**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**

PNL’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-c 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

**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

**Bellow Force**

- Important as tether length and subsequently weight, increases.

F = kx

- F: Force exerted
- k: Spring rate
- x: Displacement

**Past Prototypes**

- First 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

**Anchoring Test**

- Bellow force results dictate how much anchoring force is needed
- Steel cable used to pull back test rim
- 3 abrasion resistant materials tested
- 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

**Acknowledgements**

- DOE/FIU Science and Technology Workforce Development Initiative
- Leonel Lagos, PhD, PMP®
- Romani Patel, MS, MBA
- Tomas Pribanic, MS