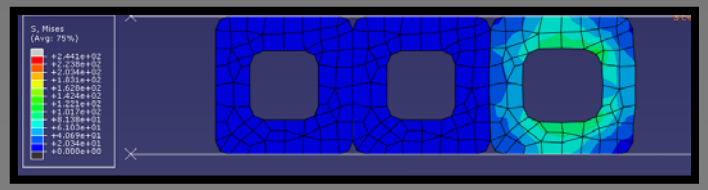


System Explanation

The peristaltic crawler is a pneumatic/hydraulic operated tool that propels itself by a sequence of pressurizations/depressurizations of its inner tubes. It has three air cavities with front and rear rims for the inner and outer bellows. The bodies inflate and deflate in sequence. The changes in pressure result in a worm like motion of the vessel by peristaltic movements. The crawler includes a frontal attachment that has a hydraulically powered unplugging tool.





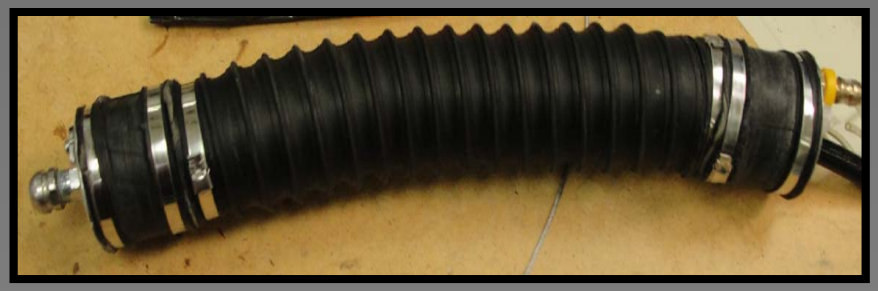


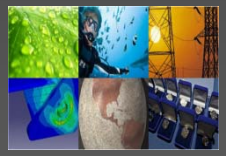
First Prototype: Proof of Concept

- Designed, assembled, and tested to provide experimental data to support the principles of motions
- Showed losses in its structural integrity when subjected to long unplugging operation

Results:

- Could navigate through a 90 degree elbow
- Supplying 206 kPa of air had a maximum pulling force of 121 N.
- Unplugged a 91.44 cm long Bentonite clay plug





Major Accomplishment

Task 2 Pipeline Unplugging and Plug Prevention

Maneuver through Elbow

Unplugging Operation

Second Prototype: Material Durability

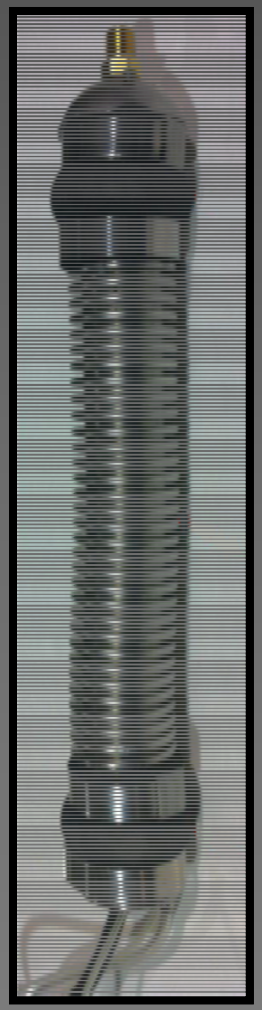
- Replaced rubber bellows with stainless steel hydroformed bellows (inner and outer)
- Automation of sequence of inflation/deflation of the cavities
- New pneumatic regulators and a vacuum chamber were implemented to improve the cycle time

Results:

- Stainless steel bellows allow a maximum pressure of 1034 kPa
- Cycle time: 16 seconds
- Maximum speed of the crawler on straight pipe is 15.24 cm/min.
- Could not turn on Victaulic elbow of 10.795 cm radius
- Was able to turn on a PVC elbow of 14.12 cm turning radius
- Unplugged a 91.44 cm long Bentonite plug and a 10 cm long Sodium Aluminum Silicate plug

Third Prototype

- The outside diameter of the unit was decreased for improved navigation capabilities
- Inner bellow was changed to an edge welded bellow to decrease the stiffness of the assembly
- 316 stainless steel rims were used for HLW environment durability
- All parts welded together eliminating potential leak points



