FIU PROJECT 1

CHEMICAL PROCESS ALTERNATIVES FOR RADIOACTIVE WASTE

Florida International University

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Project Tasks and Scope

Task 17 Advanced Topics for Mixing Processes
- experimental testing of flushing methods
  - multi-functional test loop development

Task 18 Technology Development and Instrumentation Evaluation
- development of inspection tools for waste transfer lines and DST primary tanks
- DST testbed for the evaluation of technologies

Task 19 Pipeline Integrity and Analysis
- pipeline corrosion and erosion detection
- nonmetallic materials evaluation

Task 17 - Advanced Topics for Mixing Processes

17.3 - Evaluation of pipeline flushing requirements for HLW at Hanford and Savannah River

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

17.3 Evaluation of pipeline flushing requirements for HLW at Hanford and Savannah River

Background:

- Current guidelines establish the minimum flush volume and velocity requirements which were shown as adequate for several test cases.

- TFC-ENG-STD-26, REV C-1, or STD-26)

    - Flush to line volume: at least 1.5

    - Flush velocity: 10 ft/sec or more

- RPP-RPT-59600 Rev.00

    - Flush to line volume: 1.5-3

    - Flush velocity: 1.3 to 1.8 times transfer velocity, 4 to 6ft/s

- Recent flushing tests (PNNL-17973.WTP-RPT-178 Rev. 0 and PNNL-17639. WTP-RPT-175 Rev. 0) show velocity values higher than erision-safe flush veocity limit (PNNL-18316 WTP-RPT-189 Rev. 0)

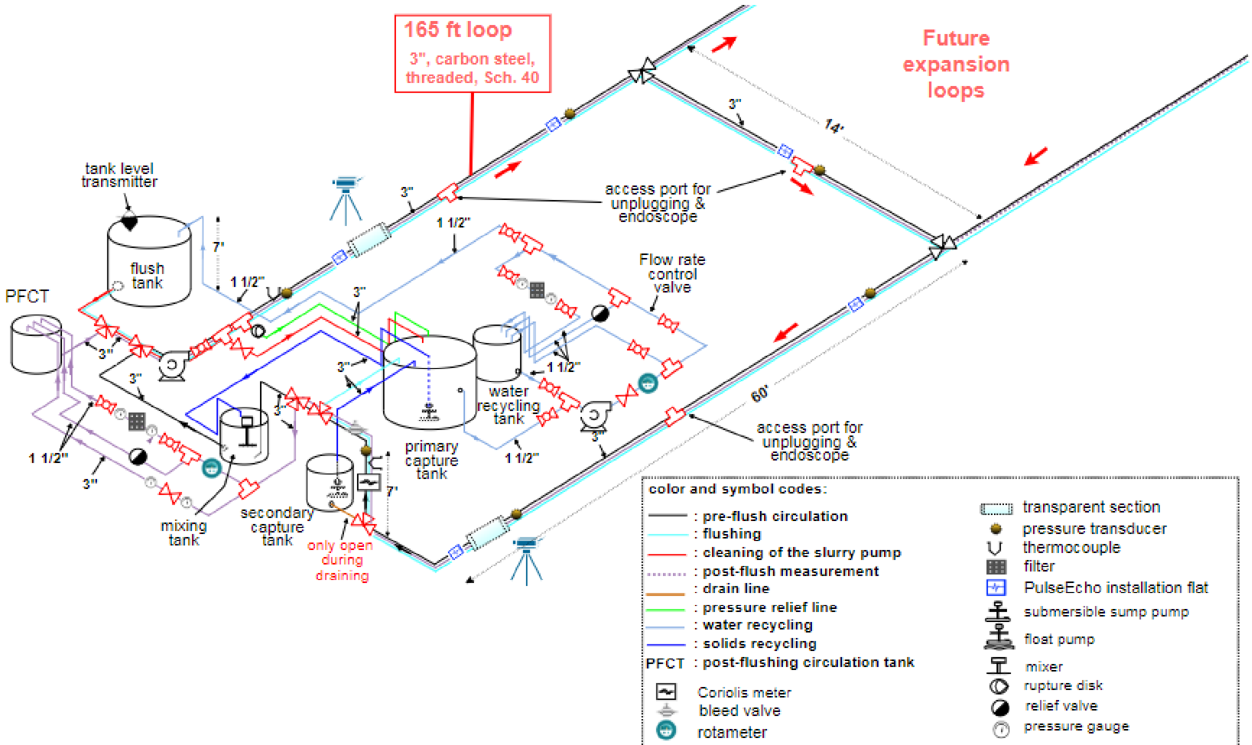
Task 17 - Advanced Topics for Mixing Processes

17.3 Evaluation of pipeline flushing requirements for HLW at Hanford and Savannah River

Accomplishments

Development of test loop:

- FIU selected the target simulant through consultations with PNNL and SRNL.
  - Simulant: 17 wt% Kaolin in water
- FIU finalized the design of a multi-functional test loop
  - Modular (165 to 800 ft), initially 165 ft, made of 3” schedule 40 pipe



Schematic of the test loop for flushing study at FIU

Task 17 - Advanced Topics for Mixing Processes

17.3 Evaluation of pipeline flushing requirements for HLW at Hanford and Savannah River

Accomplishments

Development of test plan:

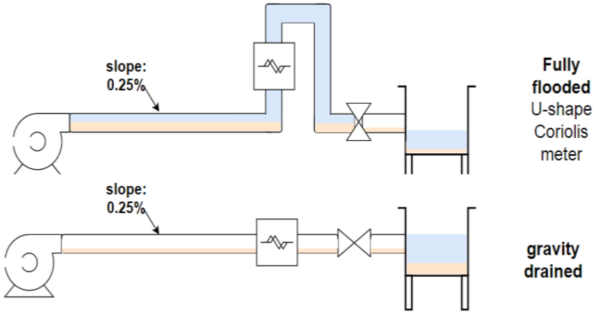
- variables in the initial test matrix (velocity mode, per-flush water volume, number of flushes)

- space and pipe line support mechanism for the test loop

- initial conditions modes to be tested (gravity drained versus fully-flooded)

Matrix for Flushing Test Using 165 ft Test Loop

Test Number	Flush Mode	Number of flushes	FTLVR (per flush)	Resultant Duration Per flush (sec)	Resultant FTLVR
1	Constant	1	2	27.4	2
2	Ramped	1	2	-	2
3	Pulsed	1	2	-	2
4	Constant	2	1	13.7	2
5	Ramped	2	1	-	2
6	Pulsed	2	1	-	2
7	Constant	1	3	41	3
8	Ramped	1	3	-	3
9	Pulsed	1	3	-	3
10	Constant	2	1.5	20.5	3
11	Ramped	2	1.5	-	3
12	Pulsed	2	1.5	-	3
13	Constant	1	4	54.8	4
14	Ramped	1	4	-	4



Task 17 - Advanced Topics for Mixing Processes

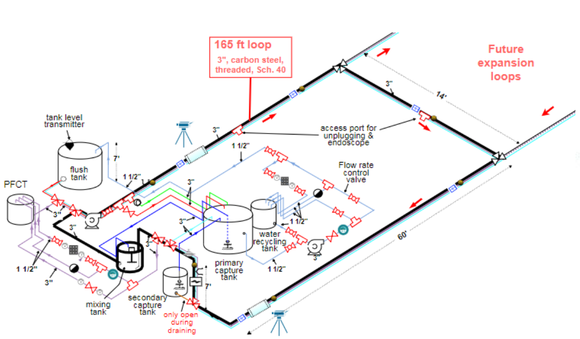
17.3 Evaluation of pipeline flushing requirements for HLW at Hanford and Savannah River

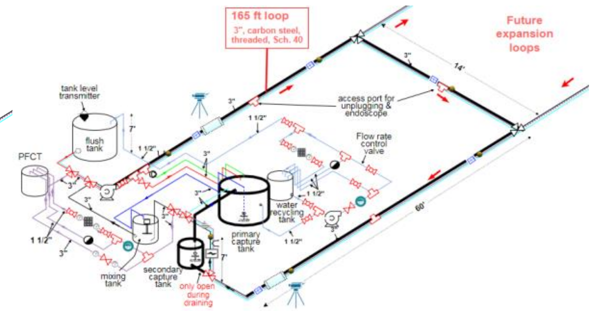
Accomplishments

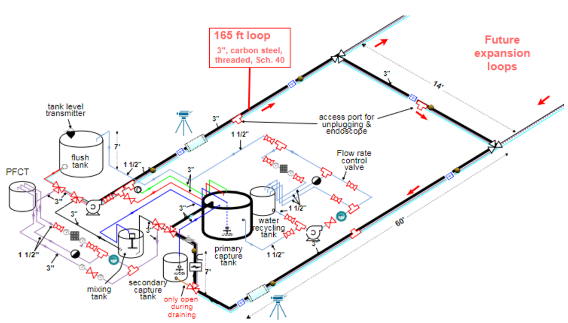
Development of test plan:

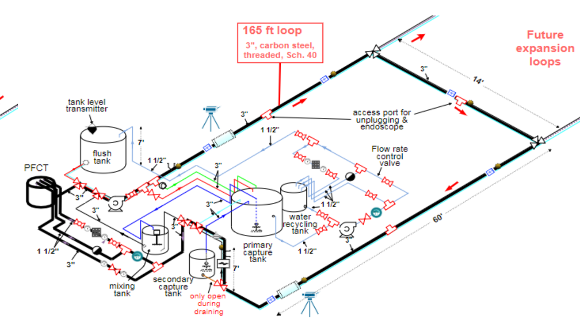
- Finalized the operations:
  - System loading
  - Drain
  - Flushing
  - Post-flush circulation
  - Pump cleaning
  - Water and sediment retrieval

- Completed sizing/selection of system elements for construction of the pipe loop









Task 17 - Advanced Topics for Mixing Processes

17.3 Evaluation of pipeline flushing requirements for HLW at Hanford and Savannah River

Currently:

- Assembly of pipe loop systems
- Evaluate functions of systems (pump operations, air removal, Coriolis meter, PulseEcho)
- Creation of initial conditions (fully flooded and gravity drained)

Proposed Scope for Performance Year 9

- Analysis of flushing performance under different velocity modes
    - Solids re-suspension (erosion) and full suspension during flushing (Imaging and PulseEcho)
    - Post-flush evaluations (fulfillment of flushing criteria)
        - Density monitoring and solids filtration during post-flush circulations, pipeline wall inspection (endoscope and PulseEcho transducer)
- Preliminary computational analysis to assist in
    - Creation of target initial conditions
    - Evaluation of flushing performance (predicting erosion with different boundary conditions. i.e., velocity modes)

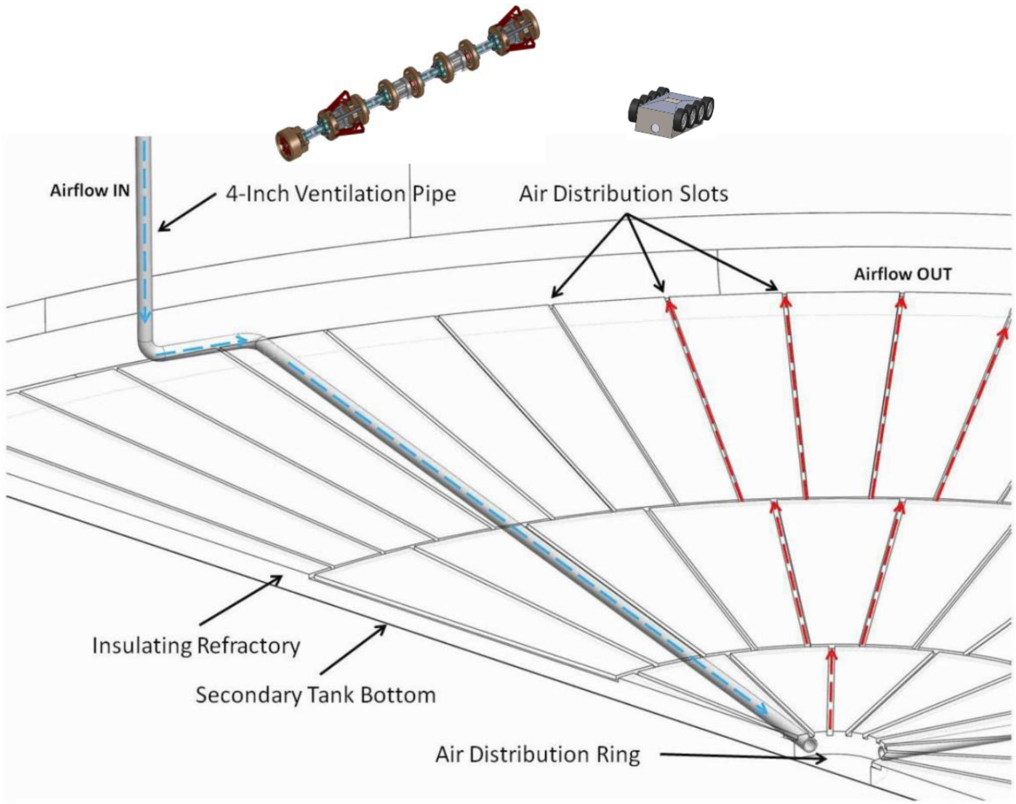
Task 18 - Technology Development and Instrumentation Evaluation

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:

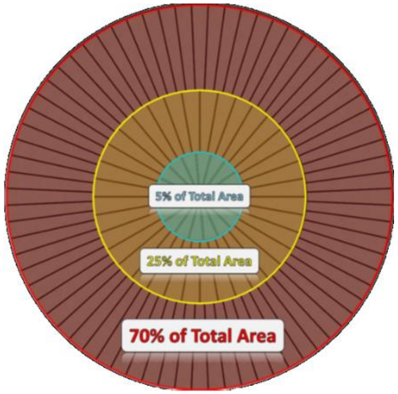
Develop cost effective inspection tools that can travel through the refractory pad air channels underneath the primary liner and the drain line channels underneath the secondary liner while providing live video feedback.

