FIU-DOE Research Review

Tues, March 31	Wed, April 1	Thurs, April 2	Fri, April 3
10:00 AM - 12:00 PM *Presentation- Env. Remediation Technologies (FIU Project 3)* Discussion of research area in support of EM **1:00 - 3:00 PM** *Presentation- Env. Remediation Technologies (FIU Project 2)* Discussion of research area in support of EM	**10:00 AM - 12:00PM** *Presentation- Workforce Development and Training (FIU Project 5)* Discussion of research area in support of EM **1:00 - 3:00 PM** *Presentation- D&D and Env. Mngt IT Research (FIU Project 4)* Discussion of research area in support of EM	**1:00 - 3:00 PM** *Presentation- High Level Waste/Waste Processing Research (FIU Project 1)* Discussion of research area in support of EM	**10:00 AM - 12:00 PM** *Wrap-up - Discussion of DOE-FIU Cooperative Agreement*

Project 1 Chemical Process Alternatives for Radioactive Waste

Dwayne McDaniel
Senior Research Scientist

FLORIDA INTERNATIONAL UNIVERSITY

Project Staff and Students

Principal Investigator: Leonel Lagos

Project Manager: Dwayne McDaniel

Faculty/Staff: Amer Awwad, Dave Roelant, Anthony Abrahao, Aparna Aravelli, Tomas Pribanic, Romani Patel, Jairo Crespo, Seckin Gokaltun, Hadi Fekrmandi

Students/DOE Fellows: Brian Castillo, Sasha Philius, Anthony Fernandez, John Conley, Dayron Chigin, Ryan Sheffield, Maximiliano Edriei, Deanna Moya, Gabriela Vazquez, Carmela Vallata

Project Clients and Collaborators

- DOE-EM
  - Gary Peterson, Steve Schneider
  - Rod Rimando
- Washington River Protection Solutions
  - Dennis Washenfelder, Terry Sams, Ruben Mendoza
- Bechtel
  - Joel Peltier, Steve 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) quantification of residual waste on the floors of staging tanks, 4) development of inspection tools for DST primary tanks, 5) Pipeline integrity analysis

Project Description

Task 2 Pipeline Unplugging and Plug Prevention

- develop novel technologies that can be utilized to remove plugs formed in HLW pipelines
- computational simulation and evolution of HLW pipeline plugs

Task 17 Advanced Topics for Mixing Processes

- computational fluid dynamics modeling of HLW processes in waste tanks

Task 18 Technology Development and Instrumentation Evaluation

- evaluation of FIU's SLIM for rapid measurement of HLW solids on tank bottoms
- development of inspection tools for DST primary tanks

Task 19 Pipeline Integrity and Analysis

- pipeline corrosion and erosion evaluation
- nonmetallic materials evaluation

DOE-FIU Cooperative Agreement

Project 1 Accomplishments

Florida International University

Project-Wide Major Accomplishments

- DOE Tank Waste Management Program Review (12/9/14)
  - Update of technical tasks and budget status
- Hanford Site Task Review (9/18/14)
  - Provide update on tasks and obtain feedback on potential new tasks and prioritization

Project 1 - Task 2.1 Asynchronous Pulsing

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Background:

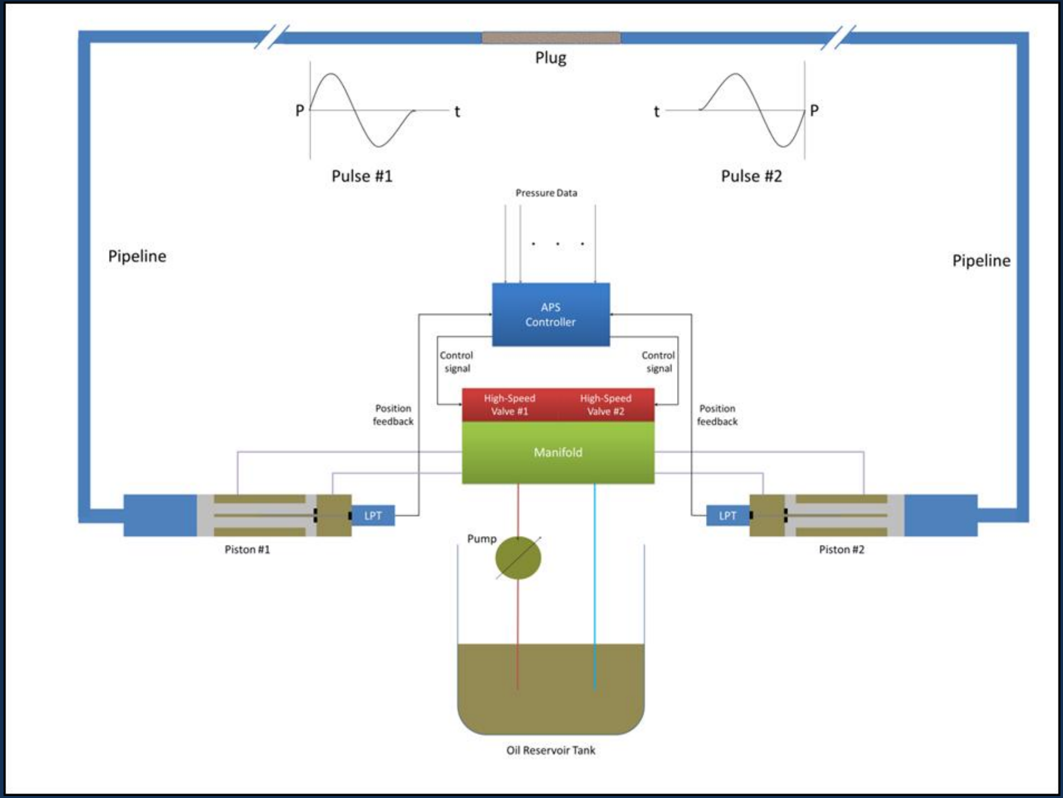
- Approximately 56 million gallons of HLW is currently being stored at Hanford. The transfer of waste to DSTs or the WTP create potential for plugging which can delay project milestones and be hazardous and expensive to repair.
- Industry call (~ 2002) - a number of pipeline unplugging technologies were evaluated. Two technologies were identified as having potential and brought back for further testing and evaluation in 2008/2009.
- FIU began developing our own technologies based on lessons learned – 1) Peristaltic Crawler, 2) Asynchronous Pulsing System

Project 1 - Task 2.1 Asynchronous Pulsing

Principle: pressure pulses created asynchronously from both sides of the plug to capitalize on dynamic loads

Previous Research:

- Designed and procured system
- Set up bench scale test – 3 in diameter pipeline with 300 psi limit, determined system operational parameters and validated operational principles
- Conducted additional studies on effects of entrained air – how to mitigate



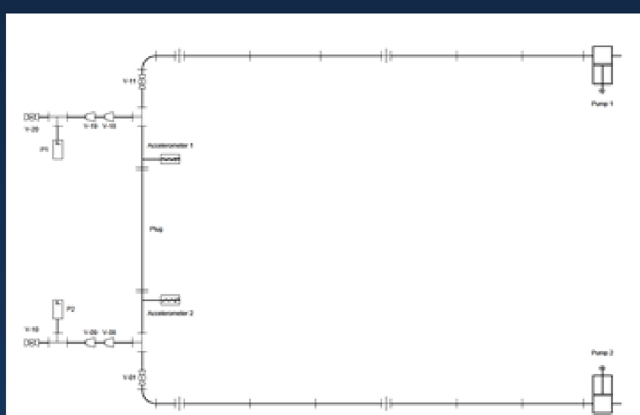
Initial bench scale set up

Project 1 - Task 2.1 Asynchronous Pulsing

Previous Testing:

Evaluate the asynchronous pulsing system on an engineering scale

Testbed
135 ft. of 3” threaded steel pipes on each side of plug (0.25% slope) instrumented with pressure transducers, accelerometers and thermocouples



Project 1 - Task 2.1 Asynchronous Pulsing

Previous Results:

- Conducted parametric testing – static pressure, pulse amplitude, pulse frequency, % air
- From parametric testing – use optimal system parameters to unplug 3ft kaolin/plaster of Paris plugs

Pulse Wave Type	Pulse Frequency (Hz)	Unplugged (Y/N)	Average Pressure Amplitude (PSI)	Cycling Time (sec)
Triangle	1.0	Yes	192.5	1973
Triangle	2.0	Yes	96.5	1403
Triangle	3.0	Yes	92.5	5273
Square	1.0	Yes	162.5	2708
Square	2.0	Yes	123.5	2172
Square	3.0	Yes	97	3297
Sine	1.0	Yes	180.5	1816
Sine	2.0	Yes	106	2557
Sine	3.0	Yes	82.5	2721

Unplugging Trials

Project 1 - Task 2.1 Asynchronous Pulsing

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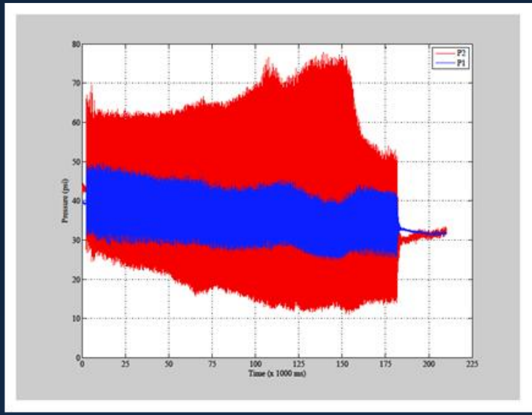
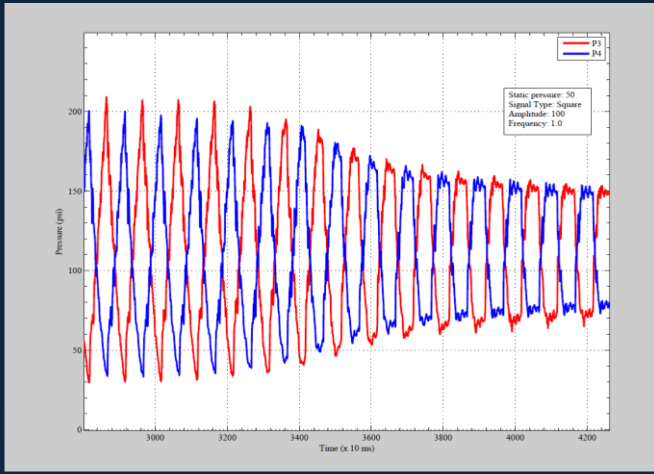
Previous Results:

Unplugging of 3-ft kaolin-plaster plugs

Plug prior to testing



Successful unplugging trial – complete breach



Pressure response to dislodged plug

Dislodged plug

Project 1 - Task 2.1 Asynchronous Pulsing

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Current Testing:

Air Entrainment Plug Testing

Air Quantity	Trail	Unplugged (Y/N)	Time Elapsed (Hrs)	Amplitude (A)	Frequency (Hz)	Wave Type
No Air	1	Y	4	100/150	1,2,3	Square
	2	Y	3	150	1	Square
	3	Y	6	150	1	Square
Half-Stroke	1	Y	4.5	150	1	Sine
	2	Y	8	150	1	Square
	3	Y	5.5	150	1	Square
Full-Stroke	1	Y	9.5	150	1	Square
	2	Y	10	150	1	Square

*All tests were performed at a baseline static pressure of 50 psi.

Project 1 - Task 2.1 Asynchronous Pulsing

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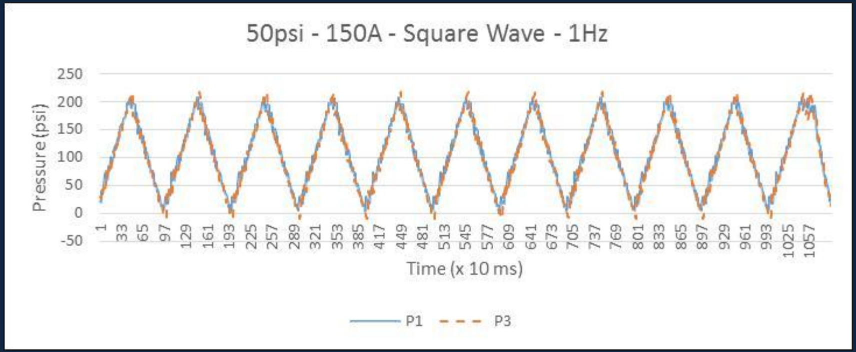
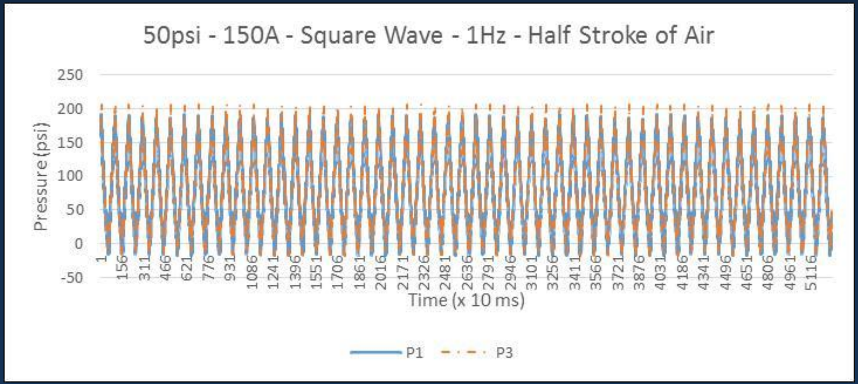
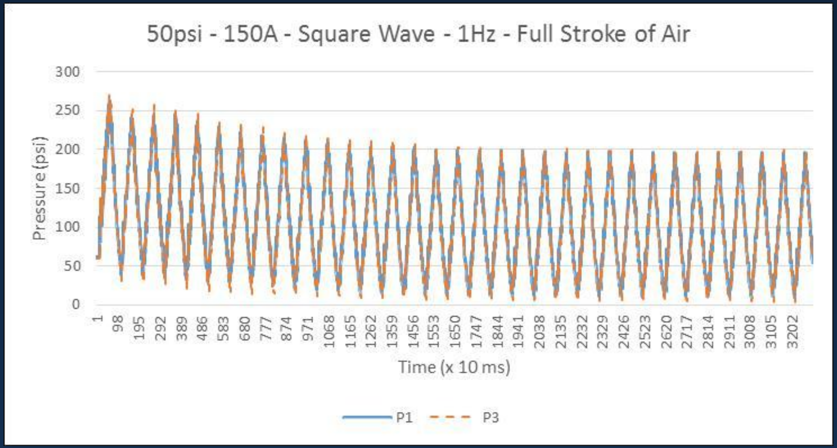
Sample Data:



No Air in System

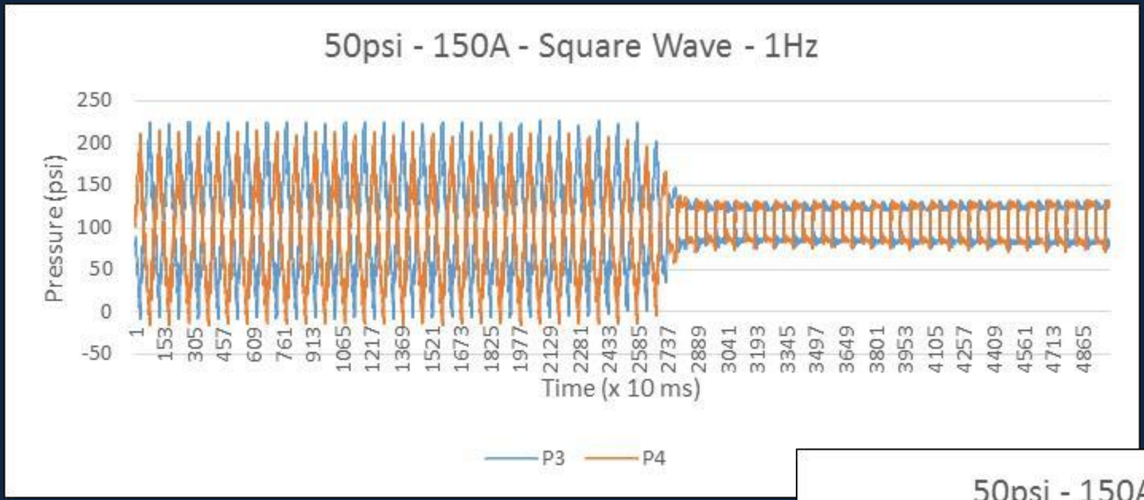


Half Stroke of Air in System



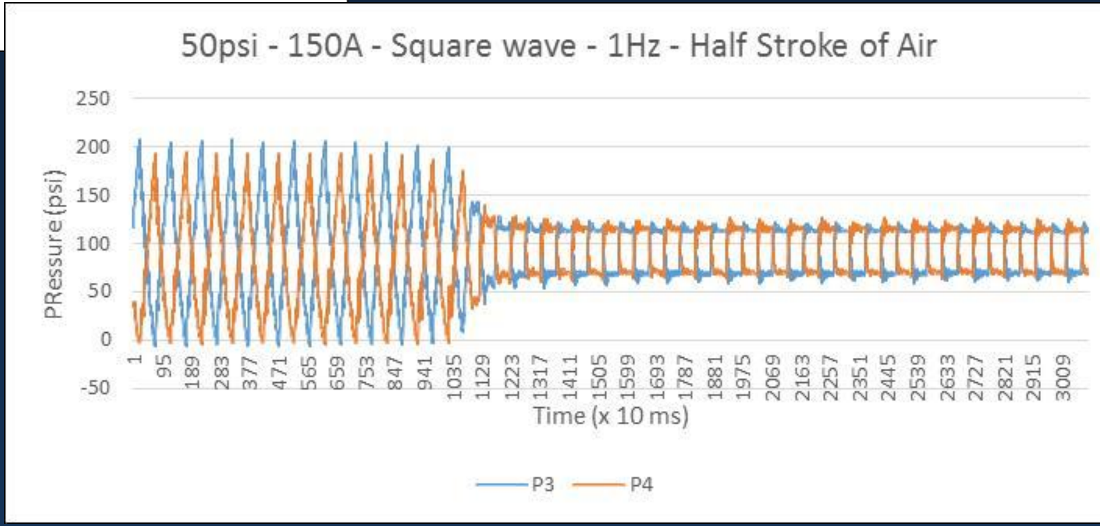
Full Stroke of Air in System – 9.5 hours

Project 1 - Task 2.1 Asynchronous Pulsing



No Air in System

Unplugging Data:



Half Stroke of Air in System

Project 1 - Task 2.1 Asynchronous Pulsing

Path Forward:

- Complete Data Analysis – for all tests
- Complete reports – milestone documents
- Investigate opportunities for onsite testing

Project 1 - Task 2.2 Computational Simulation and Evolution of HLW Pipeline Plugs

Background:

- HLW Slurry Transfer to and from tanks
  - pipeline plugging
  - past evidence
- Plugged pipelines
  - difficult and expensive to repair
  - delay the waste transfer process

Objective:

- Develop Computational Models
  - multi-physical (chemical, rheological, mechanical) processes influencing plug formation
- Multi-physics model
  - simulates the formation of a pipeline plug
  - influence of pipeline geometry/configuration on the plug development process

Project 1 - Task 2.2 Computational Simulation and Evolution of HLW Pipeline Plugs

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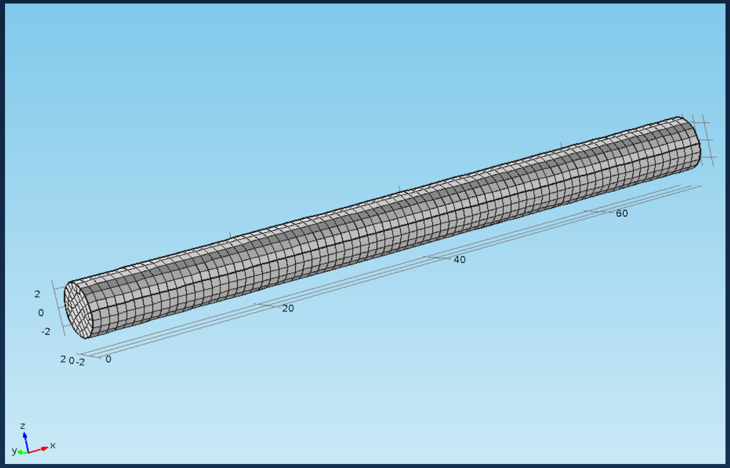
Modeling of Precipitation

- Couple modeling of flow and chemistry aspects using the mixture model interface.
- Main focus on integrating multi-physics and multi-phase models.
  - As the solids precipitate and undergo a phase change from liquid to solids, an increase in the solids fraction and changes in the particle size is expected - however this was not the case.
  - Conclusion – Incompatibility of the present software (COMSOL) for precipitation simulation.

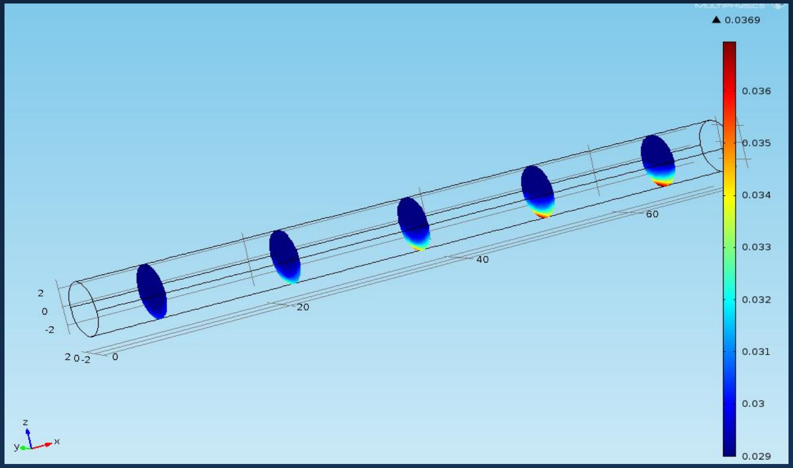
Project 1 - Task 2.2 Computational Simulation and Evolution of HLW Pipeline Plugs

3-D Modeling of Settling of Solids

- Baseline 3-D model simulating settling of solids in a horizontal pipeline as a function of particle size, solids density and volume fraction.



Meshed geometry-3D numerical model

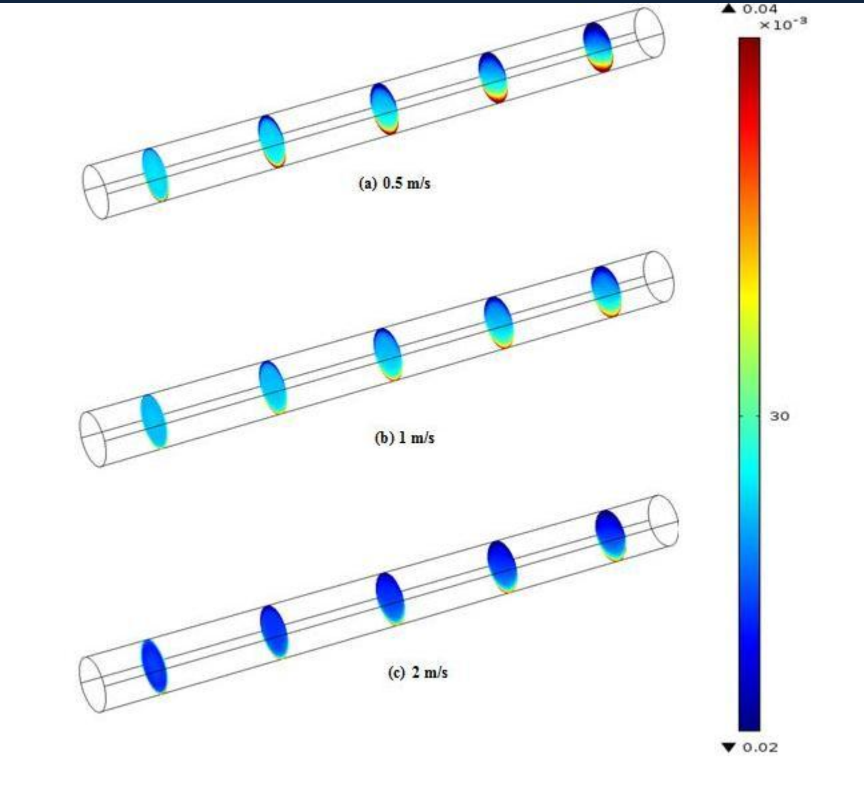


Slice plot of dispersed volume fraction
(red and yellow colors show settling location)

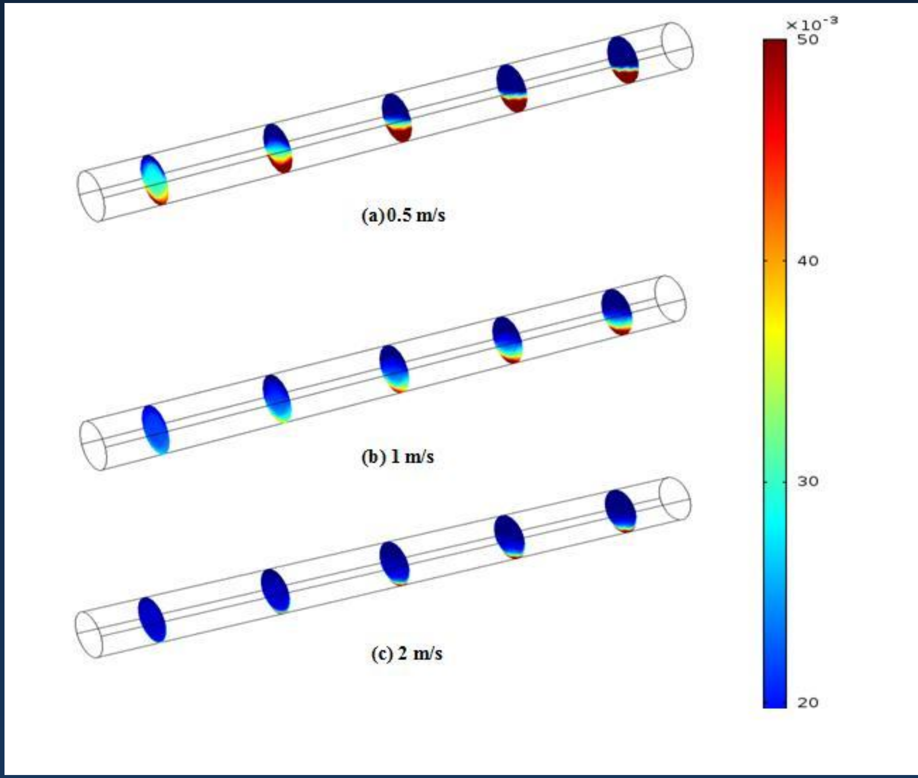
Project 1 - Task 2.2 Computational Simulation and Evolution of HLW Pipeline Plugs

