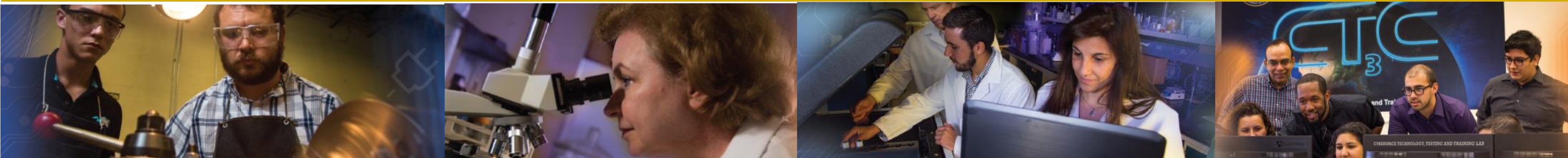
FIU PROJECT 1: DWAYNE MCDANIEL

CHEMICAL PROCESS ALTERNATIVES FOR RADIOACTIVE WASTE

FLORIDA INTERNATIONAL UNIVERSITY



FIU Personnel and Collaborators

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Project Tasks and Scope

FIU Applied Research Center

Task 17 Advanced Topics for Mixing Processes

- computational fluid dynamics modeling of HLW mixing processes in waste tanks
- experimental testing of waste transport

Task 18 Technology Development and Instrumentation Evaluation

- development of inspection tools for DST primary tanks
- evaluation of IR sensors for determining tank temperatures

Task 19 Pipeline Integrity and Analysis

- pipeline corrosion and erosion detection
- nonmetallic materials evaluation

Task 17 - Advanced Topics for Mixing Processes

17.1 - CFD Modeling of Mixing Processes in Waste Tanks

Site Needs:

Mixing and mobilization of HLW is a complicated process due to the variability of a number of flow characteristics including rheology, chemistry, PSD and percent concentration. Experimentation and development of appropriate simulants can be costly and time consuming. Improving simulation capabilities of these processes can assist in optimizing system/component designs at a significant savings. Currently, the level of fidelity of most CFD simulations does not justify the sole use of CFD packages for system design.

Year 7 Objectives:

Develop computational capability as a prediction tool to:

- Evaluate the performance of mixing mechanisms for high-level waste
- Support critical issues related to HLW retrieval and processing

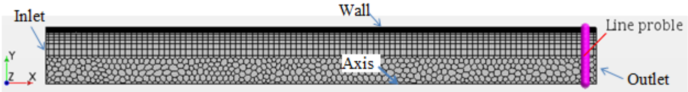
Present Tasks:

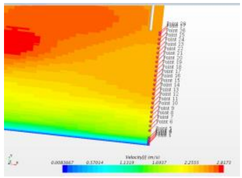
- Capabilities of Star-CCM+ code will be improved incrementally to obtain a comprehensive tool that includes the complex flow features of HLW mixing
- Star-CCM+ will be used in order to investigate accuracy of correlations used to predict impacts of the radial jets on LLW mixing

Task 17 - Advanced Topics for Mixing Processes

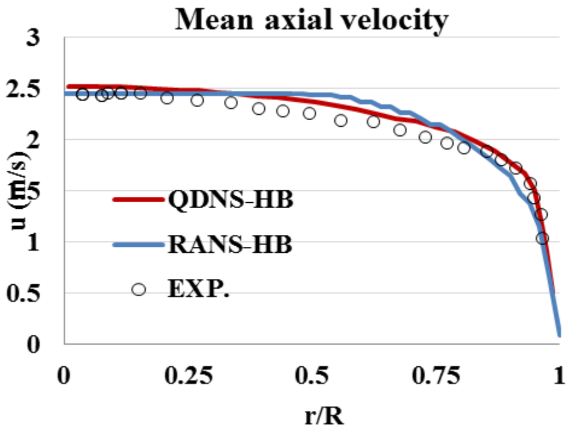
17.1 - CFD Modeling of Mixing Processes in Waste Tanks

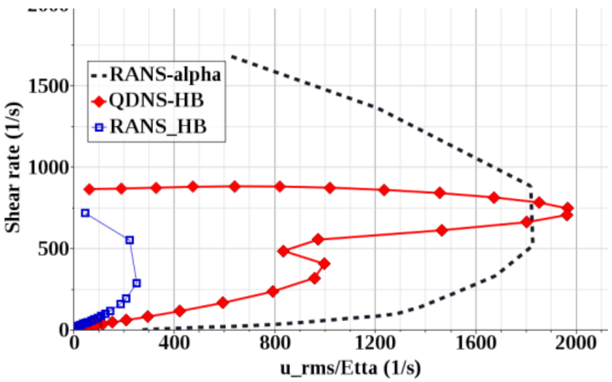
Results





- 3D modeling of non-Newtonian fluids using QDNS and RANS were validated with experimental data. Improved previous efforts to match experimental data.
- Investigated shear dependency to improve RANS modeling – QDNS and RANS were found to be significantly different.
- Our current modified RANS method also was significantly different from the QDNS shear dependency.



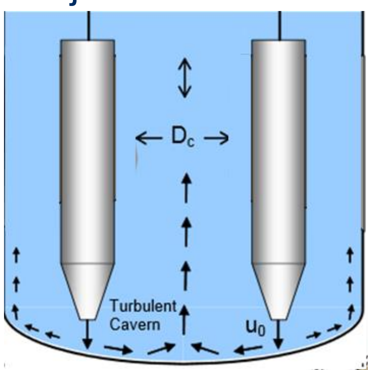


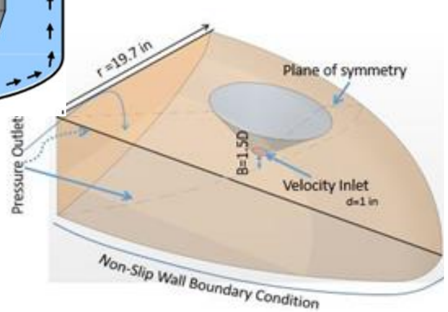
Task 17 - Advanced Topics for Mixing Processes

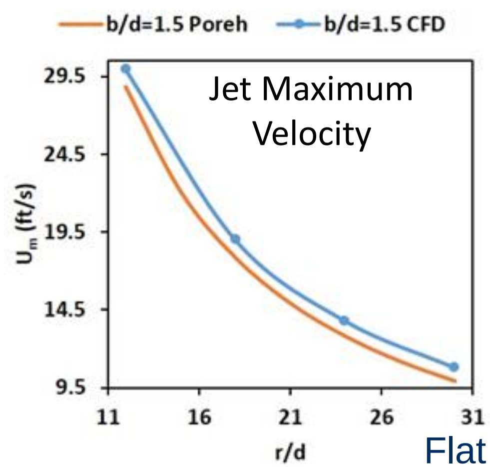
17.1 - CFD Modeling of Mixing Processes in Waste Tanks

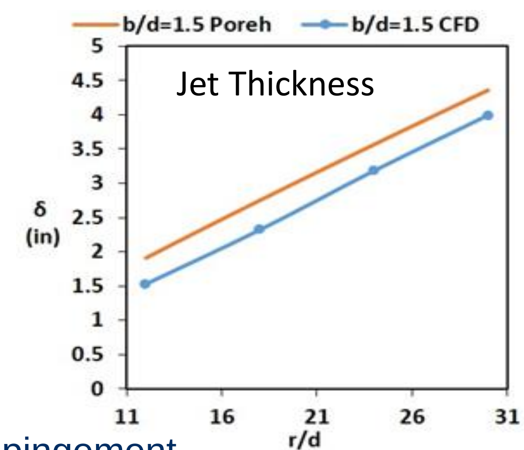
Results

- Used Star-CCM+ to validate Poreh's correlations to determine jet thickness and max velocity for various geometric configurations.
- Poreh's formula was fairly accurate for the r/b and b/d ranges of current PJM systems when predicting velocity and jet thickness.

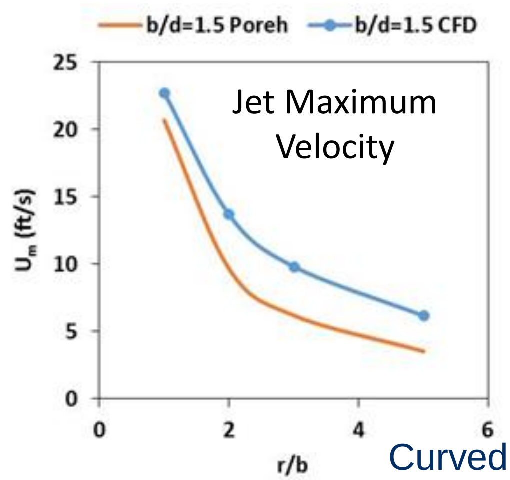


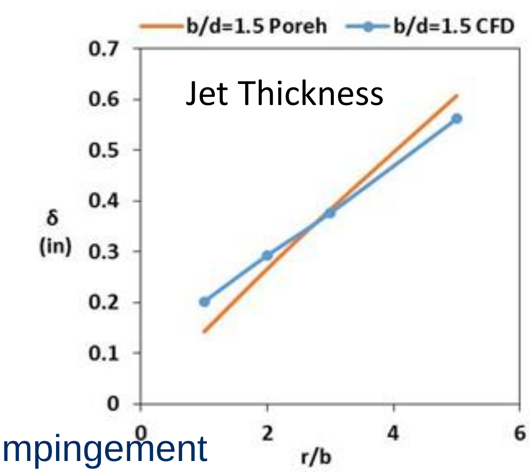






Flat Impingement





Curved Impingement

Task 17 - Advanced Topics for Mixing Processes

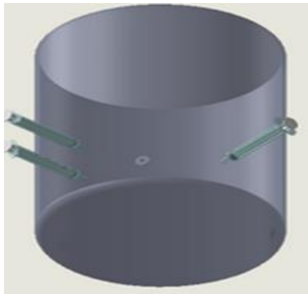
17.1 - CFD Modeling of Mixing Processes in Waste Tanks

FIU Applied Research Center

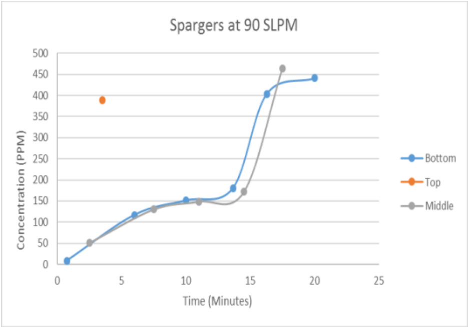
Current Efforts FIU

Need –understanding of the operation time needed to fully mix vessels at Hanford. Experimental testing on mixing time of ethanol in the sparging of Bingham plastics was performed at NETL.

