DOE-EM Cooperative Agreement FIU Performance Year 6 Research Review

Presented: April 5 - April 7, 2016

to the U.S. Department of Energy

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FLORIDA INTERNATIONAL UNIVERSITY

FIU-DOE Research Review

Tuesday April 5, 2016	Wednesday April 6, 2016	Thursday April 7, 2016
1:00-2:30 **High Level Waste / Waste Processing** **(FIU Project 1)**	10:00-12:00 Workforce Development & Training (FIU Project 4)	10:00-12:00 Wrap Up (All Projects)
2:30-4:00 D&D/IT for EM (FIU Project 3)	1:00 - 3:00 Soil/Groundwater (FIU Project 2)	

Project 1 Chemical Process Alternatives for Radioactive Waste

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Senior Research Scientist

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Project Staff and Students

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Project Clients and Collaborators

- DOE-EM
  - Gary Peterson, Steve Schneider
  - Rod Rimando
- Washington River Protection Solutions
  - Dennis Washenfelder, Terry Sams, Ruben Mendoza, Mike Thien, Jason Gunter
- Pacific Northwest National Laboratory
  - Dawn Wellman, Carl Enderlin
- Bechtel
  - Joel Peltier, Chris Gunther (NETL)

Project Description

FIU has been conducting research on several promising alternative processes and technologies that can be applied to address several operational shortcomings in the current waste processing strategy.

The implementation of advanced technologies to address challenges faced with baseline methods is of great interest to the Hanford site.

The use of field or *in situ* technologies, as well as advanced computational methods can improve several facets of the retrieval and transport processes of HLW.

FIU has worked with site personnel to identify a number of technology and process improvement needs that can benefit from FIU's core expertise in HLW. These include: 1) alternative pipeline unplugging technologies; 2) multiphase flow modeling using Star-CCM+; 3) imaging of HLW settled solids surfaces in tanks monitor PJM performance and to predict onset of DSGSEs; 4) development of inspection tools for DST primary tanks; 5) pipeline integrity analysis; and 6) evaluation of non-metallic materials in the transfer system

Project Description

Task 17 Advanced Topics for Mixing Processes

- computational fluid dynamics modeling of HLW processes in waste tanks using Star-CCM+

Task 18 Technology Development and Instrumentation Evaluation

- evaluation of FIU's SLIM for detection of precursors to DSGREs
- 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

DOE-FIU Cooperative Agreement

Project 1 Accomplishments

Florida International University

Project-Wide Major Accomplishments

- Hosted Karthik Subramanian, Chief Technology Officer at WRPS (11/18/15)
  - CTO provided insight to needs at Hanford – assist in developing tasks that are on the critical path for Hanford
- International Robotics Workshop (2/2-4/16)
  - Attended and presented poster on robotics tasks
- Hanford Task Review at FIU (3/1-2/16)
  - Four engineers from WRPS visited FIU and EM-21 participated via teleconference
  - Provided update on tasks and obtain feedback on potential new tasks and prioritization
- Tank Closure Forum (3/16/16)
  - Provide updated on robotics tasks to EM-21 and Tank Closure Group

Task 17.1 - CFD Modeling of Mixing Processes in Waste Tanks

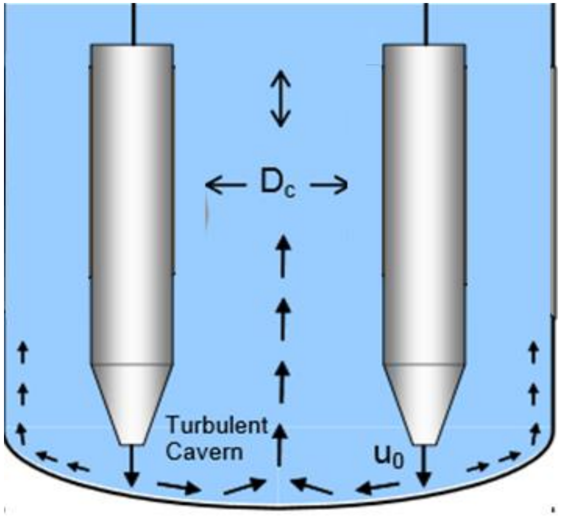
Background:

Various mixing processes are required prior to waste transfer. These involve pulse jet mixers and can be used to release the entrained gas in a controlled manner.

14-ft-diameter vessel to test PJMs

Pulse Jet Mixers (PJM)

- The PJMs contain pressurized vessels which intake the waste and discharge it back out at high velocity creating radial jets. These jets collide at the center of the vessel creating an up wash and promoting circulating motions.



PJM circulation Demonstration

Task 17.1 - CFD Modeling of Mixing Processes in Waste Tanks

Objective

- 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 17.1 - CFD Modeling of Mixing Processes in Waste Tanks

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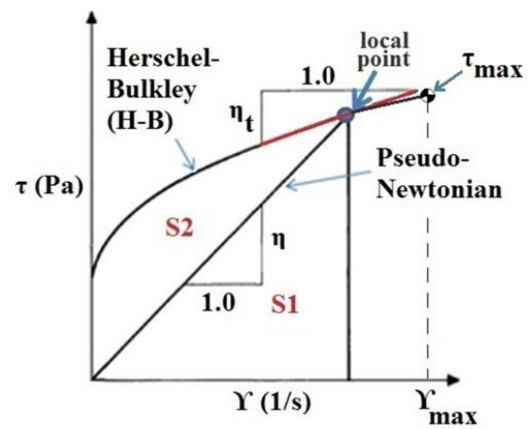
Proposed Method

- Local and global variables were defined to evaluate local and global effects of the method on the simulation results
  - $\phi = \gamma$ for the local variables
  - $\phi = \gamma_{max}$ for the global variables



Rheogram of viscoplastic materials

- Introduced two versions of the proposed method, i.e., Direct and Inverse-Alpha methods, to manipulate the rheogram of the working fluid
  - μ.subs ≡ substitute viscosity
  - n=1 for Direct method
  - n=-1 for Inverse method
  - Threshold set to zero for maximum sensitivity

$$\alpha = 2 \times \frac{\tau_y + \frac{K(\phi)^n}{n+1}}{\tau_y + K(\phi)^n} \quad \textbf{Eq.(1)}$$

$$\mu_{psudo\_Newt} = \frac{\tau_{H-B}}{\phi} = \frac{\tau_Y}{\phi} + k\,\phi^{(n-1)} \quad \textbf{Eq.(2)}$$

$$\mu_{subs.} = \begin{cases} \\ \alpha^n \times \mu_{psudo\_Newt.} & \varepsilon \geq 0 \end{cases} \quad \textbf{Eq.(3)}$$

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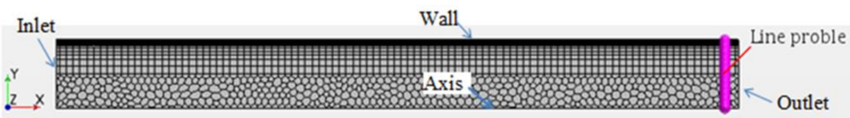
Methodology

- Implemented the Shear-Rate-Correction (SRC) method of Gavrilov and Rudyak (2014) for the problem in hand and results were compared to the results of the Alpha model versions.

$$\gamma^2_{SRC} = 2S_{ij}S_{ij} + \langle 2\, S'_{ij}S'_{ij} \rangle = 2\, S_{ij}S_{ij} + \frac{\varepsilon}{\nu}$$

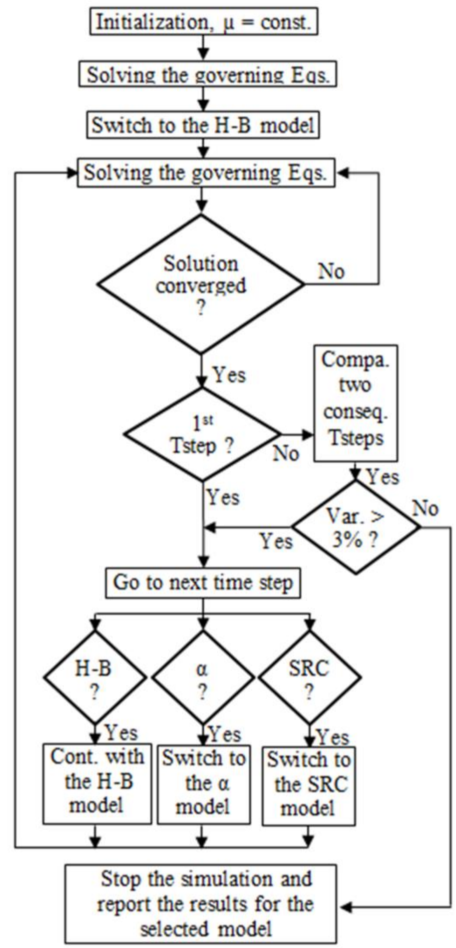
$$\mu_{SRC} = \frac{|\tau|}{\gamma_{SRC}} = \frac{\tau_Y}{\gamma_{SRC}} + k\, \gamma_{SRC}^{(n-1)}$$

- Mesh sizes of 2117, 7328, 20447, and 28615 (units: number of cells) were used



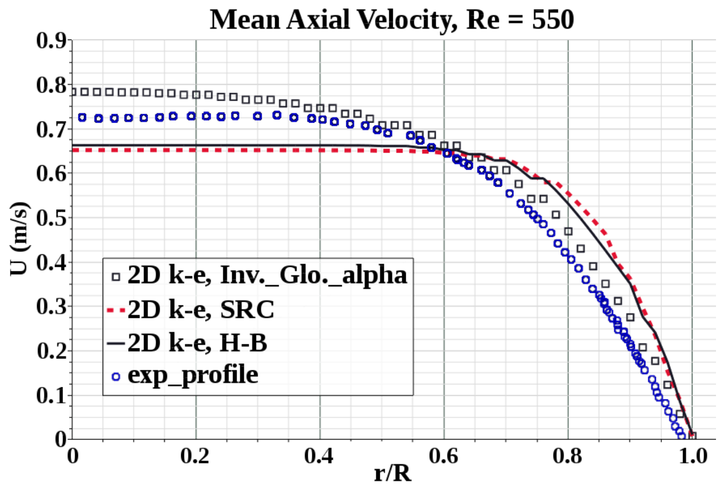
Axisymmetric comp. domain containing 2177 cells., L = 0.5m, D = 0.1m

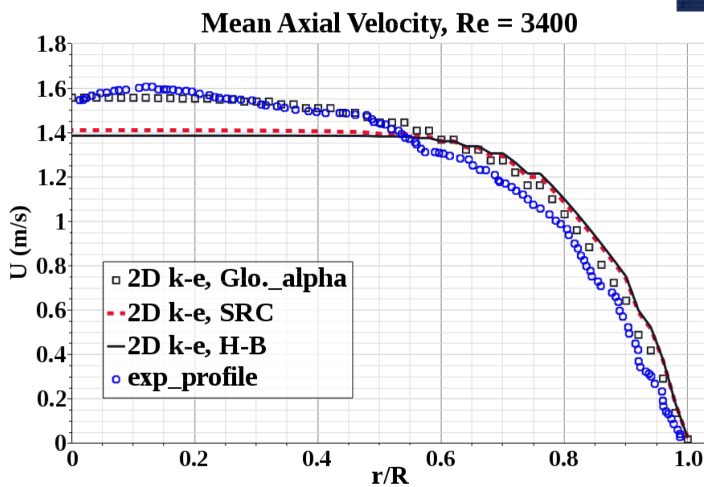
- Aqueous solution of 1.5 wt% Laponite



Algorithm for the numerical approach

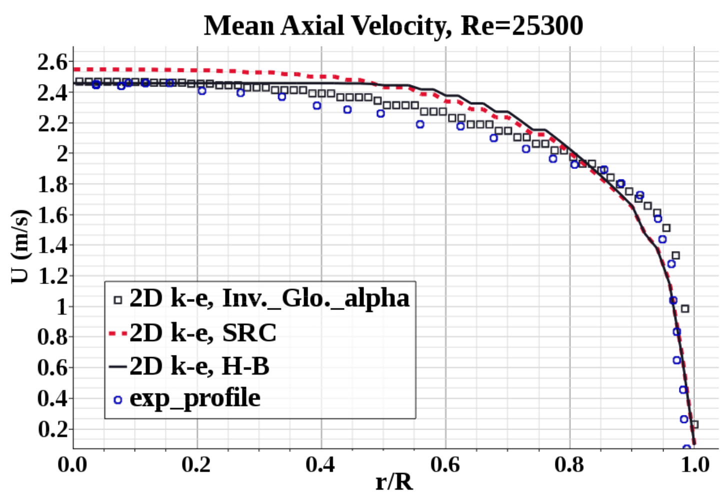
STARCCM+ Simulation Results





- Significant improvements by the alpha-method. Improvement of the error[1]:

  Laminar flow: 42%
  Transitional flow: 48%
  Turbulent flow: 61%



[1]: $Err_{imp.}\ (\%) = 100 \times \frac{|Err_{avg.})_{models} - Err_{avg.})_{H-B}|}{Err_{avg.})_{H-B}}$

CFD Modeling of LLW Processes in Waste Tanks Using Star-CCM+

- Radial Jet velocity magnitudes and jet thickness need to be adequately predicted throughout the vessel for proper functioning of the mixing vessel. The following correlations are used to predict these characteristics:

$$\delta = b * .098 * \left(\frac{r}{b}\right)^{.9}$$

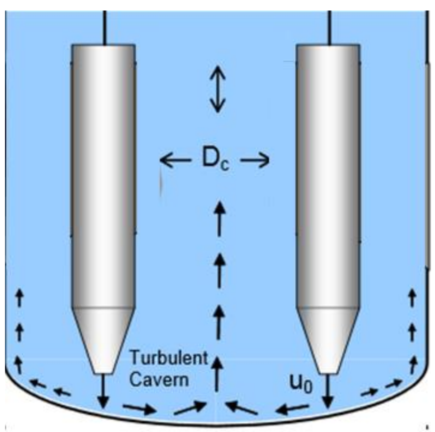
$$U_m = \frac{\sqrt{K}}{b} * 1.32 \left(\frac{r}{b}\right)^{-1.1}$$

Where:

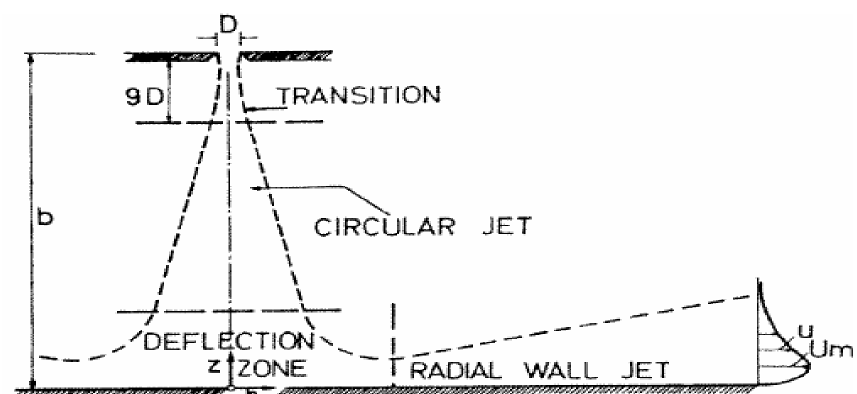
δ : Distance at which U/U_m=.5

U_m : Maximum velocity

b : Distance from orifice to impingement wall



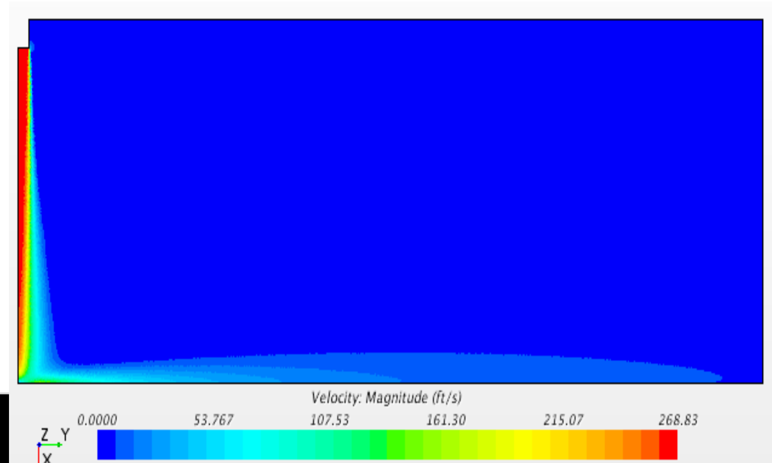
PJM cross section

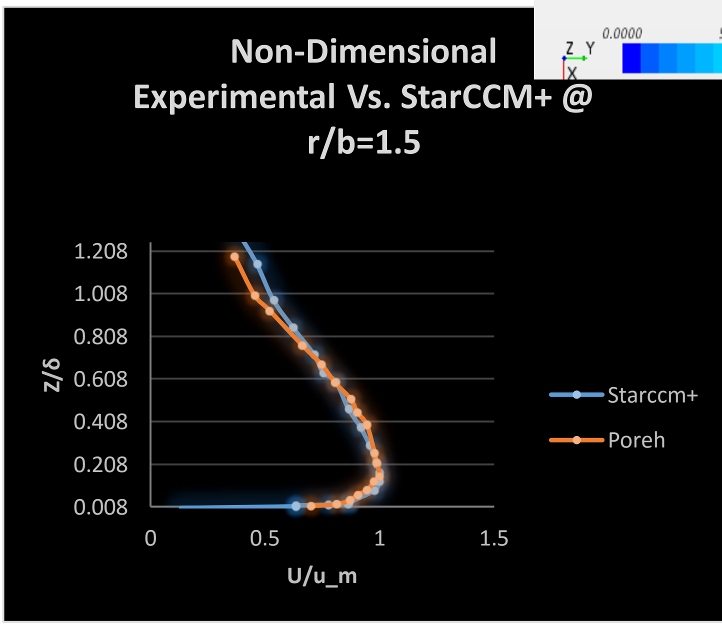


Poreh's Experimental Set up

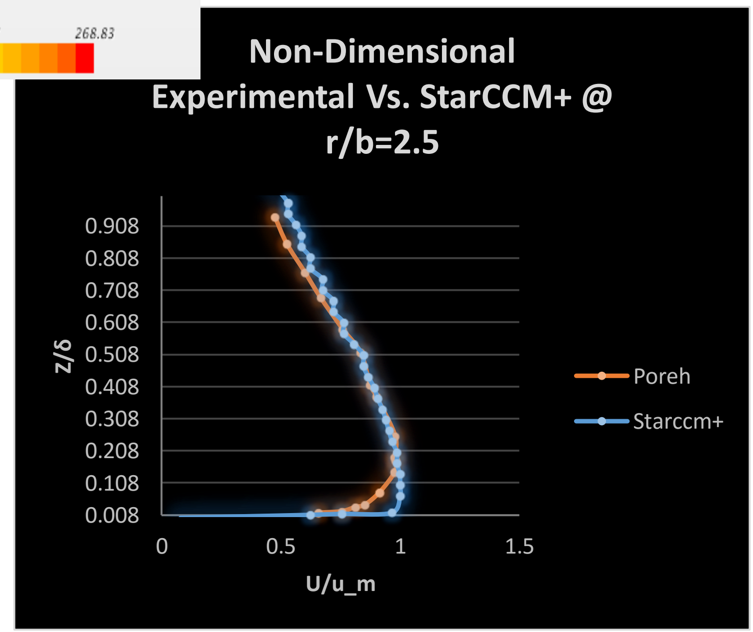
Radial Wall Velocity Profile Comparisons

Simulation of original experiment





Velocity profiles at radial jet



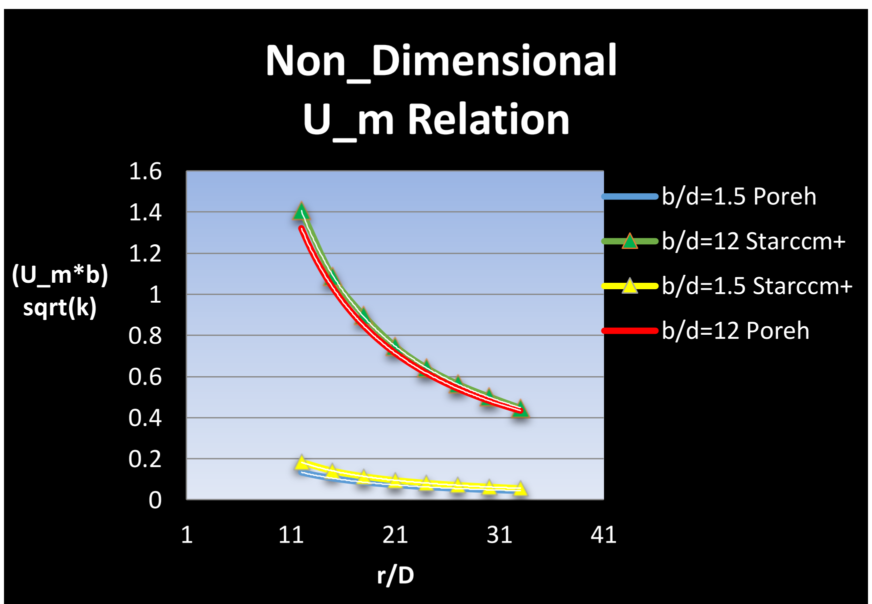
Radial Wall Correlation Comparison Results

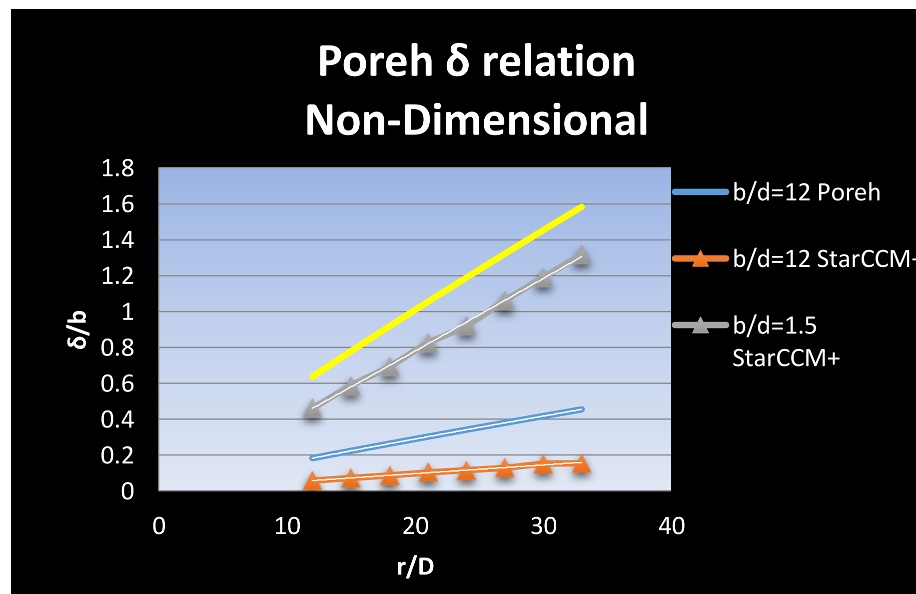
Reduction of nozzle to impingement plate surface distance

Modified Computational Domain

Maximum Velocity Correlation

Jet Thickness Correlation





Task 17.1 – Path Forward

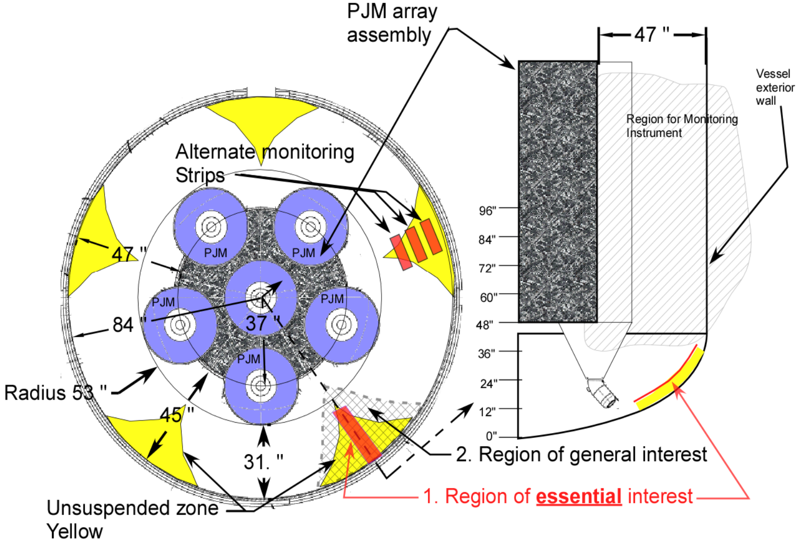
Continue to evaluate Star-CCM+ and its ability to accurately model processes that involve turbulence of non-Newtonian fluids.

- Collaborate with Chris Gunther (NETL) and Joel Peltier (Bechtel) to support CFD efforts for EM.
- Investigate Poreh's correlation on additional geometric configurations applicable to PJMs.
- Extend the development of code to augment DNS modeling of fluids exhibiting Bingham plastic characteristics. Evaluation of both the DNS and RANS models will be validated with bench scale tests and/or established models.

Task 18.1 – Solid-Liquid Interface Monitor (SLIM)

FIU has built and tested multiple prototypes of the Solid-Liquid Interface Monitor (SLIM) which consist of: (1) a commercial (custom designed) sonar; and (2) a deployment platform to insert the sonar into a Hanford HLW tank via a 4-inch riser

Technology Need: Instrumentation needed to ensure PJM operations effectively suspend all solids in these conditioning tanks.



Marine Electronics 3-D sonar (above) & Imagenex 881A profiling 2-D sonar (below)

Task 18.1 – Solid-Liquid Interface Monitor (SLIM)

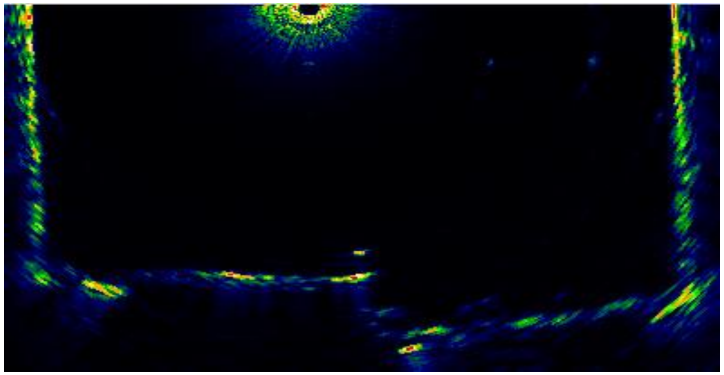
Background – Past Performance and Motivation for Current Work:

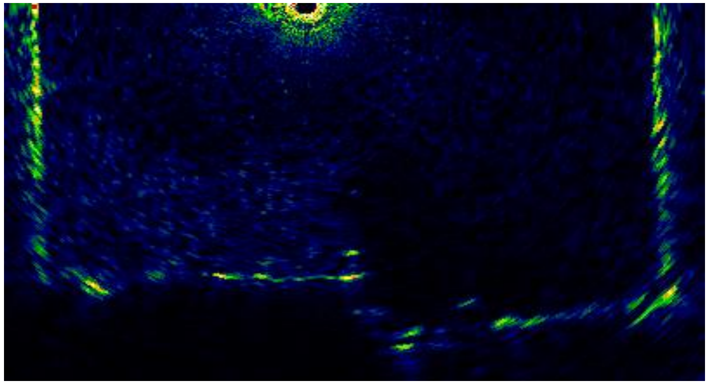
- Florida International University (FIU) developed and tested several technologies and associated deployment platforms for use in HLW tanks (sonar, electrical resistance tomography, ultrasonics, robotic crawlers, . . .)
- FIU has built and tested multiple prototypes of the Solid-Liquid Interface Monitor (SLIM) which consist of: (1) a commercial (custom designed) sonar; and (2) a deployment platform to safely and effectively insert the sonar into a Hanford HLW tank via a 4-inch (10 cm) dia. riser
- Testing with FIU's 2D sonar demonstrated accurate imaging of settled solids layer in HLW tanks while mixing with as high as 30% solids entrained in the liquid
- A Hanford HLW need has arisen to deploy a rugged imaging technology into HLW mixing tanks to determine if all solids are completely mixed (i.e., suspended and not on the floor) during all phases of mixing and retrieval

Task 18.1– Solid-Liquid Interface Monitor (SLIM)

Background – Past Performance and Motivation for Current Work:

Past testing of 2D sonar demonstrated accurate (1-3% error) imaging through 3'-5' of water with 30% kaolin solids by volume suspended in the water. Figures below are: (top) test tank 7' dia. with kaolin on part of the floor; (lower left) sonar image showing tank walls and floor with 0% solids suspended in the water; (lower right) sonar image still showing walls and floor and imaging through 3'-5' of water with 30% solids suspended.