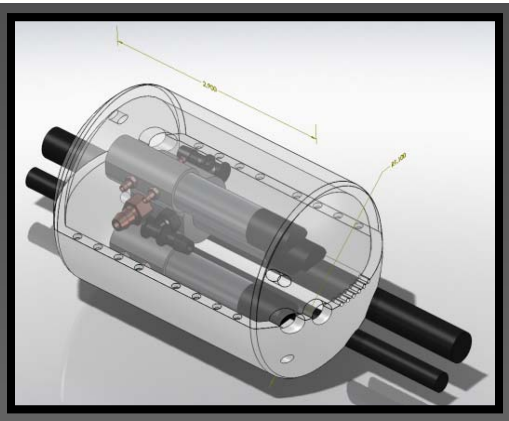
Control Unit

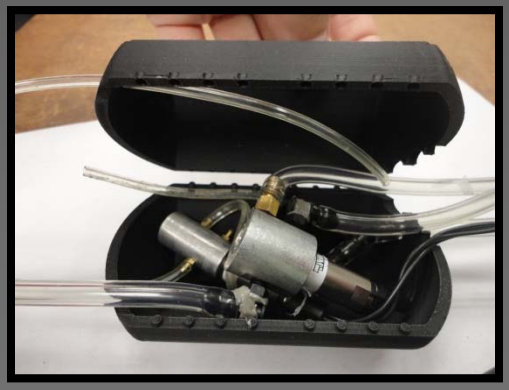
- Omron programmable logic controller (PLC)
- Ladder programming
- Forward, reverse, joystick, manual override
- Controls micro valves near crawler
- Air pressure and vacuum inputs
- Independent air regulation
- Automation of locomotion

Valve Container

- Container for pneumatic valves and lines to crawler to protect from water damage

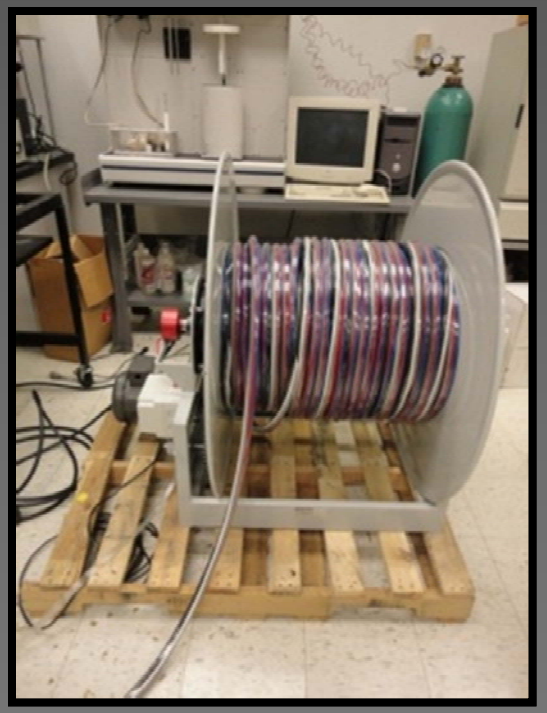
- Design Metrics of Container:
  - Fit within 7.62 cm inner diameter pipes
  - Water-proof
  - Maneuver through a 90 degree elbow with a 10.795 cm turning radii
  - Survive in a radioactive environment





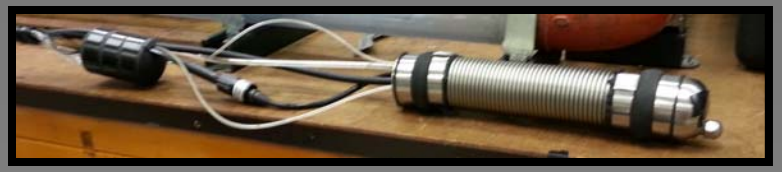
Tether

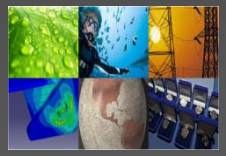
- 152.4 meters long tether-reel assembly system. The tether assembly consists of three pneumatic lines, one hydraulic line, and one multi-conductor cable jacketed together.



Improved Third Generation

- Inspection camera mounted at front of crawler to provide visual feedback of pipeline conditions
- New design of front rim to improve packaging of features onto crawler
- Thinner walled outer hydroformed bellow to improve navigational maneuverability.
- Pneumatic valves are be located behind the crawler unit (not at the control station) to significantly reduce cycle time
- Improve automation of sequence to avoid kickback
- Separate elbow navigation program





Results: Speed

3rd generation:

- Bellows set to 345 kPa and rims at 414 kPa
- Straight line navigational speed: ≈ **5.8 m/hr**

Improved 3rd generation:

- Bellows set to 69 kPa and rims at 621 kPa
- Straight line navigational speed: ≈ **11.6 m/hr**

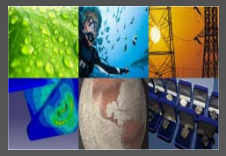
Results: Maneuverability

3rd generation:

- Bellows set to 345 kPa and rims at 414 kPa
- The crawler successfully travelled through a 10.795 cm radius elbow in ≈ **10 min**

Improved 3rd generation:

- Bellows set to 138 kPa and rims at 621 kPa
- The crawler successfully travelled through a 10.795 cm radius elbow in ≈ **6 min**