- To evaluate Star-CCM' s capability of matching experimental data pertaining to the field of non-Newtonian sparging mixing vessels.
- Gain insight into the effects of rheological and physical characteristics on mixing times for accurate prediction in PJM operation.



(Experimental setup)



(Data obtained from experimental set up)

Task 17 - Advanced Topics for Mixing Processes

17.2 - Experimental Testing of Waste Transport (New)

Proposed Scope for Year 8

Site Needs:

According to the Defense Nuclear Facilities Safety Board, a number of issues still exist regarding the slurry transport and safety strategies at Hanford. Establishing an experimental test facility that can address a variety of technical gaps associated with critical velocities and flushing techniques would be beneficial to both Hanford and Savannah River.

Objective:

- Develop an experimental test loop to bridge technical gaps related to flushing requirements and particle re-suspension. The loop should also be capable of conducting studies related to critical velocities and bed formation.
- Test loop will expand on the current 270 ft system at FIU. The system will have multiple sections with loops ranging from 150 to 1500 ft to increase applicability.

Task 17 - Advanced Topics for Mixing Processes

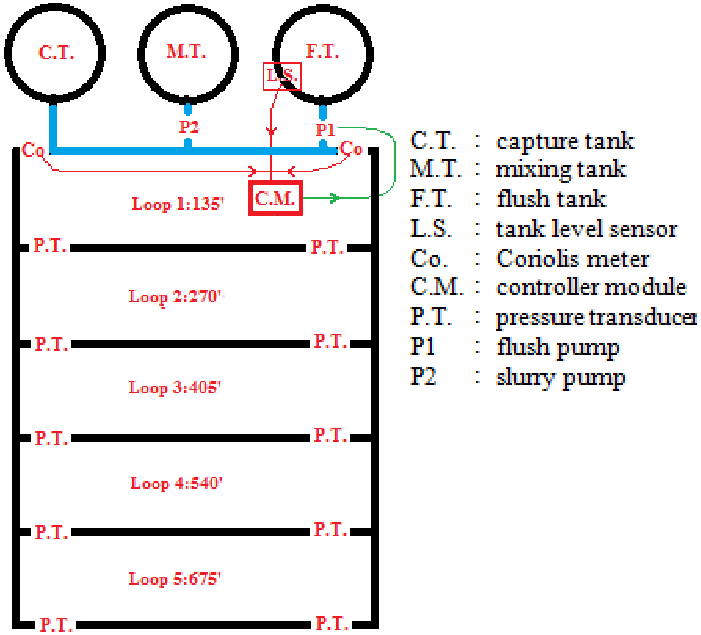
17.2 - Experimental Testing of Waste Transport (New)

Proposed Scope for Year 8

The proposed flow loop will investigate flushing operations using control feedback
- control flush volume, flow rate, pressure (pulsating flush) - avoid water hammer/granular plug formation.

Proposed loop can also assist in providing a technical basis for guideline flow rates for the transport of non-Newtonian slurry. Experimental conditions will include a system without feedback control and evaluate simulants covering a full range of particle size, density, and rheological properties.

Existing 270-feet pipeline at FIU



Potential scaled pipe loop

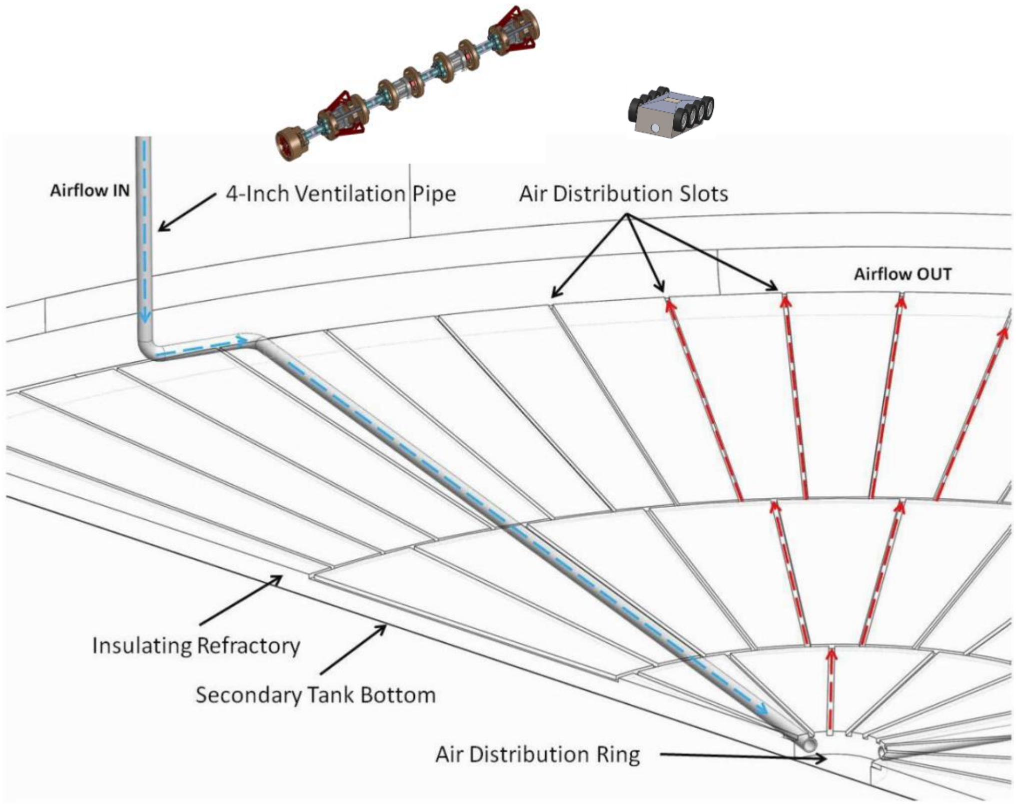
Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

Site Needs:

In 2012, tank waste was found in the annulus of AY-102. In addition, thinning (up to 70%) of the secondary liner in the annulus region has also been observed in other double shell tanks (DSTs). Understanding of the structural integrity of all DSTs at Hanford is of paramount importance - thus, the significant need for development of tools/sensors that can provide information regarding the health of the tanks.

There are three possible entry points: (1) refractory air slots through the annulus, (2) 6” leak detection piping, (3) 4” air supply piping



Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

Mini Rover

Objective:

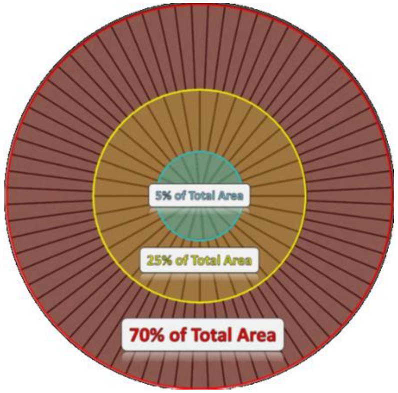
Develop cost effective inspection tools that can travel through the refractory pad air channels underneath the primary liner and the drain line channels underneath the secondary liner while providing live video feedback.

Current Task:

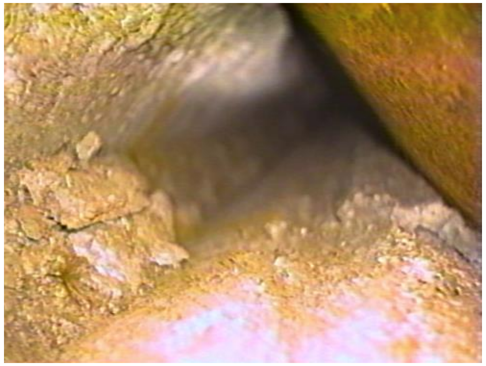
Continue to develop our miniature rover and pneumatic crawler to provide information regarding the health of the primary and secondary liners. This includes optimization of the design, development of a cable management system, sensor integration and demonstration on a full scale mockup.