Current Task:

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

Design parameters:

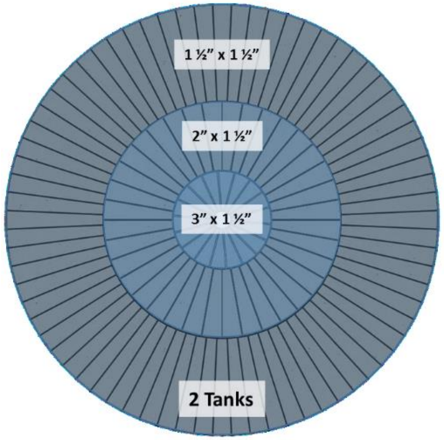
Travel through small cooling channels, remote controlled, provide live video feedback, rad hardened (~ 80 rad/hr), withstand relatively high temperatures (~ 170 °F), navigate ~ 50 feet to the tank center, maneuver through four turns, subject channel to pressures not greater than 200 psi.



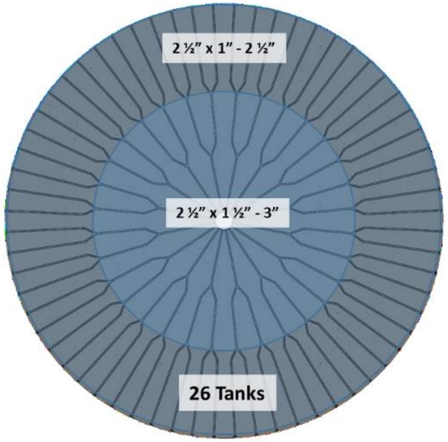
(Kayle Boomer, WRPS 2015)

AY
Tank Farm

AZ/SY/AW/AN/AP
Tank Farm



(Brandon J. Vazquez, WRPS 2015)



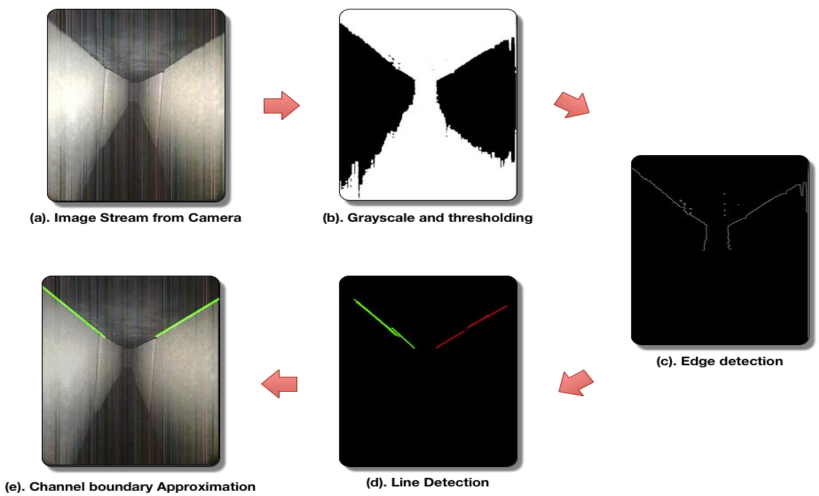
(Jason Gunter, WRPS 2015)

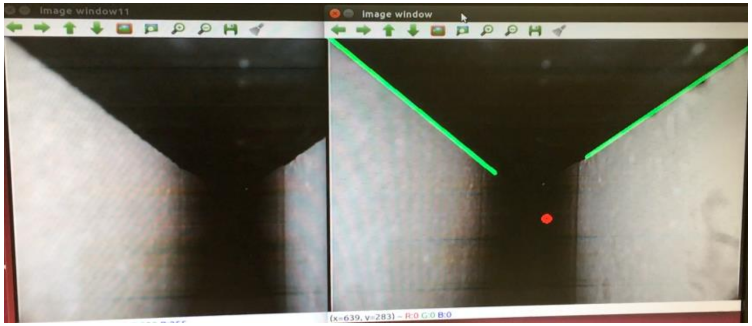
Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

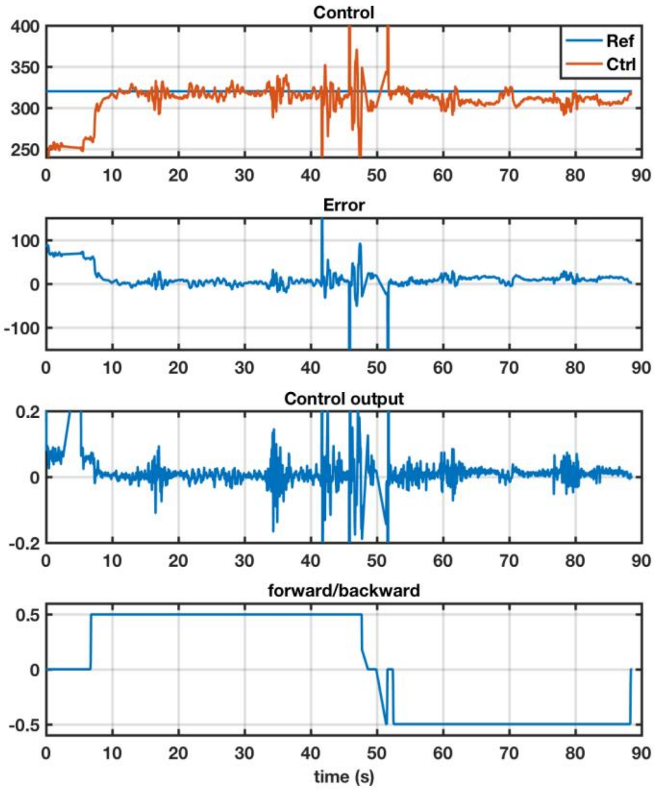
Image Processing and Lane Keeping

Image Processing Pipeline





Input Image Lane Detection

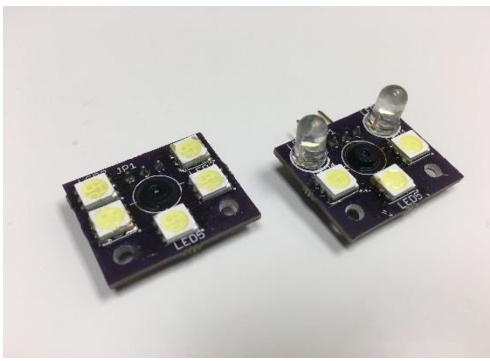


Task 18 - Technology Development and Instrumentation Evaluation

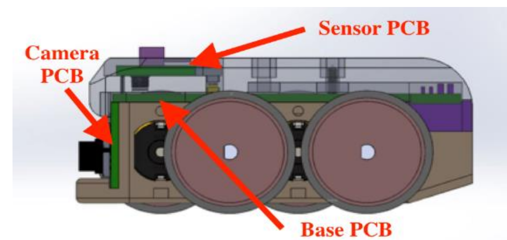
18.2 - Development of Inspection Tools for DST Primary Tanks

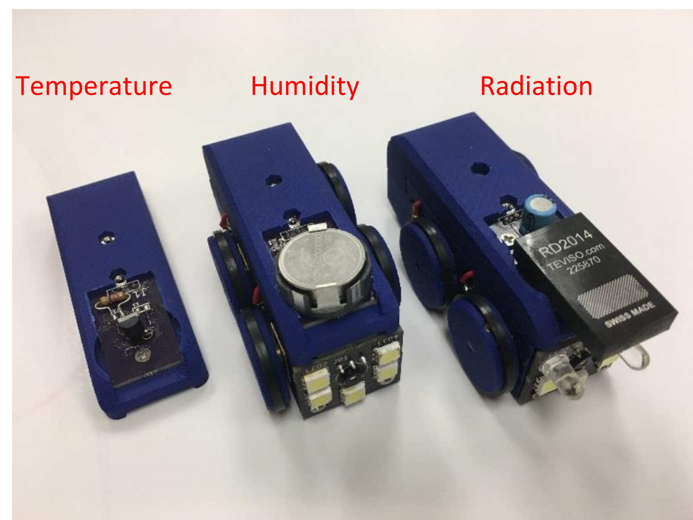
Lighting and Sensor Hoods

Lighting Configurations



Modular Sensor Hoods





Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

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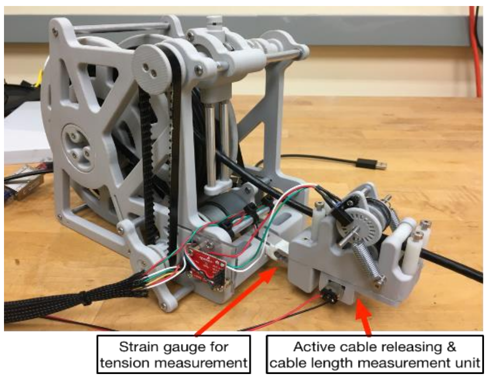
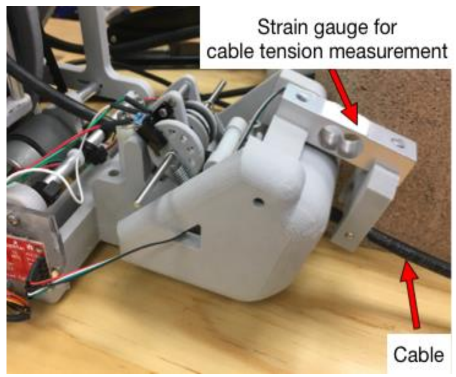
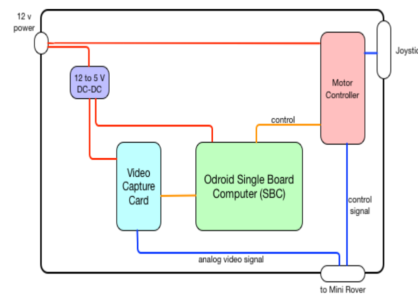
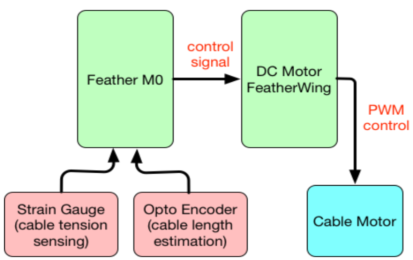
Cable Management System & Control Box

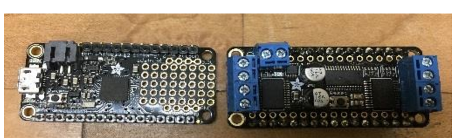


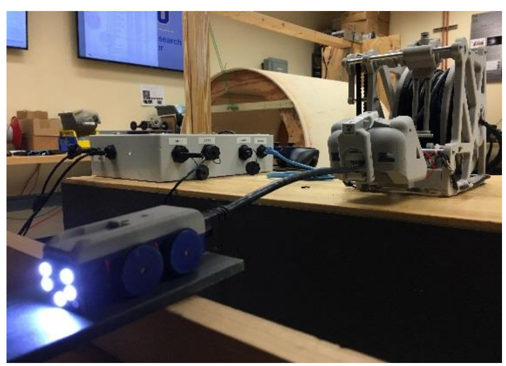




Control Box Upgrade







Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

Full-scale Sectional Mockup Testing

Task 18 - Technology Development and Instrumentation Evaluation

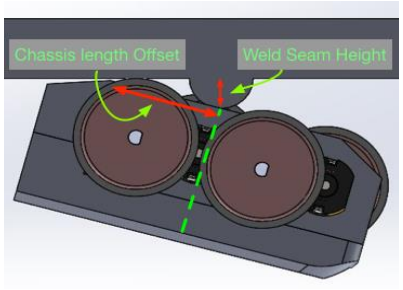
18.2 - Development of Inspection Tools for DST Primary Tanks

