Engineering Scale Testing of the Peristaltic Crawler System

for the Removal of High Level Waste Plugs at Hanford Site Pipelines

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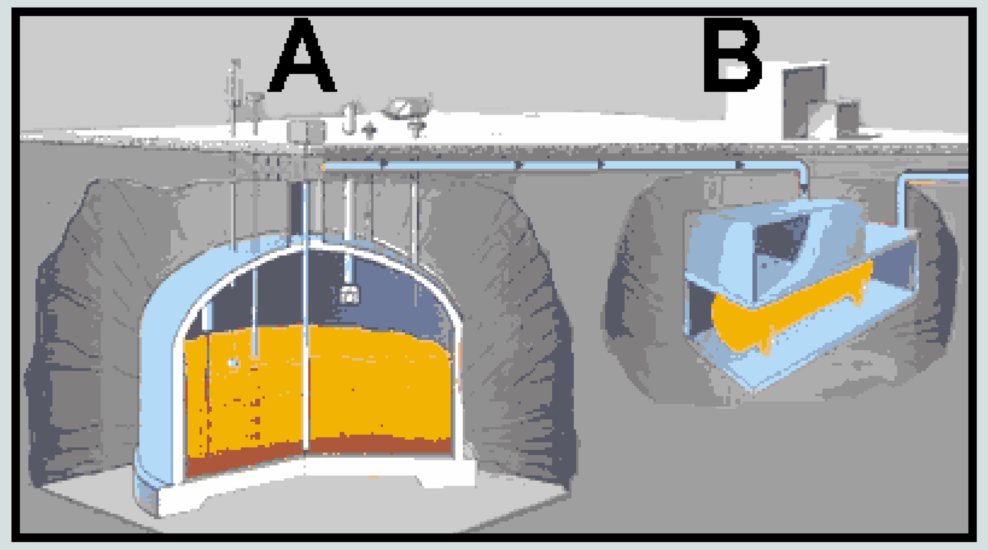
Background Information: Hanford Site

- There are approximately 56 million gallons of high level waste (HLW) on the Hanford Site
- 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
- Because of the variety of composition and characteristics in the waste some of the pipelines have formed blockages
- Removal of waste in plugged pipelines is a challenge, the plug must be located and removed without damaging the pipelines
- To continue the transfer of waste through the pipelines an unplugging tool/technology is needed to accurately locate the blockages and unplug the line



Transfer from single shell tank to double shell tank
Source: *http://www.hanford.gov/reach/viewpdf.cfm?aid=1271 10apr04*

Design Metrics & Restrictions

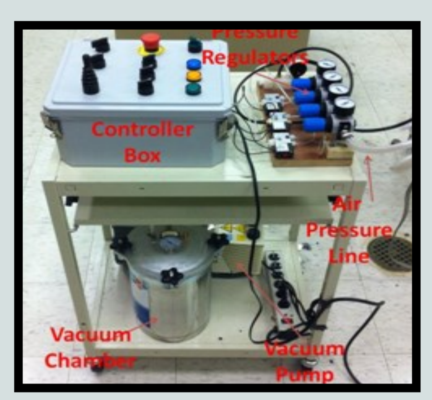
Based on Hanford site pipelines and conditions, the crawler and its components must:

- Fit within 3 inch inner diameter pipes
- Be able to pull its own weight, and that of the tether
- Maneuver through a 90 degree elbows with 4.25 turning radii
- Be capable of removing plugs without damaging the pipelines
- Survive in a radioactive environment of 10 Gy/hr
- Have a maximum operating pressure below 300 psi

System Description

- The peristaltic crawler is a pneumatic/hydraulic operated tool that propels itself by a sequence of pressurization/ depressurization of its' inner cavities
- It has three air cavities: front and rear rims, and a double wall bellow assembly
- The bodies inflate and deflate in sequence
- The changes in pressure result in a worm like motion of the vessel by peristaltic movements

A spring system located at the back rim facilitates compression of the system as well as to prevents the bellow from over-extending

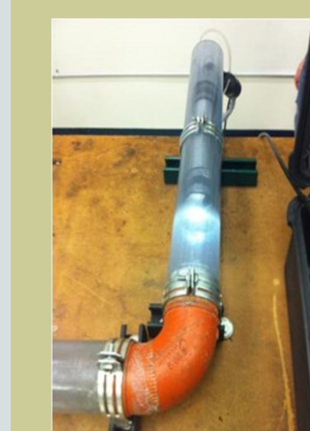


Control System

The peristaltic crawler includes a frontal attachment with a hydraulically powered unplugging tool and a camera for visual feedback of the pipelines condition