Design parameters:

Travel through small cooling channels, remote controlled, provide live video feedback, rad hardened (~ 80 rad/hr), withstand relatively high temperatures (~ 170 °F), navigate ~ 50 feet to the tank center, maneuver through four 90° turns, subject channel to pressures not greater than 200 psi

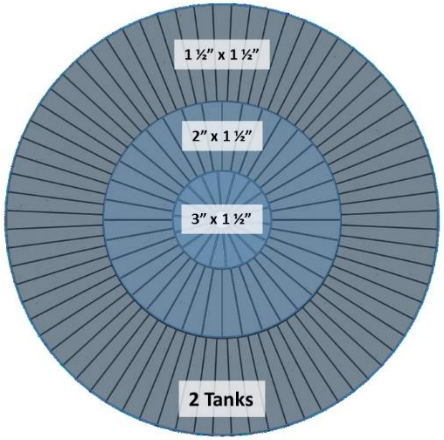


(Kayle Boomer, WRPS 2015)

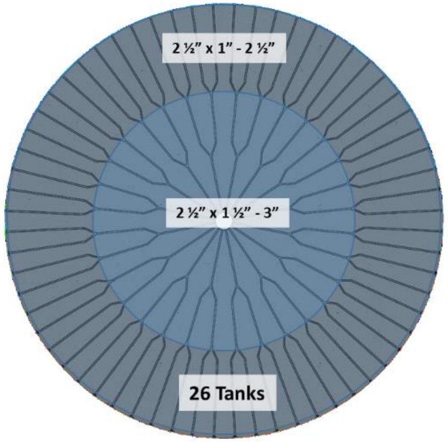


AY
Tank Farm

AZ/SY/AW/AN/AP
Tank Farm



(Brandon J. Vazquez, WRPS 2015)



(Jason Gunter, WRPS 2015)

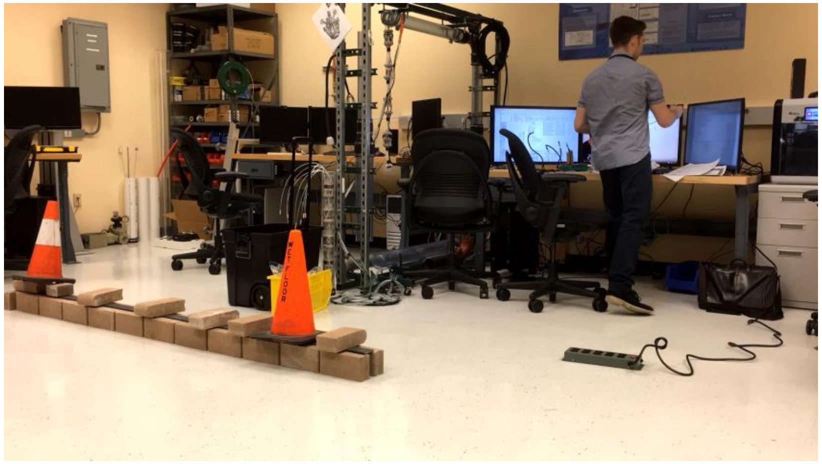
Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

Mini Rover

Bench Scale Testing

- Device weight: 0.18 lb
- Average pull force: 4.75 lb
- Tests performed at: 5V
- Power/Weight ratio: 26
- Motor rated for 3-9 V



Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

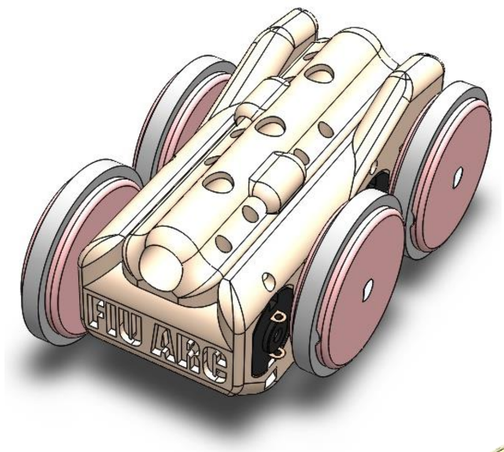
Mini Rover

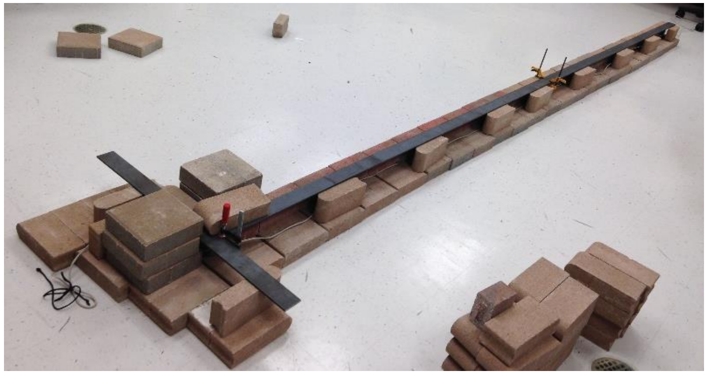
Modifications

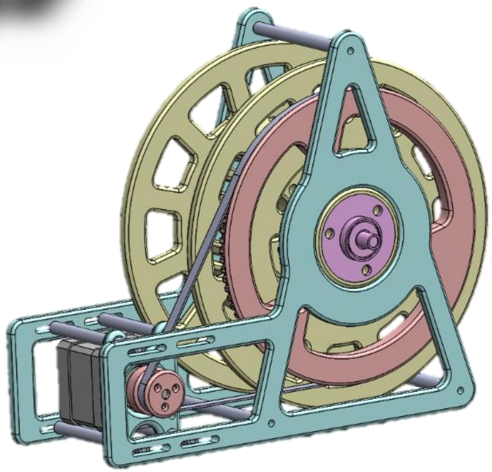
Improved design:

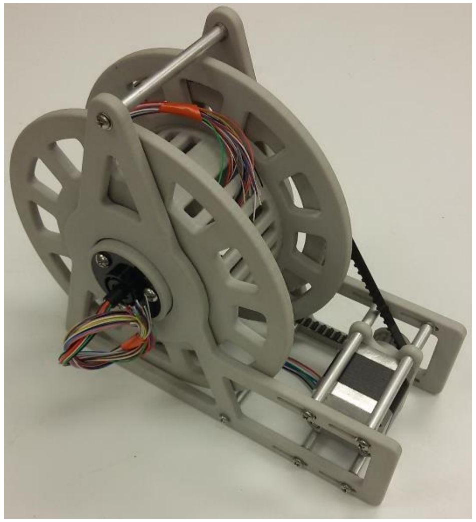
- Stronger body
- Lighter tether
- Better controls

Cable management





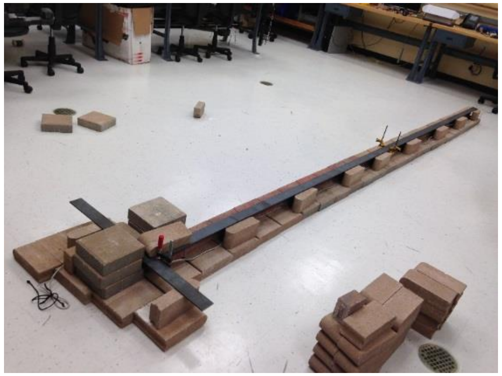




Task 18 - Technology Development and Instrumentation Evaluation

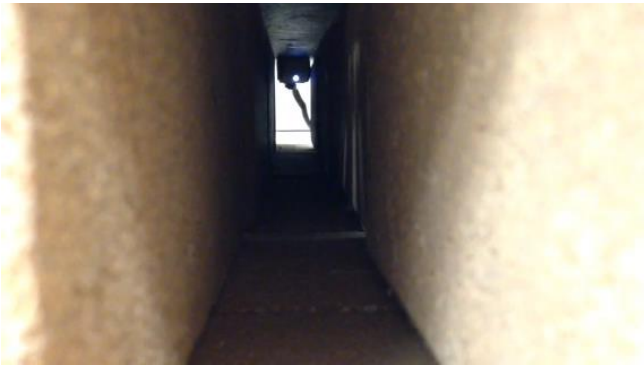
18.2 - Development of Inspection Tools for DST Primary Tanks

Mini Rover - Engineering Scale Testing



1.5” x 1.5”

- First 17 feet
- 2 90 degree turns
- 8” Between each turn

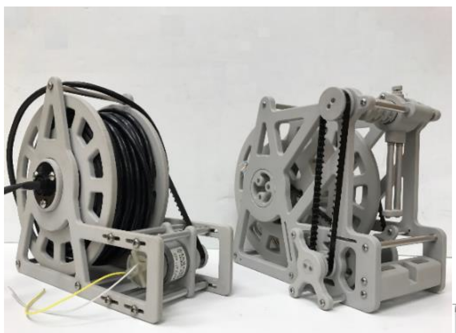


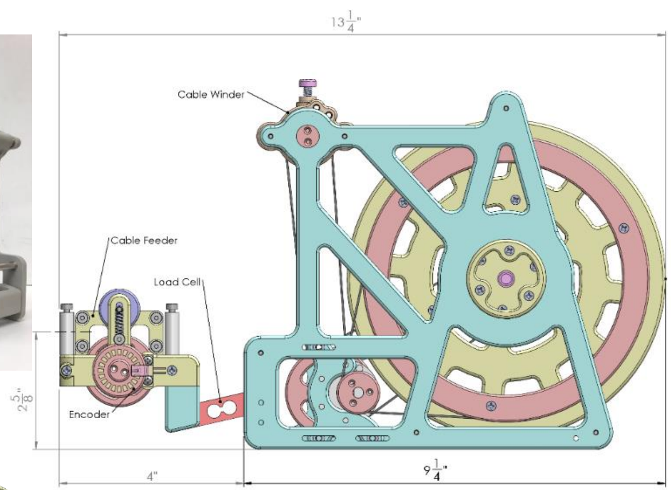
Task 18 - Technology Development and Instrumentation Evaluation