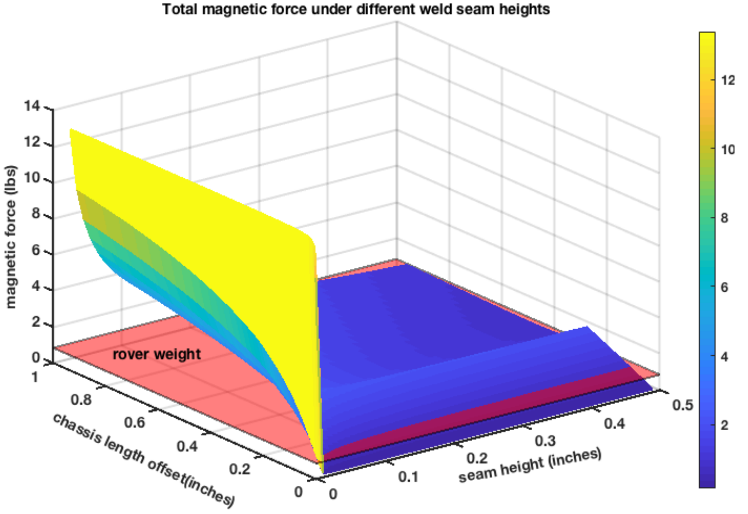
Field Test – Lessons learned

Observations and Comments from Field Engineers:

- Weld seam traversing
- Connector to the Mini Rover needs to be secured
- May or may not require cable management system

Magnetic Force vs. Weld Seam Height

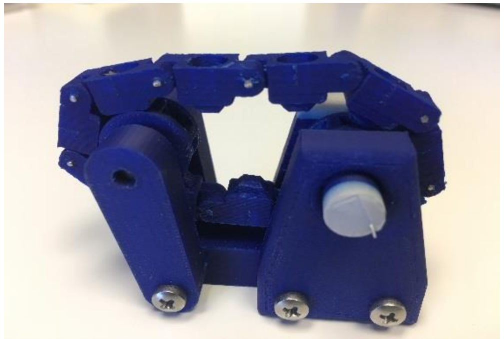




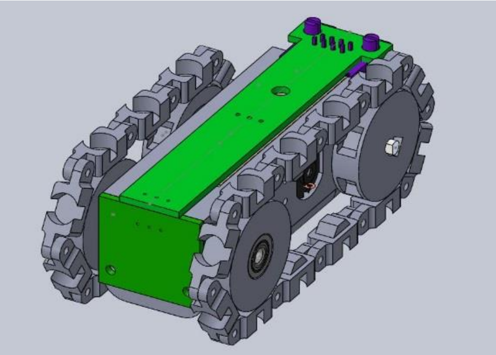
Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

Tank Track Design

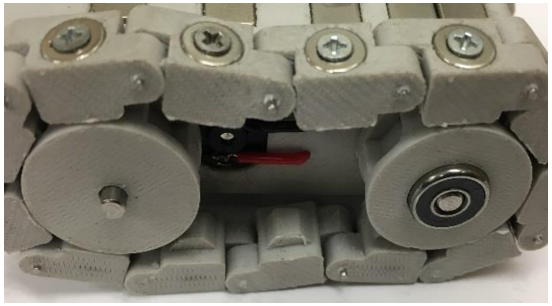


Feasibility Study

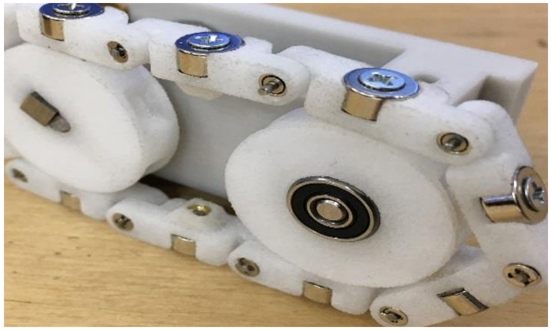


System Design

System Prototypes



ABS



Nylon

FIU Applied Research Center

Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

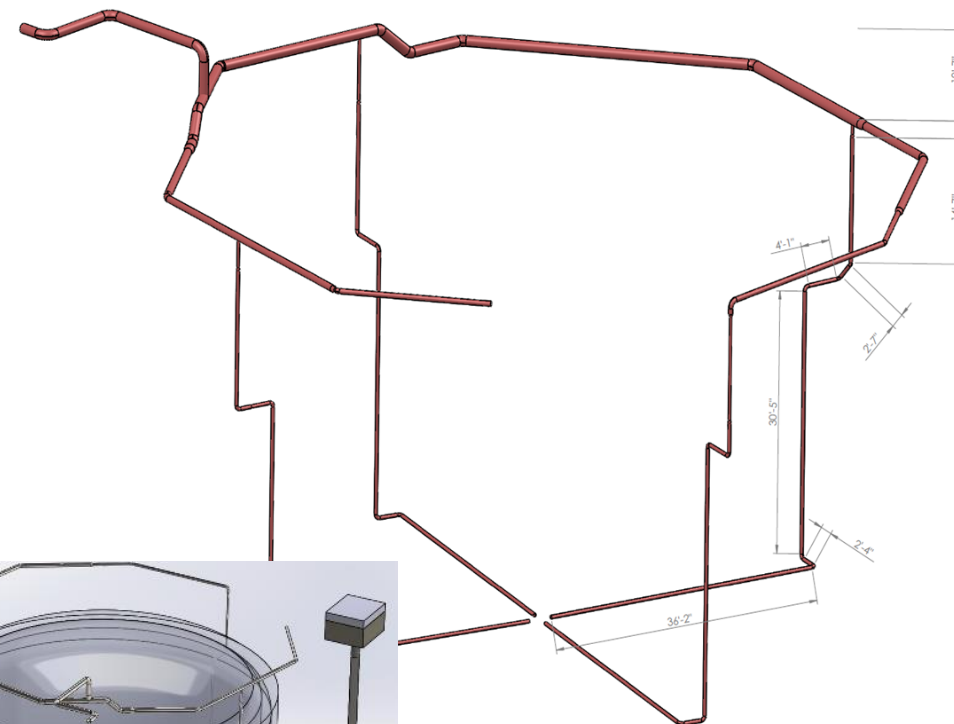
Pneumatic Crawler

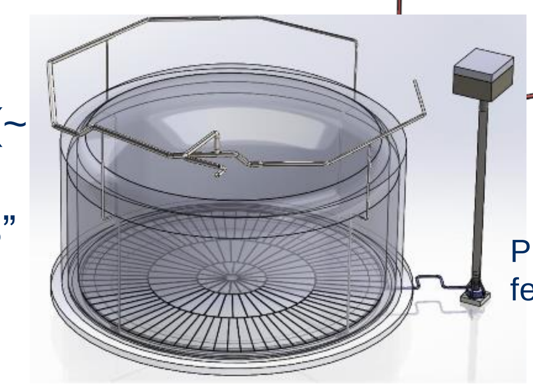
Objective:

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



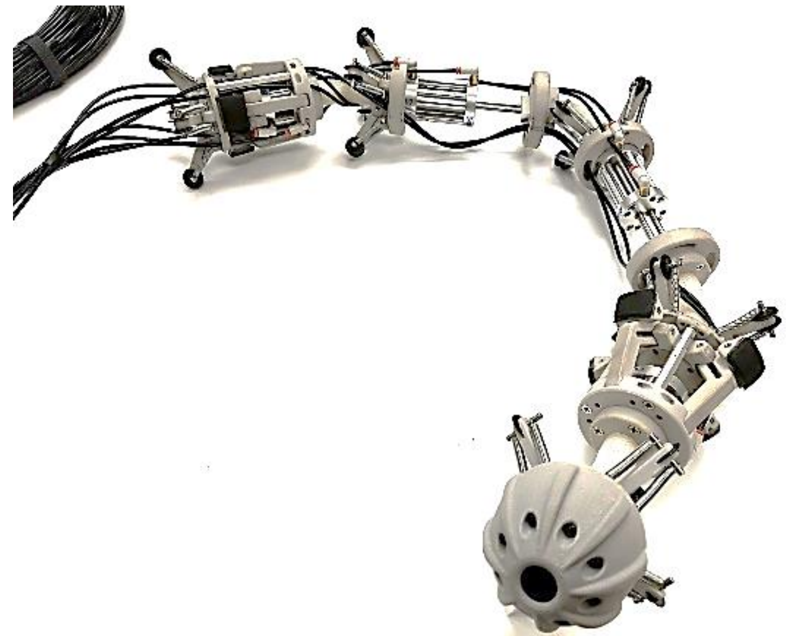


Proposed inspection -approximately 100 feet (significant portion is gravity fed)

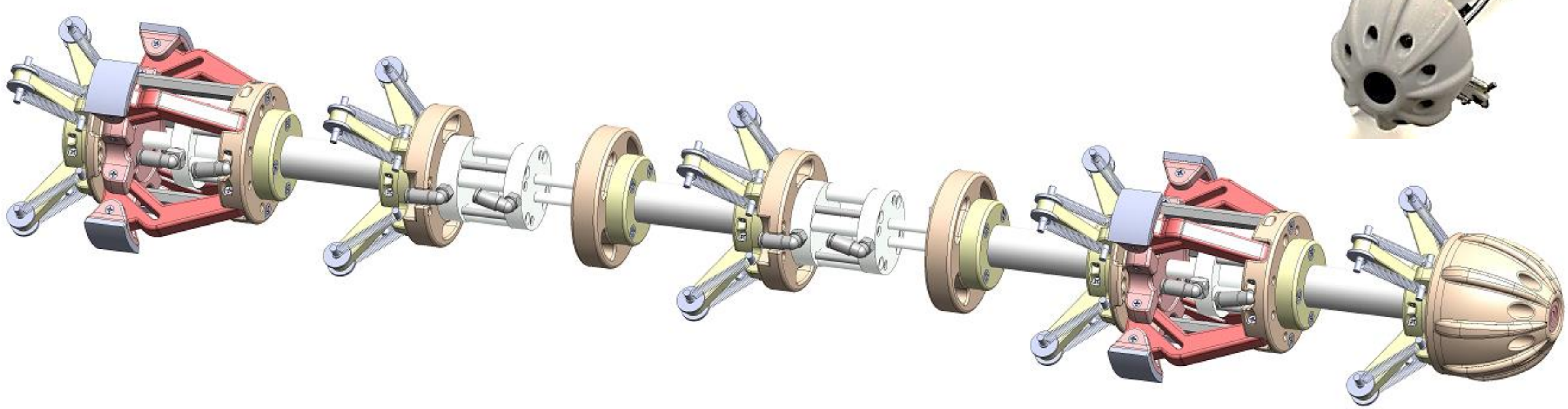
Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

Pneumatic Crawler



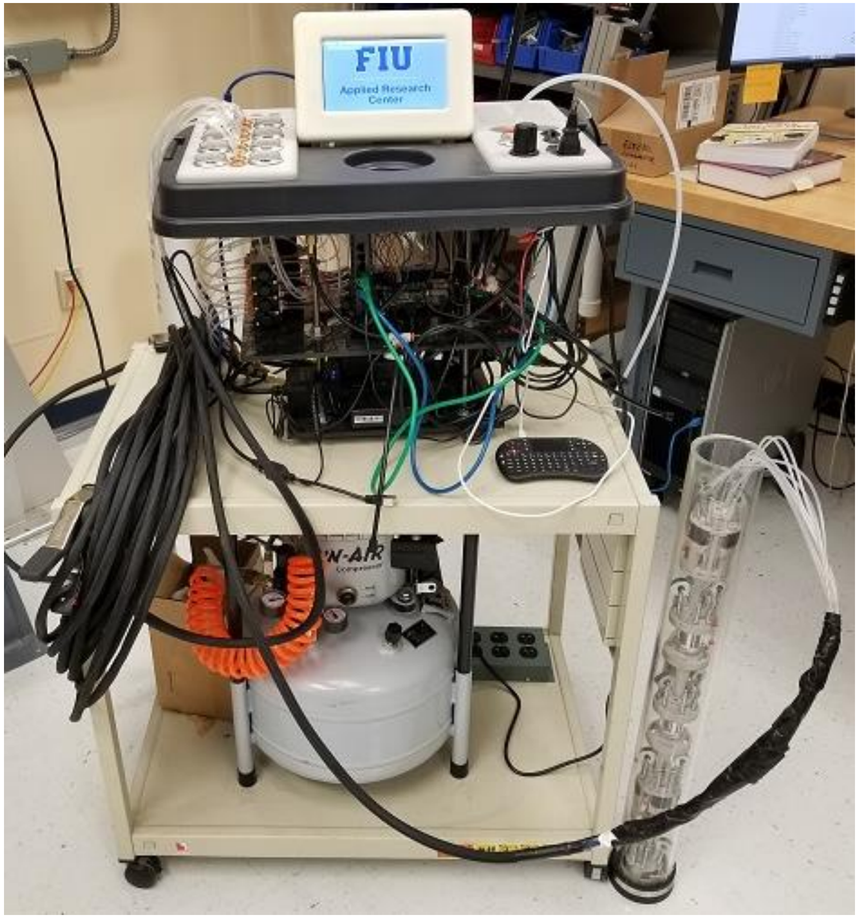
- Pneumatic actuators emulate the contractions of the peristaltic movements
- Movement does not require embedded electronics and electric actuators
- Suitable for highly radioactive environments with potential exposure to flammable gases



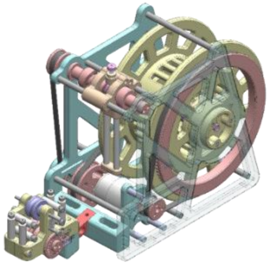
Task 18 - Technology Development and Instrumentation Evaluation