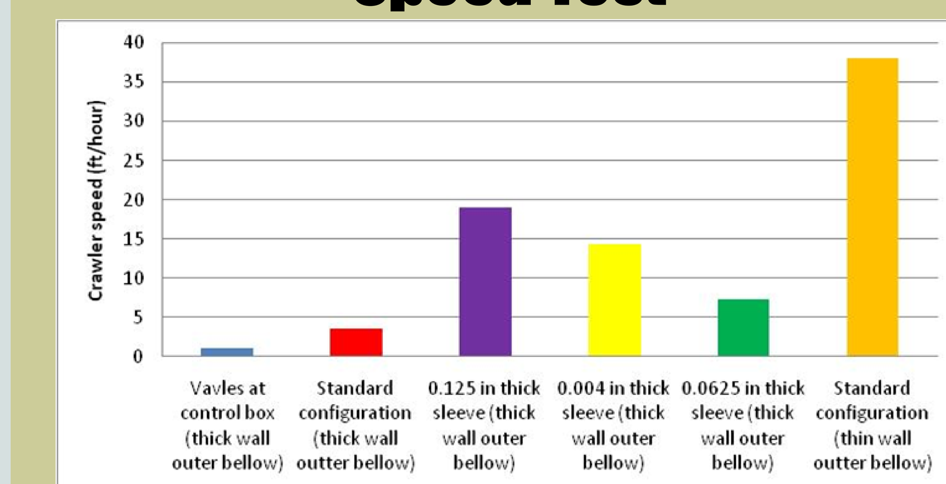
Experimental Testing

Bench Scale Testing



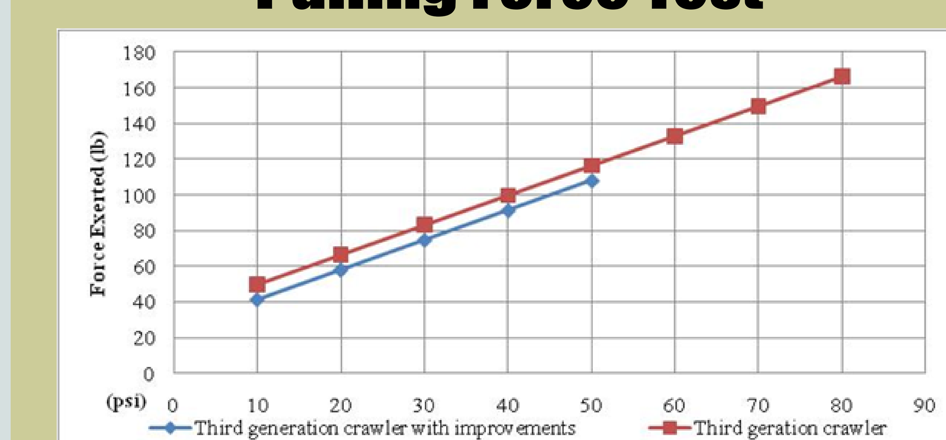
- Demonstrated a navigational speed of 38 ft/hr
- Successfully performed unplugging operations on Bentonite, Kmag, and Na-Al-Si plugs
- Generated an axial Force of 108 lbs
- Test where also performed to determine the duration of the rims before they rupture and have to be replaced

Speed Test



The graph shows the results of the speed test conducted on a 3 foot straight section using multiple outer bellow configurations

Pulling Force Test



Pulling force tests were conducted using the outer thinner wall bellow configuration. The maximum force recorded was 108 lb with a supplied air pressure of 50 psi. The graph shows the previous and latest results of the force test conducted