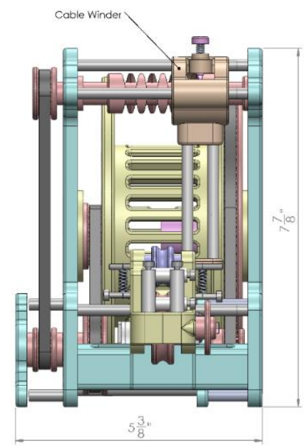
18.2 - Development of Inspection Tools for DST Primary Tanks

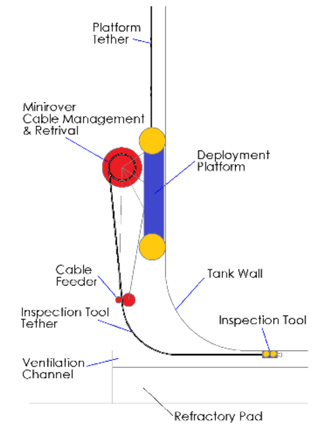
Mini Rover - Cable Management

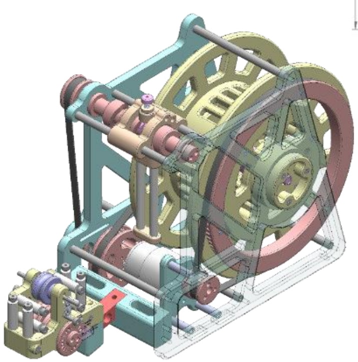
Goal: To design a system to let out/recover the tether of the rover with precision

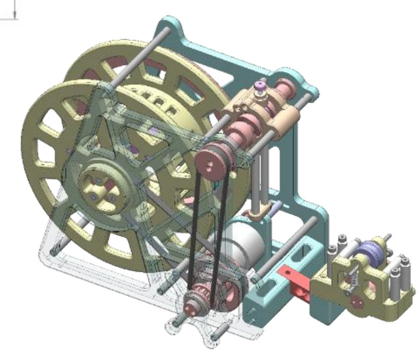








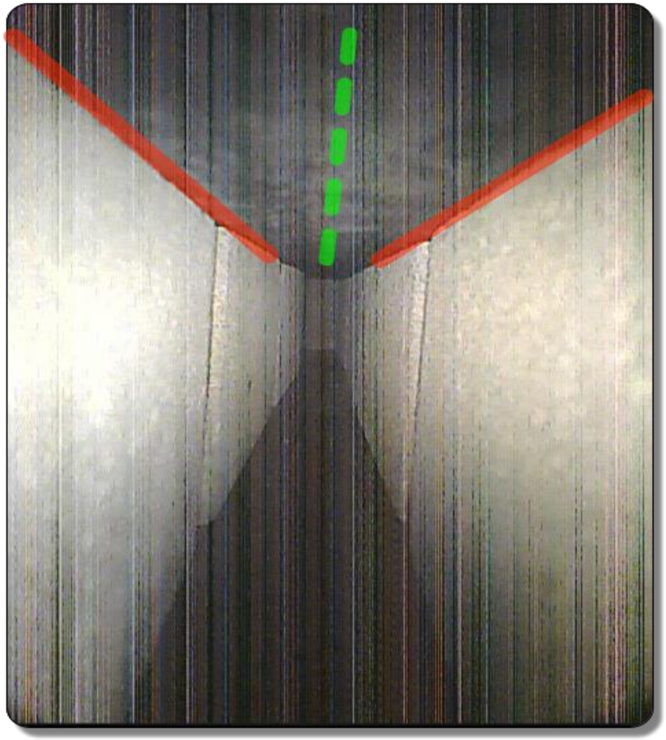


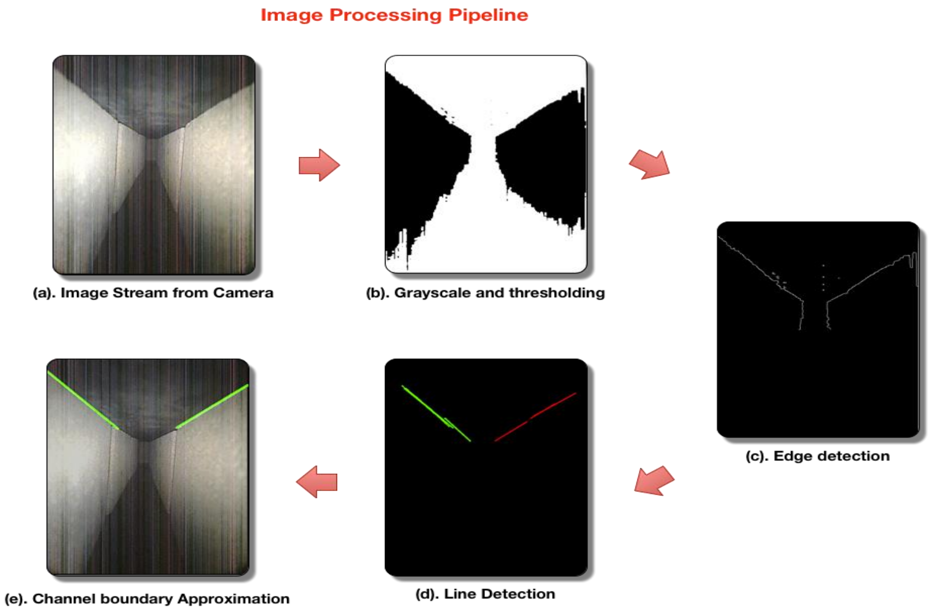


Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

Mini Rover - Visual Based Control





Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

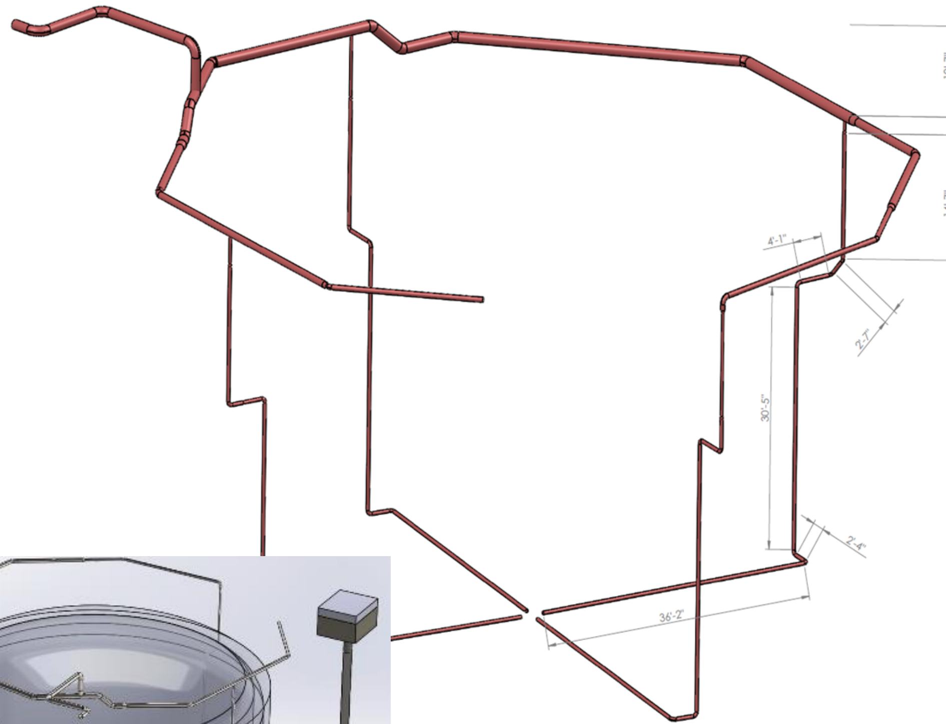
Pneumatic Crawler

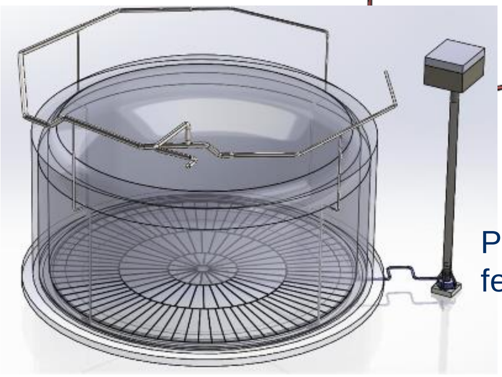
Objective:

To develop an inspection tool that crawls through the air supply pipe that leads to the central plenum of the primary tank of the DSTs at Hanford and provides video feedback

Design parameters:

- Remotely controlled
- Video feedback recorded for future analysis
- Radiation hardened (~ 80 rad/hr)
- Exposure to elevated temperatures (~ 170 F)
- Maneuver in pipes and fittings with 3" and 4" diameter
- Navigate through elbows, bends, transitions and vertical runs





Proposed inspection -approximately 100 feet (significant portion is gravity fed)

Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

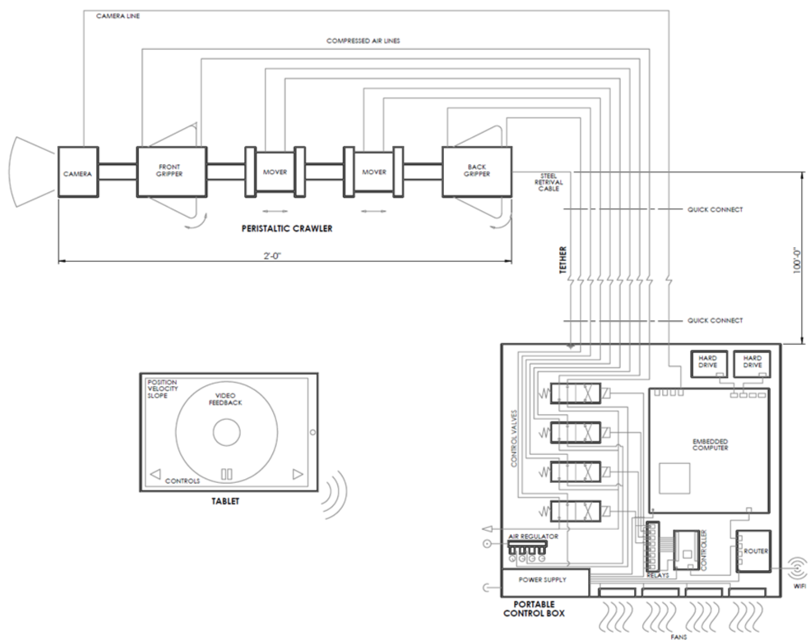
Pneumatic Crawler

The basic design is composed of five modules:

- Front camera
- Front and back grippers
- Two middle movers

Fully automated movement, remotely controlled by a handheld device

Fully customizable programmable control interface



Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

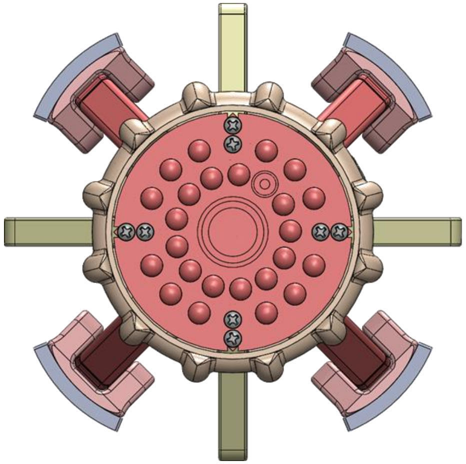
FIU Applied Research Center

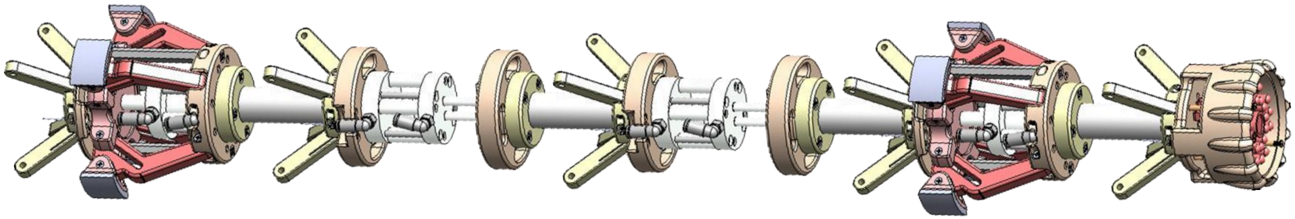
Pneumatic Crawler

Pneumatic actuators emulate the contractions of the peristaltic movements

Movement does not require embedded electronics and electric actuators

Suitable for highly radioactive environments with potential exposure to flammable gases

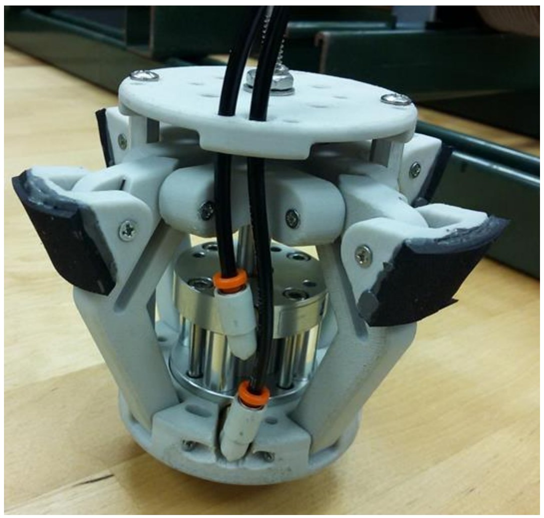




Task 18 - Technology Development and Instrumentation Evaluation

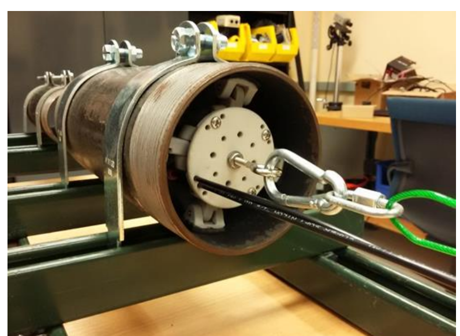
18.2 - Development of Inspection Tools for DST Primary Tanks

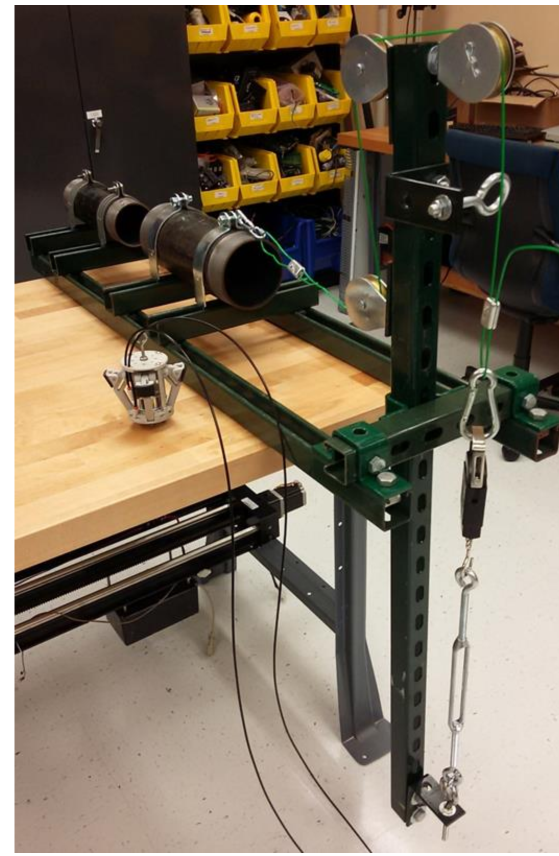
Pneumatic Crawler



The current grippers are able to provide a maximum gripping force of ~40 lbs

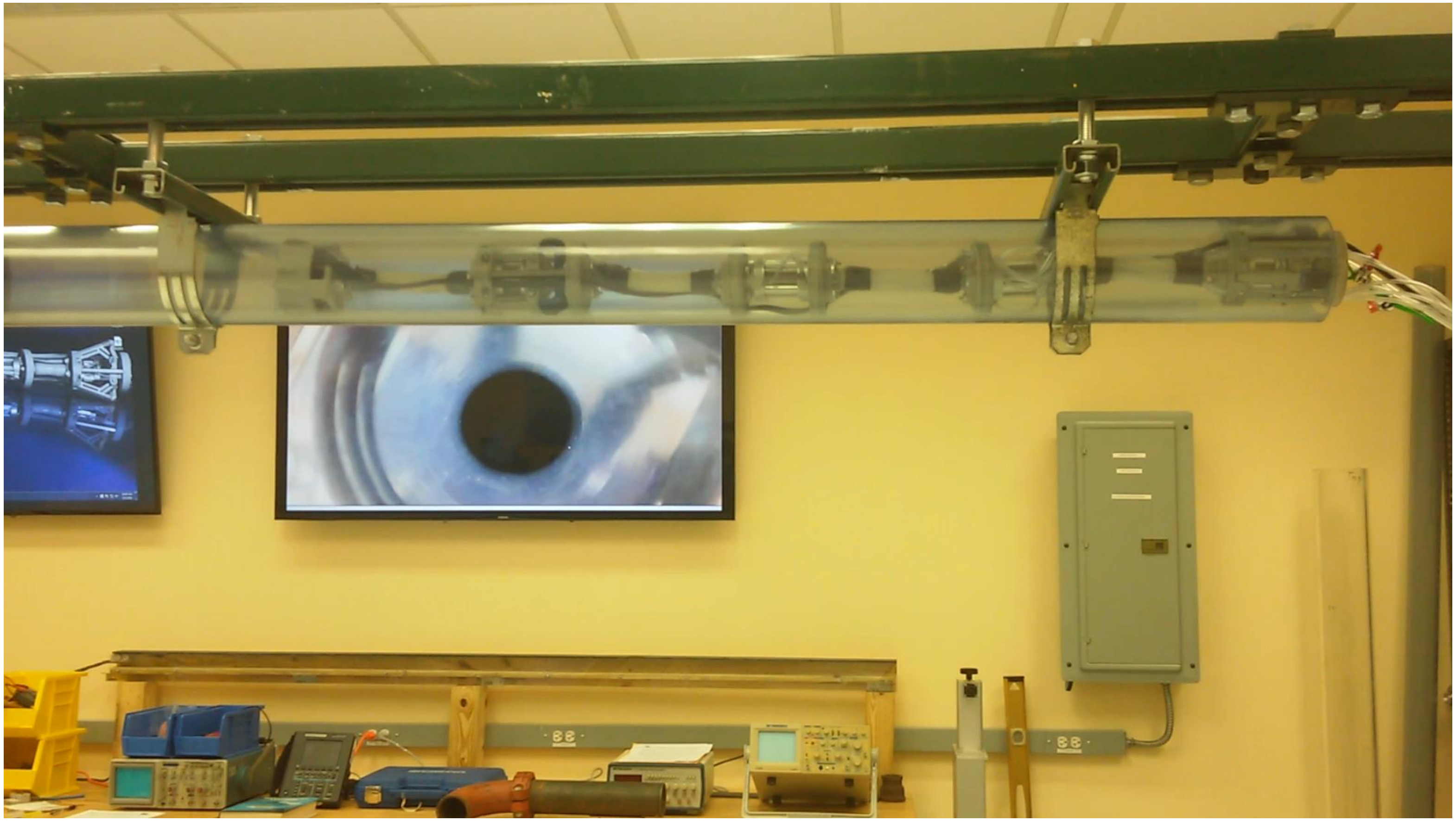
This is also the maximum force with which the mover modules can propel the crawler in the forward direction





