Peristaltic Crawler for Pipeline Unplugging

Sabri Tosunoglu, PhD **Jose Matos [DOE Fellow]** Tomas Pribanic, MS

Introduction

- 56 million gallons of HLW on Hanford site
- Transferred via pipelines from single to double shell tanks
- Full and partial plugs in pipelines delay waste transfers
- Repairs consume millions in tax dollars

Design Metrics

- Hanford pipelines dictate that a crawler must:
- Fit within 3” inner diameter pipes
- Maneuver 90° elbows with 4.25” turning radii
- Survive a radioactive environment of 10 Gy/hr
- Not exceed 300 psi
- Be equipped to remove plugs typical of Hanford Pipelines

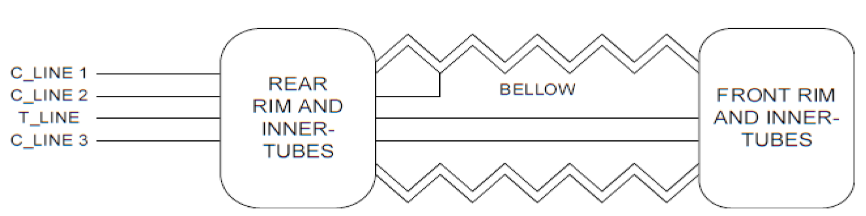
Plug Characterization

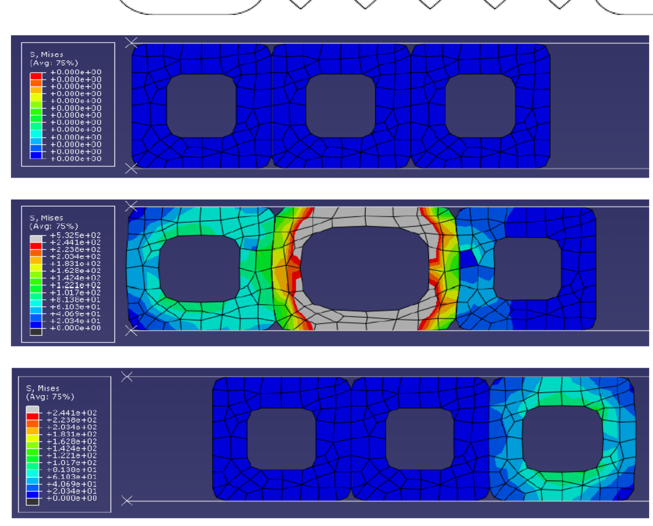
PNNL’s research into plug types provided the following information:

- ***Easiest***
  Sludge type: Bentonite clay
- ***Medium***
  Hardpan: Kmag
- ***Toughest***
  Salt-cake: Sodium Aluminum Silicate

System Explanation

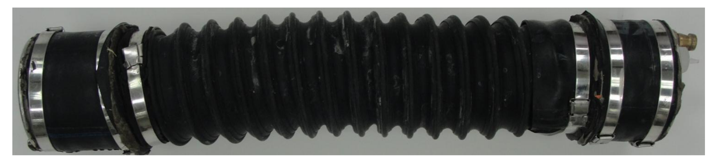
- Three air cavities
- Front and rear rims, inner and outer bellows
- Bodies inflated and deflated in sequence
- Worm-like motion
- Unplugging tool mounted in front



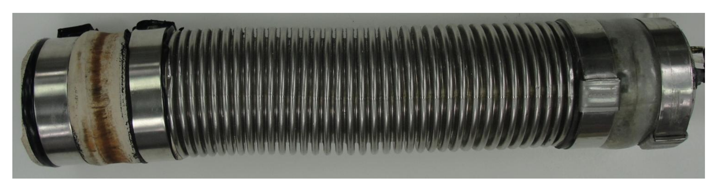


Past Prototypes

- First prototype served as proof-of -concept
- Rubber and aluminum construction, flexible but not durable
- Inner tubes on ends held by c-v clamps
- Employed pressure washer to destroy 1’ bentonite plug