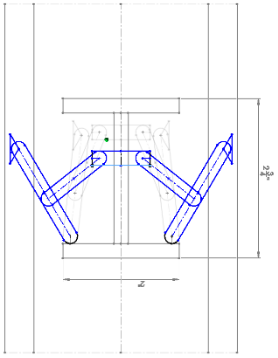
18.2 - Development of Inspection Tools for DST Primary Tanks

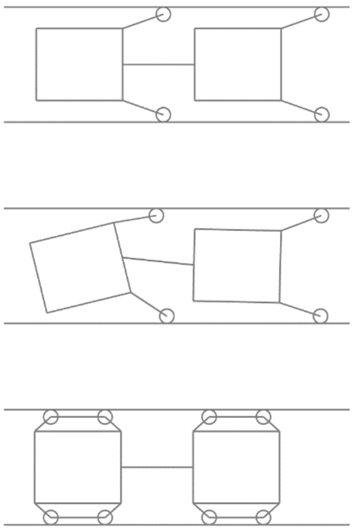
Overall System, Testing & Improvements



- Cable management system
- Electric powered
- Guide mechanism



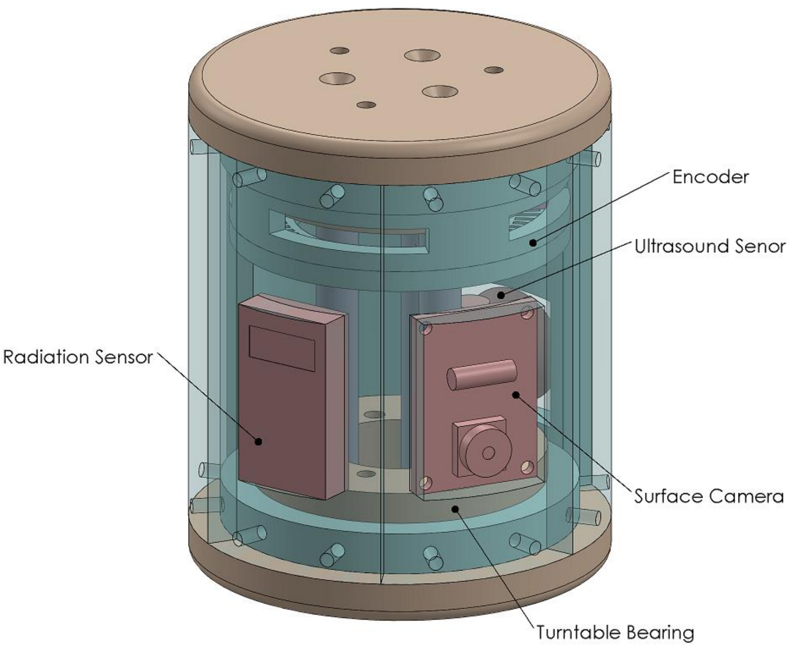


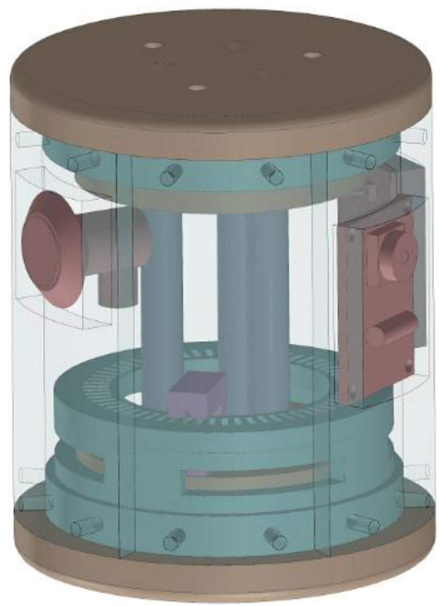


Task 18 - Technology Development and Instrumentation Evaluation

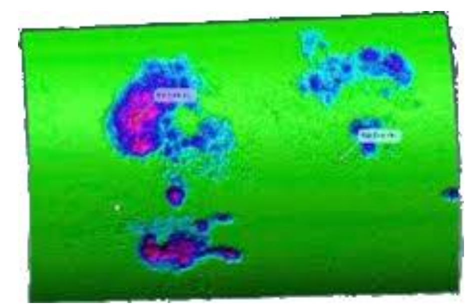
18.2 - Development of Inspection Tools for DST Primary Tanks

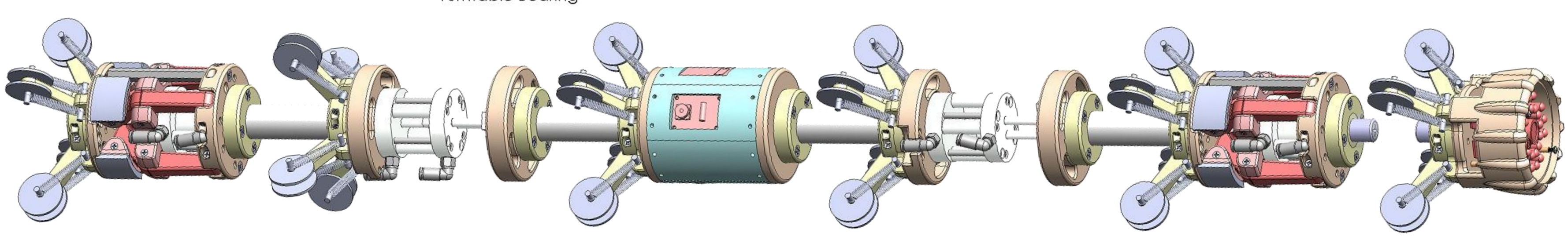
Instrumentation Module & Pipeline Integrity Evaluation





Corrosion & Erosion Mapping

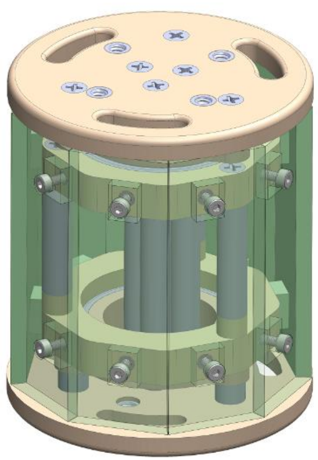


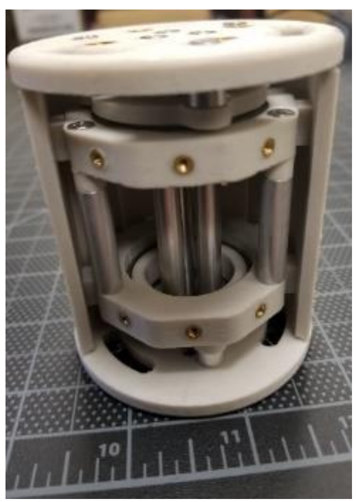


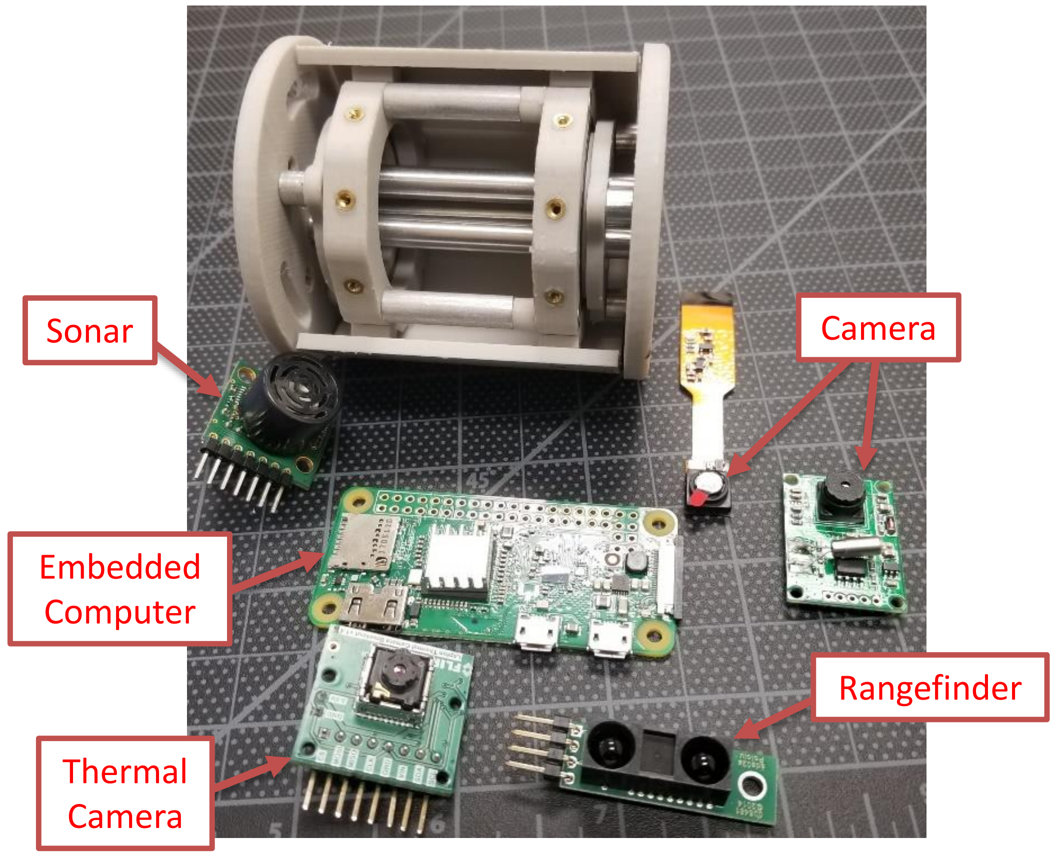
Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

Instrumentation Module Prototype



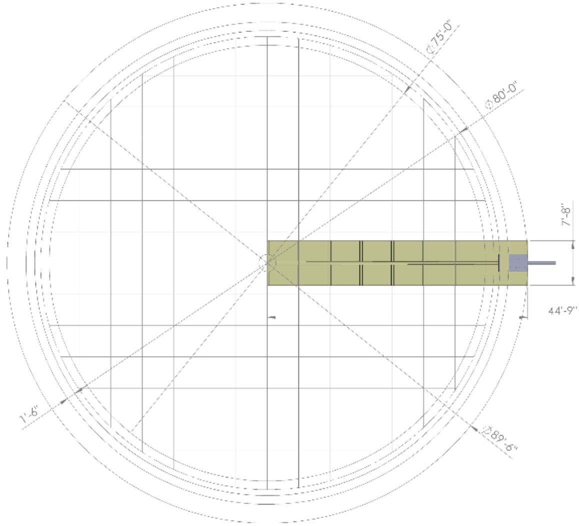




Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

Sectional Mockup of DSTs

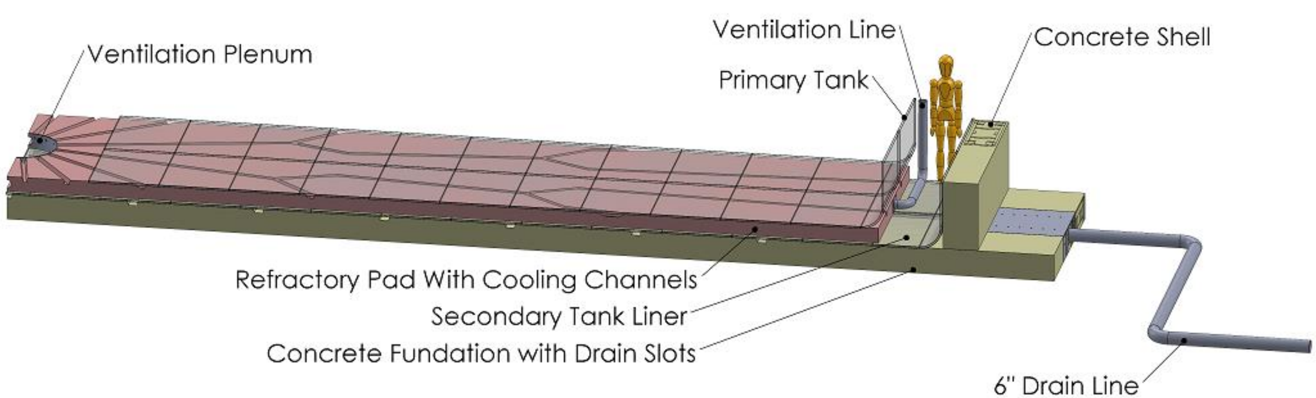


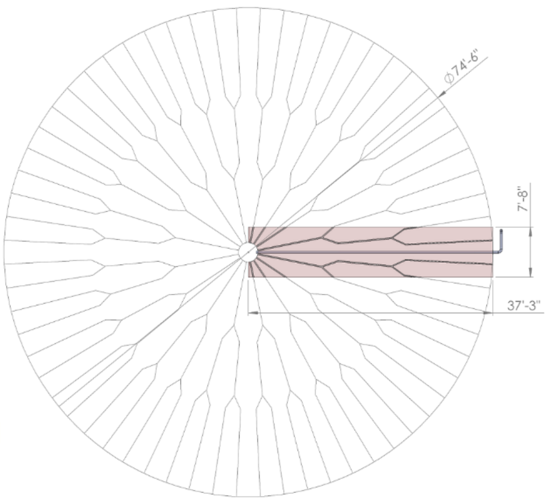
Objective: To design a full-scale sectional mockup of the DST to evaluate inspection technologies and robotic devices.