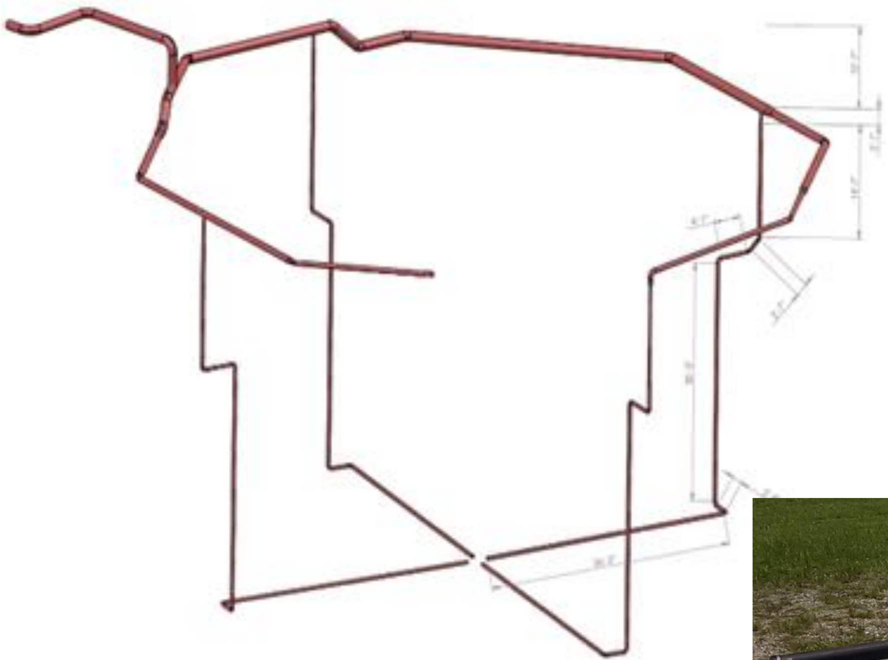
Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks



Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks



Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

Sectional Mockup of DSTs

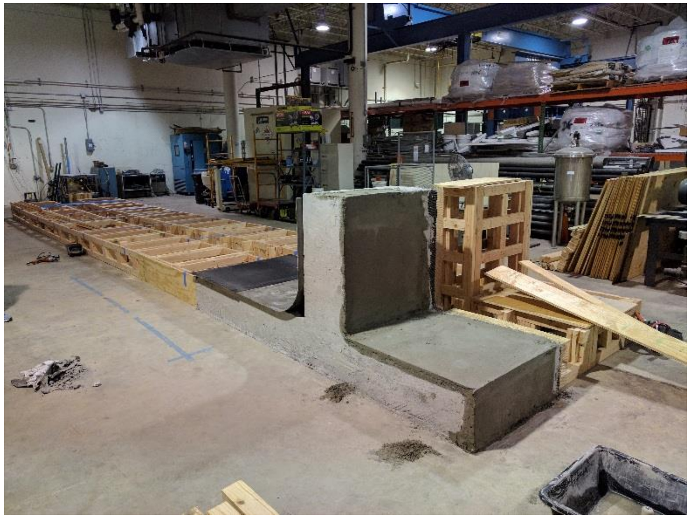
Objective: To design a full-scale sectional mockup of the DST to evaluate inspection technologies and robotic devices.

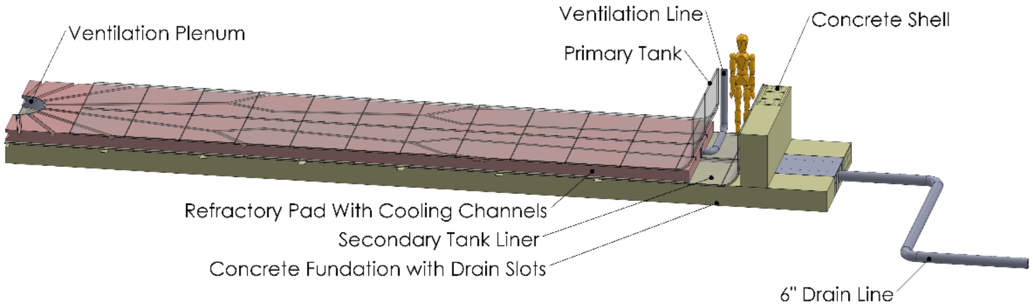
Modular design: various refractory and drain line configurations, different plate thicknesses, predefined defects.

Simulate inspections of refractory pad, primary liner, drain slots, secondary liner and central plenum.

Evaluate tank integrity – corrosion, wall thickness, defects, welds, cracks

Dimensions 38' length x 8' width x 12' height





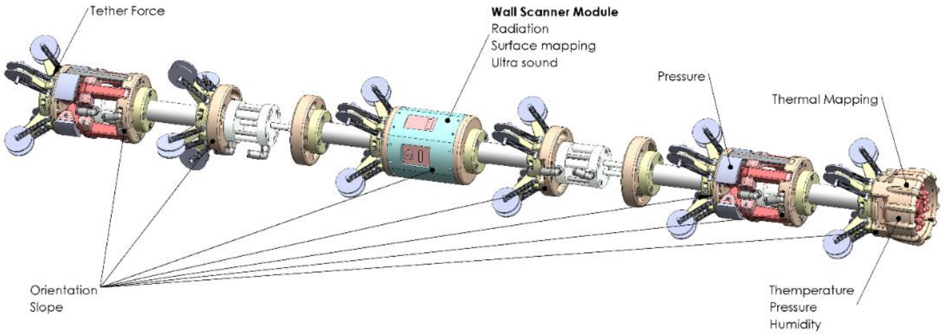
Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

Sectional Mockup of DSTs

Task 18 - Technology Development and Instrumentation Evaluation

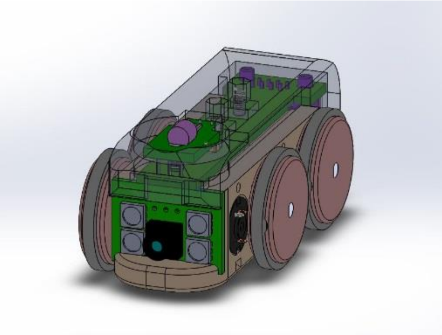
18.2 - Development of Inspection Tools for DST Primary Tanks

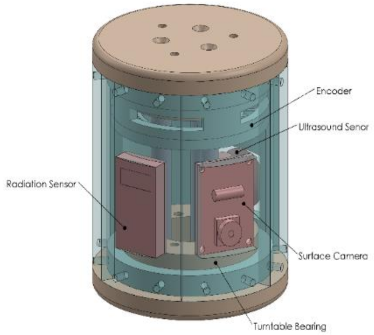


Proposed Scope for Year 8

Crawler:

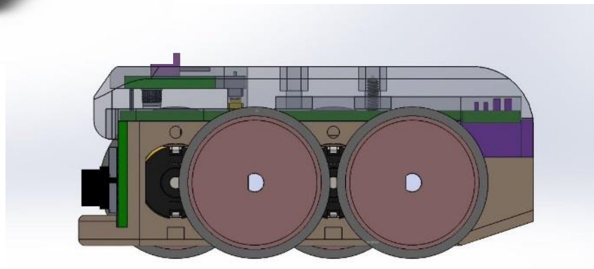
- Validate systems in mock up
- Sensor integration - temperature, radiation, UT
- Develop inspection tool for 6 inch leak detection line





Rover:

- Validate systems in mock up
- Integrate system with robotic platform
- Sensor integration - temperature, radiation
- Integrate UT sensor system for NDI



Task 18 - Technology Development and Instrumentation Evaluation

18.3 - Investigation Using an Infrared Temperature Sensor to Determine the Inside Wall Temperature of DSTs

<u>Site Needs:</u>

Operating Specifications for the DSTs (OSD-T-151-00007) specifies the temperature requirements for waste

- Current temperature methods
  - process knowledge, approximations, measuring devices and modeling
  - at least10 feet from the wall due to equipment and technical constraints
- Models estimate wall conditions
  - Typically not validated with field data

<u>Objective:</u>

Demonstrate the use of an IR sensor to approximate the inside wall temperature of DSTs

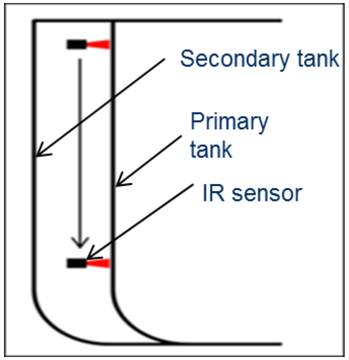
- Utilize bench scale tests and heat transfer calculations