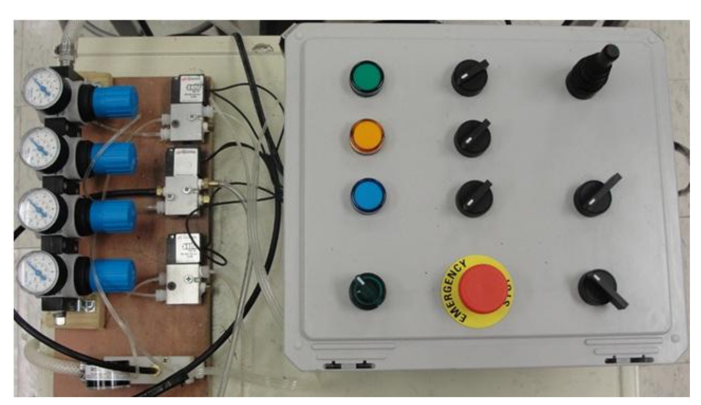


- Second prototype: material upgrades
- Hydro formed inner and outer bellows
- Flanges welded on ends
- Polyurethane sleeves held by ½” clamps
- Destroyed 3’ sodium aluminum silicate plug



Control Setup

- Omron Programmable Logic Controller (PLC)
- Ladder Programming
- Forward, reverse, joystick, manual override
- Electronic solenoid valves
- Air pressure and vacuum inputs
- Independent air regulation