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

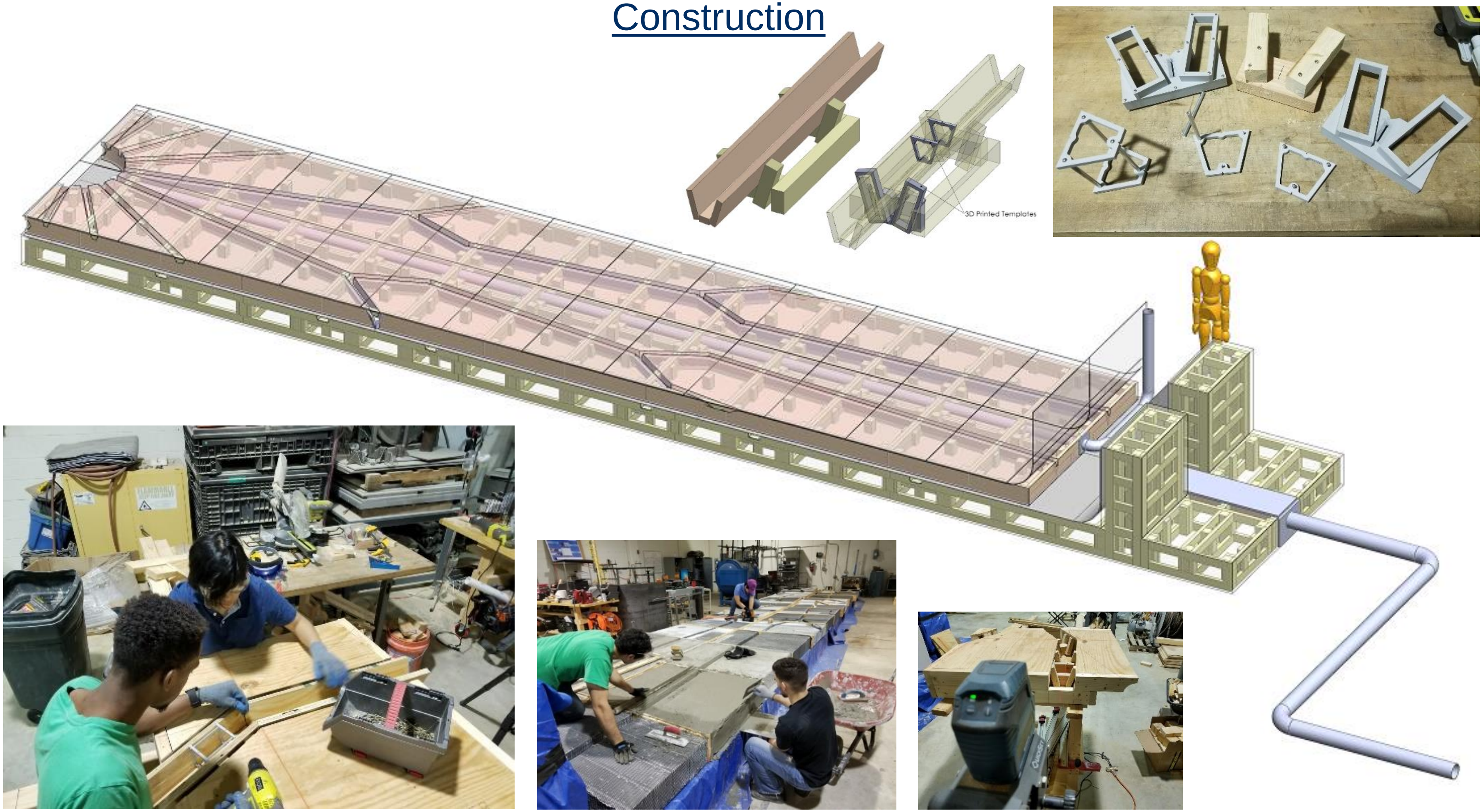




Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

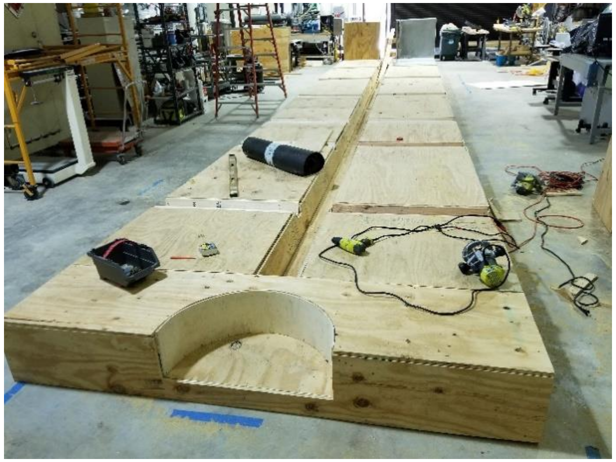
Construction



Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

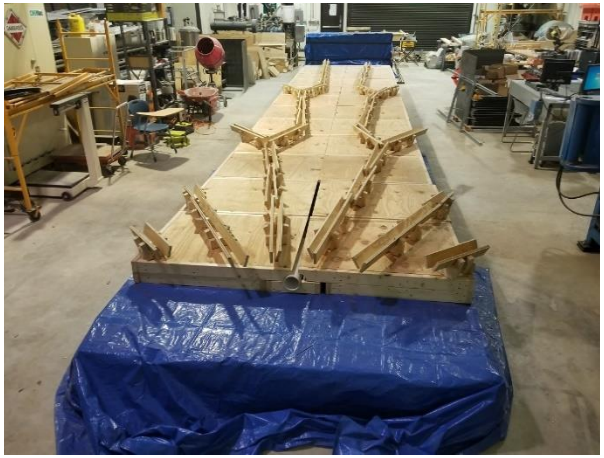
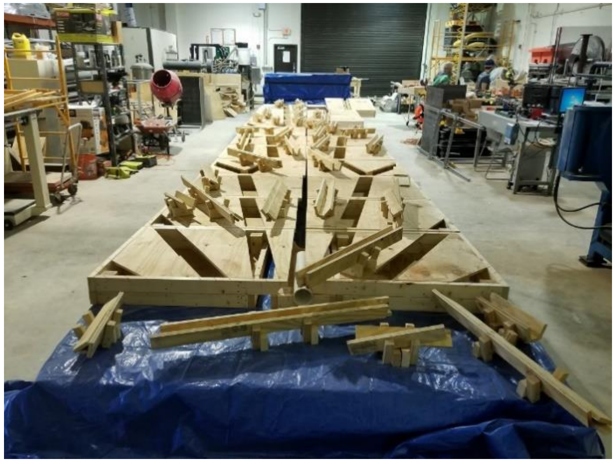
Foundation

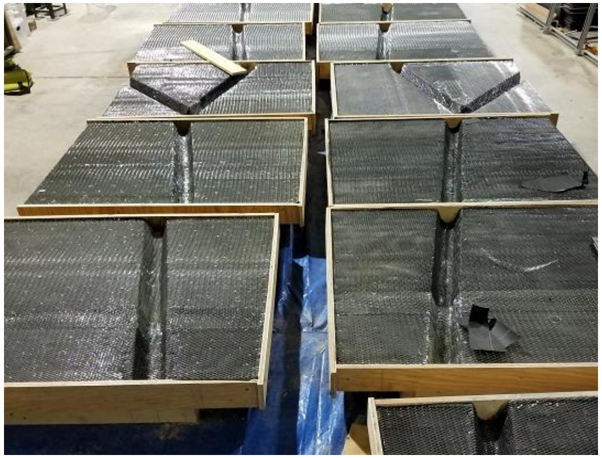
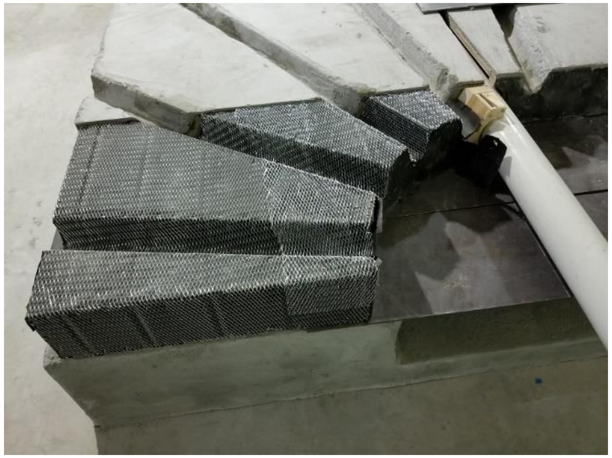


Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

Refractory

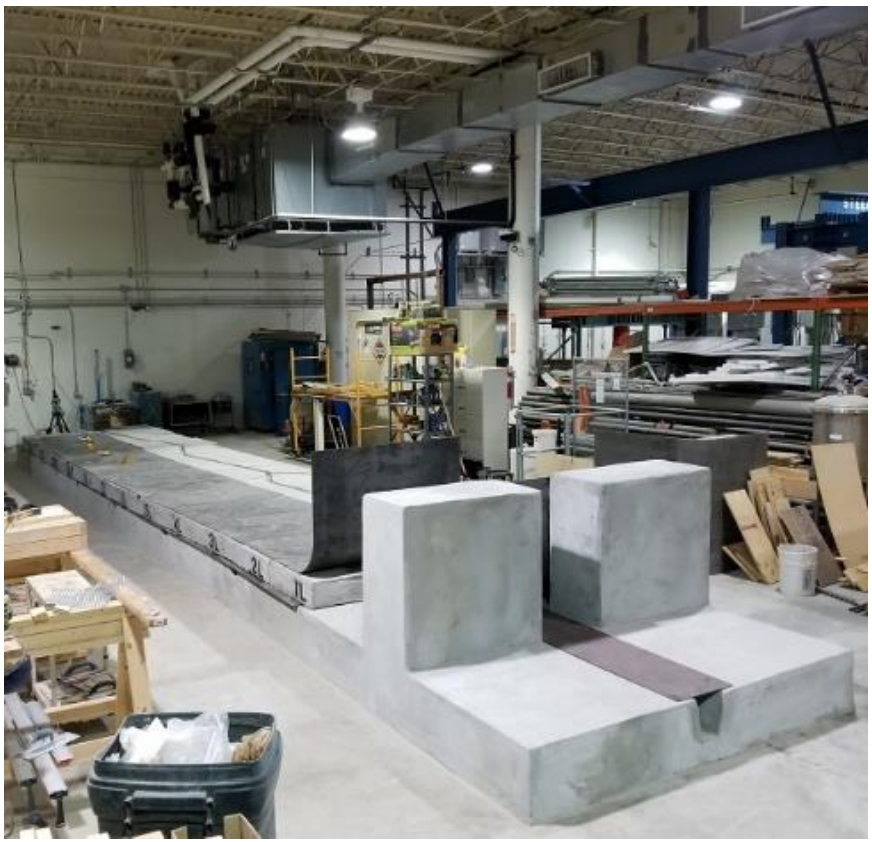




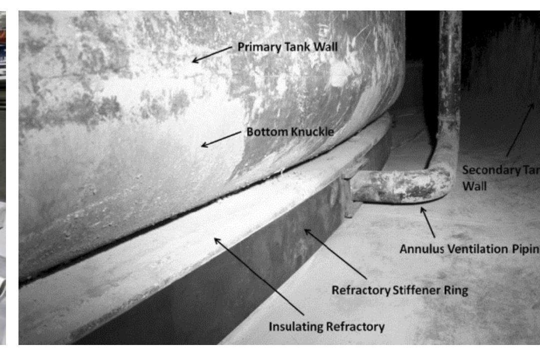



Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

Mockup

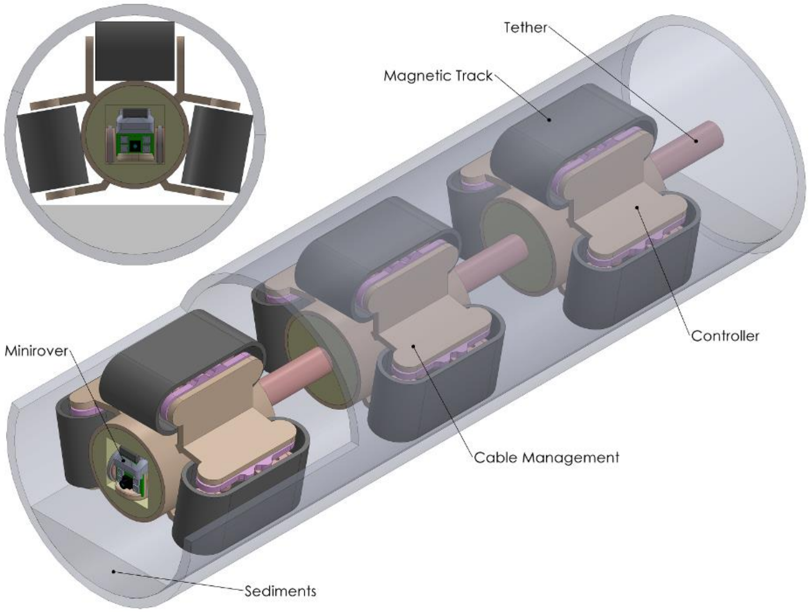


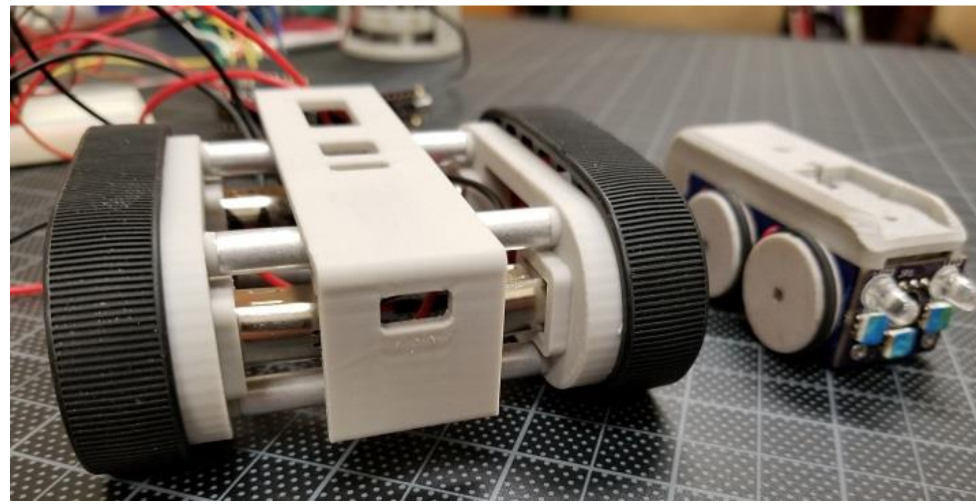


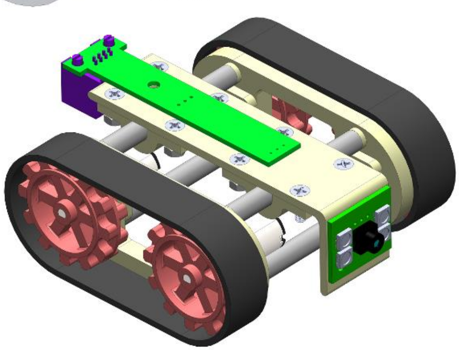
Task 18 - Technology Development and Instrumentation Evaluation

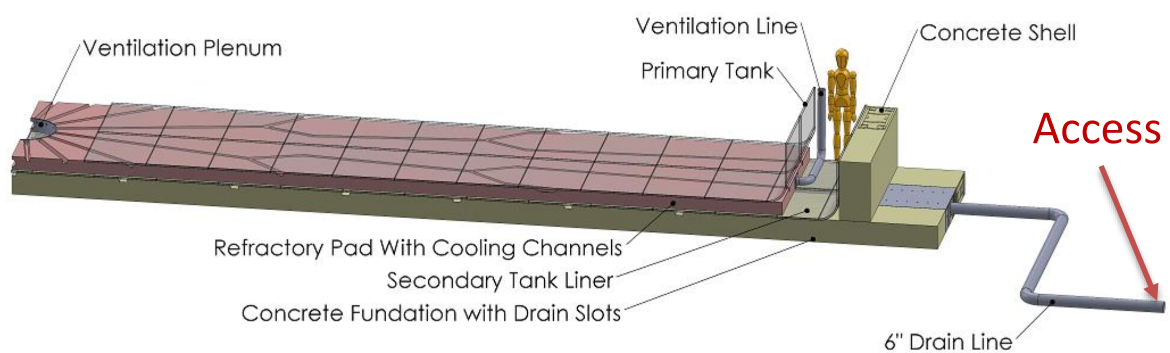
18.2 - Development of Inspection Tools for DST Primary Tanks

Secondary Liner Inspection





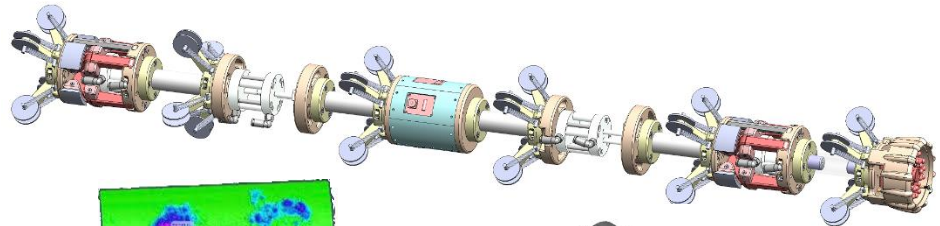




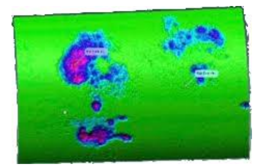
Task 18 - Technology Development and Instrumentation Evaluation

18.2 - Development of Inspection Tools for DST Primary Tanks

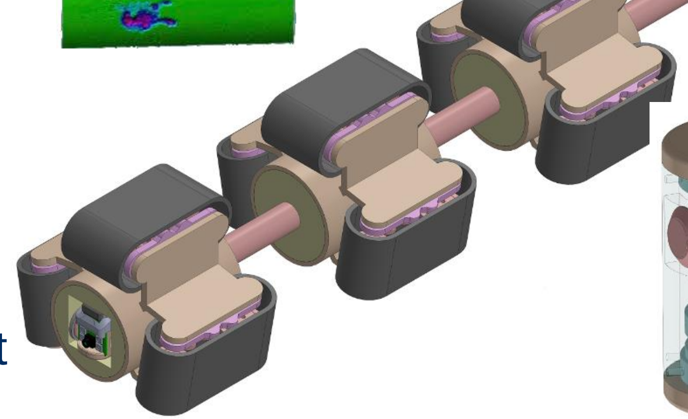
Proposed Scope for Year 9

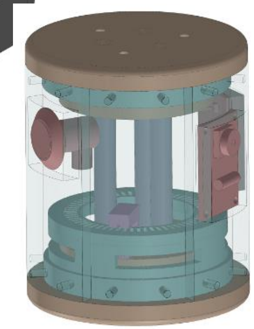


Crawler:



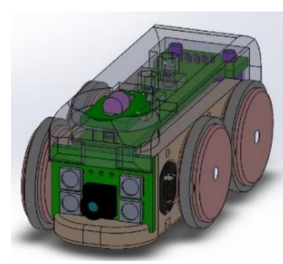
- UT sensor integration and validation
- Continue to develop inspection tool for secondary liner that travels through 6 inch leak detection line

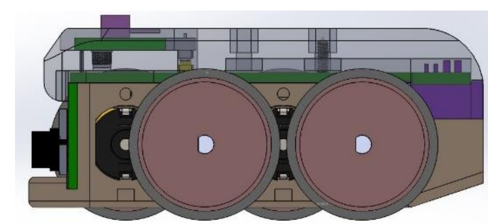




Rover:

- Continue tank track design and testing
- Visual-based localization along the slot
- Integrate UT sensor system for NDI
- Develop a smaller version of the system that can traverse around the corners in the refractory of A-101





Task 18 - Technology Development and Instrumentation Evaluation

18.3 – Support for H-Canyon (New)

Proposed Task for Performance Year 9

Investigate approaches/coatings to protect the walls in the exhaust channel at H-Canyon.

- Conduct literature review on fixatives/coatings that can protect the wall surfaces and potentially mitigate the damage
- Investigate deployment strategies and robotics systems that can operate within the canyon.

Task 19 - Pipeline Integrity and Analysis

19.1 - Pipeline Corrosion and Erosion Evaluation

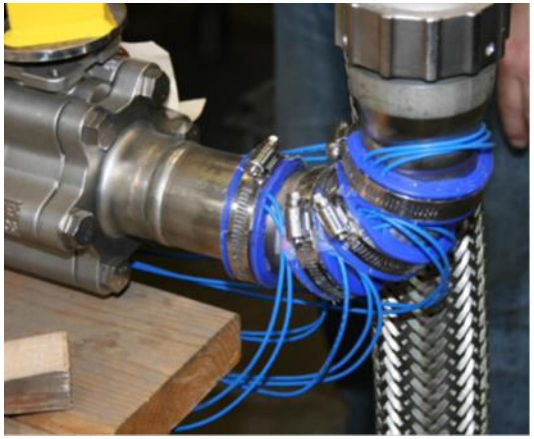
FIU Applied Research Center

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

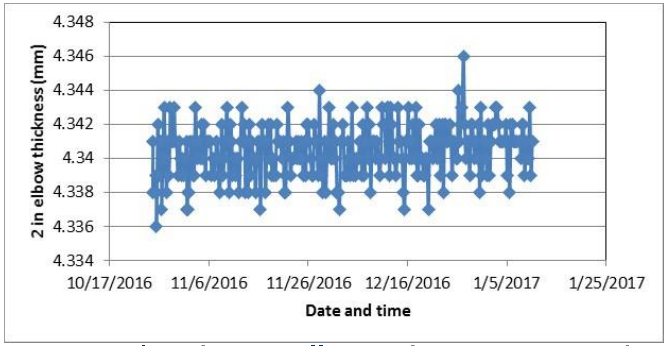
19.1 - Pipeline Corrosion and Erosion Evaluation

Previous Efforts:

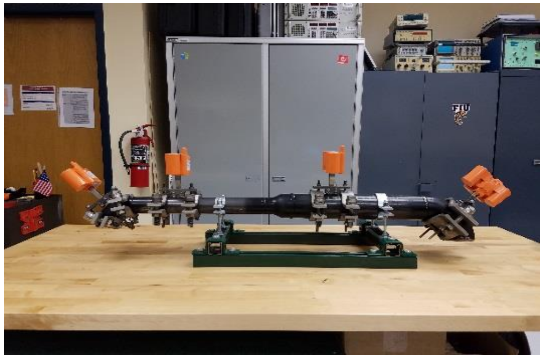
- Conducted a review of alternative sensor systems that meet the site requirements
- Evaluated various couplants (gel and dry) for UT sensing using an Olympus dual element sensor
- Down selected to Permasense and Ultran sensors
- Bench scale testing of wireless Permasense system on a two and three inch pipe section.
- Validated data over 6 months
- Sensor accuracy – 0.04 mils (0.01 mm)

Ultran UT sensors

Permasense – guided wave sensors



Results data collected over 4 months



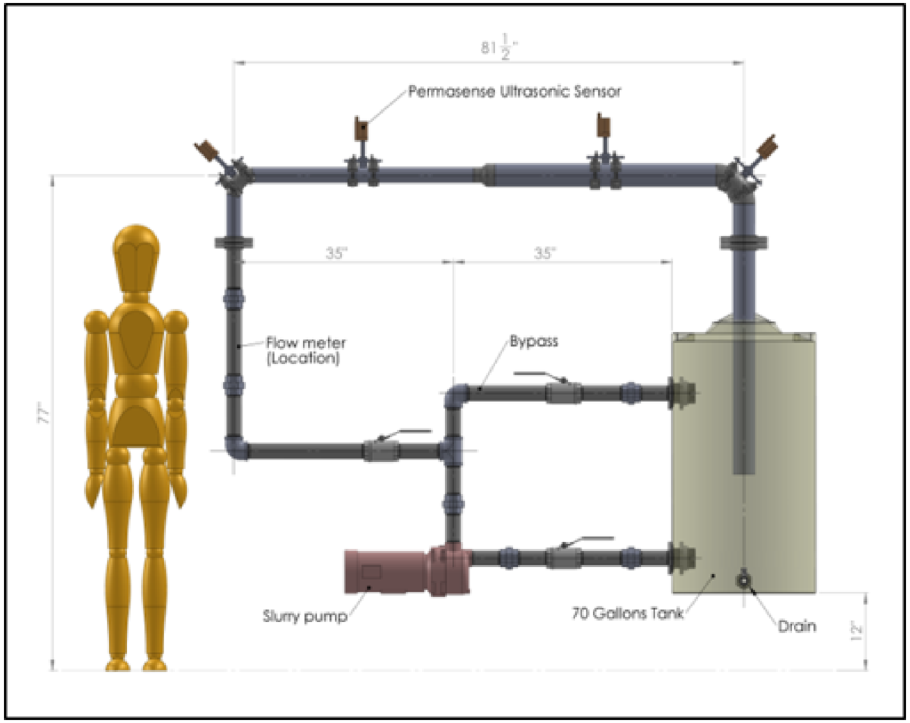
Initial bench scale test bed

Task 19 - Pipeline Integrity and Analysis

19.1 - Pipeline Corrosion and Erosion Evaluation

Current work - Engineering scale testing:

- In-house designed test loop
- Pipe wear formation using abrasive solutions



Pipe loop model

Task 19 - Pipeline Integrity and Analysis

19.1 - Pipeline Corrosion and Erosion Evaluation

Engineering scale testing:

Test loop includes:

- 4 Permasense guided wave sensors
- 2 and 3 inch pipe sections (straight sections and elbows)
- Sand/water mixture
- 3 HP centrifugal pump - up to 2.5m/s and 110 gpm
- Sand particle sizes - 400 to 1600 microns
- By-pass system to control flow rates

Pipe loop assembly

Task 19 - Pipeline Integrity and Analysis

19.1 - Pipeline Corrosion and Erosion Evaluation

FIU Applied Research Center

Current work - Engineering scale testing:

- Test matrix - 7 months using 900 micron sand particles
- Data collection - 6 to 12 hrs. frequency

Simulant	Circulation Period (estimated)
Water (loop validation)	1 week
Sand and water slurry (5%)	3 months
Sand and water slurry (8%)	2 months
Sand and water slurry (10%)	2 months

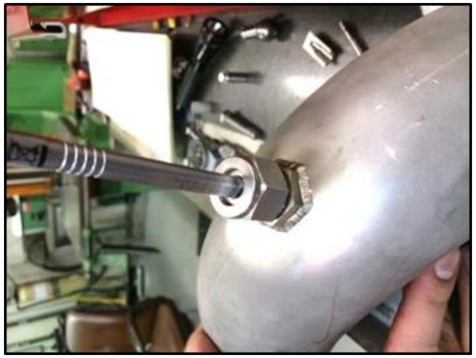
Task 19 - Pipeline Integrity and Analysis

19.1 - Pipeline Corrosion and Erosion Evaluation

Current work - Evaluate SRNL Erosion Coupons:

- Purpose
  - Incorporate an additional method to measure sensitive wear rate
  - Shorten the test durations
  - Provide a correlation between UT sensor data and mass loss data
- Benefits
  - Strengthen the defensibility of the data collected from the long-term flow loop test
  - Provide quantifiable data on erosion patterns and scar depth
  - Provide wear data on alternative materials
- Method
  - Phase array UT sensors (pencil sensors) - thickness accuracy (0.0001 inch)
  - Gravimetric measurements - mass loss (~ 0.00001 g)

Erosion coupon



Coupon and UT sensor on an elbow

Task 19 - Pipeline Integrity and Analysis

19.1 - Pipeline Corrosion and Erosion Evaluation

Proposed Scope for Performance Year 9

- Complete initial testing with the sand-water simulant (5% solids) and monitor real-time changes in pipe thicknesses.
- Complete subsequent testing with higher solids loading.
- Modify the test loop – capable of evaluating the sensors ability to withstand elevated temperature and humidity while providing accurate measurements.
- Explore the option of conducting material tests on eroded pipe sections.

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.

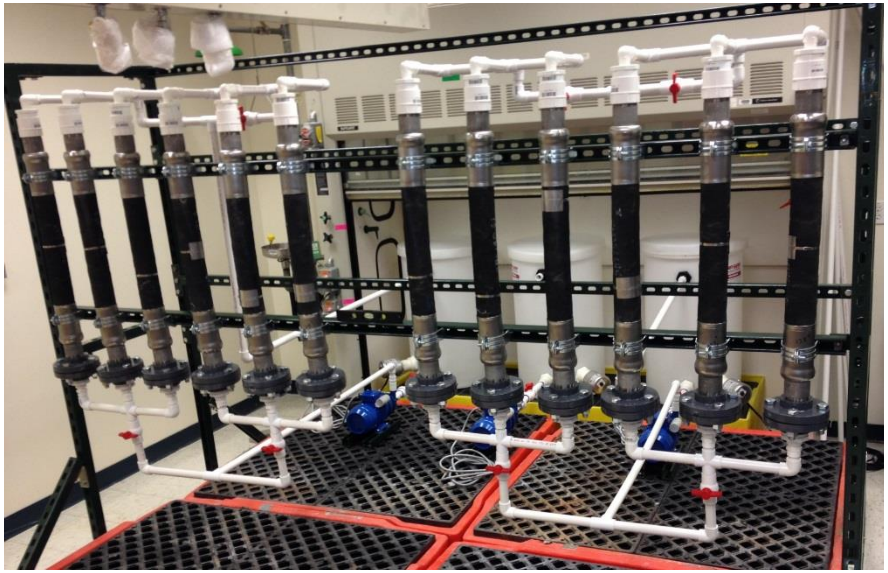
Objective:

- 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.

FIU Applied Research Center

Aging Loop

- The in-service configuration aging experimental setup consisted of 3 independent pumping loops with two manifold sections on each loop.
- Each manifold section held three test samples and was used for a corresponding exposure time of 6 months and 1 year.
- Each test sample consisted of a HIHTL hose section, an EPDM O-ring and a Garlock® gasket placed in a series configuration.
- The coupon aging consisted of one coupon aging vessel submerged in each of the three test loop's storage tanks.

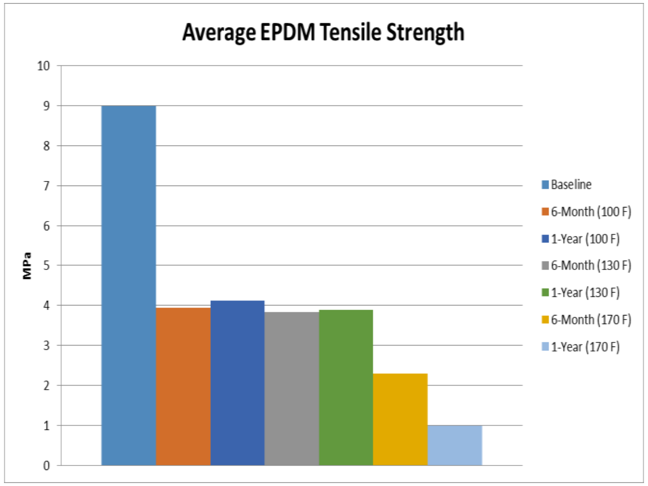


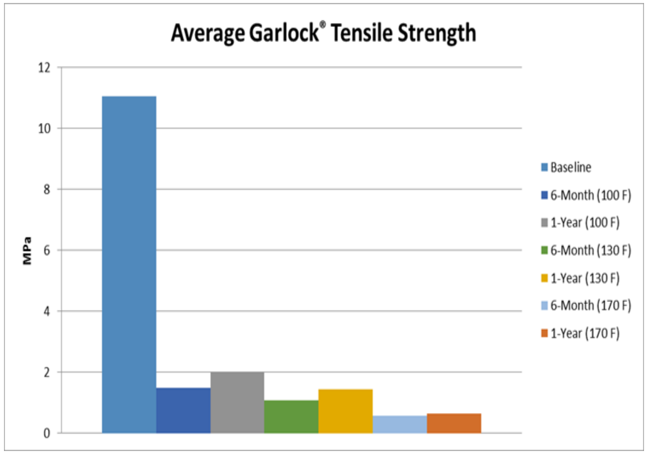
Task 19 - Pipeline Integrity and Analysis

19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

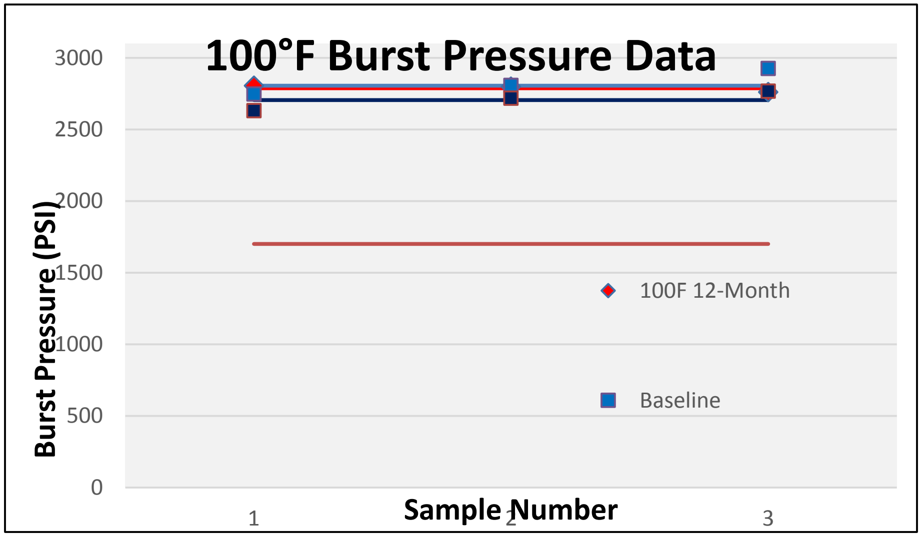
Previous Testing:

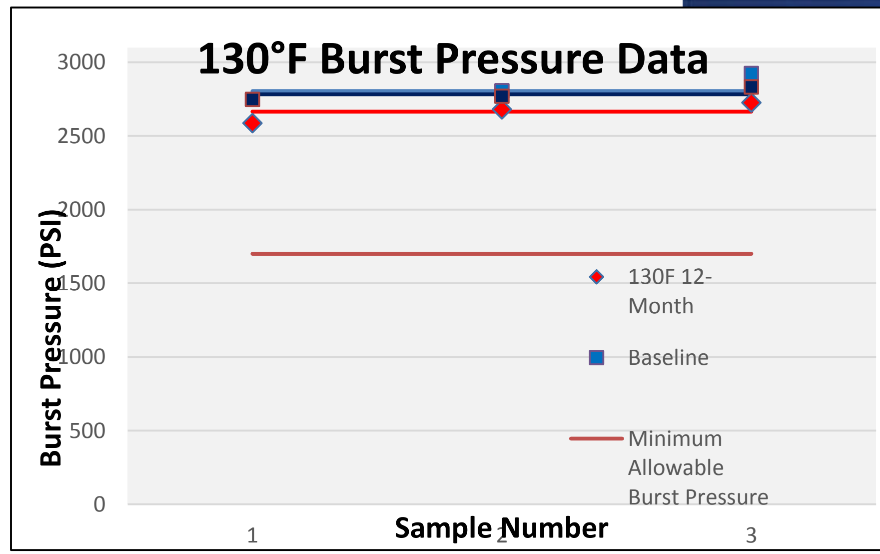
- All material samples had baseline mechanical performance and properties tested prior to any exposure.
- Each material sample was "aged" by exposure to a 25% sodium hydroxide solution at ambient (100˚F), operating (130˚F) and design temperatures (170˚F) for a duration of 180 and 365 days.
- Tests were conducted on both material coupons as well as in-service configuration assemblies.
- After aging, the mechanical/material properties of the samples were again measured to identify any degradation in the properties.