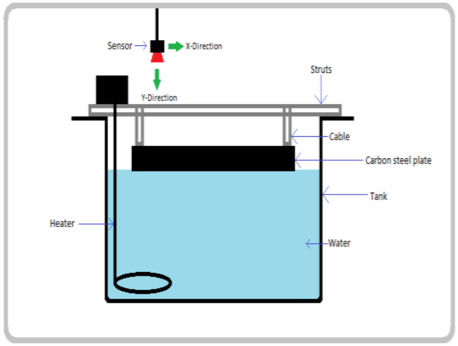
Task 18 - Technology Development and Instrumentation Evaluation

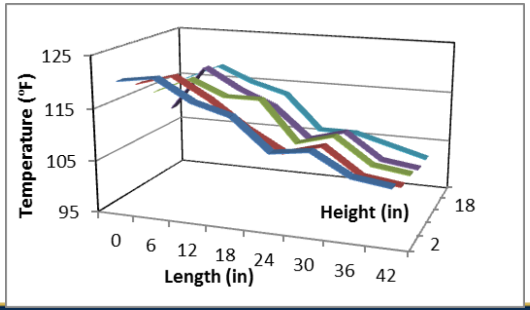
18.3 - Investigation Using an Infrared Temperature Sensor to Determine the Inside Wall Temperature of DSTs

<u>Accomplishments:</u>

- Developed test plan to evaluate IR sensor
  - Vary plate thickness, water temperature, sensor elevation, distance of sensor to tank wall
- Procured IR Sensor (Raytek MI3)
  - Initial system configuration
- Conducted emissivity tests
  - material calibration (carbon steel)
- Completed bench scale testing
  - construction of the bench scale test bed and executing the test plan





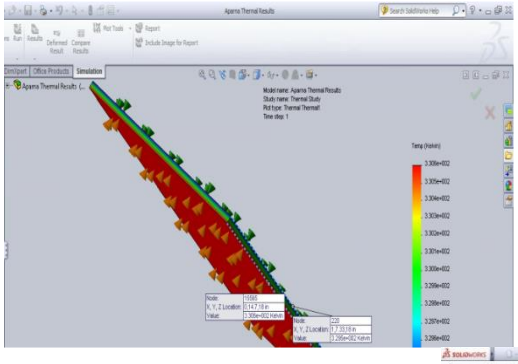


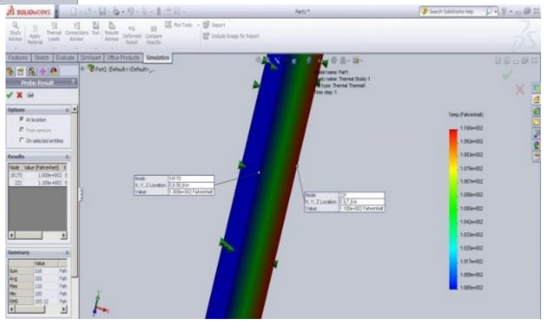
Task 18 - Technology Development and Instrumentation Evaluation

18.3 - Investigation Using an Infrared Temperature Sensor to Determine the Inside Wall Temperature of DSTs

Accomplishments:

- Modeling and simulation
  - Developed model to estimate internal wall temperature simulation of heat transfer in the DSTs





Proposed Scope for Performance Year 8

- Future testing, based on feedback from site engineers
- Validate systems in full scale mock up
- Integrate sensor into robotic systems

Task 19 - Pipeline Integrity and Analysis

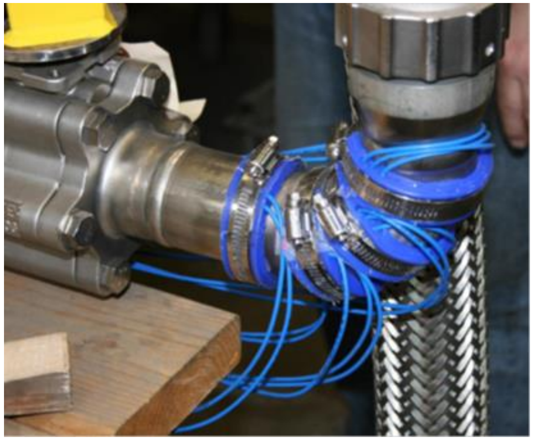
19.1 - Pipeline Corrosion and Erosion Evaluation

Site Needs:

Due to uncertainties regarding the structural integrity of pipelines at Hanford, a Fitness-for-Service (FFS) program for the Waste Transfer System has been implemented.

A direct inspection and assessment of the condition of buried pipelines is required to evaluate the corrosion and erosion wear rates.

To predict the existing system's remaining useful life



UT sensors

Objective:

Investigate the use of remote permanently mounted Ultrasonic Transducer (UT) systems for measuring pipe wall thickness

Task 19 - Pipeline Integrity and Analysis

19.1 - Pipeline Corrosion and Erosion Evaluation

Accomplishments:

- Evaluated various couplants (gel and dry) for UT sensing using an Olympus dual element sensor
  - Dry couplants provided inconsistent results
  - Vacuum testing was conducted to evaluate removal of air gaps
- Conducted a review of alternative sensor systems that meet the site requirements
  - dry couplant, small sizes, accuracy of 0.001 in, semi permanent mounting, rad environment
- Down selected sensors to two
  - Permasense guided wave sensors – limited to 2 sensors for 2 in diameter pipes
  - Ultran Group – couplant free sensors


Ultran WD 25-2 UT sensors

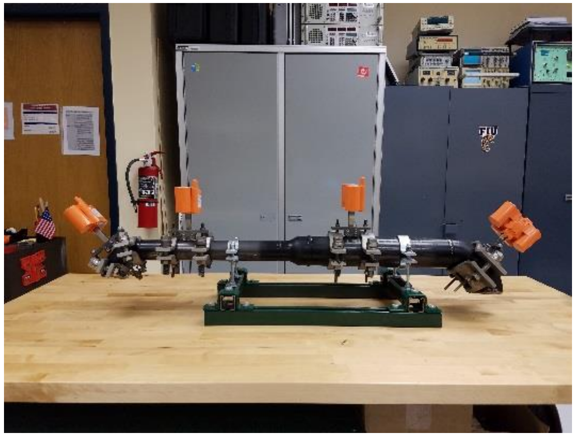
Permasense – guided wave sensors

Task 19 - Pipeline Integrity and Analysis

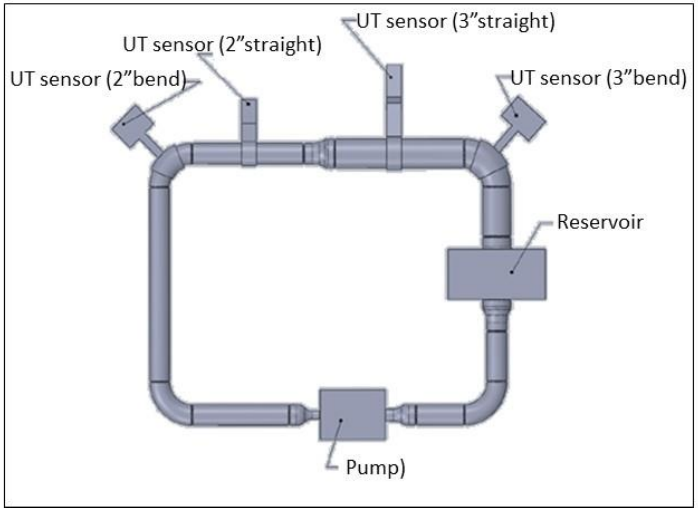
19.1 - Pipeline Corrosion and Erosion Evaluation

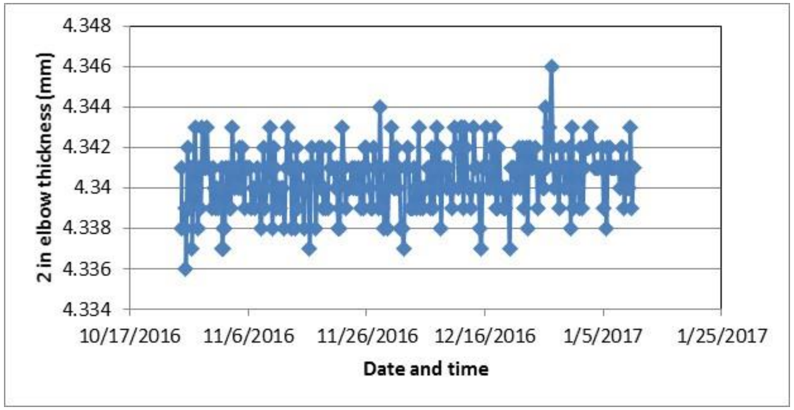
Accomplishments:

- Bench scale testing of wireless Permasense system on a two and three in pipe.
- Validated data over 4 months
- Currently devolving test loop for accelerated aging using saline solution, NaOH and sand/water solution



Initial bench scale test bed





Results data collected over 4 months

Task 19 - Pipeline Integrity and Analysis

19.1 - Pipeline Corrosion and Erosion Evaluation

Proposed Scope for Performance Year 8

- Finalize the construction of the experimental test loop to validate the use of the sensors.
- Erode/corrode the pipe with the simulant and monitor changes in the pipe thicknesses real time.
- Investigate the potential integration of the small Ultran sensors into robotic devices.