Influence of Particle Size

45 µm



200 µm



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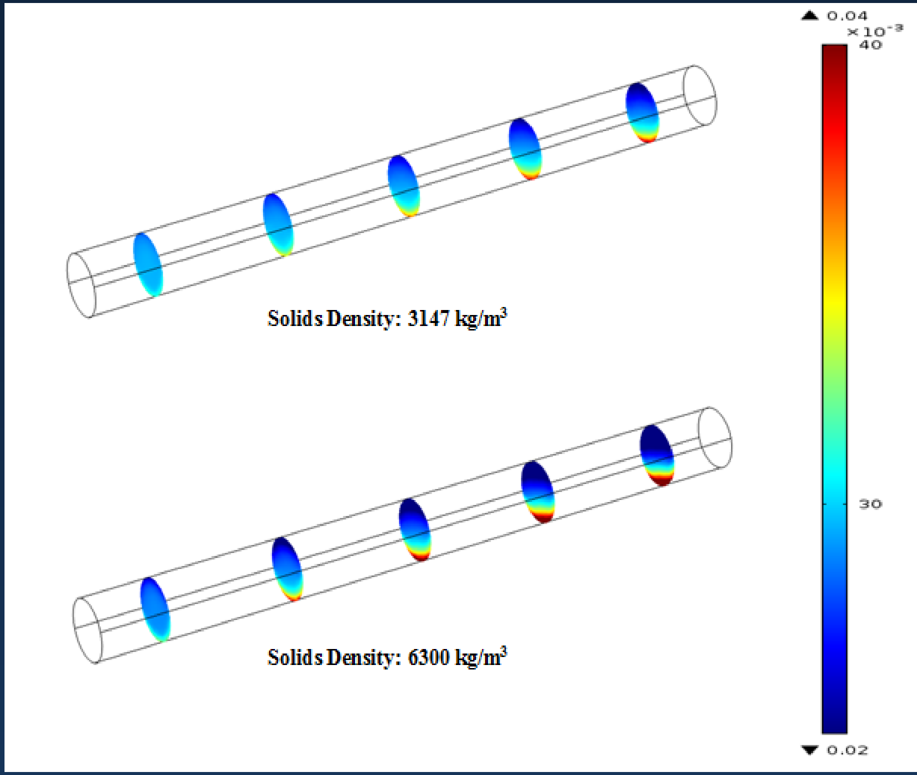
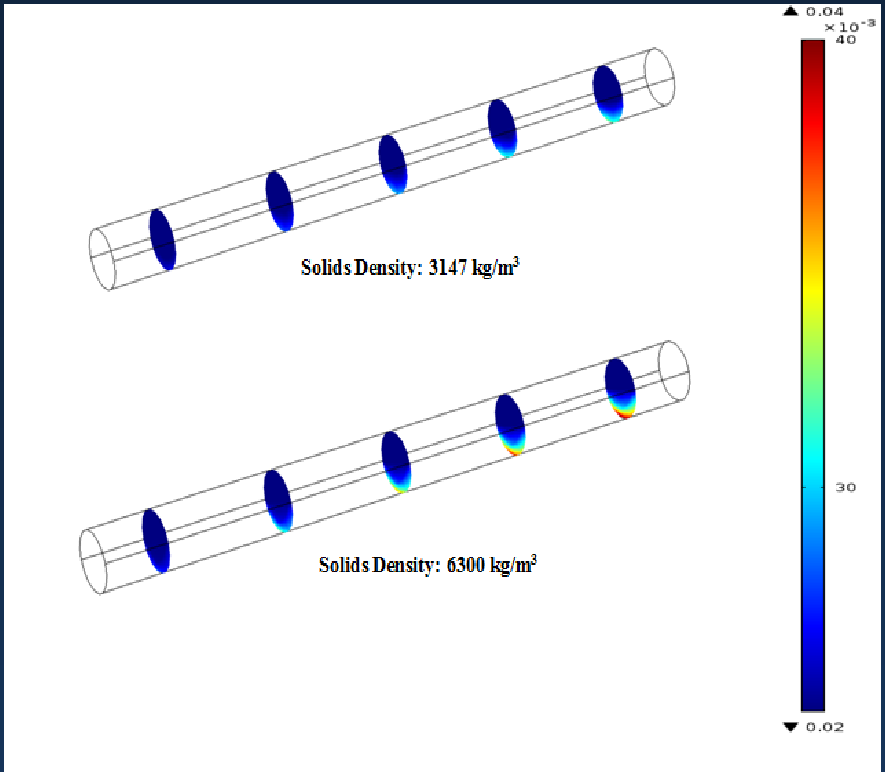
Influence of Solids Density

V=0.5 m/s



V=2 m/s



Project 1 - Task 2.2 Computational Simulation and Evolution of HLW Pipeline Plugs

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Influence of Solids Volume Fraction

Flow Velocity (m/s)	Solids volume fraction 2.9%	Solids volume fraction 5.8%	Solids volume fraction 10%
0.5	3.53%	6.84%	11.32%
0.8	3.35%	6.57%	10.98%
1	3.27%	6.42%	10.80%
2	2.90%	6.13%	10.44%
4	2.90%	5.90%	10.20%
6	2.90%	5.90%	10.12%

Project 1 - Task 2.2 Computational Simulation and Evolution of HLW Pipeline Plugs

Numerical Simulation Matrix

	Model Verification Study				
Test Configuration	**1**	**2**	**3**	**4**	**5**
Particle diameter (μm)	14.4	37.7	129.5	182.3	203.9
Solids Density (kg/m^3)	2500	7950	3770	2500	7950
Solids volume fraction (%)	9.8	9.3	8.7	7.4	3.0
Liquid density (kg/m^3)	1146	1647	1151	999	1026
Liquid viscosity (cP)	10.2	9.3	4.5	1.5	1.6

Project 1 - Task 2.2 Computational Simulation and Evolution of HLW Pipeline Plugs

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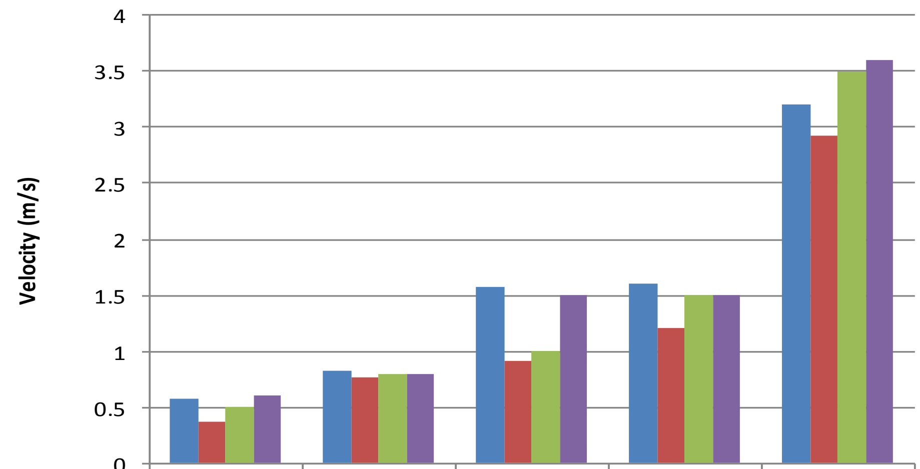
Comparison of Results – Numerical, Empirical and Experimental



	Case 1	Case 2	Case 3	Case 4	Case 5
Empirical Correlations (m/s)	0.58	0.82	1.58	1.61	3.2
PNNL Experimental Results (m/s	0.37	0.76	0.91	1.21	2.93
FIU 3-D Comsol Results (m/s)	0.5	0.8	1	1.5	3.5
FIU 2-D Comsol Results (m/s)	0.6	0.8	1.5	1.5	3.6

- Numerical simulations agree with experimental and empirical results.
- Negligible variance between the critical velocities computed using 2-D and 3-D models.

Project 1 - Task 2.2 Computational Simulation and Evolution of HLW Pipeline Plugs

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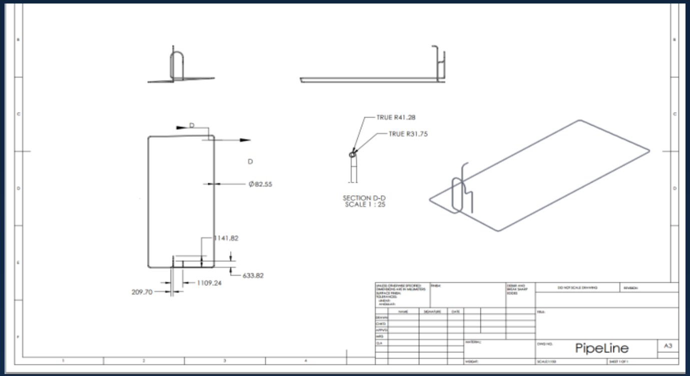
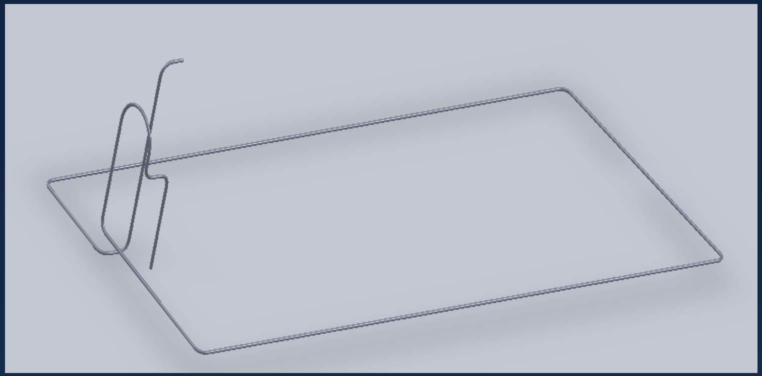
Application of Simulation Tool – PNNL Test Loop

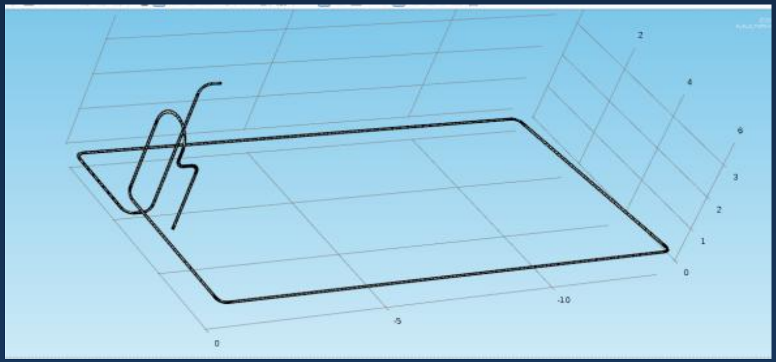
Geometry (Drawing)



3D Model



Finite Element Mesh



Project 1 - Task 2.2 Computational Simulation and Evolution of HLW Pipeline Plugs

Path Forward:

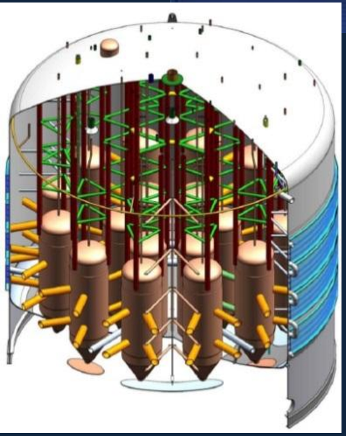
- Current model
  - Settling of solids in a horizontal pipeline
- Future models
  - Include the influence of pipeline geometry/configuration on the plug development process.
  - Effect of bends, tees, vertical segments and reducers
  - Effect of valves and connectors
- Minimal variance between the results of 2D and 3D numerical models
  - Horizontal pipeline
- Future models
  - Effect of complex geometry on 2D and 3D numerical models

Project 1 - Task 17.2 CFD Modeling of HLW Processes in Waste Tanks

Background:

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

14-ft-diameter vessel to test PJMs (Hanford Vit Plant's Facebook page)



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
- Overall Goal:
  - Develop a CFD model based on the Star-CCM+ framework to simulate the turbulent jet-flow in non-Newtonian fluids that show Bingham plastic behavior.
  - Execute verification and validation analysis for the uncertainty prediction in the results of Star-CCM+ software for benchmark cases of multiphase flow.