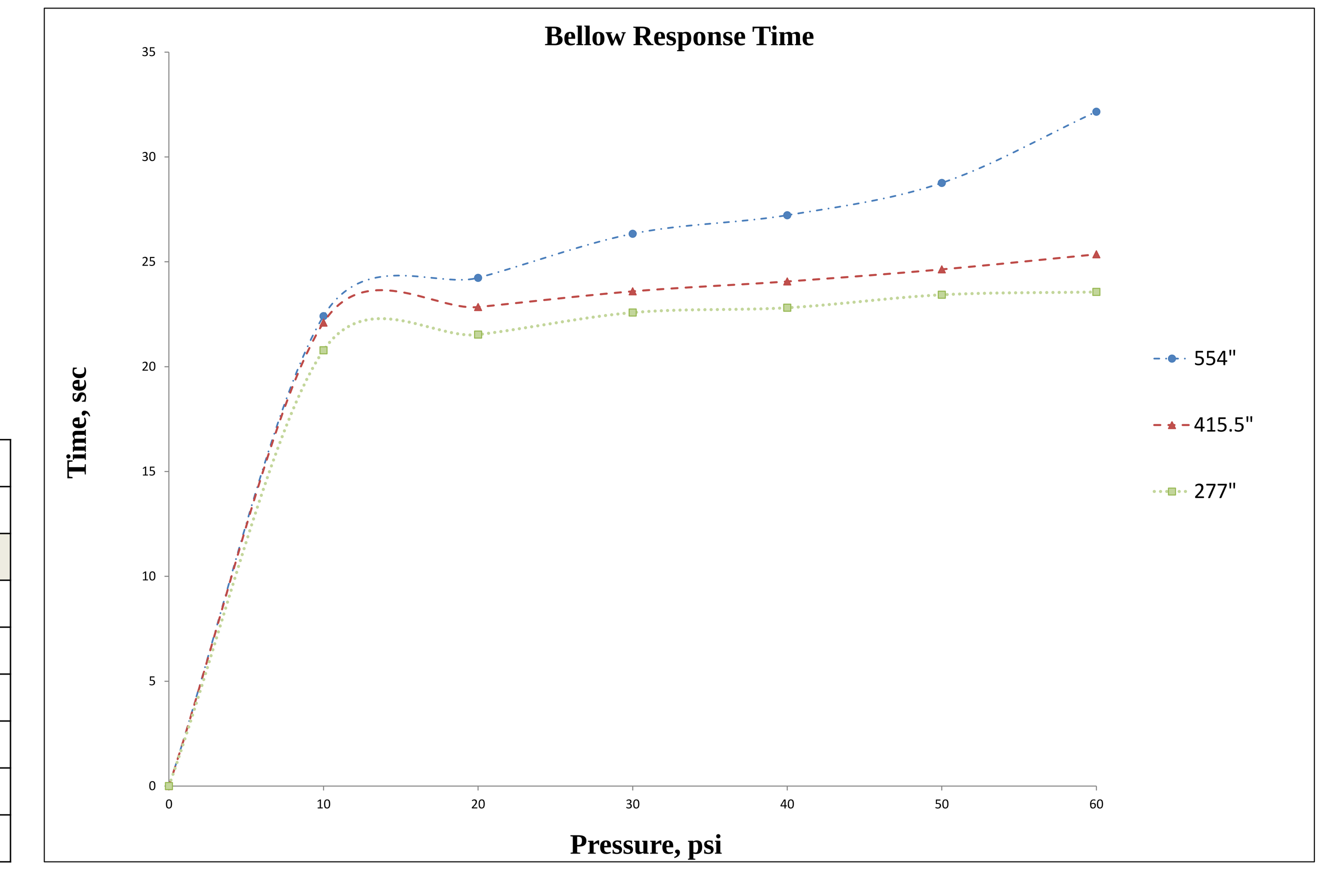
3rd Prototype Development

- Combines advantages of previous prototypes
- Seeks to avoid their drawbacks
- Smaller O.D., hydro formed outer bellows, improves cornering
- Edge-welded inner bellows
- 316 stainless steel rims
- Possible integration of onboard valves

Bellow Response

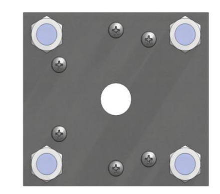
- Time needed for bellows to reach a set air pressure
- Tested in 10 psi increments from 10 to 60 psi
- Measured by gauge at base of bellows
- Testing for each pressure performed three times
- Entire tests repeated with shorter air feed lines

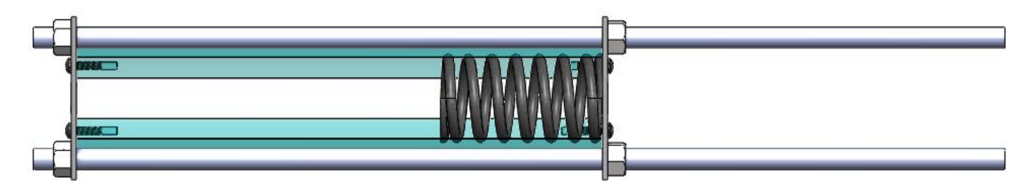
	Tube Lengths (inches)		
	554"	415.5"	277"
Pressure, psi	Final Time (s)	Final Time (s)	Final Time (s)
10	22.408	22.100	20.780
20	24.234	22.843	21.530
30	26.336	23.593	22.581
40	27.220	24.064	22.811
50	28.760	24.640	23.430
60	32.156	25.358	23.564



Bellow Force

- Important as tether length and subsequently weight, increases.