Fatigue Testing

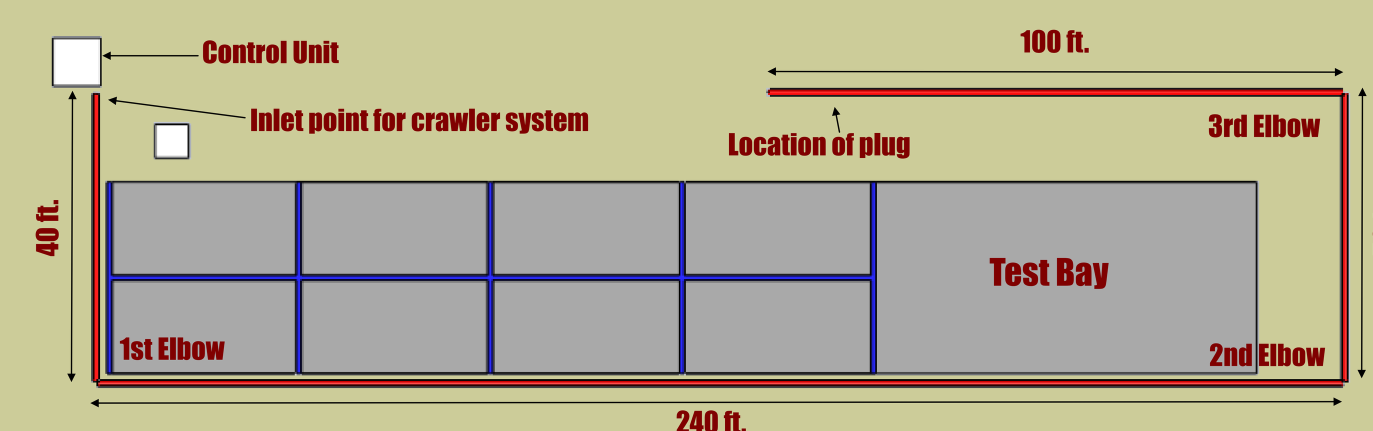
- It is estimated that total of 3,600 cycles will be required for the unit to navigate a 500 ft pipeline
- Different materials, configurations, and clamping pressures were tested to decrease the failure of the cavities
- Kevlar gasket placed between the clamps and the flexible cavity made for the best tested material
- The largest number of cycles recorded without failure was 1,260

Crawler with prototype rims

- An experimental fixture having the same outer diameter as the back rim was assembled and test were performed to determine the best configuration for the rims (length between the clamps)
- Increasing the distance between the clamps increases the number of cycles until failure, however it makes it more difficult to navigate 90º turns. A distance of 1.25 inches was chosen

Experimental Fixture

Engineering Scale Testing



- The experimental large scale testbed (illustrated in the image above) is 430 feet in length and consists of 24 straight sections and three 90° elbows assembled with couplings
- The pipes sections used are grade 10 carbon steel pipes and have an inner diameter of 3.26 inches

Navigational Tests

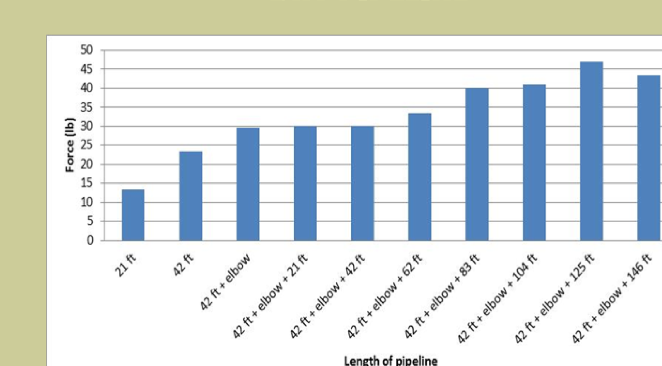
Navigational tests were conducted using the engineer scale testbed. The performance of the system showed two mayor limitations due to effects resulting from using a longer pipeline

1. Friction force between the tether and the pipeline increases dramatically with distance
2. Fatigue failure of the cavities, the rims rupture after a certain number of cycles

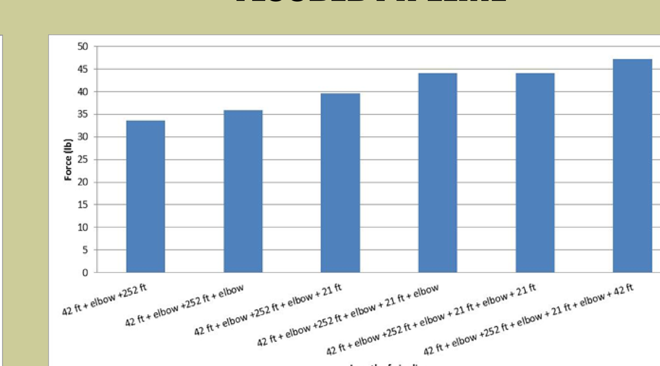
Pulling Tests

- Friction between the tether and the pipeline created extreme pulling requirement over long distances
- Elbows significantly increase pulling requirements
- Flooding the pipe provided a drastic decrease in the required pulling force

DRY PIPELINE



FLOODED PIPELINE



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