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

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Introduction

The retrieval of radioactive material at the Hanford Site produced vast quantities of high level waste (HLW).

First, single –shell tanks (SST) were used to hold the HLW. These SSTs have outlived their useful life which 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 as an additional barrier. It is estimated that up to 2 m³ of radioactive waste might have leaked from the inner shell of a DSTs.

There is to be a complete transfer of this HLW to secure double shell tanks by 2040. This transfer is done via pipelines.

Because of the variety in composition and characteristics of the waste, some of the pipelines have formed blockages.

These full and partial plugs delay waste transfers and require manual intervention to repair; therefore they are extremely expensive, consuming millions of dollars and further threatening the environment.

To continue the transfer of waste through the pipelines, an unplugging tool/technology is needed to accurately locate the blockages and unplug the line. Complete transfer is Necessary in order to ensure tank farm clean up.

Objective

The pneumatic crawler will be capable of applying enough force to pull its own weight, including the tether line, while maneuvering through 90° elbows at a 10.795 cm radius.

The crawler will be agile and be able to crawl through horizontal and up vertical sections of the pipeline. An unplugging tool will be mounted to the front of the crawler for removing plugs.

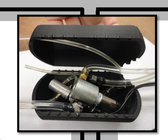
Design Metrics

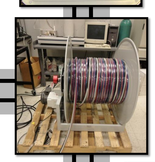
Based on Hanford pipelines, the crawler and its components must:

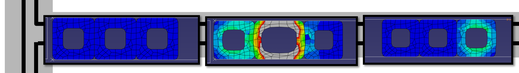
- Fit within 7.62 cm inner diameter pipes
- Be able to pull its own weight including weight of tether
- Operate below 2.07 MPa
- Be capable of removing plugs that exist in pipelines
- Maneuver through a 90° elbow with a 10.795 cm turning radii
- Survive in a radioactive environment

System Explanation and Components

- Pneumatic/hydraulic operated tool propelled by a sequence of pressurizations/depressurizations of its inner tubes
- Three pneumatic valves held in a **container** supply air to cavities
- **Omron programmable logic controller** (PLC) program inflate and deflate the bodies in sequence causing worm-like motion
- Frontal attachment has a hydraulically powered unplugging tool
- **500 foot long tether reel assembly** : 3 pneumatic lines, 1 hydraulic line, and 1 multi-conductor cable jacketed together.





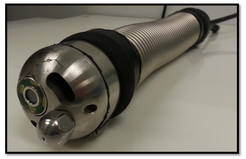


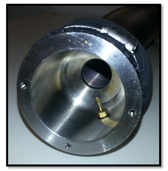
Third Prototype

- Hydroformed outer bellow for relatively high internal pressure
- Edge welded inner bellow to decrease the stiffness
- 316 stainless steel rims used for HLW environment durability
- Parts welded together eliminating potential leak points
- Hydraulic and pneumatic lines jacketed together
- Pneumatic valves located behind the crawler unit to significantly reduce cycle time
- Outer Bellow wall thickness: 0.15 mm

Improved Third Prototype

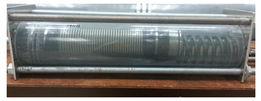
- Outer bellow wall thickness was reduced to allow superior flexibility
- Water proof camera installed for viewing capabilities while in the pipeline
- 15° water nozzle mounted as unplugging tool
- Front rim was resigned to a diameter of 5.715 cm and an inner diameter of 4.31 cm for better packaging
- Frontal helmet was redesigned to hold the camera and water nozzle into place and allow space for waste to travel back through after unplugging





Bellow Force

- As the tether length increases so will the weight. It is important that the crawler is able to carry its own weight as well as that of the tether.
- Set up:
  - Spring (F=kx)
  - F: Force exerted = 1.21 kN
  - k: spring rate = compresses 23.3 kN/m
  - x: Maximum displacement = 0.052 m



- Analytically

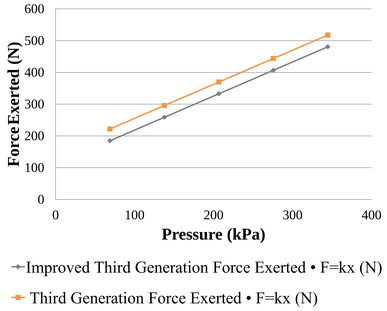
Force = Pressure * Area

Area = Cross Sectional Inner Area - Cross Sectional Outer Area

	Improved Third Generation	
Pressure (kPa)	Spring Displacement (cm)	Force Exerted • F=kx (N)
68.95	0.79	184.88
137.90	1.11	258.83
206.84	1.43	332.79
275.79	1.75	406.74
344.74	2.06	480.69

	Third Generation	
Pressure (kPa)	Spring Displacement (cm)	Force Exerted • F=kx (N)
68.95	0.95	221.86
137.90	1.27	295.81
206.84	1.59	369.76
275.79	1.91	443.71
344.74	2.22	517.66

Bellow Force Test



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

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**

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**

Future Work

The Peristaltic Crawler is a versatile platform that can improve DOE's unplugging toolbox

- Large scale pipeline testing
- Manufacture a radioactive resistant and waterproof container for pneumatic valves
- Bellow fatigue testing
- Additional unplugging tests for new nozzle

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