Project 1 - Task 17.2 CFD Modeling of HLW Processes in Waste Tanks

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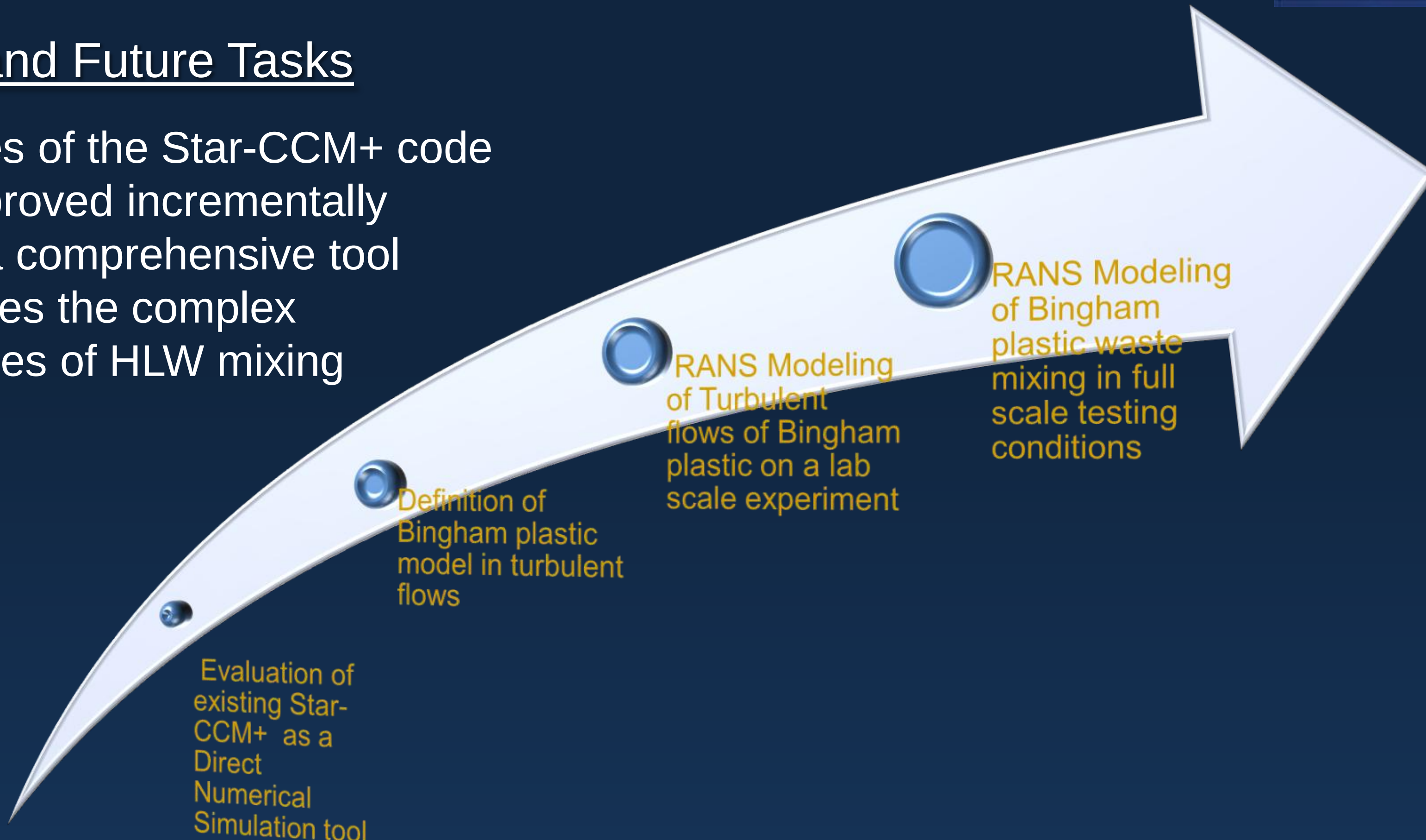
Present and Future Tasks

Capabilities of the Star-CCM+ code will be improved incrementally to obtain a comprehensive tool that includes the complex flow features of HLW mixing



Project 1 - Task 17.2 CFD Modeling of HLW Processes in Waste Tanks

Evaluation of Star-CCM+

- DNS of turbulent flow through a pipe will be replicated as done in Shams et al (2011) using Star-CCM+.
- Results will be compared with Kasagi's DNS data base

	DNS(e)	DNS(u)	PIV	LDA	HWA
$Re_c = \langle v_z \rangle_c D/\nu$	6950	6950	7100	7200	7350
$Re_b = \langle v_z \rangle_b D/\nu$	5300	5300	5450	5450	5600
$Re_* = u_* D/\nu$	360	360	366	371	379
$\langle v_z \rangle_c / u_*$	19.31	19.29	19.38	19.39	19.40
$\langle v_z \rangle_b / u_*$	14.73	14.74	14.88	14.68	14.76
$\langle v_z \rangle_c / \langle v_z \rangle_b$	1.31	1.31	1.30	1.32	1.31
$C_f = \langle \tau_{rz} \rangle / \frac{1}{2}\rho \langle v_z \rangle_b^2$	$9.22 \cdot 10^{-3}$	$9.21 \cdot 10^{-3}$	$9.03 \cdot 10^{-3}$	$9.28 \cdot 10^{-3}$	$9.18 \cdot 10^{-3}$
δ^* / R	0.127	0.126	0.124	0.130	0.128
θ^* / R	0.068	0.068	0.068	0.071	0.070
$H = \delta^* / \theta^*$	1.86	1.85	1.83	1.83	1.82

Mean flow quantities to be replicated (1994, Eggels et al)

Project 1 - Task 17.2 CFD Modeling of HLW Processes in Waste Tanks

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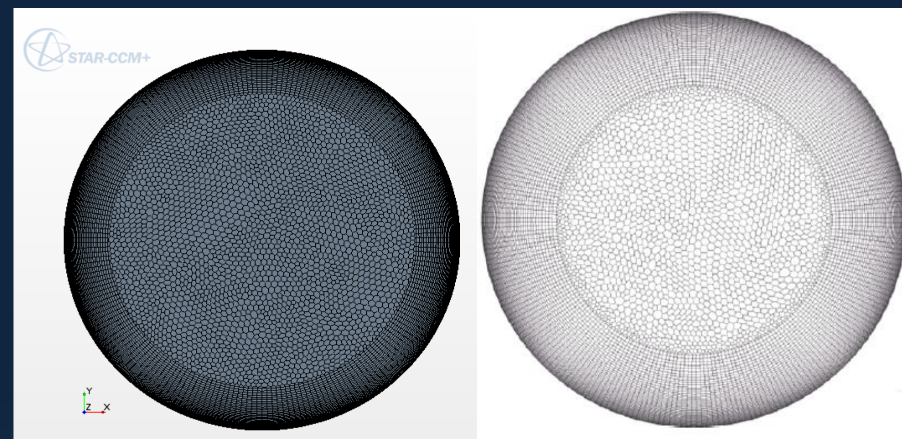
Meshing

Successful Polyhedral mesh with prism offset layers created using equal number of grid points.

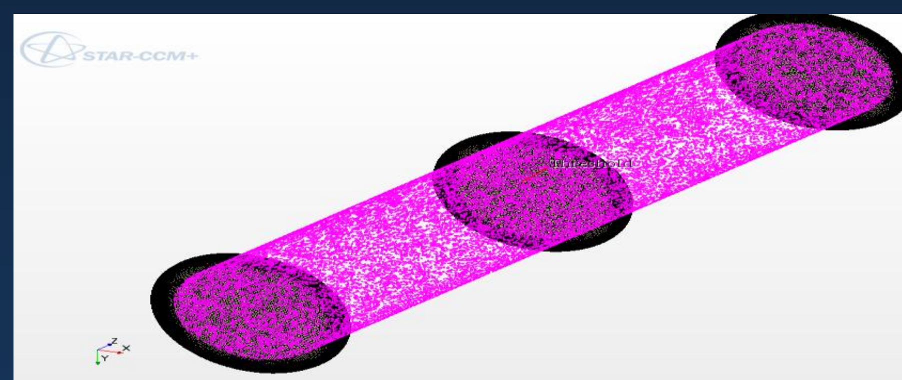
(# of mesh elements)



Modeling and Mesh comparison

Grid Point quality

The Cell Quality, Face Validity, and Volume Change surpassed minimum thresholds.



Cell Quality < .3

Project 1 - Task 17.2 CFD Modeling of HLW Processes in Waste Tanks

Physical conditions

- Mass flow inlet and pressure outlet boundaries were set.
- Inlet and outlet periodic interface was made.
- Sub-grid viscosity coefficient in LES parameters was set sufficiently low to enable Q-DNS .
- Second order central scheme with 5% boundedness for space discretization in combination with second order implicit scheme for time integration was set.

Project 1 - Task 17.2 CFD Modeling of HLW Processes in Waste Tanks

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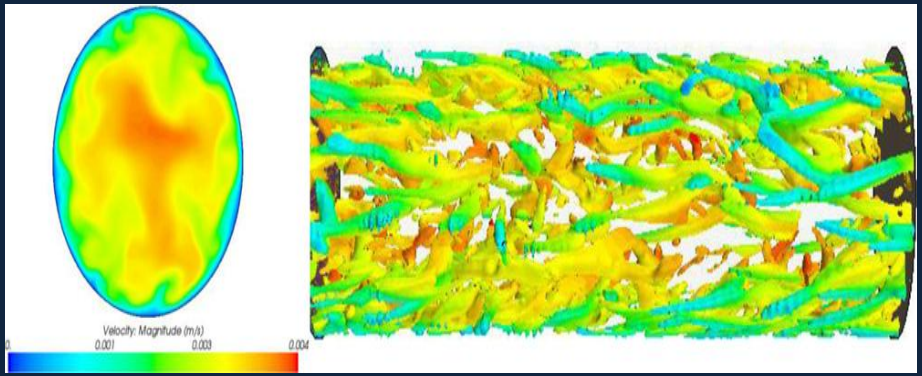
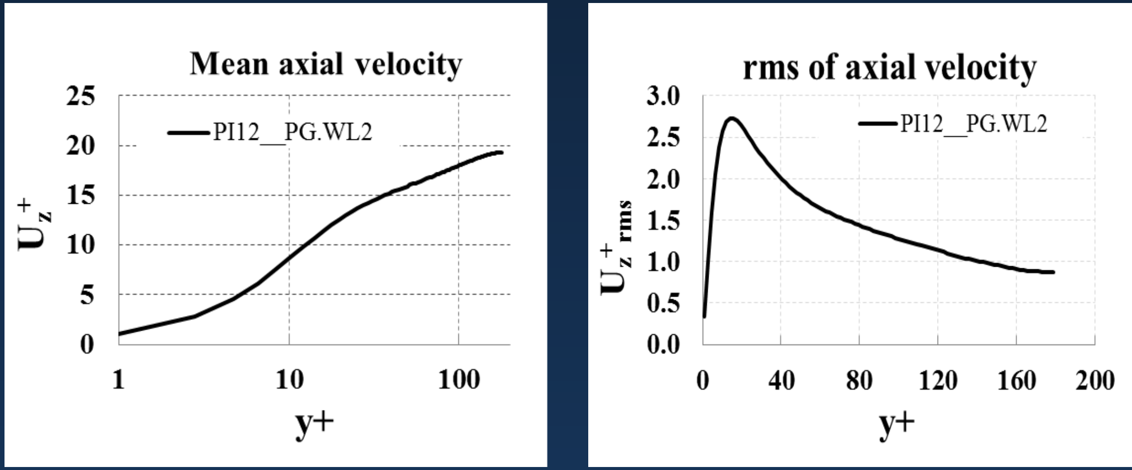
Results

Physics and meshing have been implemented. Currently the simulation is being produced for proper output values.



Target Iso-countours of velocity field (2011, Shams et al)



Target Mean (Left) and RMS (right) Axial Velocities Along the pipe

Project 1 - Task 17.2 CFD Modeling of HLW Processes in Waste Tanks

Current State of Research

1. Star-CCM+ software general training (100% complete)
2. Star-CCM+ software license acquisition (100% complete)
3. Computer cluster hardware resource acquisition (100% complete)
4. Collaboration with DOE liaisons (ongoing)
   1. Had conference call with Dr. Peltier (Bechtel), Dr. Guenther(NETL) and Mr. Rimando (DOE) on tasks for FY14.
   2. Communicating with Bridgette Rosendall (Bechtel) on her recent work evaluating Star-CCM+ for turbulent Bingham flows.
5. Literature review on DNS for single-phase and multi-phase turbulent flows (75% complete)
6. Benchmarking Star-CCM+ for a single-phase Newtonian DNS simulation (25% complete)
   1. Identified experimental data
   2. Set-up computational grid
   3. Undergoing numerical runs

Project 1 - Task 17.2 CFD Modeling of HLW Processes in Waste Tanks

Path Forward

- The definition of turbulence in a Bingham fluid with a RANS representation is not well defined. As of now there is no RANS based CFD tool that can accurately predict the behavior of Bingham type fluids under turbulent flow conditions that would exist in the operation of the PJMs.
- RANS only provides large-eddy shear rate which is orders of magnitude smaller that the real value so the shear rate model needs to be corrected in any RANS simulation.
- Turbulence in a Bingham fluid with a DNS representation is well defined and the shear rate at grid-cell level can be represented.
- FIU is conducting small scale DNS to understand the shear rate behavior by verifying against experiments or comparative data. (FY15)
- Another parameter to analyze is the relaxation time for Bingham fluid which is considered to be instantaneous for ideal conditions but a finite time exists in real gelling scenarios. (FY16)
- Finally settling solids can be added later and the effects of the Biot number can be considered as future tasks in the upcoming years. (FY17)

Project 1 - Task 18.1 Evaluation of FIU's SLIM for Rapid Measurement of HLW Solids on Tank Bottoms

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 solids in HLW tanks with as high as 30% solids entrained in the liquid while mixing
- A new 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

Project 1 - Task 18.1 Evaluation of FIU's SLIM for Rapid Measurement of HLW Solids on Tank Bottoms

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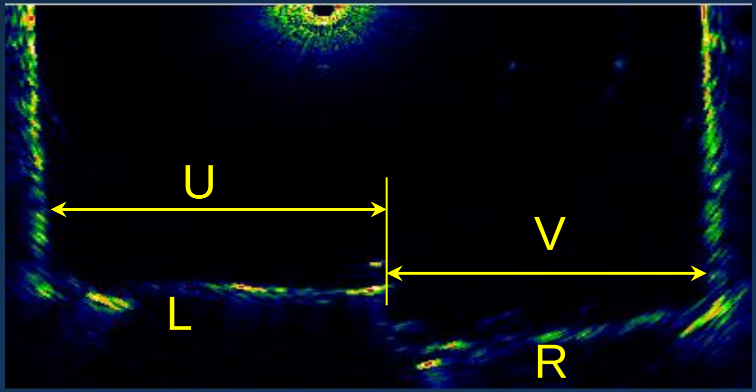
FIU's Commercial, 2D and 3D Sonars:

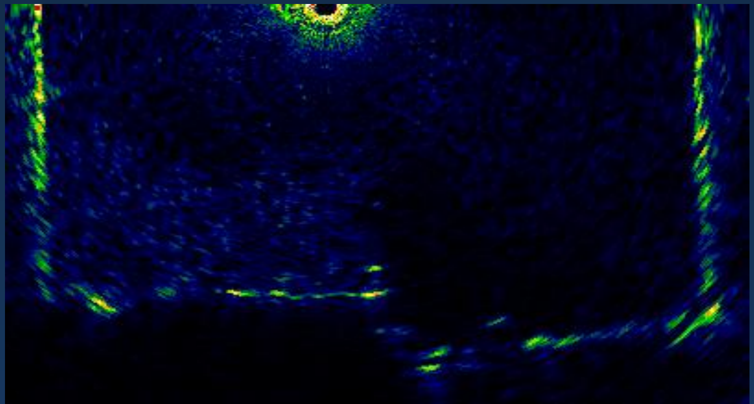
Imagenex 881A profiling 2-D sonar (left) & Marine Electronics 3-D sonar (right)

Project 1 - Task 18.1 Evaluation of FIU's SLIM for Rapid Measurement of HLW Solids on Tank Bottoms

Background – Past Performance and Motivation for Current Work:

Past testing of 2D sonar demonstrated accurate (1-3% error) imaging through 7 ft of water with 30% kaolin solids entrained. Figures below are: (top) test tank 7' dia. with kaolin on part of the floor; (lower left) image of sonar with 0% solids entrained; (lower right) image of sonar with 30% solids entrained.