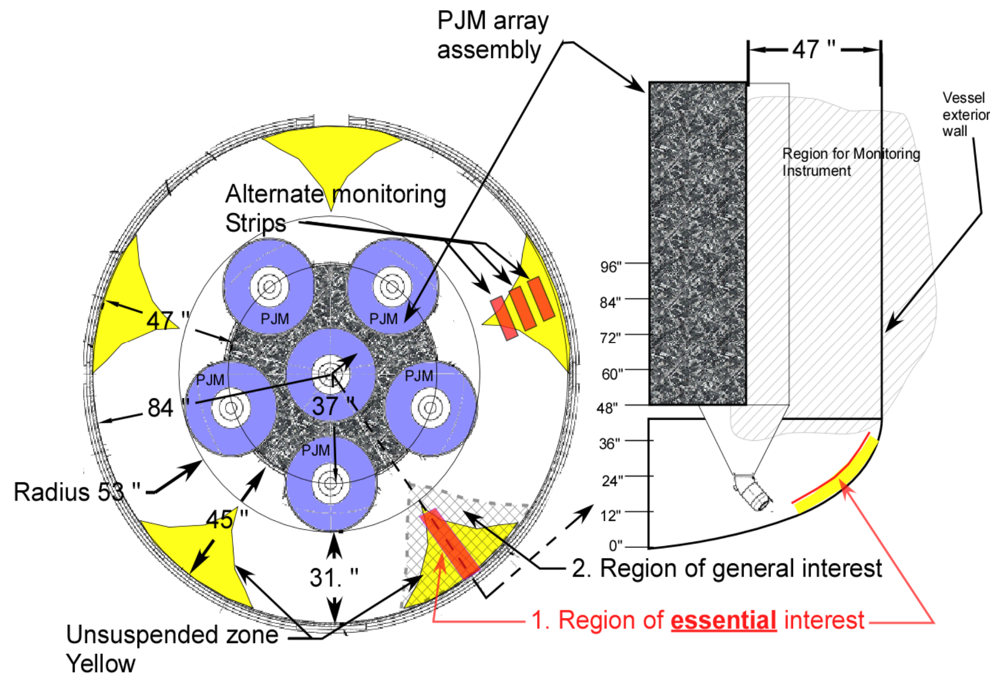
Task 18.1 Evaluation of FIU's SLIM for Rapid Measurement of HLW Solids on Tank Bottoms

Background

Pulse Jet Mixer (PJM) operations are conducted in Hanford's conditioning tanks. The PJM operations are used to mix and suspend undissolved solids

Floor areas between 2 PJMs have been shown to be areas where solids can settle. (see figure to the right)

Technology is required in order to ensure PJM operations effectively suspend all solids in these conditioning tanks



Cross-sections of conditioning tank thru one region of expected settled solids
Left: horizontal cross-section near tank bottom
Right: vertical cross-section thru settled solids area

Task 18.1 Evaluation of FIU's 3D Sonar for Small Changes in Surface Layer of HLW as an Indicator of DSGREs

Objective:

- Monitor the settled solids layer in double shelled tanks to image any increase in volume of the waste as an indicator of the buildup of gas in the deep sludge layers

Challenge:

- Create a continuous monitoring capability using data filtering, processing and 3D visualization allowing operators to see any increase in height (volume) of the settled solids layer in the tanks

Initial Results:

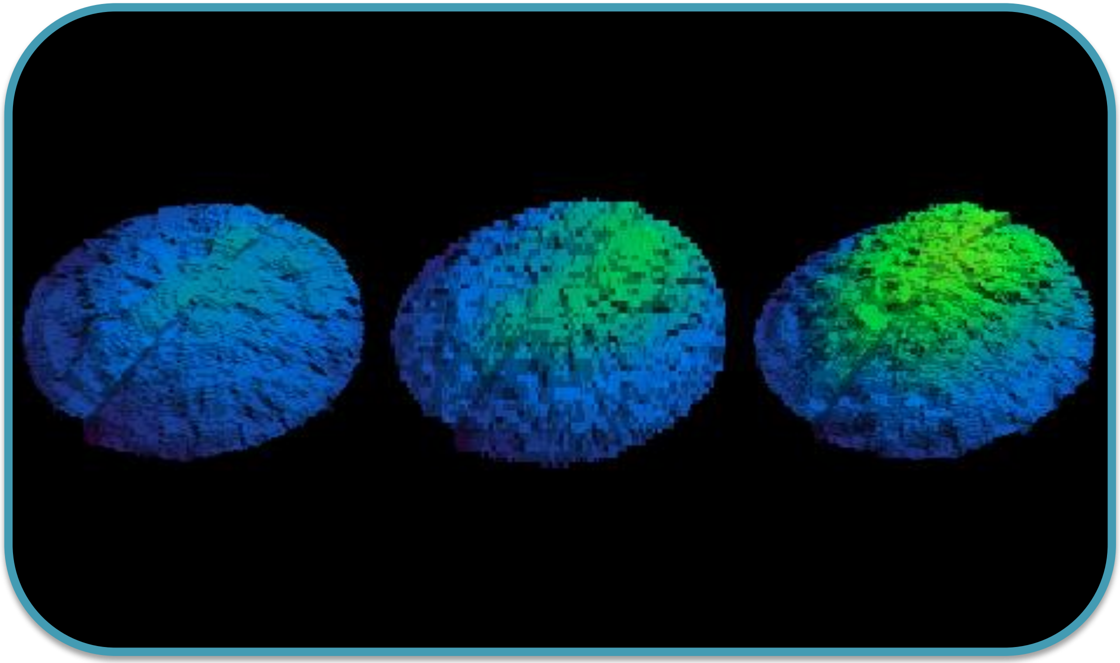
- Accuracy to 6 mm is easily imaged at a sonar to solids distance of 30 cm (1 ft)
- Future tests will determine how close the sonar comes to its 1% accuracy or 3 mm at 30 cm distance

Task 18.1 Evaluation of FIU's 3D Sonar for Small Changes in Surface Layer of HLW as an Indicator of DSGREs

FIU Applied Research Center

Results:

Sand was mounded over an air bladder and placed on the test tank floor. Air was added in 2 stages to the bladder under the sand.



Three Sonar Images
Left: sand over empty bladder;
Middle: sand surface after air is added;
Right: sand surface after 2nd increment of air is added

Task 18.1 - Evaluation of FIU's 3D Sonar for Small Changes in Surface Layer of HLW as an Indicator of DSGREs

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Future Planned Research:

- Executing a test plan to assess the accuracy of the 3D sonar for measuring small changes in the height of a settled solids layer which would equate to a minimum detectable volume increase in HLW
- Developing a 3D visualization tool for imaging the post-processed sonar data to allow operators the ability to see changes in the height and volume of HLW over time as an indicator of gas buildup
- Automating the sonar operation to allow for continuous monitoring and continuous post processing and visualization of the settled solids surface in HLW tanks
- Applying the sonar to image bubbles
- Applying the sonar to measure the settling rates of various HLW surrogates

Task 18.2 - Development of Inspection Tools for DST Primary Tanks

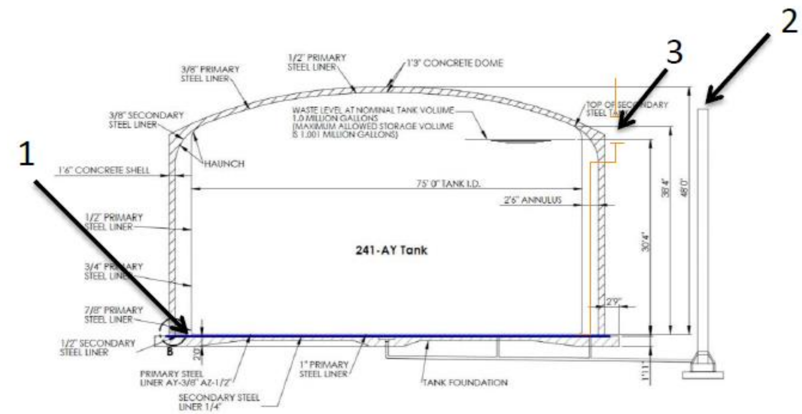
FIU Applied Research Center

Background:

Tank waste was found in the annulus of tank AY-102.

An inspection tool is required to isolate and pinpoint the source of the material entering Tank AY-102 annulus space

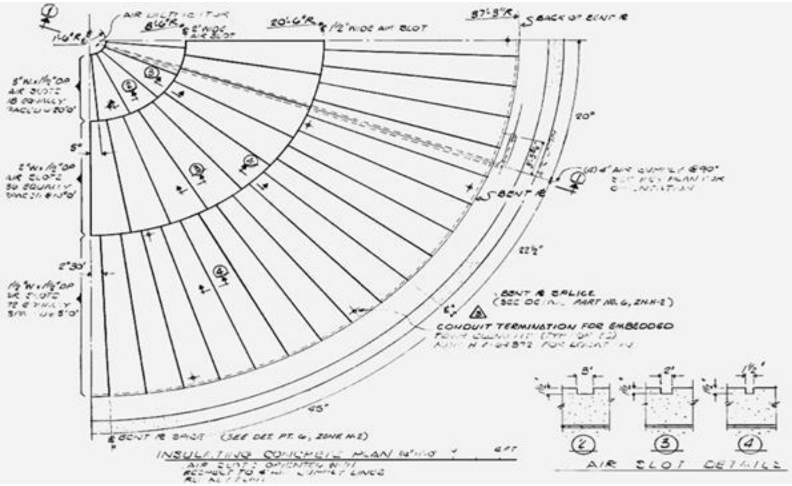
There are three possible entry points: (1) refractory air slots through the annulus, (2) 6” leak detection piping, (3) 4” air supply piping



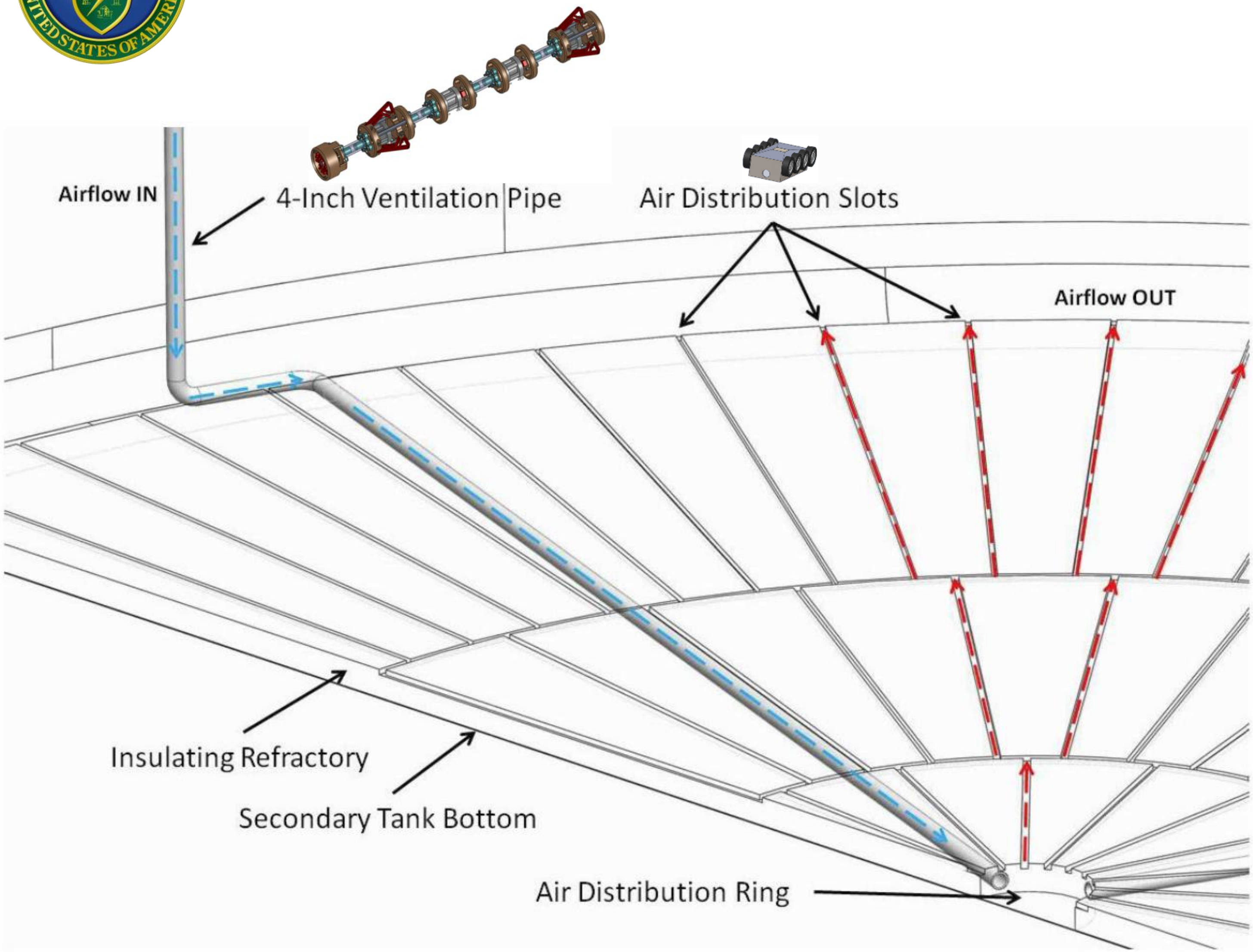
Air Channel Path:

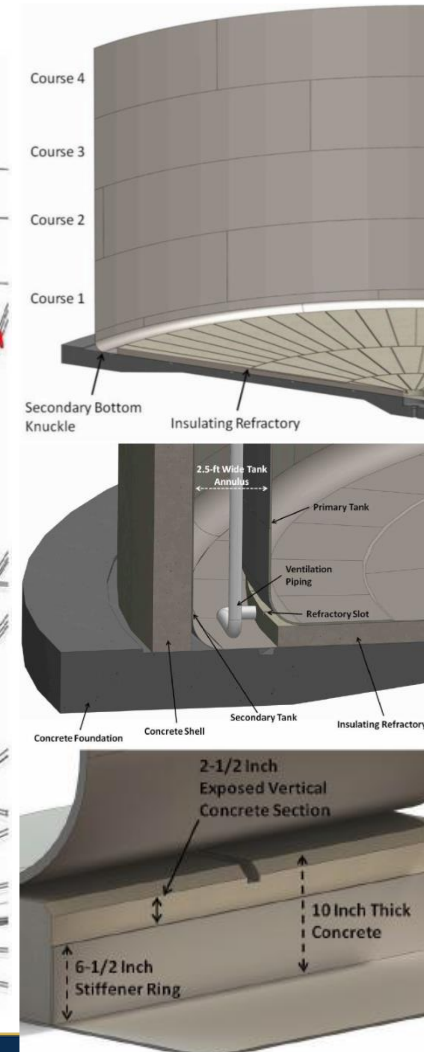
Channels arranged in 3 sections, with two 90° turns connecting each:

- (1) 17 feet of 1 ½“by 1 ½“ square slots
- (2) 12 feet 1 ½“by 2” square slots
- (3) 7 feet of 1 ½“by 3“ square slots



AY-102 Cooling Refractory Pad





Task 18.2 - Development of Inspection Tools for DST Primary Tanks

Objective: To develop an inspection tool that navigates through the refractory pad air channels under the primary liners of the DST's at Hanford while providing live video feedback

Design parameters:

- Travel through small cooling channels with dimensions as small as 1.5" x 1.5"
- Device will be remote controlled
- Device will be inserted through a riser to the annulus floor
- Provide live video feedback
- Device will need to be rad hardened (~ 80 rad/hr)
- Device will withstand relatively high temperatures (~ 170 °F)
- Device must not subject the channel walls to pressures greater than 200 psi, the compression strength of the refractory material.
- Navigate ~ 50 feet to the tank center, while maneuvering through four 90° turns (First phase – 17 feet, no turns)