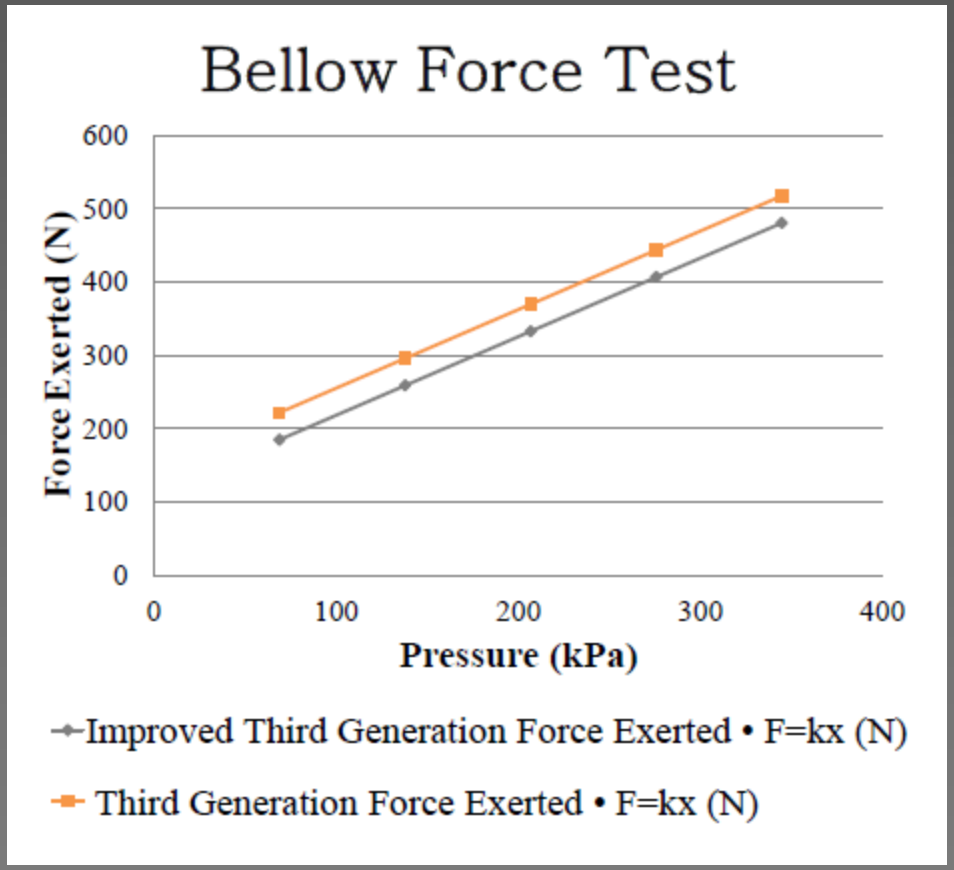
Results: Bellow Response

- Time needed for bellows to reach a set air pressure
- Measured by gauge at base of bellows
- Testing for each pressure performed three times

	Improved 3rd Generation Extra Thin Wall Bellow		
	Expansion Time (s) to 165 kPa	Compression Time to 254 mm/Hg	Overall Cycle Time (s)
	23.00	27.00	50.00
	22.00	28.00	50.00
	20.00	28.00	48.00
Average	22.67	27.67	49.33

	3rd Generation Thin Wall Bellow		
	Expansion Time (s) to 165 kPa	Compression Time to 254 mm/Hg	Overall Cycle Time (s)
	20.00	31.00	51.00
	19.00	32.00	51.00
	21.00	29.00	50.00
Average	20.00	30.67	50.67

Results: Bellow Force



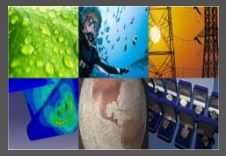
- As tether length increases so will its weight. It is important that the crawler is capable of carrying its own weight.

- Hooke's Law:

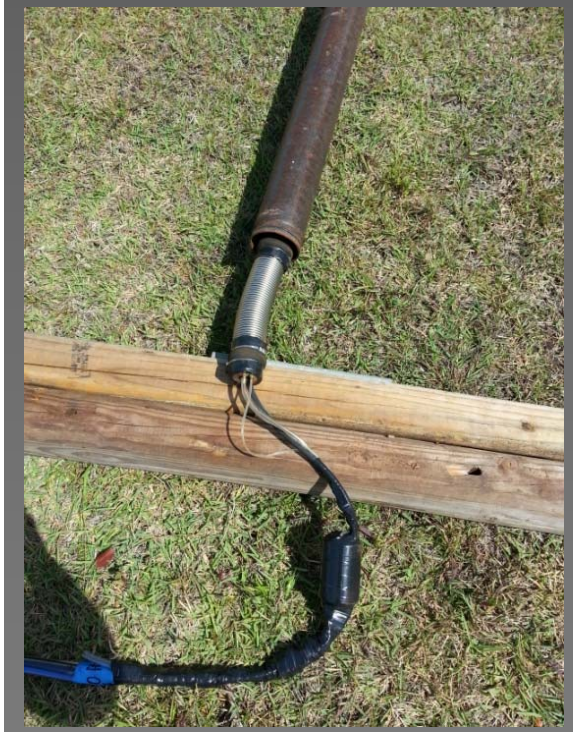
F: Force exerted = 1.21 kN

K: spring rate = 23.3 kN/m

X: Maximum displacement = 0.052m



Path Forward: Large Scale Testing and Unplugging



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