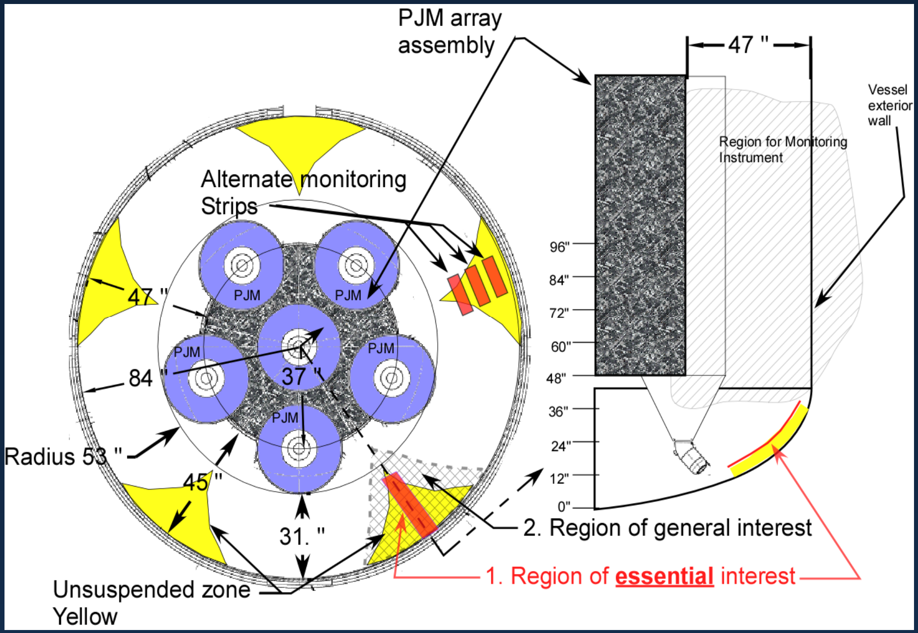




Project 1 - Task 18.1 Evaluation of FIU's SLIM for Rapid Measurement of HLW Solids on Tank Bottoms

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

Project 1 - Task 18.1 Evaluation of FIU's SLIM for Rapid Measurement of HLW Solids on Tank Bottoms

FIU Applied Research Center

Objective:

- Meet the new Hanford technology need for rapid imaging (even during vigorous mixing) of solids on the floor of conditioning (mixing) tanks by
  - Determining the sonar system parameters to optimize the image resolution;
  - Measuring the time required to create sonar images for relevant sonar system parameters and ranges; and
  - Showing the sonar can identify if mixing is complete (i.e., no solids remaining on the tank floor).

Initial Results:

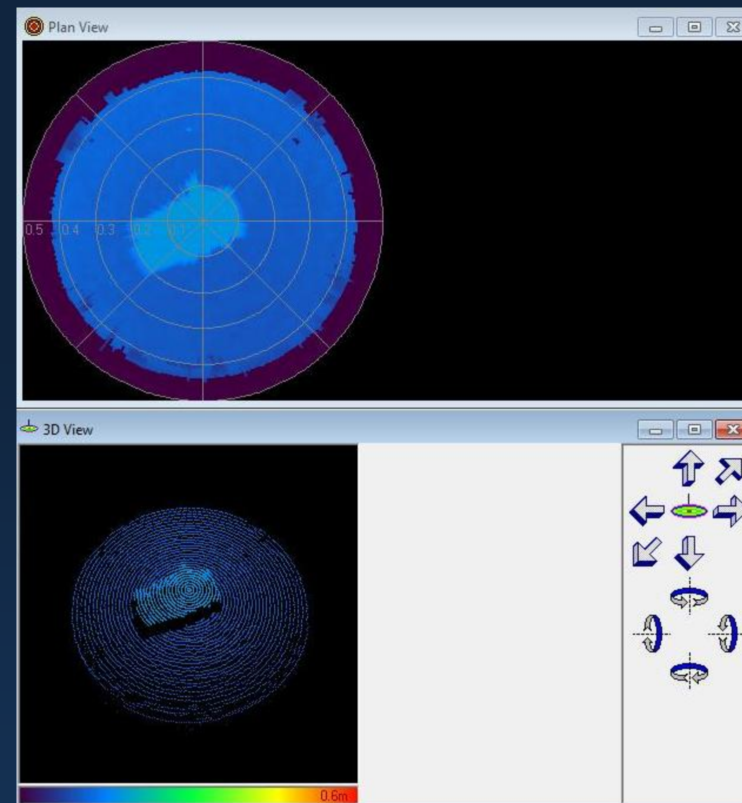
- Initial tests demonstrated that FIU's 3D sonar could successfully image solids on a tank floor in times under 1 minute, solids volume estimates with <5% error

Project 1 - Task 18.1 Evaluation of FIU's SLIM for Rapid Measurement of HLW Solids on Tank Bottoms

FIU Applied Research Center

Results

Initial tests measured simple objects such as the brick imaged to the left. Accuracy of distance to the brick and dimensions of the brick varied from 0.1 – 4%



Sonar image of a brick 1.0m below 3D sonar head.

Project 1 - Task 18.1 Evaluation of FIU's SLIM for Rapid Measurement of HLW Solids on Tank Bottoms

Results

Demonstrated that limited floor areas could indeed be imaged with good resolution in less than a minute (results ranged from 15 to 45 seconds). Testing also revealed the optimal settings for the sonar system for this application.

The 3 critical parameter optimizations are:

1. Maximum number of steps along each 2-D scan and hence the number of pulses along each 2-D scan;
2. Minimum number of rotation motor steps (fewest number of 2-D scans taken since the time for the motor to rotate between scans is long compared to the time between pulses along a 2-D scan);
3. 30-degree viewing angle setting allowing for sonar to be placed close to the floor area with settled solids in order to maximize the number of sonar pulses on the field of view.

Project 1 - Task 18.1 Evaluation of FIU's SLIM for Rapid Measurement of HLW Solids on Tank Bottoms

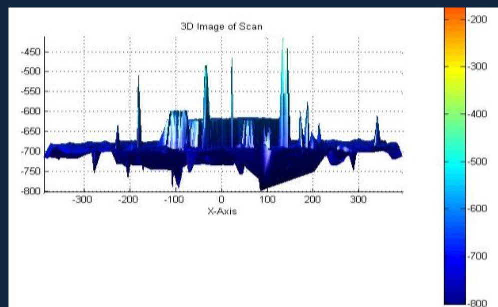
Results

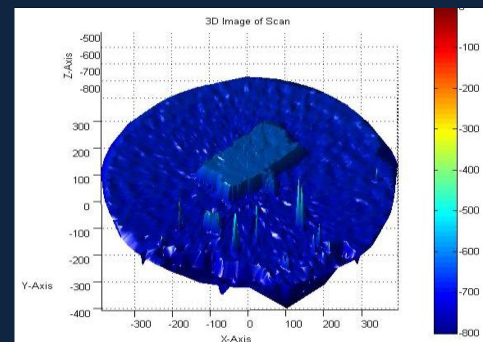
- Since the commercial sonar imaging software does not work when there are not sufficient number of 2D swaths created to render a 3D image, FIU developed its own imaging algorithms (images follow)
- Since there is a desire to automate the sonar imaging to identify if solids are on the floor and if yes, the volume of solids, FIU created several data processing filters and a volume estimation algorithm (examples follow)
- Since it is necessary to image while mixing, FIU has designed experiment and set up the experiment to test the performance of the 3D sonar from 0-30% entrained solids

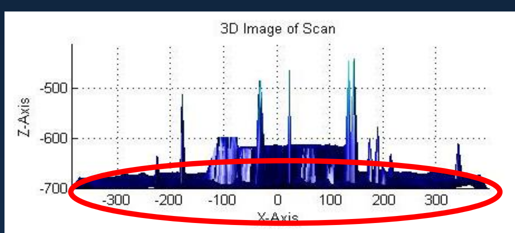
Project 1 - Task 18.1 Evaluation of FIU's SLIM for Rapid Measurement of HLW Solids on Tank Bottoms

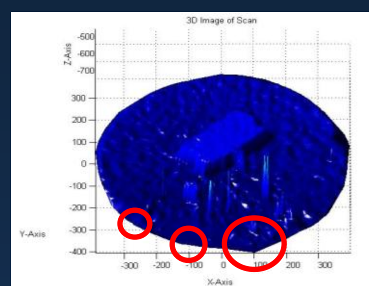
FIU Applied Research Center

Unfiltered data



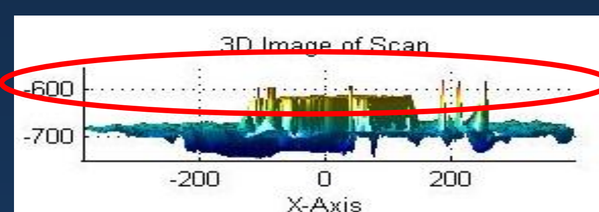


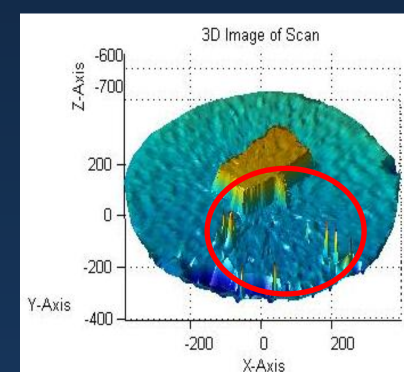




Filtered to remove double reflections (appear as below floor or past walls)

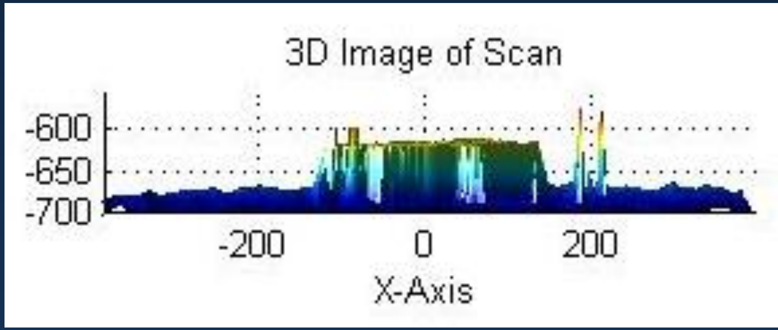
Filtered to remove or reduce anomalous data (appear as large spikes, discontinuities)

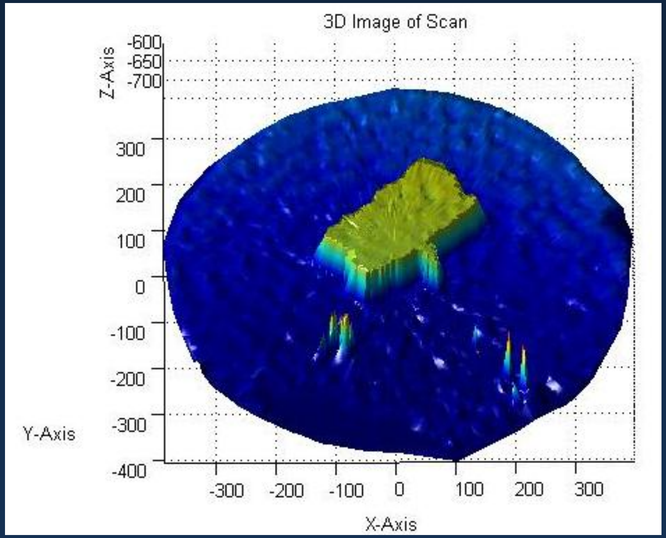




Project 1 - Task 18.1 Evaluation of FIU's SLIM for Rapid Measurement of HLW Solids on Tank Bottoms

Final filtering to further reduce anomalous data (appear as large spikes, discontinuities)