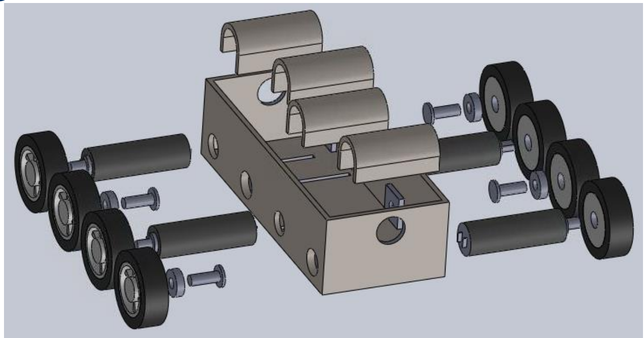
Initial Designs

General approach

- Use of tank-treads for improved maneuverability
- Upside down travel to avoid refractory debris (via magnets)

Early prototypes

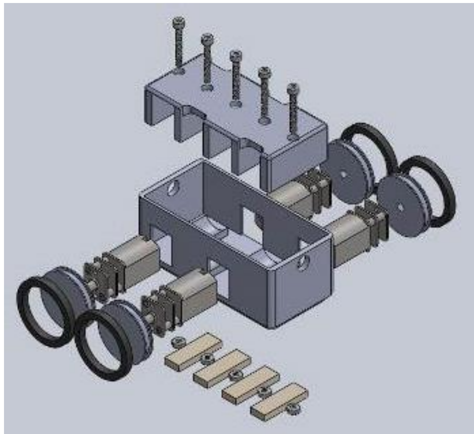
- Insufficient pulling force
- Inadequate clearance with tank surface
- Cumbersome reassembly
- Difficulty overcoming obstacles (small wheels)

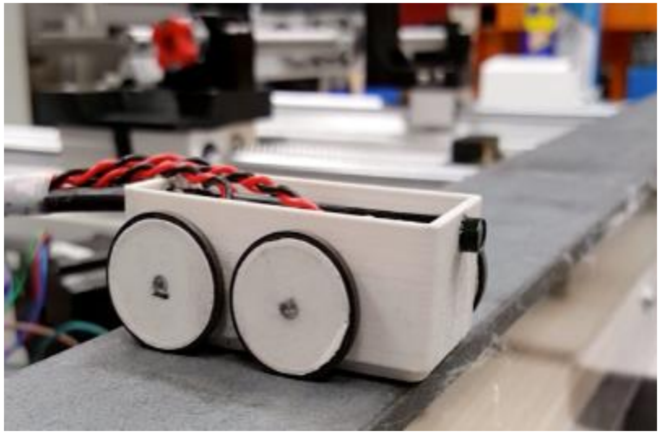


Current Prototype

The general design of the inspection tool has been completed and a prototype was assembled. Modifications that led to significant improvement in the performance include:

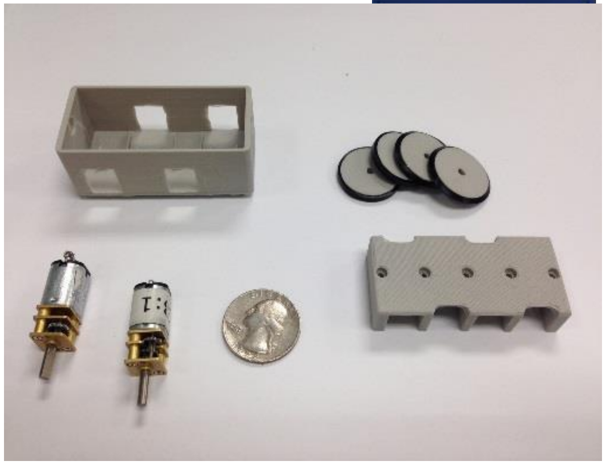
- Wheels being 3D printed and the diameter was increased by 6 mm to improve obstacle avoidance ability
- With the larger wheels, stronger motors, capable of 10x the amount of torque were used
- Brackets that fix the motors in place, allowing for motor replacement in the event of a motor failure
- Motors that utilize metal gears versus plastic gears





System Components

The components that make up the current design include:



- Arduino Uno board with ATMega328 microcontroller
- Eggsnow USB Borescope Endoscope 5.5mm inspection camera
- 298:1 Micro Metal Gearmotor (4)
- 3D printed 20mm x 3 mm wheels (4)
- Square-Profile O-Ring for wheels
- 3D-printed body and bracket
- Neodymium magnet - 3/4” x 1/8” x 1/10” –3 lb pull force (4)
- Tether: 10M in length, 6mm wide and expandable to 11 mm wide, braided sleeving

Bench Scale Testing

Maximum pull force:

Device weight: 0.18 lb

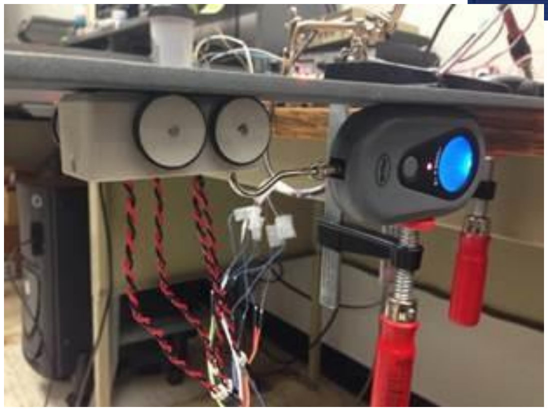
Average pull force: 4.75 lb

Tests performed at: 5V

Power/Weight ratio: 26

Motor rated for 3-9 V

Maximum pull force measured in 15 experiments:



Bench Scale Testing

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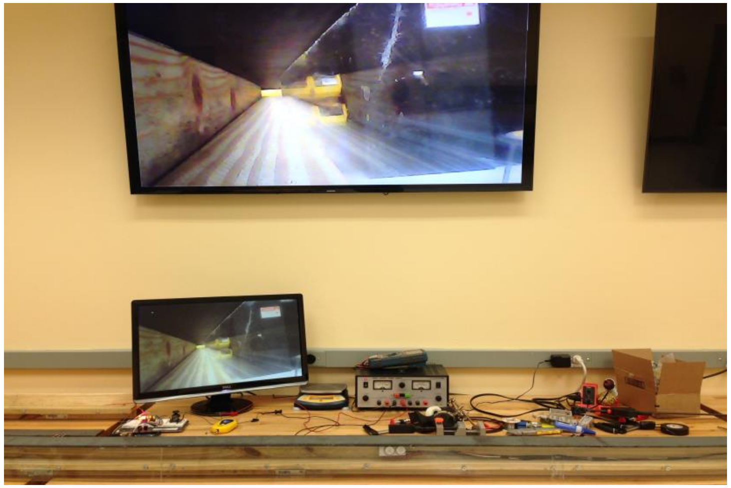
A mock-up of the outside channels with a 1.5” x 1.5“ cross section was manufactured.

- Successful navigation of the first 17 feet while pulling the tether and providing video feedback
- Effective maneuvering and path correction



Bench Scale Testing

Air Supply Line Inspection Tool

FIU Applied Research Center

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

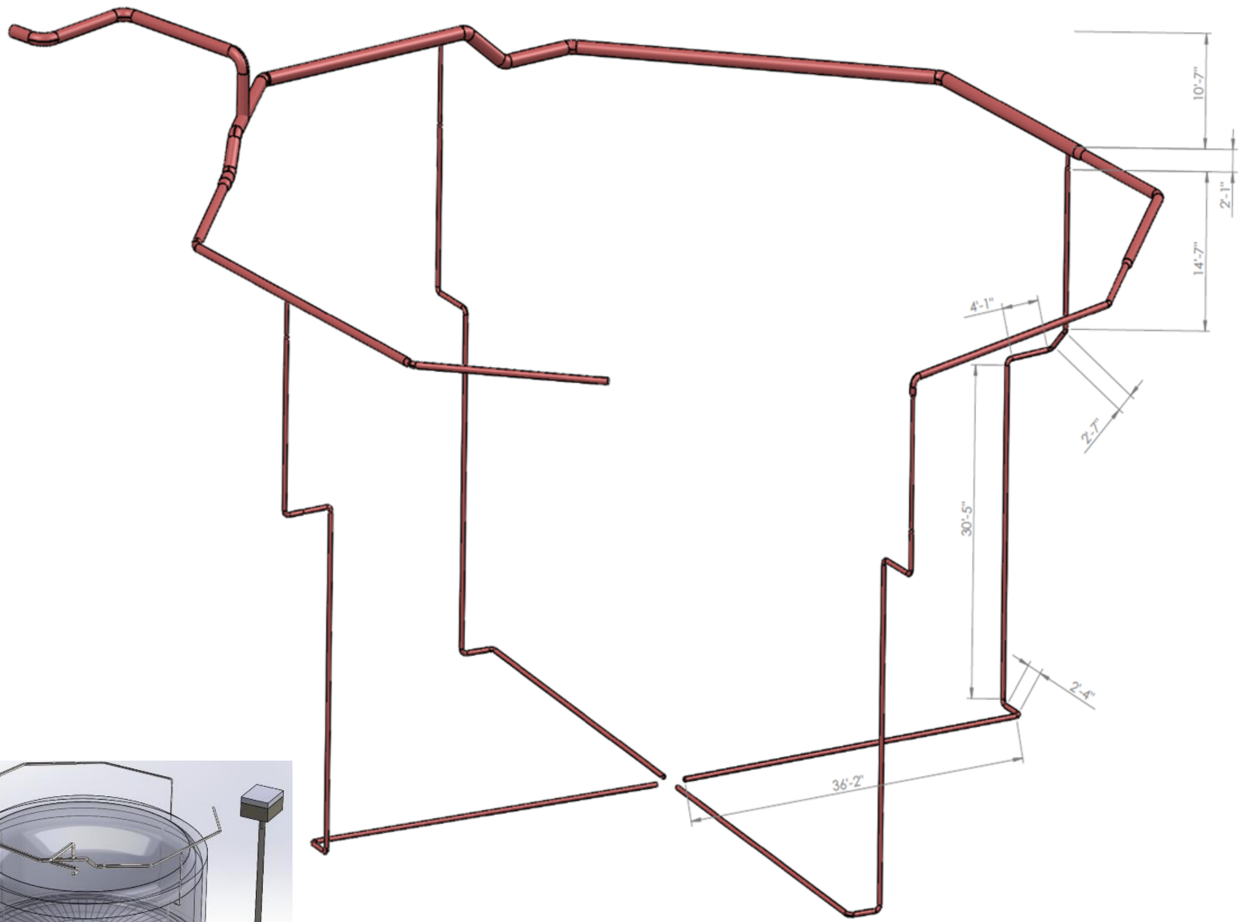
Design parameters:

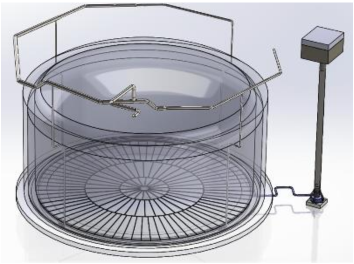
- Device will be remote controlled
- Video feedback will be recorded for future analysis
- Device will need to be radiation hardened (~ 80 rad/hr)
- Device will withstand high temperatures (~ 170 F)
- Device will be used in pipes and fittings with 3” and 4” diameter
- Device will turn through elbows, bends, and transitions
- Device will crawls through vertical runs

Inspection Path (AY-102)

The proposed inspection distance will be approximately 100 feet with a significant portion being gravity fed.

The path is made up of schedule 40 pipes which are 3 and 4 inches in diameter, with reducers and several elbows.





Conceptual Design

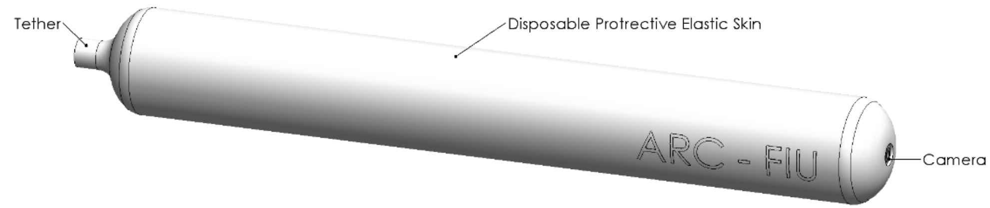
The inspection tool has a modular design.

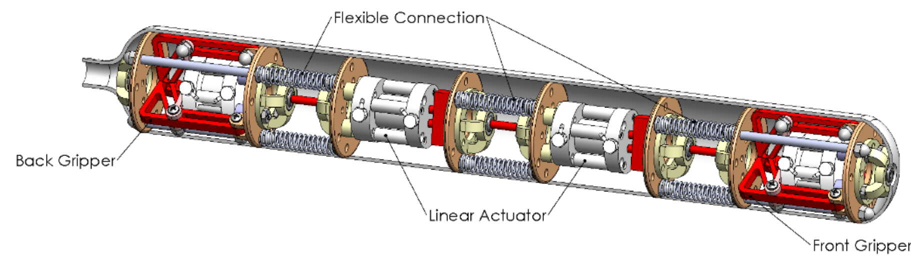
The device is composed of interchangeable modules connected with rigid links.

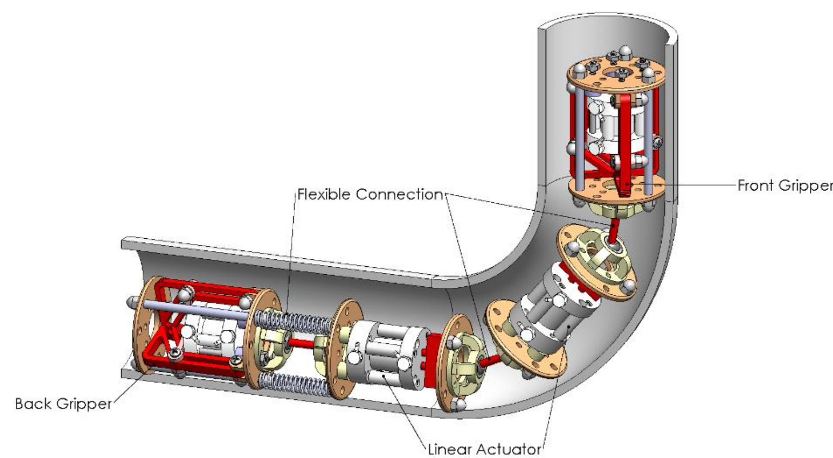
The modular approach has the potential to be customized for specific tasks with the addition of extra modules.

For instance adding:

- instrumentation,
- material sampling, and
- pipe repair.