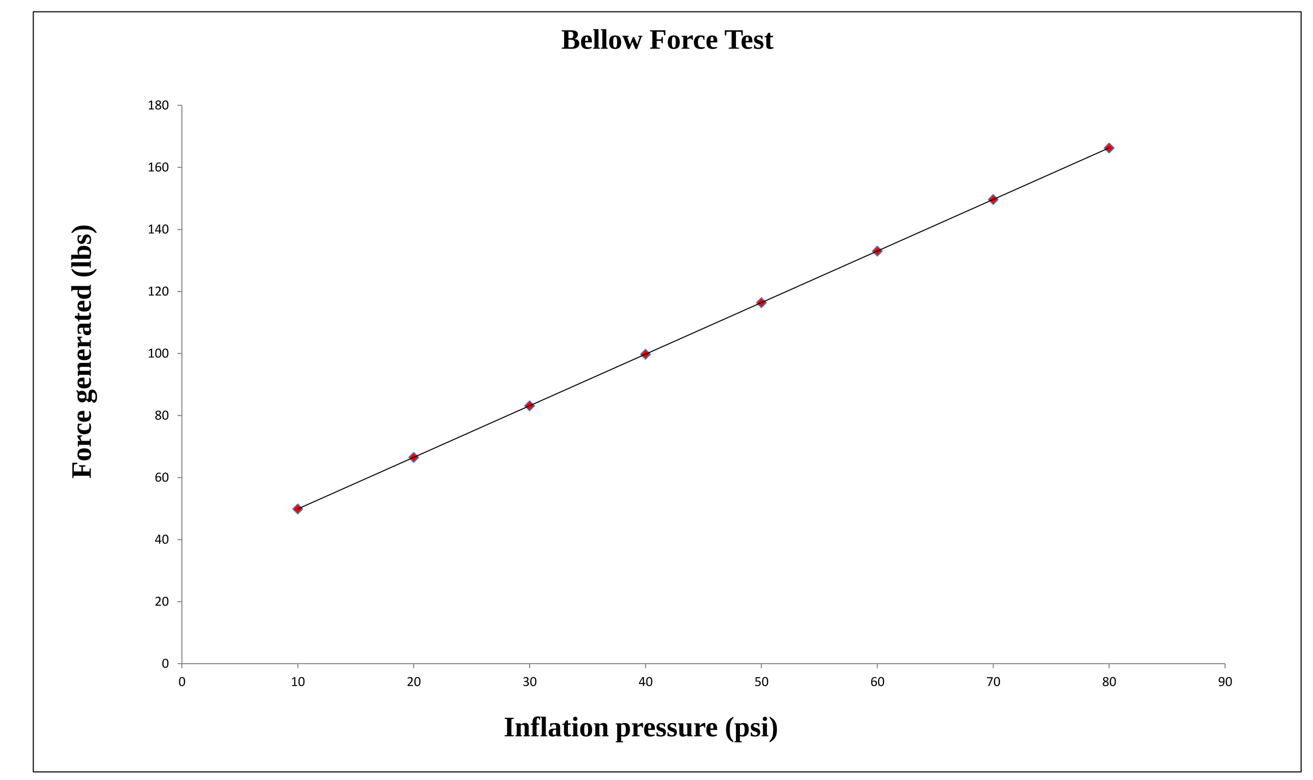
F= kx

F: Force exerted — 274 lb of force
K: spring rate — Compresses 133 lb/in spring
X: displacement — 2.06 inches

Analytically

- Force=Pressure*Area
- CS area inner-CS area outer

Inflation Pressure (psi)	Spring Displacement (in)	Force Exerted (lbs)	Force Exerted (lbs)
10	3/8	49.88	16.63
20	1/2	66.5	16.63
30	5/8	83.13	16.63
40	3/4	99.76	16.63
50	7/8	116.38	16.63
60	1	133.01	16.63
70	1 1/8	149.64	16.63
80	1 1/4	166.26	16.63



Anchor Force

- Bellow force results dictate how much anchoring force is needed
- Steel cable used to pull back test rim
- 3 abrasion resistant materials tested
- 2 materials overruled by cornering constraints
- 1/8 inch abrasion resistant material tested up to 175 lb
- Anchor capacity gauged at various inflation pressures
- 30, 40, 50 psi: anchor 50,150,175 lbs respectively

Conclusions

- More testing is required for anchor material
- Development of composite bellows will improve speed and agility
- Integration of valves on main body will improve system response
- New unplugging tools must be developed
- Packaging of features onto crawler presents considerable challenge

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