Project 1 - Task 18.1 Evaluation of FIU's SLIM for Rapid Measurement of HLW Solids on Tank Bottoms

FIU Applied Research Center

Current Status

- Experimental plan and experimental setup completed for imaging while mixing experiment
- 3D Sonar had a sudden decrease in imaging performance in Jan. and was sent to the manufacturer in late Feb. for diagnostics and repair
- Additional tests with FIU's 2D sonar is ongoing while the 3D sonar is repaired
- Tests of the mixing pump's ability to suspend up to 30% solids (kaolin clay) is ongoing

Future Work

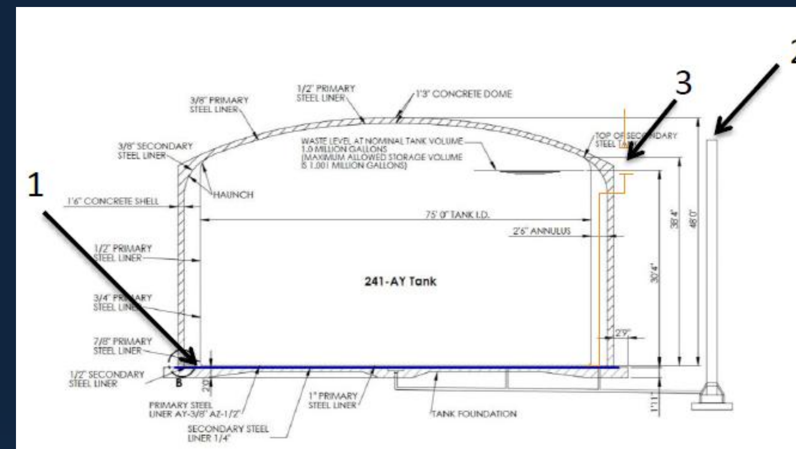
- Complete testing of 3-D sonar during mixing with volume % solids of 0% to 30% with <30 sec total imaging time (Apr. – May)
- Present all test results to Hanford engineers (June)
- Obtain functional and test requirements for full-scale testing of SLIM in order to deploy in a mixing tank

Project 1 - Task 18.2 Development of Inspection Tools for DST Primary Tanks

FIU Applied Research Center

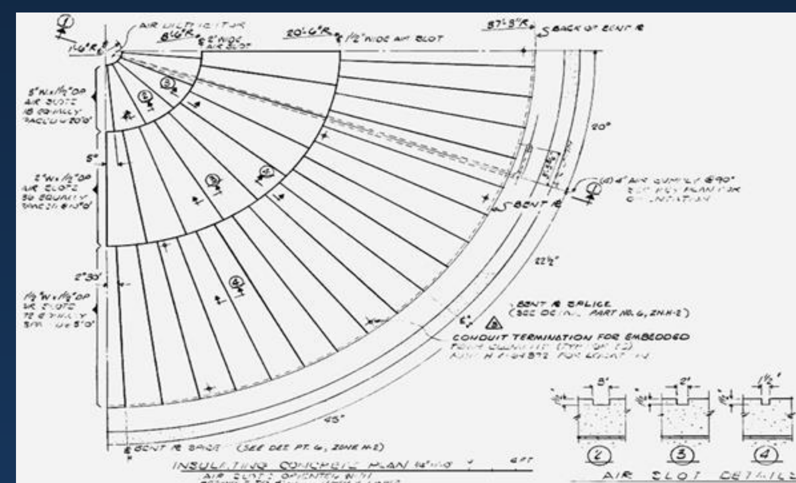
Background:

- 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



Project 1 - 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

- Device will be remote controlled
- Device will be inserted through a riser to the annulus floor
- Video feedback will be recorded for future analysis
- Device will need to be radiation 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.

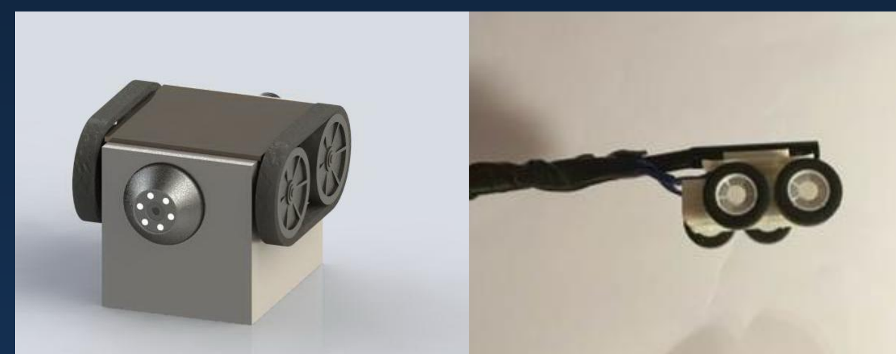
Project 1 - Task 18.2 Development of Inspection Tools for DST Primary Tanks

Proposed Concept:

- The body would consist of a camera with attached tether and motors connected to “tank tread” wheels.
- To avoid building up debris while crawling through the channel on the refractory pad and potentially destroying the refractory pad, the proposed design has a magnet on the tool base, so that it can travel upside down along the bottom of the tank.

First Prototype:

- Dimensions appropriate to travel through first section
- Capable of inverted travel
- Torque output sufficient to pull tether 17 ft

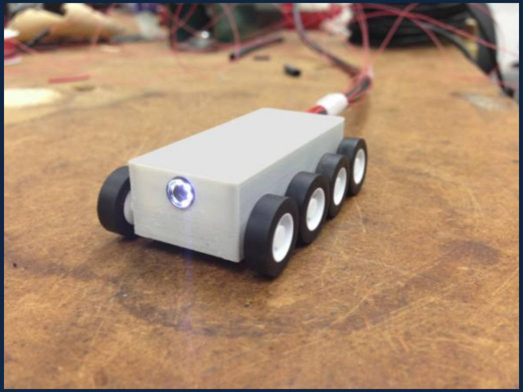


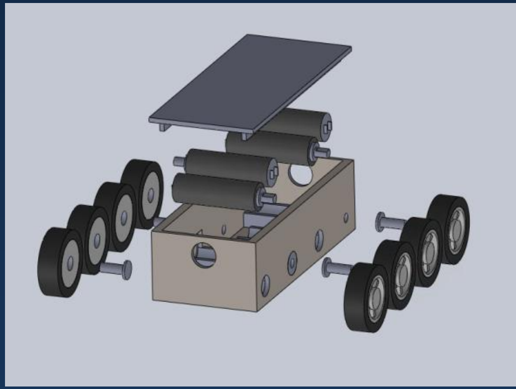
Initial proposed concept (left)
First prototype (right)

Project 1 - Task 18.2 Development of Inspection Tools for DST Primary Tanks

<u>Current prototype:</u>

- Addition of 4, free-rolling wheels
- Body modifications
  - house the camera
  - Inspection tool bottom lofted
- Removal of wheel hub
- More intuitive control method

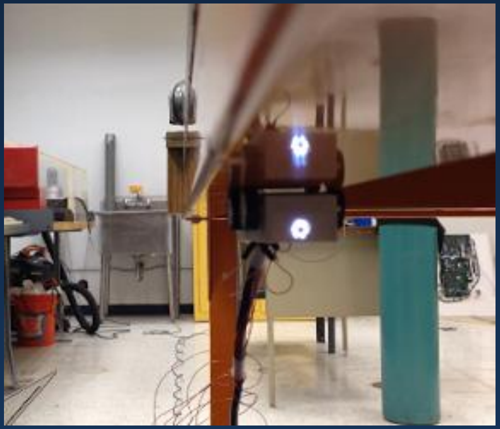




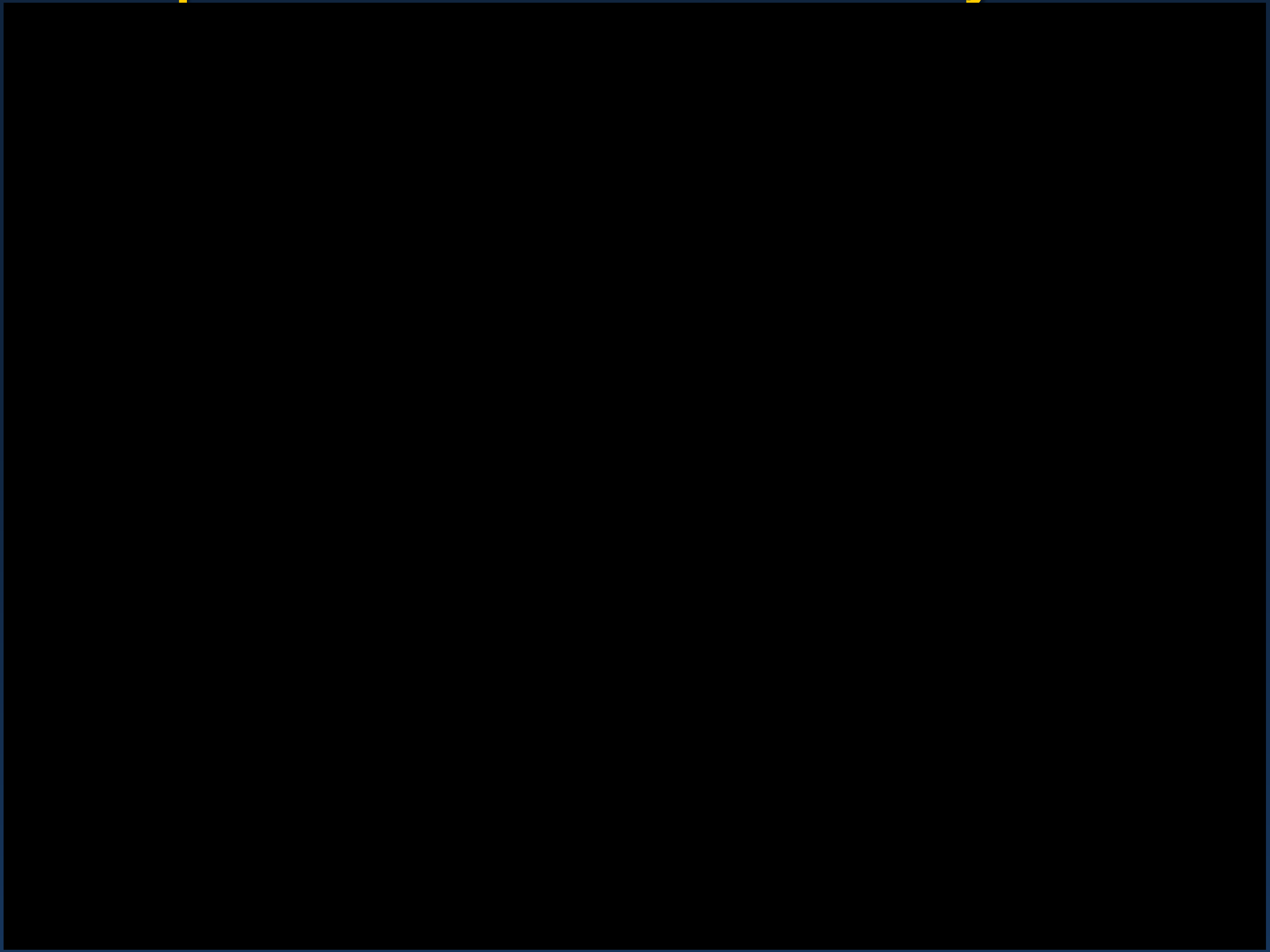
Project 1 - Task 18.2 Development of Inspection Tools for DST Primary Tanks

Testing at 5 V:

- Preliminary tests completed representing 17 ft of tether drag around corner performed
- Maximum force test performed at 24.3 gf inspection tool weight
  - Static stall at 199.1 gf + 3 ft of tether
  - Dynamic stall torque - 265 gf + 3 ft of tether



Project 1 - Task 18.2 Development of Inspection Tools for DST Primary Tanks



Project 1 - Task 18.2 Development of Inspection Tools for DST Primary Tanks

Path Forward:

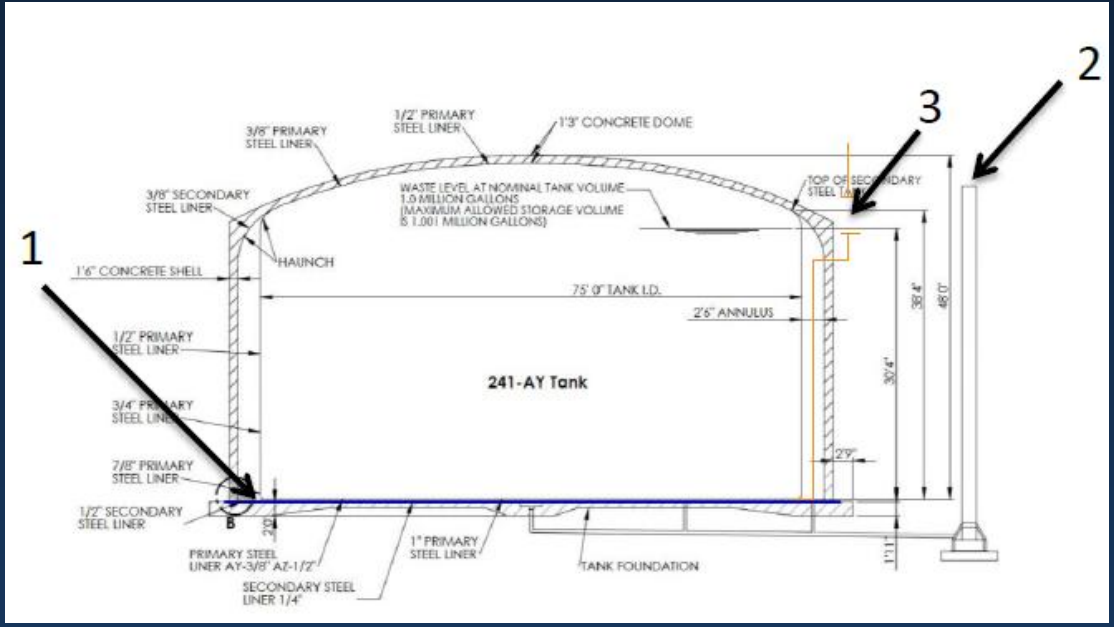
- Construct test bed representing tank path and appropriate dimensions
- Perform isolated tests to determine tether drag force
- Explore design modifications to make 90° turn (i.e. reduced width wheels, length of body)

Project 1 - 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) air channels under tank,
  - (2) 6” leak detection piping, and
  - (3) 4” air supply piping.