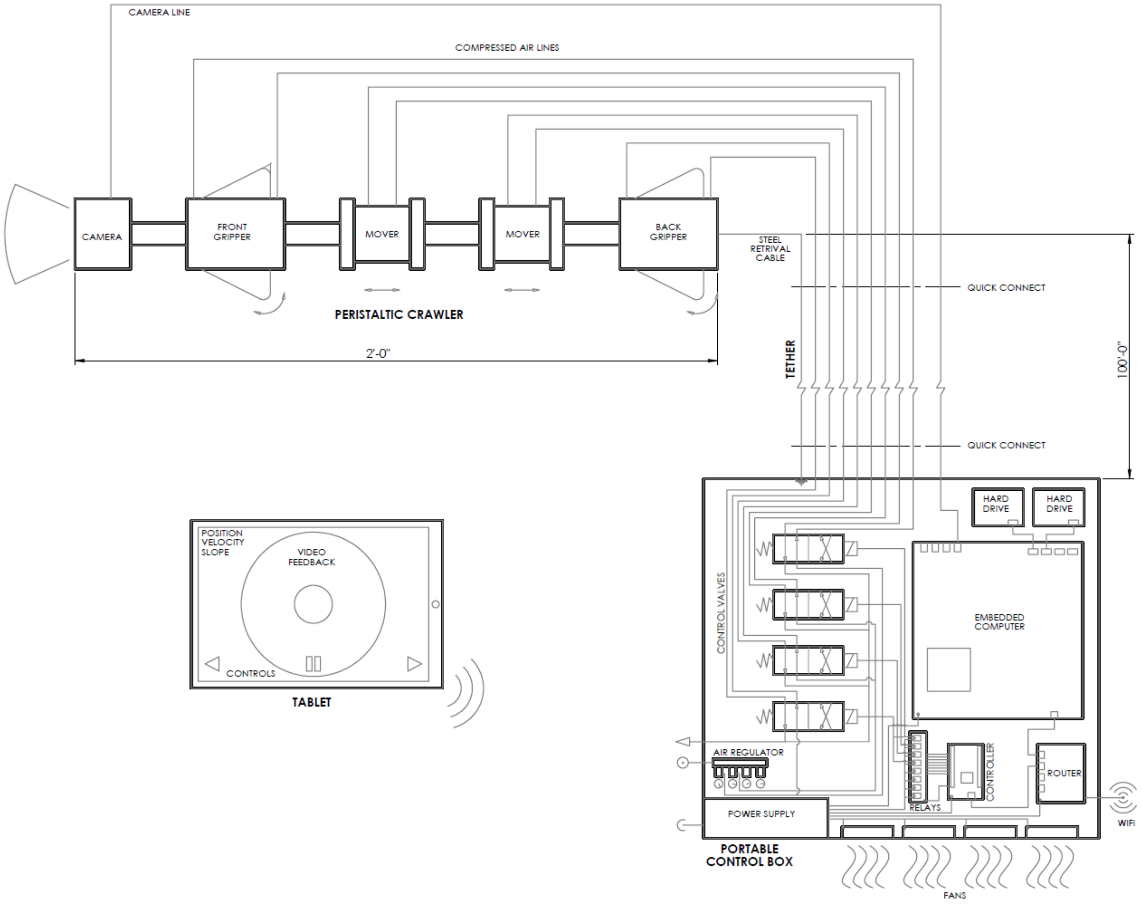
Overall Systems

The basic design is composed of five modules:

- a front camera,
- front and back grippers, and
- two middle movers.

The movement is fully automated, which is remotely controlled by an handheld device.

The tool uses a programmable control interface and is customizable.

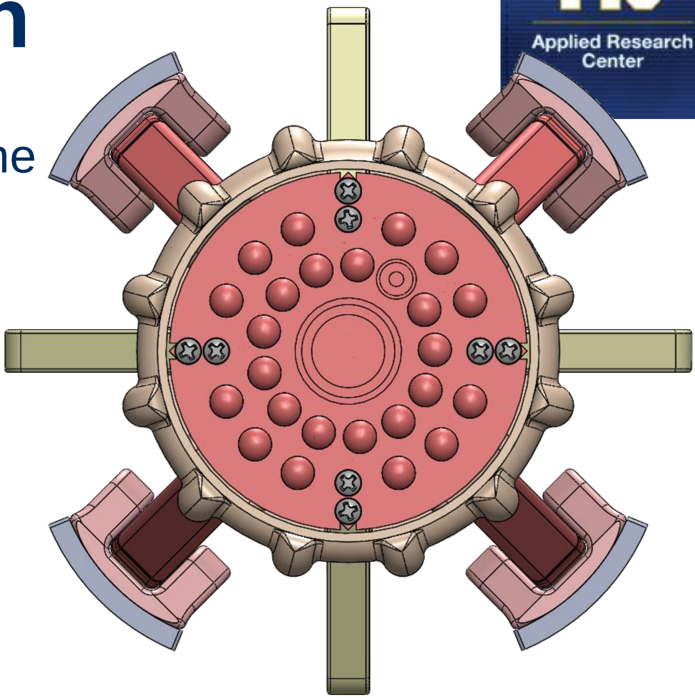


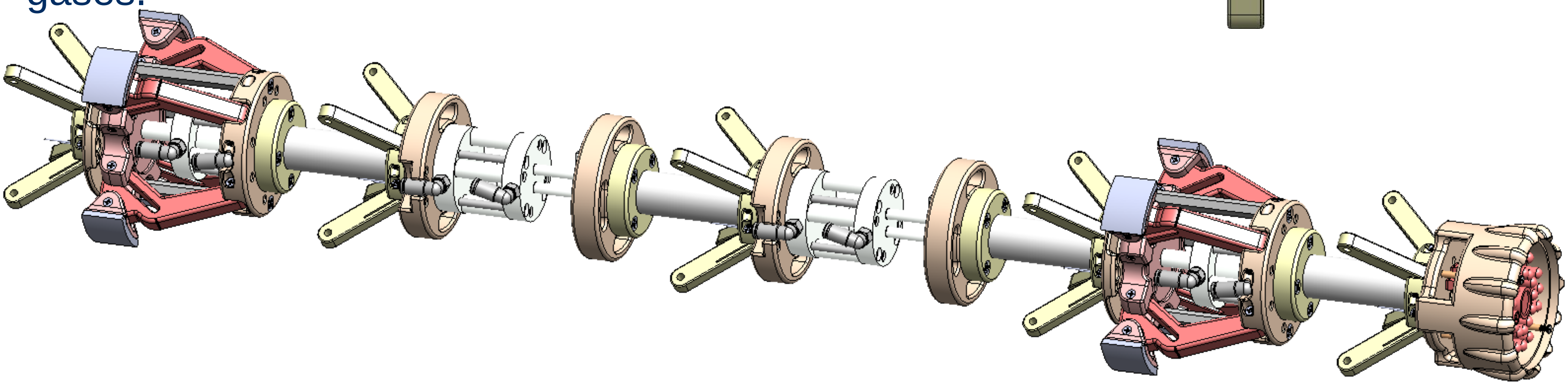
The Design

The crawler uses pneumatic actuators to emulate the contractions of the peristaltic movements.

The movement does not require embedded electronics and electric actuators.

The tool is suitable for highly radioactive environments with potential exposure to flammable gases.



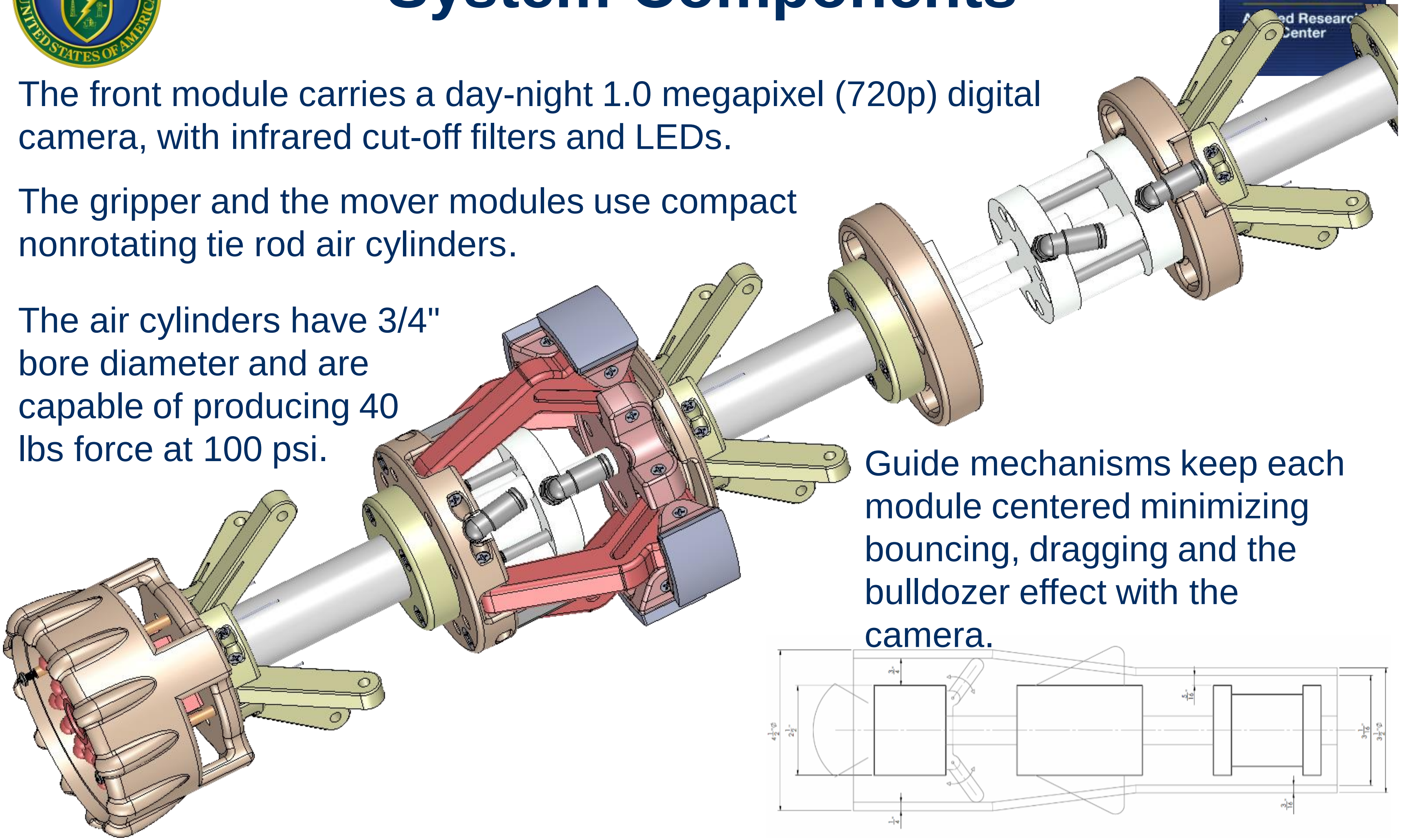


System Components

The front module carries a day-night 1.0 megapixel (720p) digital camera, with infrared cut-off filters and LEDs.

The gripper and the mover modules use compact nonrotating tie rod air cylinders.

The air cylinders have 3/4" bore diameter and are capable of producing 40 lbs force at 100 psi.

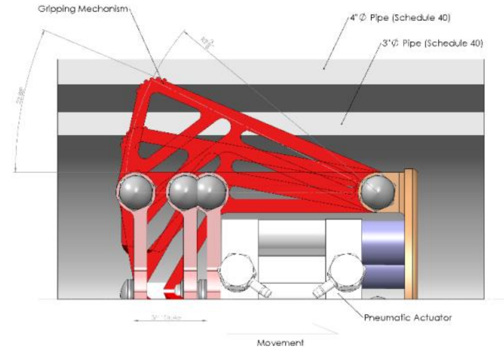


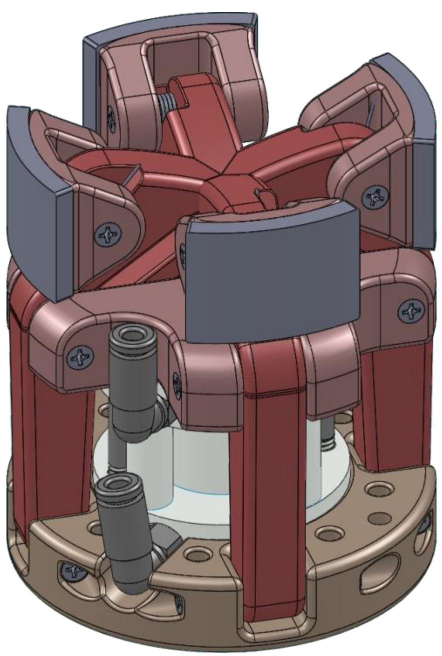
Guide mechanisms keep each module centered minimizing bouncing, dragging and the bulldozer effect with the camera.

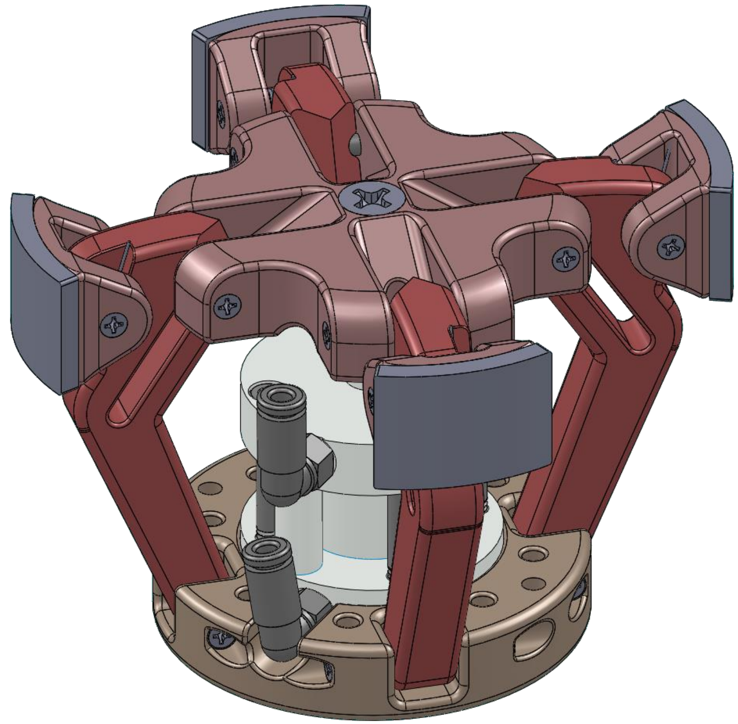
Gripper Module

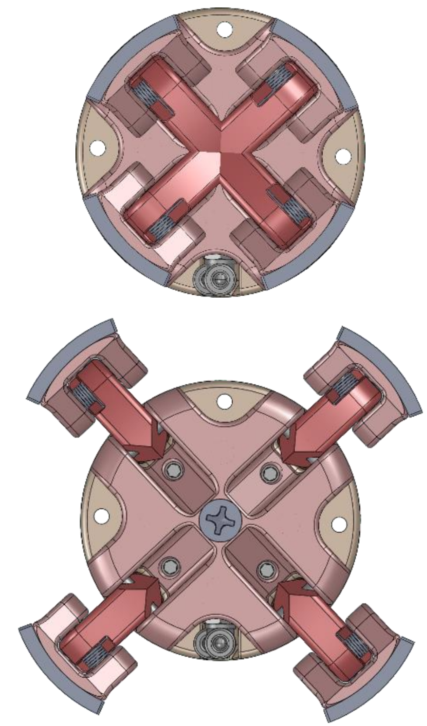
Maximizing the strength of the gripper is a major factor in the design of the peristaltic crawler.

A stronger grip would allow the device to carry additional modules, and to inspect longer pipelines.