Task 19 - Pipeline Integrity and Analysis

19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

Site Needs:

Nonmetallic materials are used in the US DOE's Hanford Site Tank Farm waste transfer system. These include inner primary hoses in the HIHTLs, Garlock® gaskets, EPDM O-rings, and other nonmetallic materials.

Nonmetallic materials are exposed to β and γ irradiation, caustic solutions as well as high temperatures and pressure stressors. How they react to each of these stressors individually has been well established, but simultaneous exposure of these stressors is of great concern.

Objective:

- Provide the Hanford Site with data obtained from experimental testing of the hose-in-hose transfer lines, Garlock® gaskets, EPDM O-rings, and other nonmetallic components under simultaneous stressor exposures.
- Due to experimental testing location limitations, no radiation exposure testing will be conducted.

Task 19 - Pipeline Integrity and Analysis

19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

Phase 1 Test Plan:

- Phase 1 will be limited to EPDM material testing (HIHTL, O-rings and gaskets). EPDM was selected for this phase of testing due to its use in multiple applications within the Hanford waste transfer system.
- Material will be simultaneously exposed (aged) to both high temperature (85^{o}F, 130^{o}F and 180^{o}F) and caustic solution stressors.
- A 25% sodium hydroxide solution will be used as the chemical stressor.
- Material will be aged while in-service configuration as well as coupons for 180 and 360 days.
- Post exposure mechanical performance testing will be conducted including burst pressure tests, leak tests (in-service configuration) and stiffness, tensile strength tests (coupons).

Task 19 - Pipeline Integrity and Analysis

19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

- Due to limitations in resources – 24 coupons were manufactured by Riverbend
  - 6 room temp (180, 360 days)
  - 6 operating temp (180, 360 days)
  - 6 elevated temp (180 360 days)
  - 3 baseline testing
  - 3 additional – elevated temp for 60 days if needed
- A test loop was designed and manufactured that will age the HIHTLs, O-rings, gaskets and material coupons.

Task 19 - Pipeline Integrity and Analysis

19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

Baseline Results

Blowout tests:

- 3 hose coupons were tested with an average blowout pressure of 2805 psi

In-configuration leak tests:

- 3 flanges and 3 O-rings were leak tested in configuration at 150 psi and 255 psi respectively

Material tests:

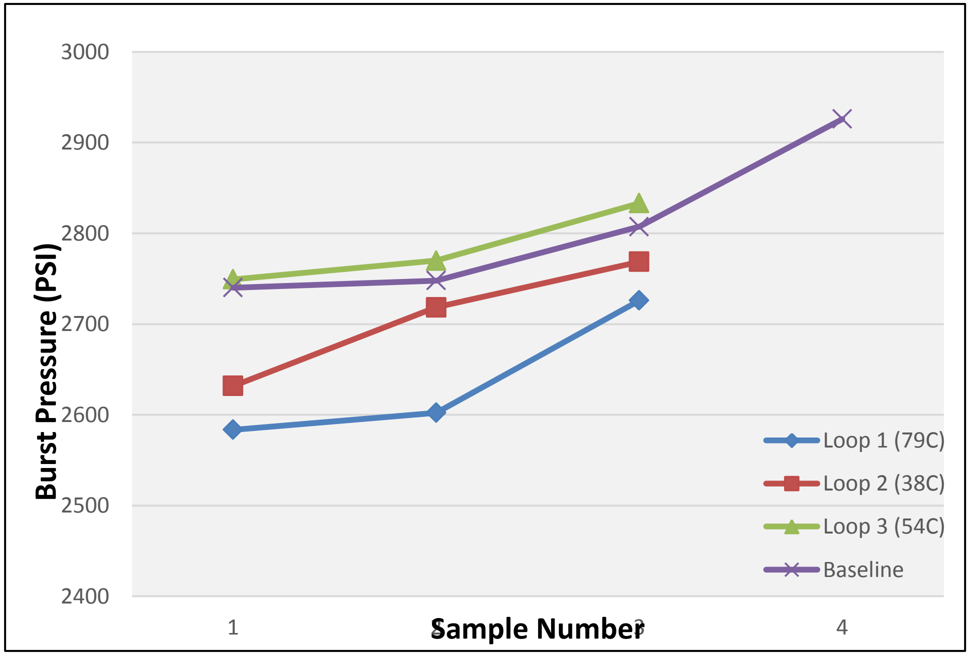
- Tensile tests – peak load, stress, modulus for EPDM and Garlock coupons
- Hardness tests

Task 19 - Pipeline Integrity and Analysis

19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

6-Month Testing - HIHTL

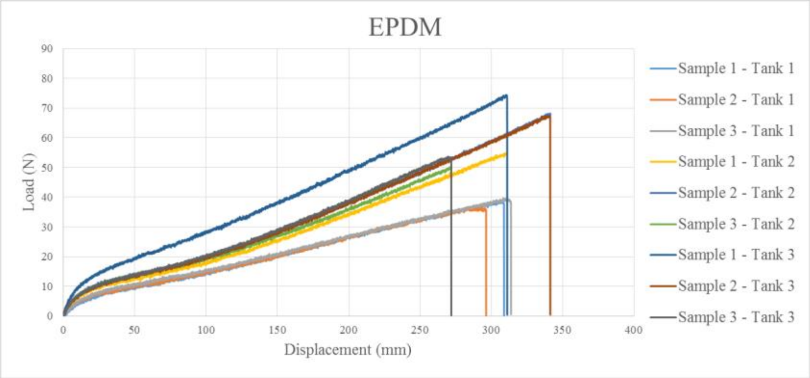
- Three samples from each loop were pressurized until rupture.
- Pressure profile as well as initial and final lengths were measured.
- Rupture pressure was compared to baseline values.

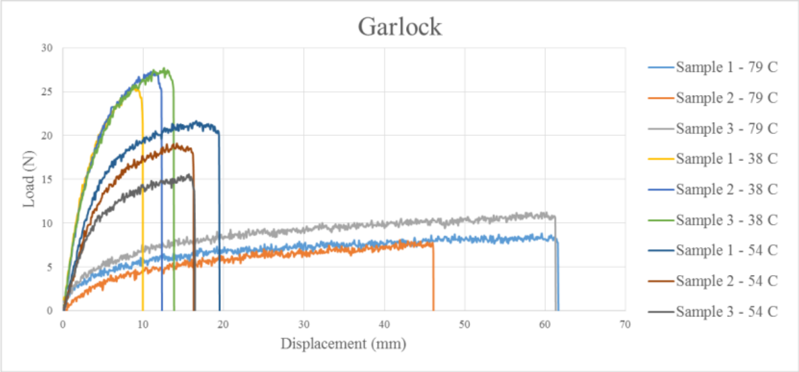


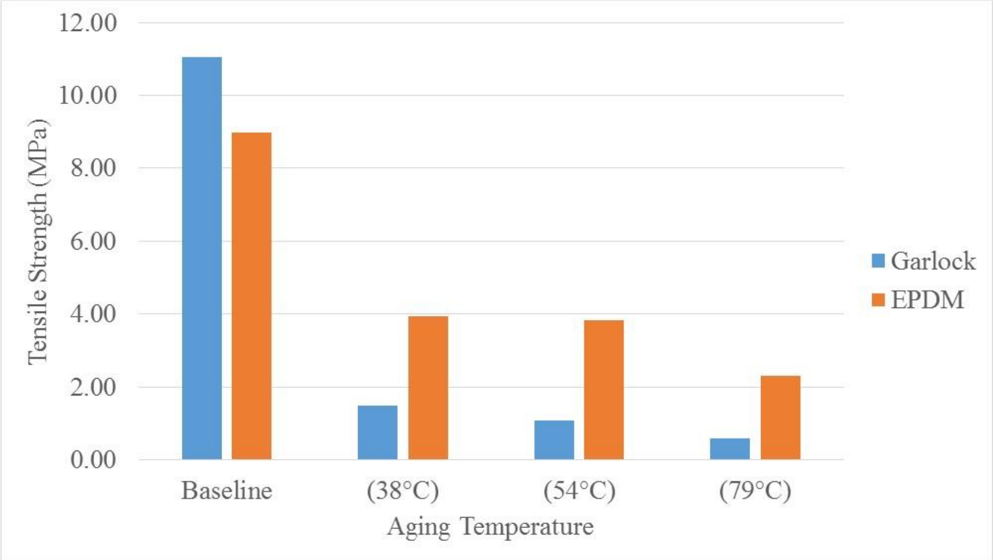
Task 19 - Pipeline Integrity and Analysis

19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

6-Month Testing - Coupons







Task 19 - Pipeline Integrity and Analysis

19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

Microscopy Analysis

- Coupons are being prepare for baseline and 6 month aged HIHTL specimens from all three loops
- Surface of coupons will be evaluated using a scanning electron microscope with energy dispersive X-ray spectroscopy (SEM-EDX)
- Information will be obtained on changes in the surface microstructure and the level of diffusion of NAOH into the EPDM

Baseline and aged coupons from HIHTL

Task 19 - Pipeline Integrity and Analysis

19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

Proposed Scope for Performance Year 8

- Continue to age the non-metallic components for the 1 year intervals.
- After the 1 year of aging, specimens will be removed and tested to determine the level of degradation in strength and material properties.
- Based on results of testing, additional data points may be needed for evaluation or modifications to the current system may need to be incorporated.
- Additional stressors may also be considered for testing.