Project 1 - Task 18.2 Development of Inspection Tools for DST Primary Tanks

Objective: To develop an inspection tool that crawls through a 4” air supply pipe that leads to the central plenum of the primary tank of the DSTs at Hanford and provides video feedback

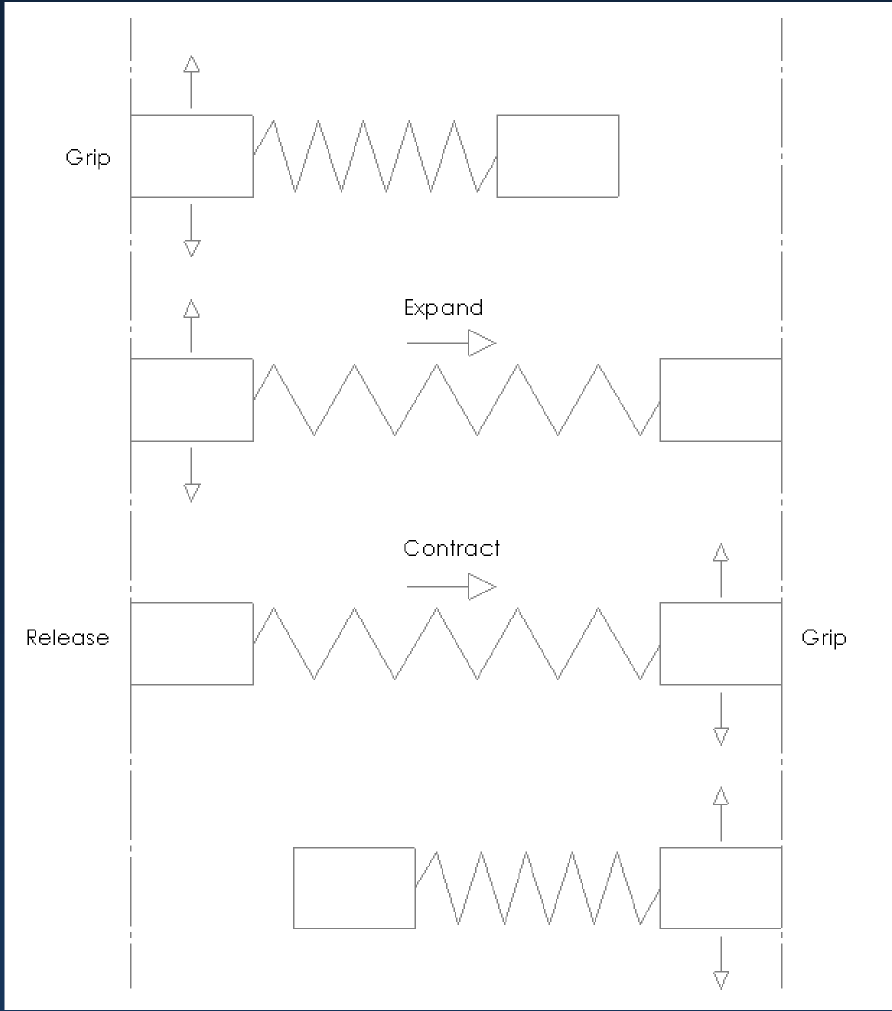
Design parameters

- 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 relatively 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

Project 1 - Task 18.2 Development of Inspection Tools for DST Primary Tanks

Proposed Concept:

- The new conceptual design is a peristaltic crawler, that uses pneumatic actuators to emulate the contraction movements. The design is based on existing crawlers developed at FIU.
- The main advantage of using a peristaltic locomotion in the design of inspection tools is that the device can crawl inside a pipeline without using any external moving parts, such as wheels and continuous tracks.
- The device can be fully encapsulated with a disposable protective skin, which is suitable for decontamination in harsh environments and critical applications

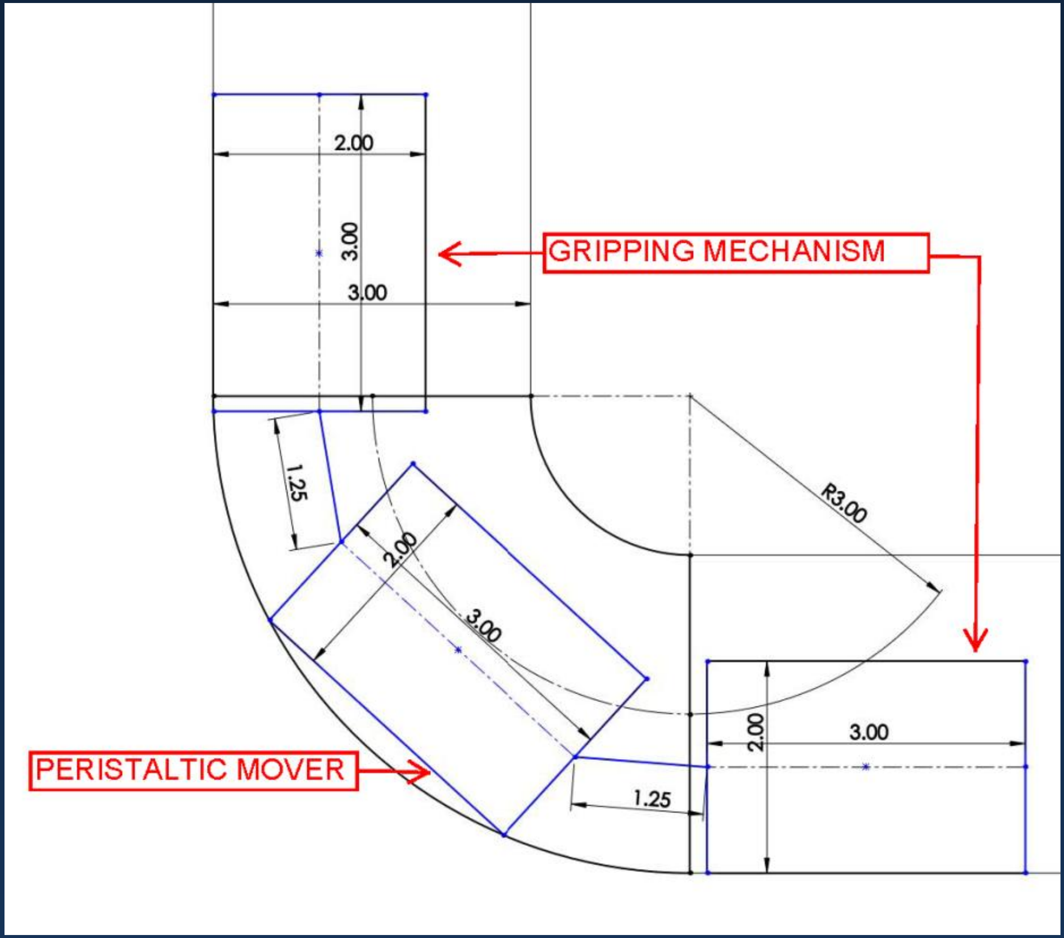


Project 1 - Task 18.2 Development of Inspection Tools for DST Primary Tanks

FIU Applied Research Center

Proposed Concept:

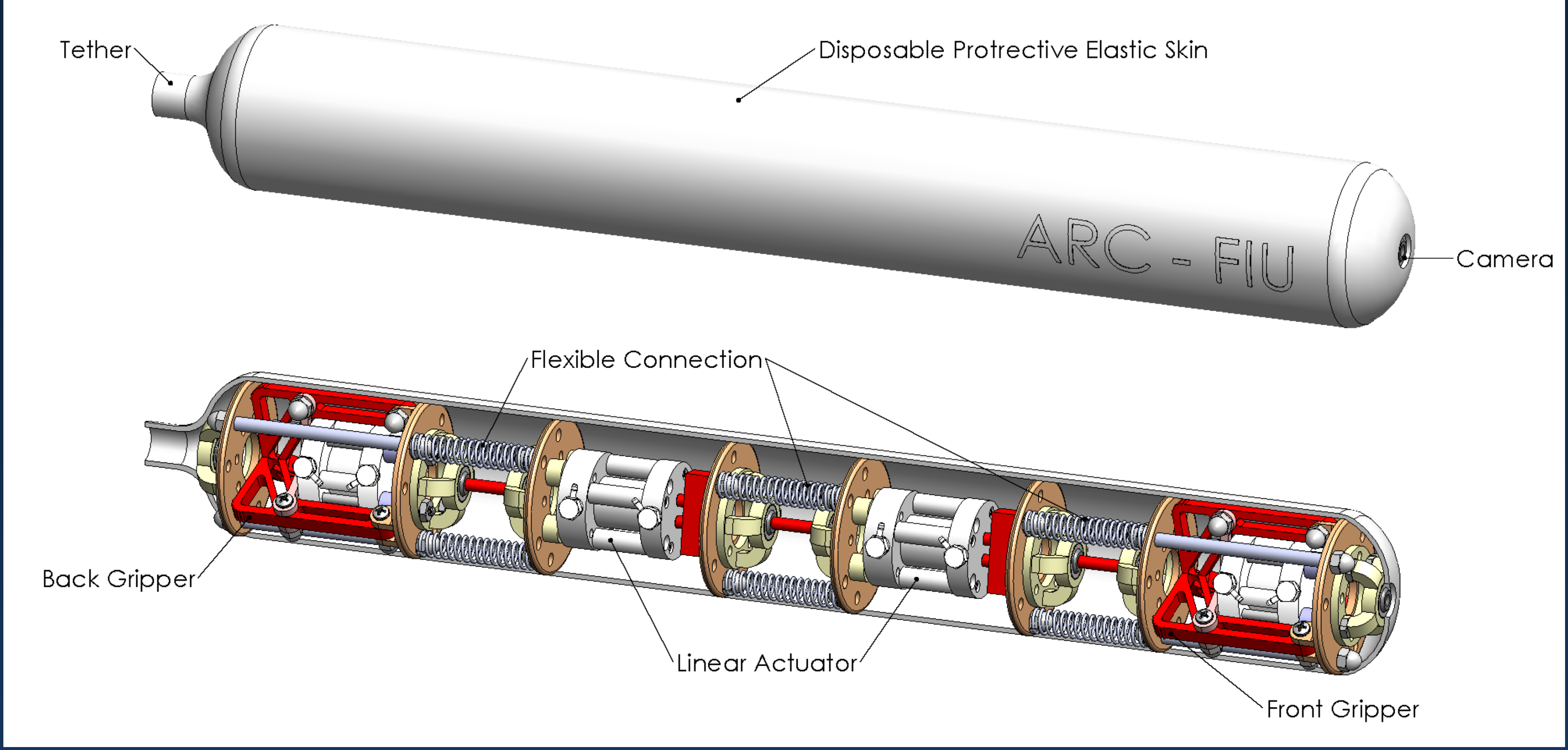
- The new inspection tool has a modular design.
- The device is composed of interchangeable modules connected with rigid links.
- The modular approach has the potential to be customized for specific tasks with the addition of extra modules.
- For instance adding:
  - instrumentation,
  - material sampling, and
  - pipe repair.