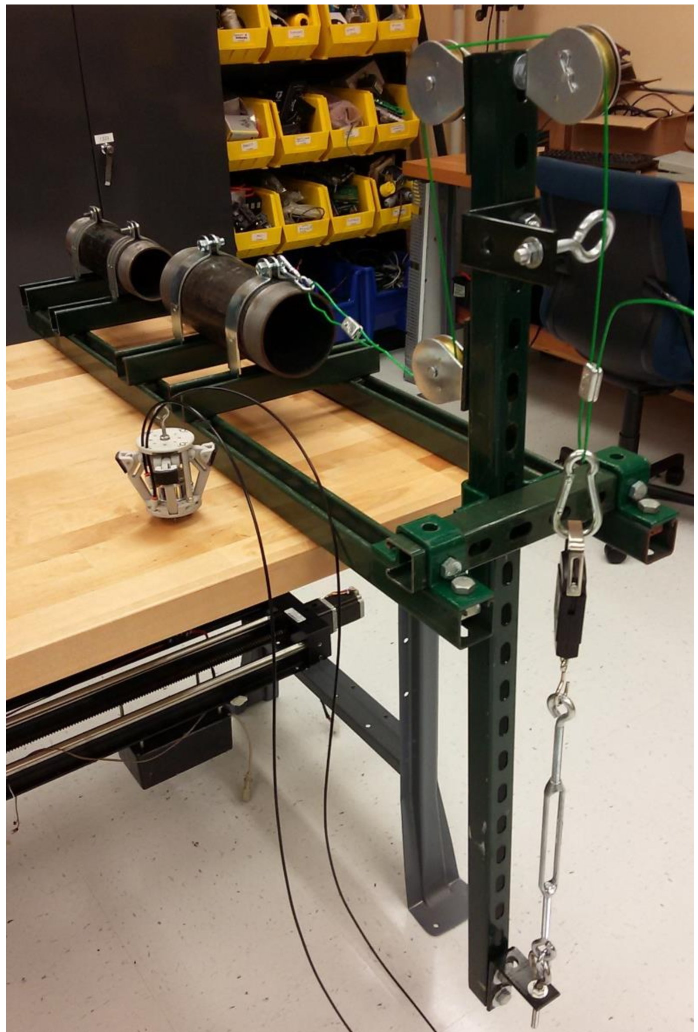


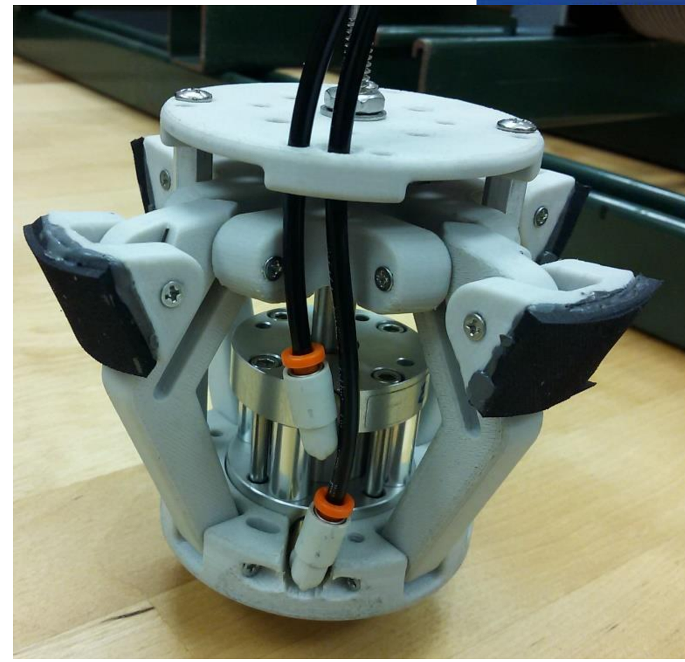


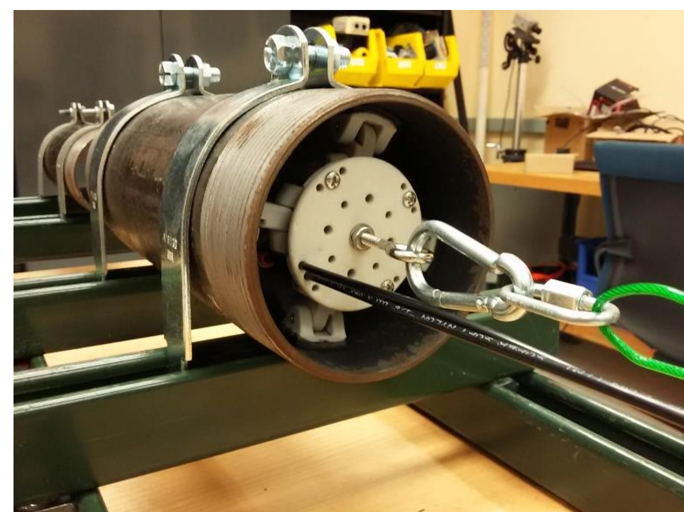
Bench Scale Testbed

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

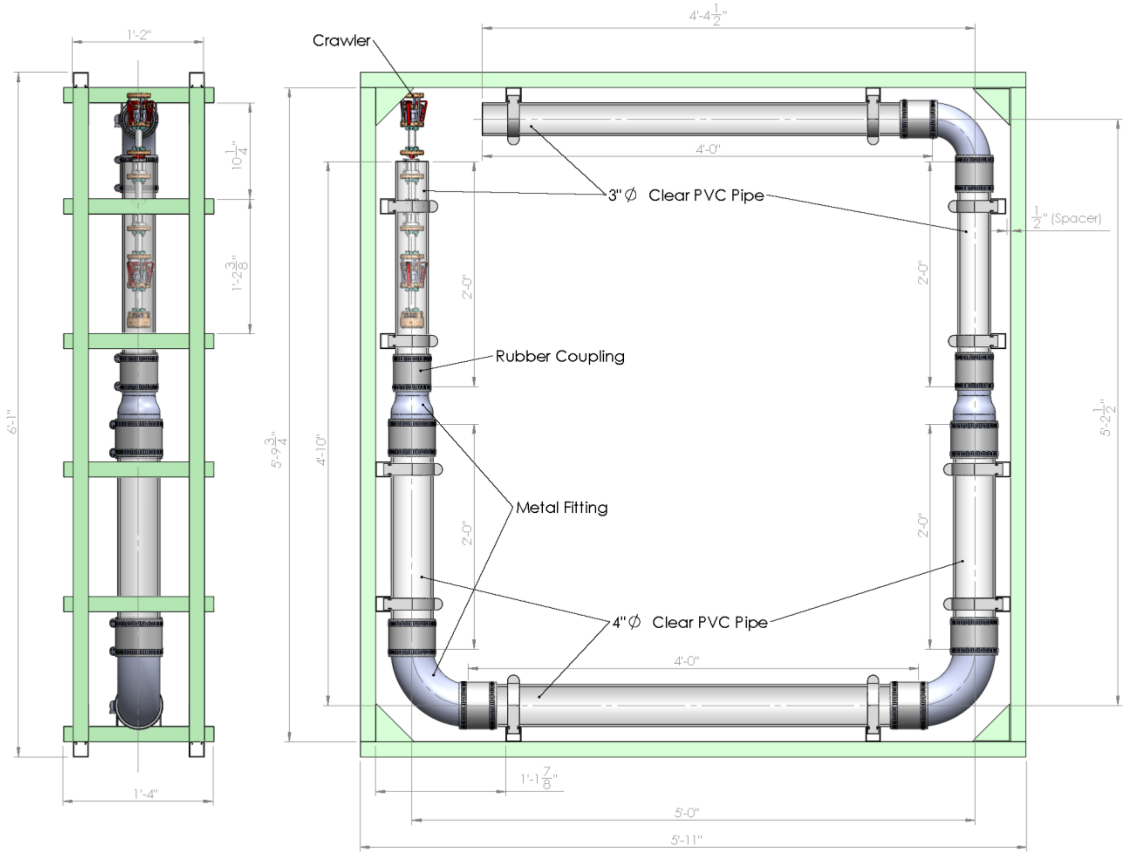
This is also the maximum force with which the mover modules can propel the crawler in the forward direction.

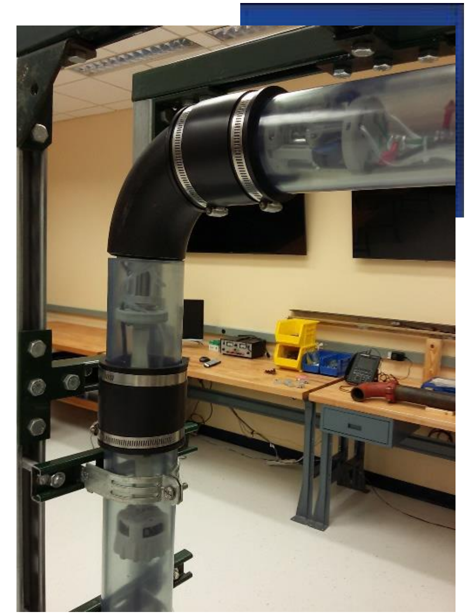






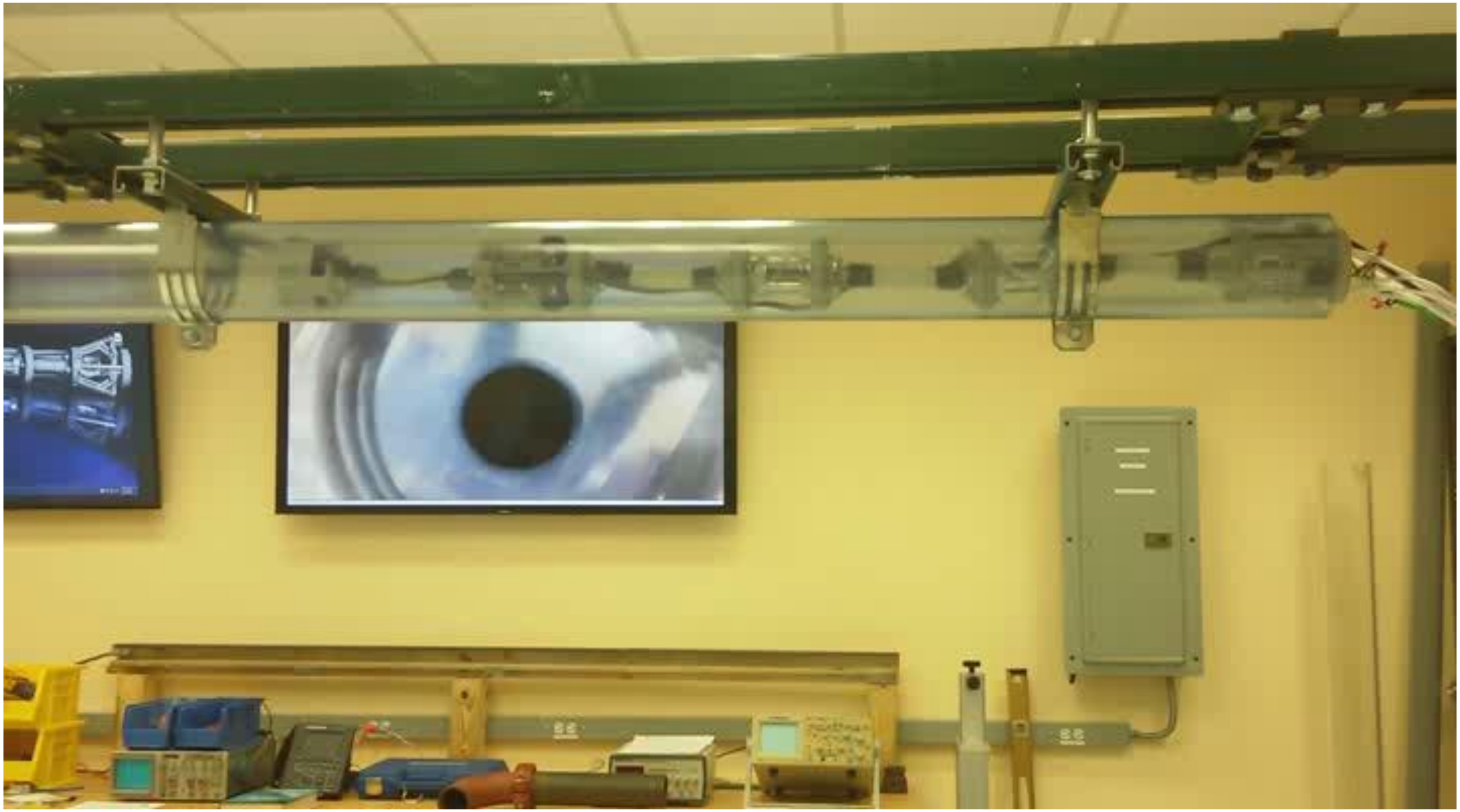
Bench Scale Testbed





Based on maneuverability bench scale tests, the crawler has great potential to accomplish the proposed inspection.

Bench Scale Testbed



Task 18.2 - Path Forward

<u>Crawler</u>

- Develop full-scale mock up test bed
- Develop delivery mechanism for easy deployment
- Provide feedback of other inspection parameters (temp, rel hum, rad)
- Redesign a radiation hardened version using electric actuators
- Scale the design for inspection in smaller pipe sizes

<u>Rover</u>

- Develop full-scale mock up test bed
- Develop delivery mechanism for easy deployment
- Provide feedback of other inspection parameters (temp, rel hum, rad)
- Redesign a radiation hardened version

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

Background:

- Operating Specifications for the Double-Shell Storage Tanks (OSD) (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
    - some never validated with real data

Objective:

- Demonstrate the use of an IR sensor to approximate the inside wall temperature of DSTs
  - Utilizing bench scale tests and heat transfer calculations

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

Method

- Sensor attached to inspection tools/camera
  - ("piggy backing")

Benefits

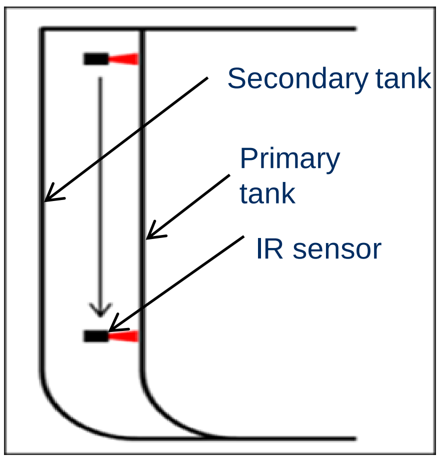
- Ensure operational limits are met
- Evaluate current thermal models (validation/improvement)
- Understand temperature gradients to estimate solid waste levels

Sensor Requirements

- Must be a non-contact pyrometer
- Must be mounted and remote controlled
- Should be wired (long wire must be available 50'-75')
- Must be able to get temperature from dull/rusty carbon steel
- Must be able to get accurate reading from a distance of 1-3 ft.
- Software must support data logging
- Temperature measurements will be 0°F to 250°F
- Able to operate in an environment of 40°F to 150°F
- Equipment must have adjustable emissivity
- Must be able to fit in a size of 6" x 6" x 6" or 8" x 4" x 4".

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

Current approach for measuring tank temperature from inside the annulus.