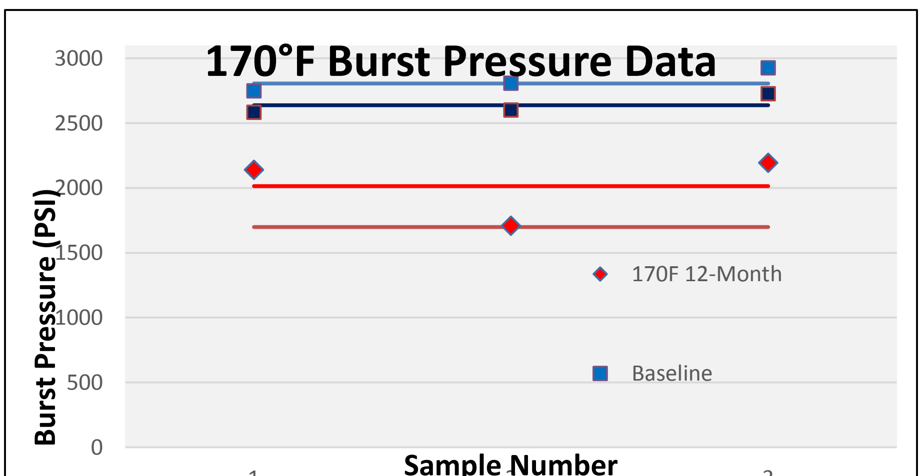




Pressure Test Results

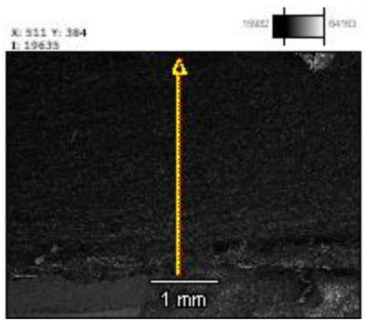




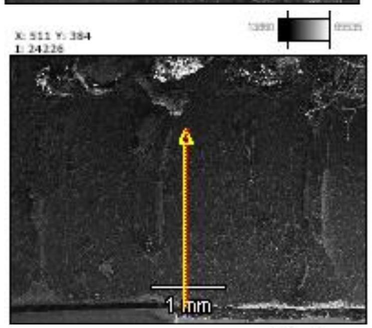


SEM – EDX Results

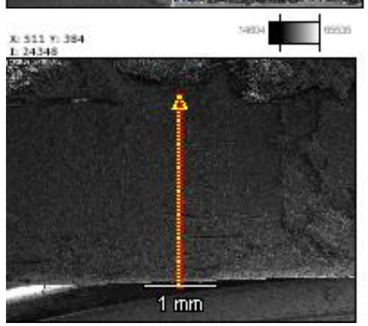
100°F Sample

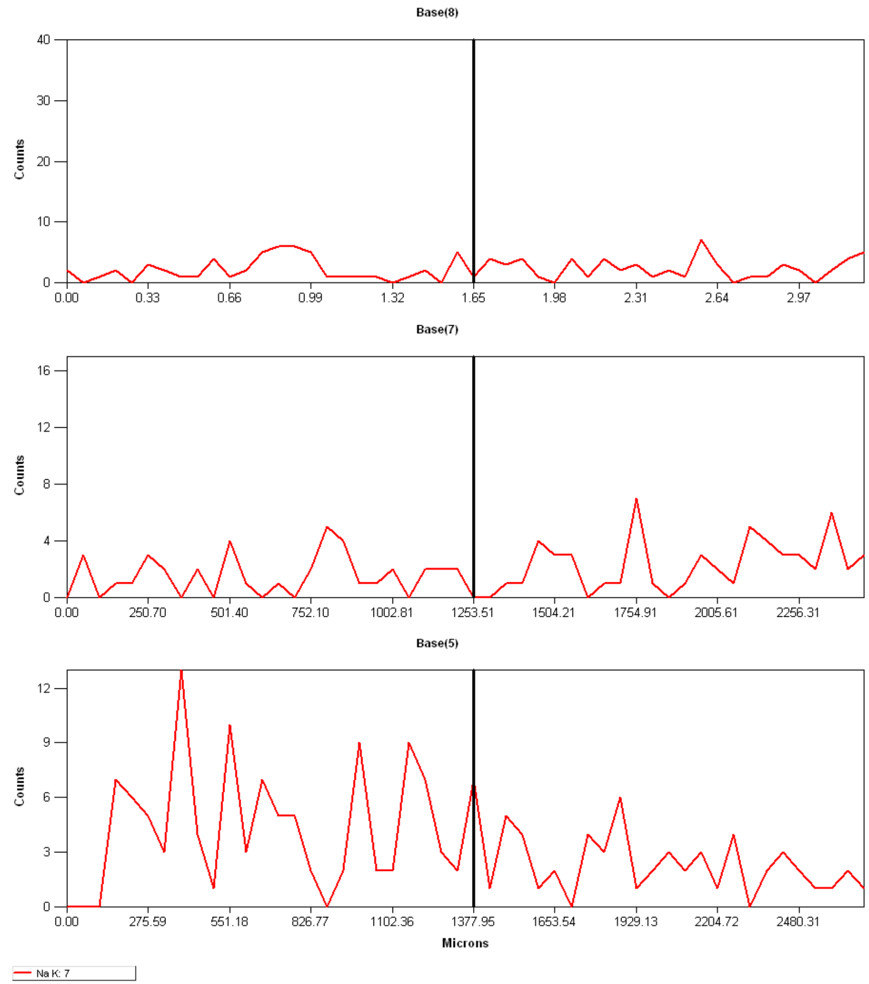


130°F Sample

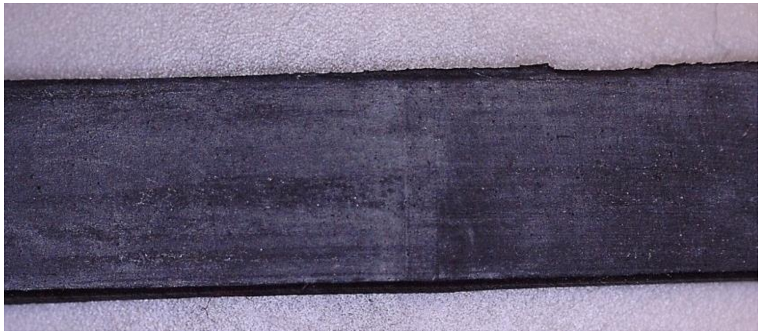


170°F Sample

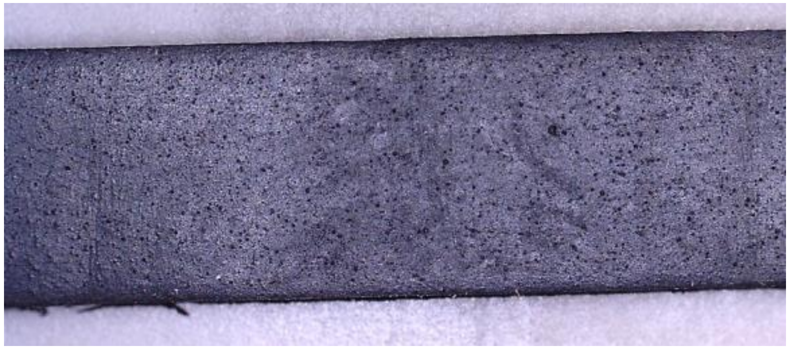




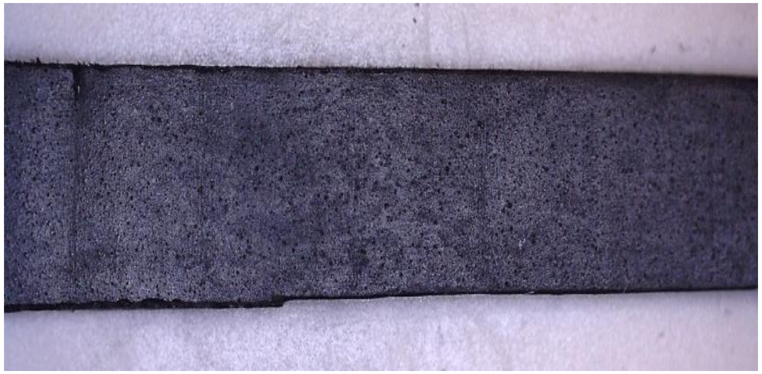
6-month Coupon Visual Inspections



Baseline Specimen



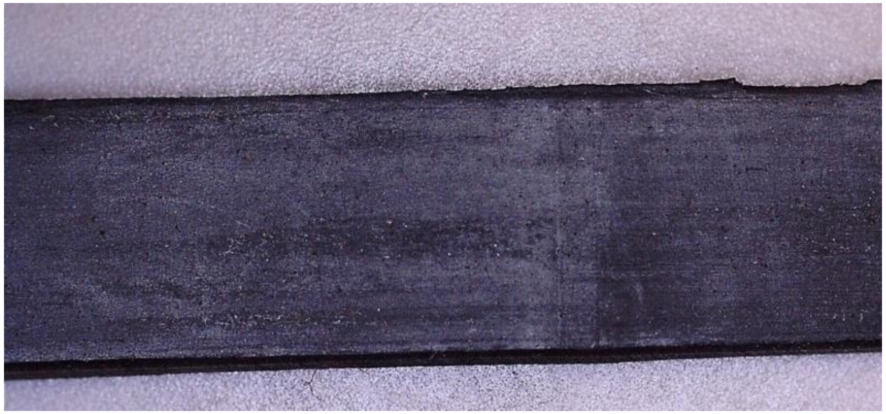
6-Month 100°F



6-Month 130°F

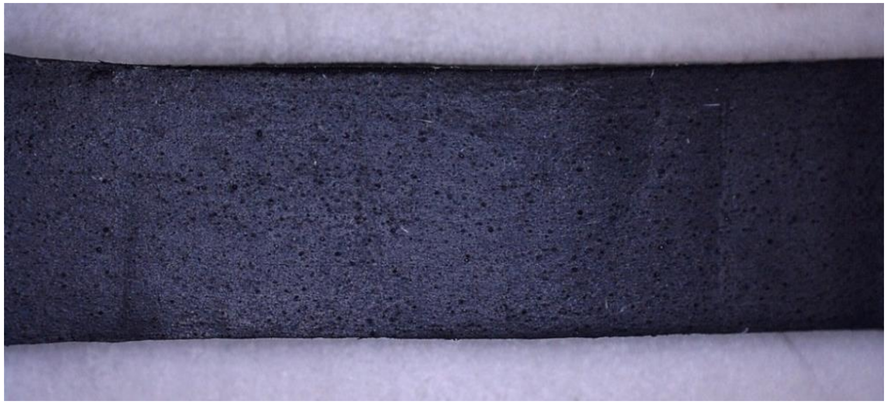
6-Month 170°F

12-Month Coupon Visual Inspections



Baseline Specimen

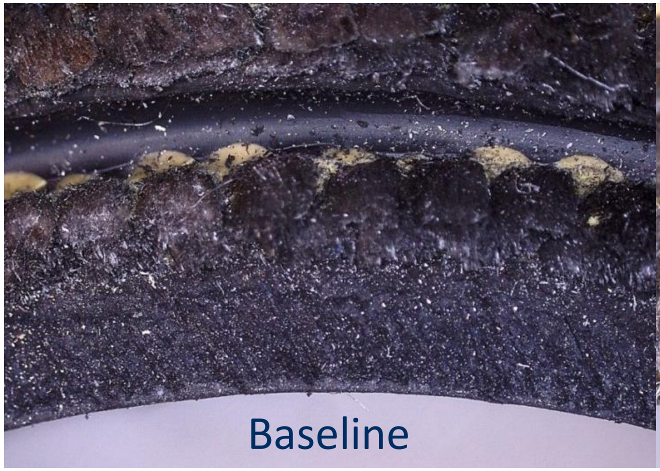
12-Month 100ºF

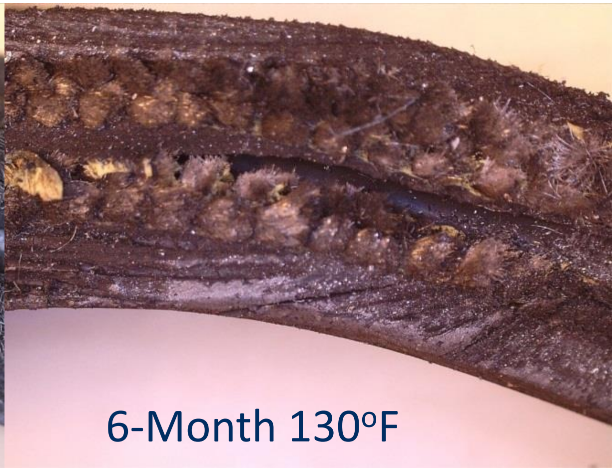


12-Month 130ºF

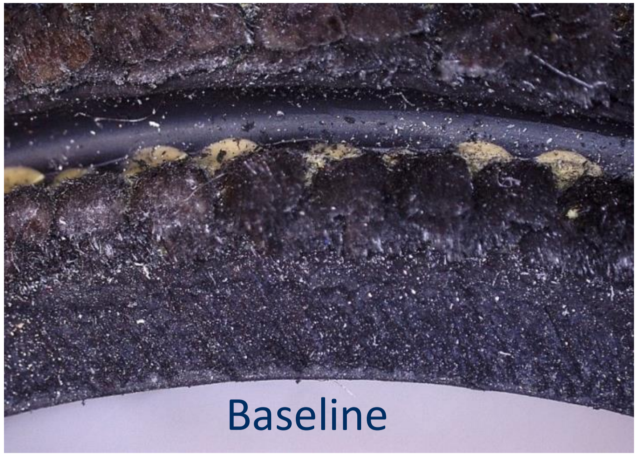
12-Month 170ºF

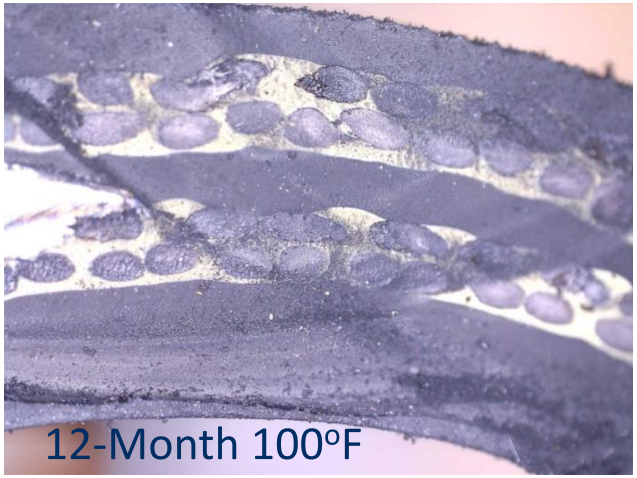
6-Month Hose Visual Inspections





12-Month Hose Visual Inspections





Task 19 - Pipeline Integrity and Analysis

19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

Proposed Scope for Performance Year 9

- Complete SEM-EDX on both the HIHTL coupons and the material coupons.
- Reconfigure aging loop to accommodate the two remaining hose sections as well as EPDM and Garlock® coupons. (Investigate obtaining additional HIHTL coupons)
- A single loop will be utilized to age the two hose sections at 170°F.
- The stressor will be limited to hot water at 170°F for a 12-month duration.
- After the 1 year of aging, specimens will be removed and tested to determine the level of degradation in strength and material properties.

Task 20 – Support for Technology Evaluation Using DST Mockup

Proposed Scope for Performance Year 9

- Provide access to DOE-EM and its contractors to use FIU's DST sectional mockup to evaluate the viability of inspection tools, robotic systems and sensors.
- Provide support for the testing and evaluation
- Work with engineers to make modifications to the mockup, as needed.