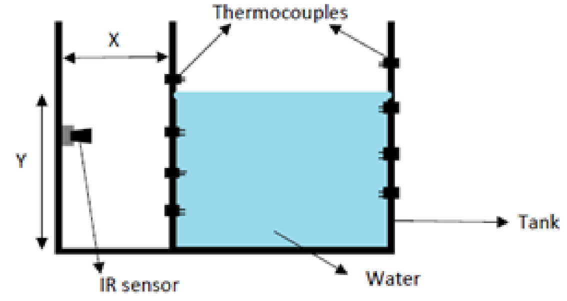
Block diagram of the DST annulus

IR sensor (Raytek MI3) attached to the inspection camera

Experimental Approach

Design Parameters

- Plate thickness (tank wall)
  - 1/2 in, 3/4 in and 7/8 in (based on 241 AN tank drawings)
- Water temperature
  - 120°F - 170 °F
- Measurement height
  - 1 ft. - 4 ft.
- IR sensor distance
  - 0.5 ft. - 2.5 ft.



Distance	Y = 1.0	Y= 2.0	Y = 3.0	Y = 4.0
X = 0.5	T=[120 170]	T=[120 170]	T=[120 170]	T=[120 170]
X = 1.0	T=[120 170]	T=[120 170]	T=[120 170]	T=[120 170]
X = 1.5	T=[120 170]	T=[120 170]	T=[120 170]	T=[120 170]
X = 2 .0	T=[120 170]	T=[120 170]	T=[120 170]	T=[120 170]
X = 2.5	T=[120 170]	T=[120 170]	T=[120 170]	T=[120 170]

X - horizontal distance in the annulus (ft.); Y- vertical height (ft.); T -temperature of water (^{0}F)

Theoretical Calculations

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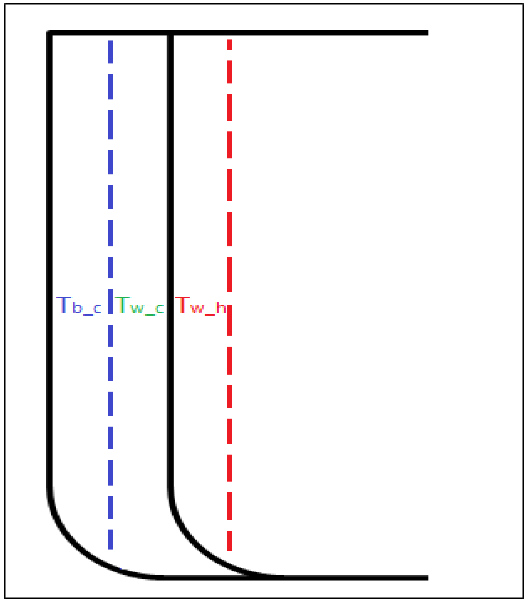
Heat Transfer Relations

$$Q = U \cdot A \cdot (T_{w\_h} - T_{b\_c})$$

$$U = \frac{1}{\frac{1}{h_w} + \frac{d}{k} + \frac{1}{h_a}}$$

$$T_{w\_c} = T_{w\_h} - \frac{Q \cdot d}{k \cdot A}$$



- T_{b_c} – Bulk mean temperature of cold air in the annulus
- T_{w_c} – Boundary Temperature on the outer side of the primary tank
- T_{h_c} –Temperature on the inside of the primary tank
- Q – Total heat transferred
- U – Overall heat transfer coefficient
- *h* – convective heat transfer coefficient

Task 18.3 - Path Forward

- Develop pseudo full scale mock up testing
  - Tank fabrication
  - Sensor emissivity calibrations
- Develop advanced heat transfer models for accurate temperature prediction
  - At tank wall
  - Inside the tank
- Investigation of annulus deployment techniques
  - Integration with inspection tools (crawler/rover)

Task 19.1 - Pipeline Integrity and Analysis

Background:

- Uncertainties in the structural integrity of pipelines at Hanford
  - Fitness-for-Service (FFS) program for the Waste Transfer System
  - A direct inspection and assessment of the condition of buried pipelines

Objectives:

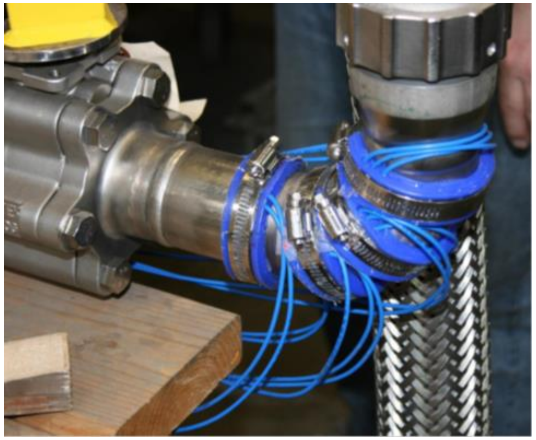
- Investigate the use and types of remote permanently mount Ultrasonic Transducer (UT) systems for measuring pipe wall thickness
- Determine wear rates to predict the existing system's remaining useful life.
- Estimate the design allowances needed for new piping and pipe jumpers.

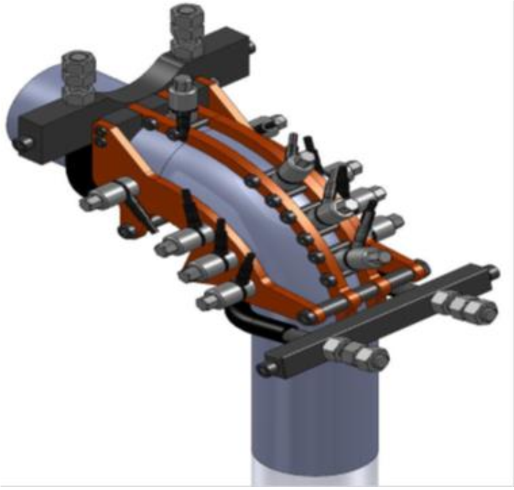
Task 19.1 - Pipeline Integrity and Analysis

Pervious Efforts

Remote Permanently Mounted Pipe Wall Ultrasonic Thickness Measurement Devices

- Some of the POR104 components had sensors installed to provide real time thickness measurements.
- Alternative approaches for mounting the sensors are being investigated





Task 19.1 - Pipeline Integrity and Analysis

Sensor systems (Ultrasonic Transducers) investigated

- Dual element sensor (Olympus)
  - Dry couplant tests (acqualene – elastomer)
  - Vacuum bag tests
- Flexible smart sensors (Acellent Technologies)
- Guided wave sensors(Permasense)
- Couplant free sensors (Ultran Group)
- EMAT and DCUT (Innerspec)

Task 19.1 - Pipeline Integrity and Analysis

Olympus dual element sensor (D790 SM)

- Requires a gel couplant
- Portable and easy to use
- Provides accurate readings
- Suitable for high temperatures
- Size is larger for 2” diameter pipes

Task 19.1 - Pipeline Integrity and Analysis

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Olympus sensor – Vacuum tests and dry couplant tests

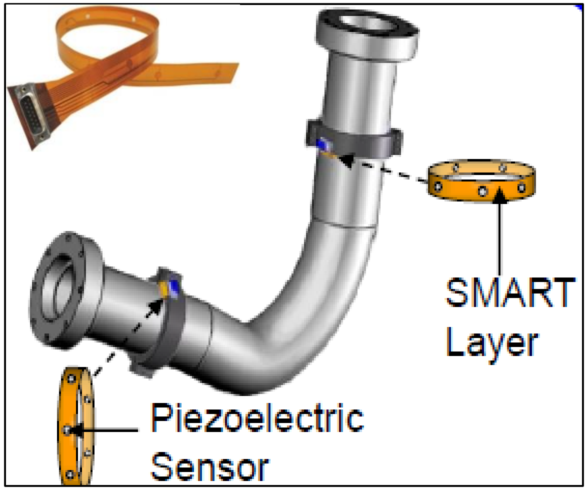
	Gel Couplant (Glycerin)		Dry Couplant (Aqualene)		Error (%)	
	Top	Extrados	Top	Extrados	Top	Extrados
90° Elbow (carbon st)	0.239	0.210	0.312	0.310	30.5	44.7
90° Elbow (cast iron)	0.265	0.25	0.32	0.32	20.7	26.4
	Diameter (smaller)	Diameter (larger)	Diameter (smaller)	Diameter (larger)	Diameter (smaller)	Diameter (larger)
Reducer (carbon st)	0.235	0.275	0.301	0.325	28.0	18.1

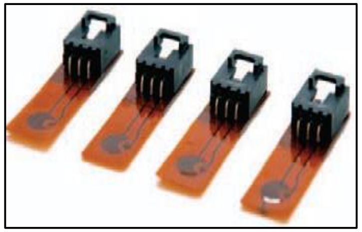
Thickness results using an Olympus UT sensor (D790 SM)

Task 19.1 - Pipeline Integrity and Analysis

Flexible smart sensors (Acellent Technologies)

- Embedded, pre-network of sensors
- Detects the irregularities inside the pipe walls
  - Useful for pitting corrosion detection
- Suitable for 2'' diameter pipes
- Remote monitoring system (no wires)
- Mounted using an aerospace grade epoxy

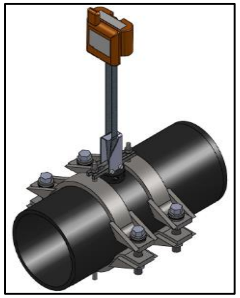


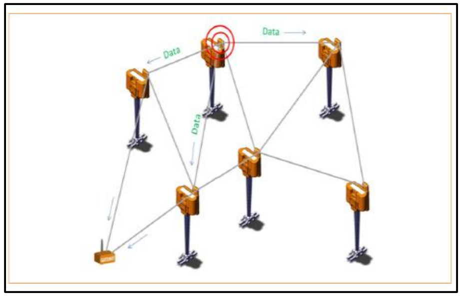


Task 19.1 - Pipeline Integrity and Analysis

Guided Wave Sensors (Permasense)

- Integrated wireless system
- Guided wave technology
- Mechanical mounting system
- Maximum of 2 sensors for 2'' diameter pipes
  - (to avoid cross talks)





Task 19.1 - Pipeline Integrity and Analysis

Couplant free sensors (Ultran Group)

- Require no couplant
- Dry contact (polystyrene base)
- Mini sensors (~6.4 mm dia)
- Up to 8 sensors mounted on 2'' diameter pipes
- Suitable for high temperatures

Ultran WD 25-2 UT sensors

Experimental set up

Task 19.1 - Pipeline Integrity and Analysis

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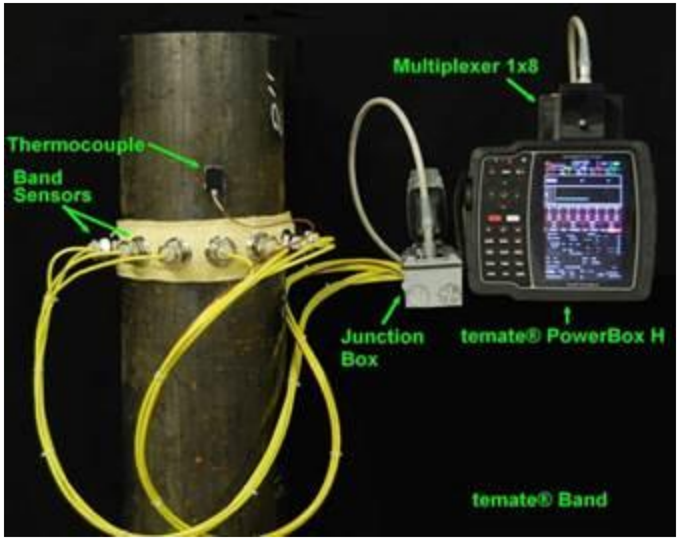
EMAT and DCUT sensors (Innerspec)

- Require no couplant
- EMAT (Electro magnetic acoustic transducers)
- DCUT (Dry coupled acoustic transducers)
- 6-8 sensors mounted on 2'' diameter pipes
- Suitable for high temperatures
- Inbuilt mounting system



EMAT Temate band

Task 19.1 - Path Forward

- Bench scale testing of selected sensors
  - Guided wave sensors (Permasense)
  - Ultran couplant-free sensors
- Investigate mounting systems for selected sensors
- Investigate integration with inspection tools
  - crawler and mini-rover or other existing platforms

Task 19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

Background:

- 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 19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

Previous Efforts

- Test plan for the irradiation of nonmetallic materials (Sandia Report)
  - RPP-PLAN-50529
- Banded (Band-it) and Swaged Hose in Hose Transfer Line (HIHTL) Assembly, Service Life Verification Program (Lieberman Report)
  - RPP-6711, Rev.3, Appendix L

Task 19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

Phase 1 Test Plan:

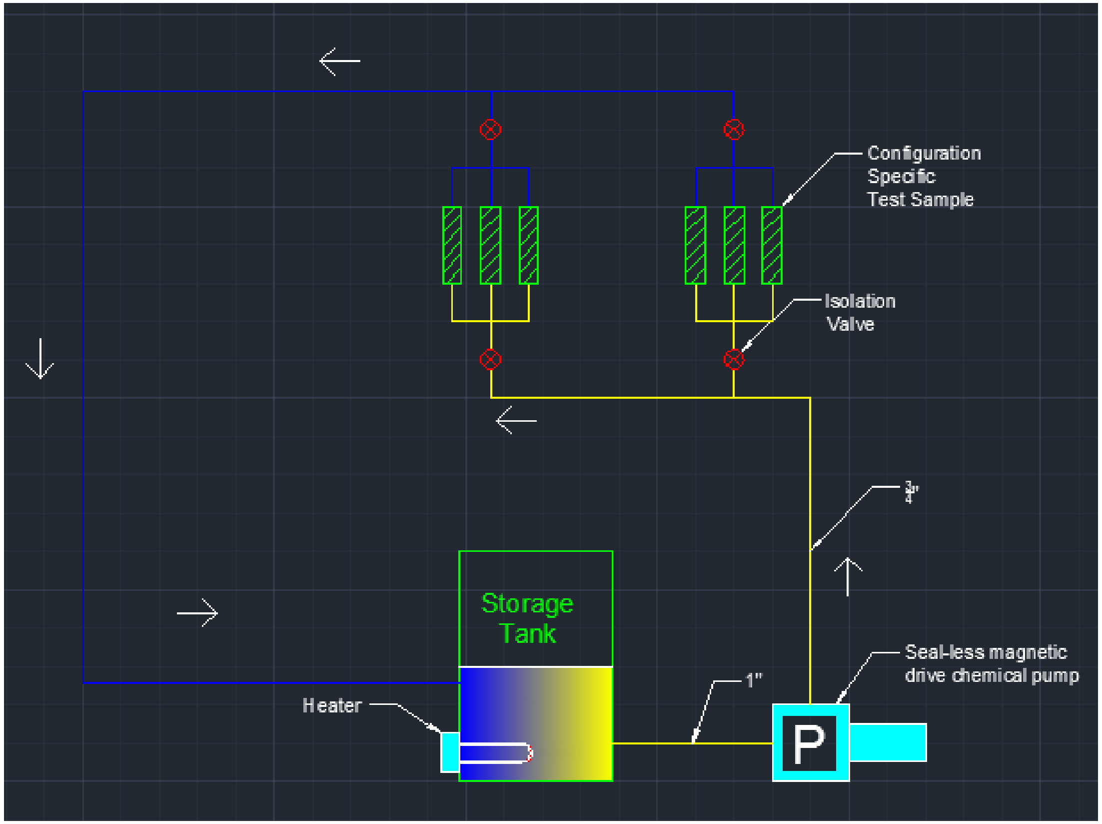
- Phase 1 will be limited to EPDM material testing (HIHTL, O-rings and gaskets). EPDM was selected for this phase of testing due to its use in multiple applications within the Hanford waste transfer system.
- Material will be simultaneously exposed (aged) to both high temperature (85^{o}F, 130^{o}F and 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 19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

In-Service Configuration Aging

- The in-service configuration aging experimental setup will consist of 3 independent pumping loops with three manifold sections on each loop.
- Each of the 3 loops will be run at a different temperature that corresponds to ambient (85ºF), operating (130ºF) and design (180ºF) temperatures.
- Each manifold section holds three test samples and be used for a corresponding exposure time of 180 and 360 days.
- Test samples will consist of either an EPDM inner hose, Garlock® gasket or an EPDM O-ring.

Task 19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System



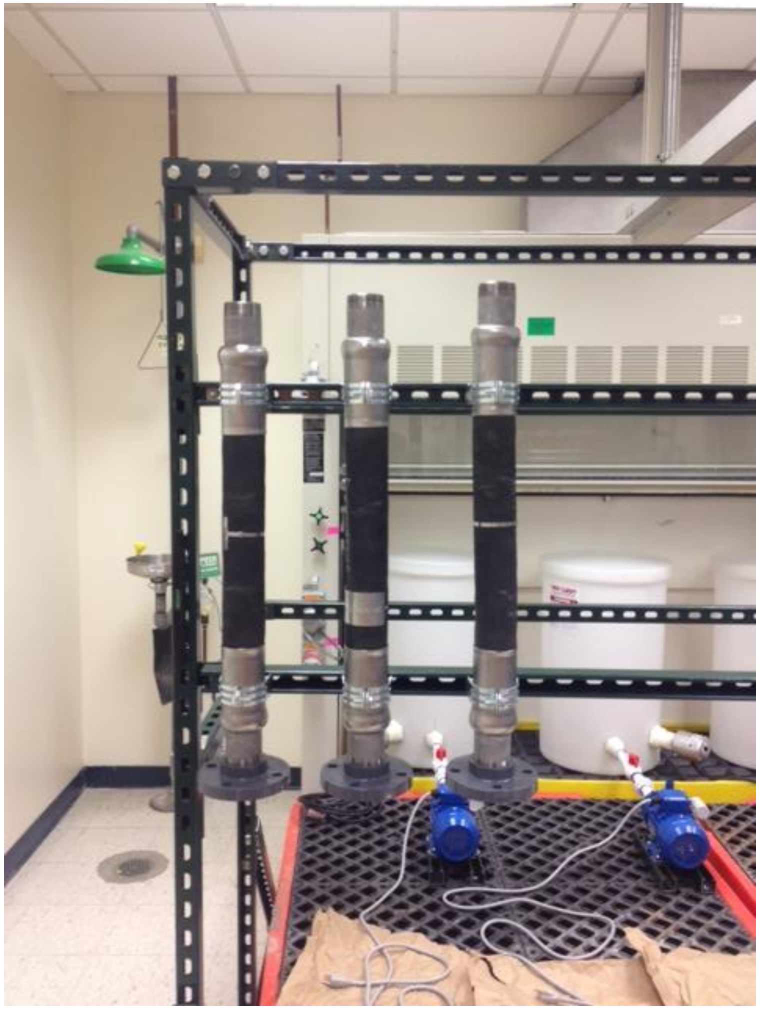
In-Service Configuration Aging Loop

864 inches of HIHTL

26 inch specimens were to be cut and fittings will be installed at Riverbend

Task 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
- Some coupons with swaged fittings had slight variations in length (average exposed tube ~16 +/- 1.5 in).
- Variations will be noted when pressure testing.

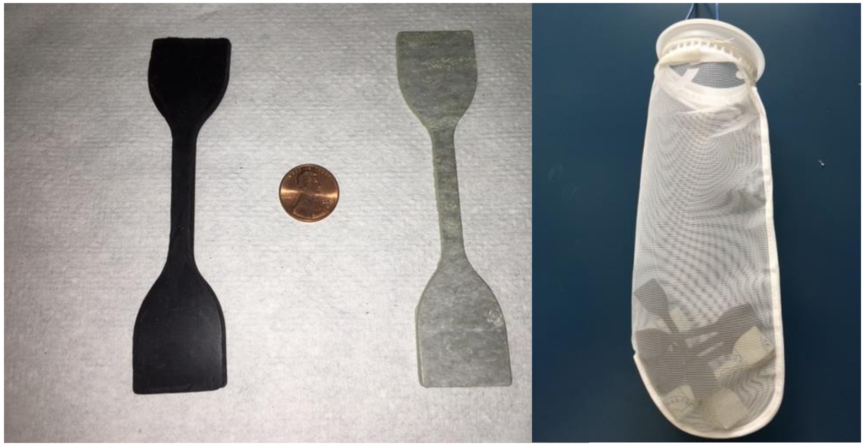


Task 19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

Task 19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

Coupon Aging:

- Coupon aging experimental setup will consist of 3 temperature controlled circulating fluid baths maintained at three different temperatures of (85°F, 130°F and 180°F).
- The circulating fluid will be a 25% sodium hydroxide solution.
- Each bath will have two sacks with ten coupons suspended in each sack.
- Each rack will be submerged in the bath for a duration of 180 or 360 days.



Task 19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

Coupon Aging Matrix

Days Exposure	Ambient Temperature (70°F)	Operating Temperature (130°F)	Design Temperature (180°F)	Baseline
0				10 coupon samples
180	10 coupon samples	10 coupon samples	10 coupon samples	
360	10 coupon samples	10 coupon samples	10 coupon samples	

Task 19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

Quantification of Material Degradation:

- In order to quantify how each sample was affected by the exposure to the caustic and temperature stressors, post-exposure mechanical testing will be conducted.
- In-Service Configured Components
  - Post-exposure mechanical testing will include hose burst and O-ring leak tests as per ASTM D380-94 and ASTM F237-05, respectively.
  - The tests will be conducted on the 18 aged test samples (6 from each test temperature with 3 at each exposure time).

Burst Pressure Rig

Task 19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

Quantification of Material Degradation:

Coupons

- Coupon properties to be evaluated include specific gravity, dimensions, mass, hardness, compression set, and tensile properties.

Test 1	Dimension change (ASTM 543)
Test 2	Specific gravity and mass change (ASTM D792, ASTM 543)
Test 3	Tensile strength (ASTM D412)
Test 4	Compression stress relaxation (ASTM D6147)
Test 5	Ultimate elongation (ASTM D412)
Test 6	Hardness measurements (ASTM 2240)

Task 19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

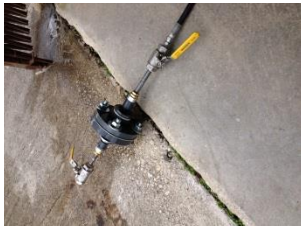
Baseline Results

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



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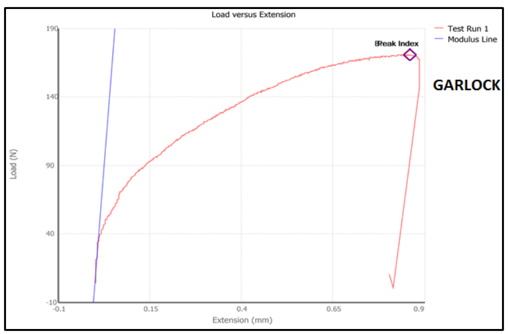
Task 19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

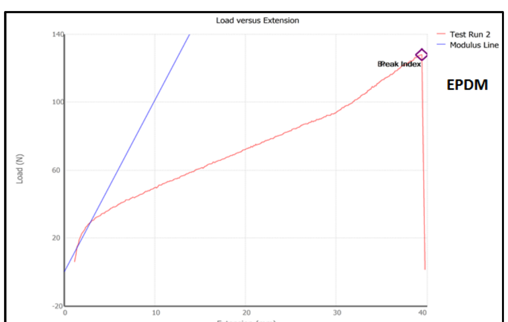
Baseline Results

Tensile tests:

- EPDM & Garlock coupons were tested



Average Test Run Results - Garlock		
Display Name	Value	Unit
Peak Stress	0.003	kN/mm^2
Peak Load	0.17367	kN
Strain at Break	0.0167	mm/mm
Modulus	3.03967	kN/mm^2
Width	25	mm
Thickness	2.381	mm



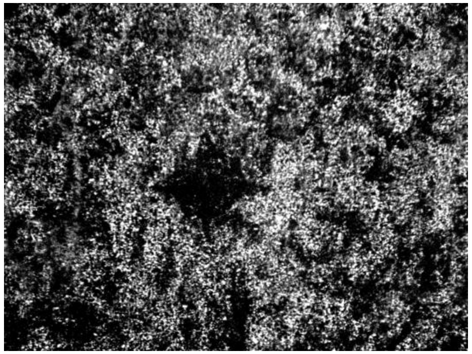
Average Test Run Results - EPDM		
Display Name	Value	Unit
Peak Stress	0.002	kN/mm^2
Peak Load	0.13133	kN
Strain at Break	0.76367	mm/mm
Modulus	0.00833	kN/mm^2
Width	25	mm
Thickness	2.381	mm

Task 19.2 - Evaluation of Nonmetallic Components in the Waste Transfer System

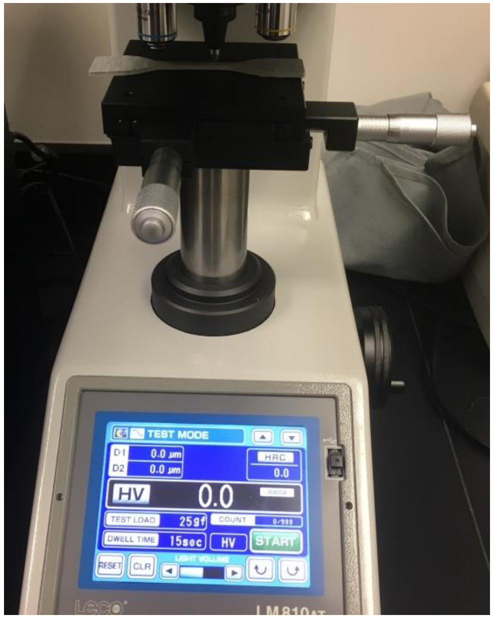
Baseline Results

Hardness tests:

- Garlock coupons were tested



Microscope view of test indentation

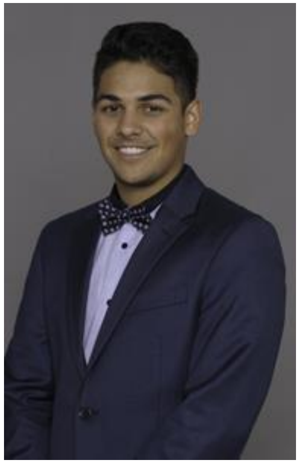


GARLOCK DATA	
Vickers	Rockwell
4	54
3	54
4	54
4	54
4	54
4	54
4	54
4	54
4	54
5	54.1
5	54.1
AVERAGE VALUES	
4.09	54.02

Task 19.2 – Path Forward

- Continue to age the non-metallic components for the 6 month and year intervals.
- Based on results of testing the HIHTL samples, additional data points may be needed for evaluation. Additional coupons would then be acquired and modifications will be made to the test loop, if needed.
- Additional stressors may also be incorporated into the testing.

Project 1 – Internships



John Conley (DOE Fellow - Class of 2014)

- Washington River Protection Solutions (WRPS) under the mentorship of Terry Sams/Dave Shuford.

Anthony Fernandez (DOE Fellow – Class of 2014)

- WRPS under the mentorship of Ruben Mendoza.

Maximiliano Edrei (DOE Fellow – Class of 2014)

- National Energy Technology Lab (NETL) under the mentorship of Chris Guenther.

Meilyn Planas (DOE Fellow – Class of 2014)

- WRPS under the mentorship of Terry Sams.

Project 1 – Conferences & Presentations

Waste Management 2016

- Improving the Accuracy of Computational Fluid Dynamics Simulations of Nuclear Waste Mixing using Direct Numerical Simulations, Reza Abbasi, Max, Edrei, Seckin Gokaltun, and Dwayne McDaniel
- Development of Inspection Tools for the AY-102 Double-Shell Tank at the Hanford DOE Site, Anthony Abrahao, Hadi Fekrmandi, Erim Gocke, Ryan Sheffield and Dwayne McDaniel
- Sonar Testing, Imaging, and Visualization for Applications in High Level Waste Tanks, David Roelant, Hadi, Fekrmandi and Gene Yllanes
- Evaluation of Nonmetallic Components in the Hanford Waste Transfer System, Amer Awwad, Jose Rivera, Dwayne McDaniel, John Conley and Anthony Fernandez

Project 1 – Conferences & Presentations

FIU Applied Research Center

Student Posters at Waste Management 2016

- Modifications and Enhancements to the Robotic Pipe Inspection Tool to be utilized for the DOE High Level Waste Project at the Hanford Site - Erim Gokce (DOE Fellow)
- Rapid Imaging of Solids in High Level Waste Tanks at Hanford - Gene Yllanes (DOE Fellow)
- Stainless Steel Corrosion: Feed Properties Affecting Material Selection for LAWPS Piping at Hanford Site - John Conley (DOE Fellow)
- Radial Jet Impingement Correlation Investigation - Maximiliano Edrei (DOE Fellow)
- Heat Transfer Calculations for the Use of an Infrared Temperature Sensor - Meilyn Planas (DOE Fellow)
- Development of a Miniature Motorized Inspection tool for the Hanford DOE Site Tank Bottoms - Ryan Sheffield (DOE Fellow)

Project 1 – Conferences & Presentations

FIU Applied Research Center

Technology Coordination Meeting with National Laboratories hosted by WRPS – June 2015

- Chemical Process Alternatives for Radioactive Waste (Updates on FIU DOE-EM HLW projects) Dwayne McDaniel

International Workshop on the Use of Robotic Technologies at Nuclear Facilities – February 2016

- Robotic Technology Research at Florida International University for the Department of Energy - Environmental Management, Dwayne McDaniel, Leonel Lagos, Hadi Fekrmandi, Anthony Abrahao, Ryan Sheffield, and Erim Gokce

Tank Closure Forum - March 2016

- Development of Inspection Tools for the AY-102 Double-Shell Tank at the Hanford DOE Site, Dwayne McDaniel

American Nuclear Society (ANS) - August 2016

- Development of a Peristaltic Crawler for the Inspection of the High Level Waste Tanks at Hanford, Anthony Abrahao, Erim Gokce and Dwayne McDaniel
- Development of a Miniature Inspection Tool for the AY-102 Double-Shell Tank at the Hanford DOE Site, Hadi Fekrmandi, Ryan Sheffield and Dwayne McDaniel