Project 1 - Task 18.2 Development of Inspection Tools for DST Primary Tanks

FIU Applied Research Center

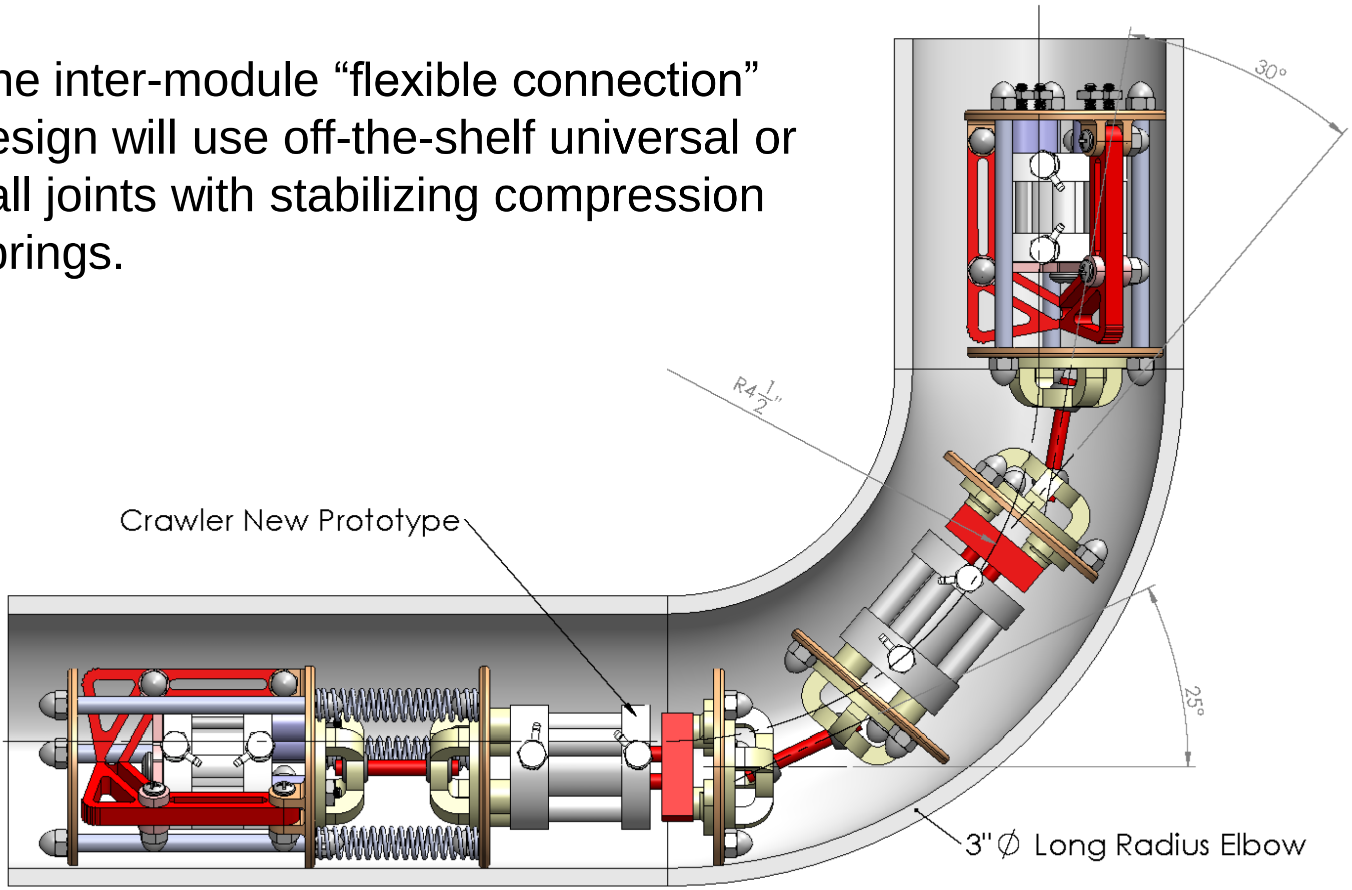
Proposed Concept:



Project 1 - Task 18.2 Development of Inspection Tools for DST Primary Tanks

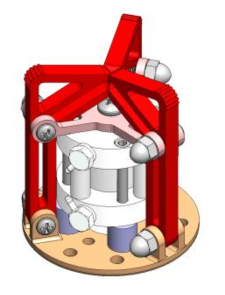
Proposed Concept:

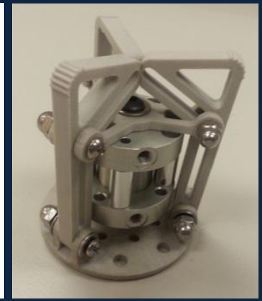
The inter-module "flexible connection" design will use off-the-shelf universal or ball joints with stabilizing compression springs.

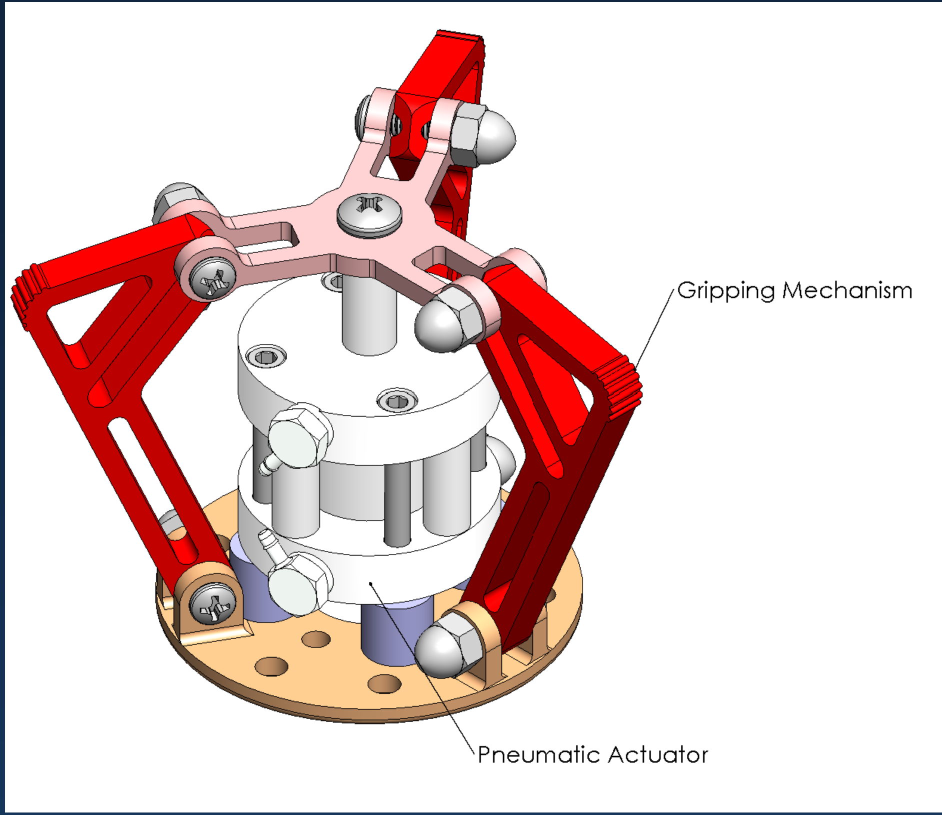


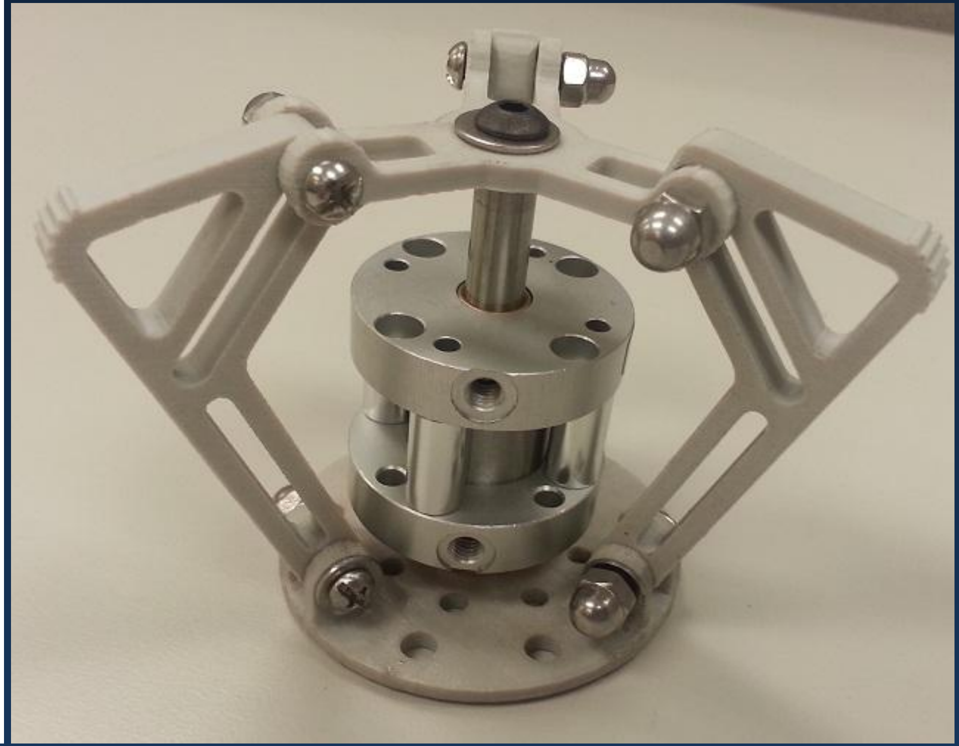
Project 1 - Task 18.2 Development of Inspection Tools for DST Primary Tanks

Proposed Concept:





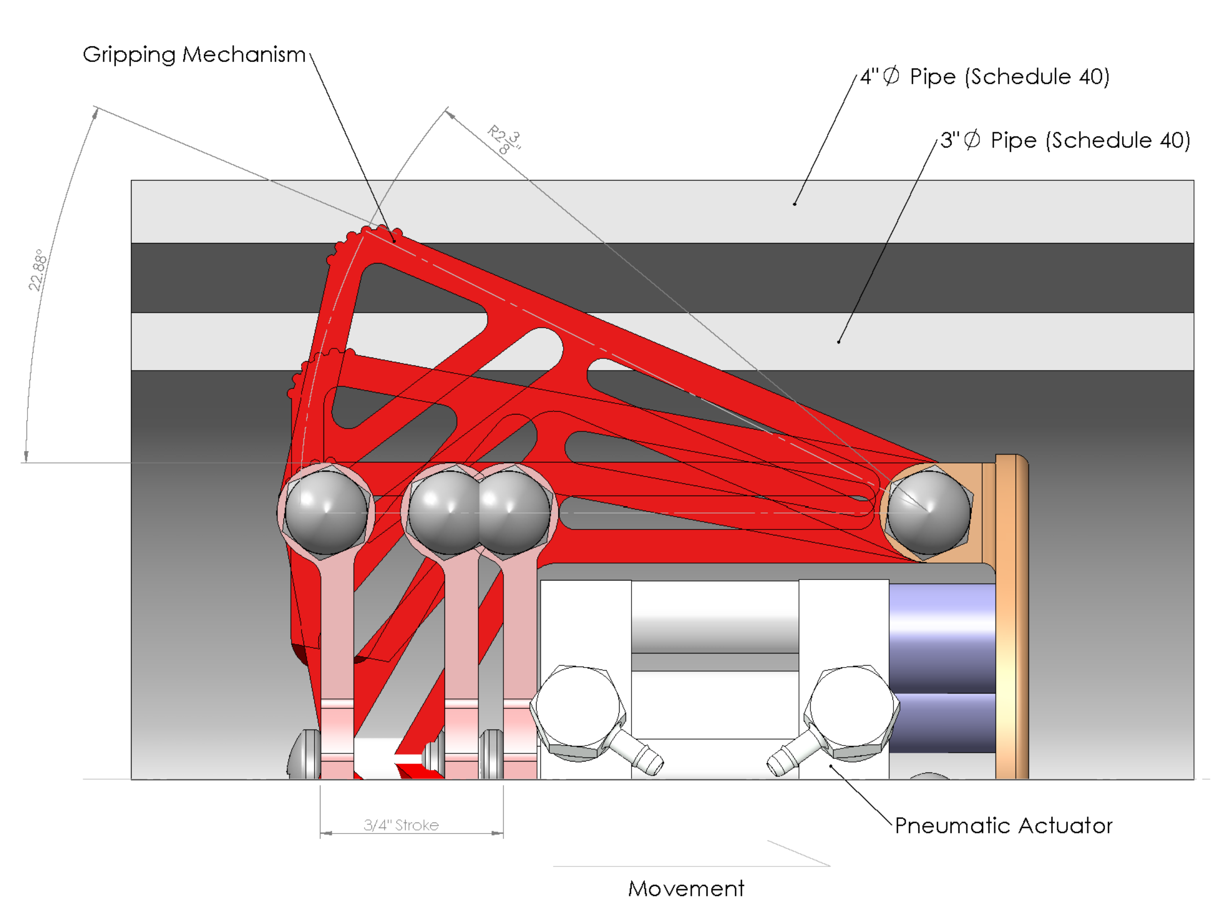


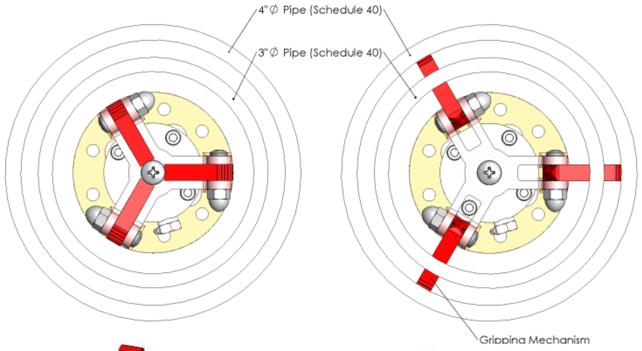


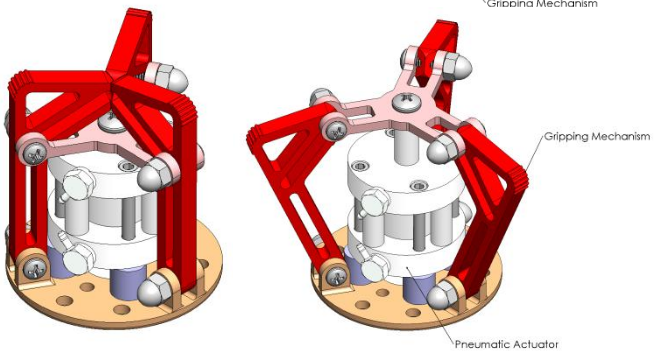
Project 1 - Task 18.2 Development of Inspection Tools for DST Primary Tanks

Proposed Concept:

The mechanism is designed to be self-locking. Possibly allowing gripping forces greater than the 40 lbs provided by the pneumatic actuator.







Project 1 - Task 18.2 Development of Inspection Tools for DST Primary Tanks

Path Forward:

- Develop initial prototype
- Conduct functional testing
- Make design modifications as needed

Project 1 - Task 19.1 Pipeline Integrity and Analysis

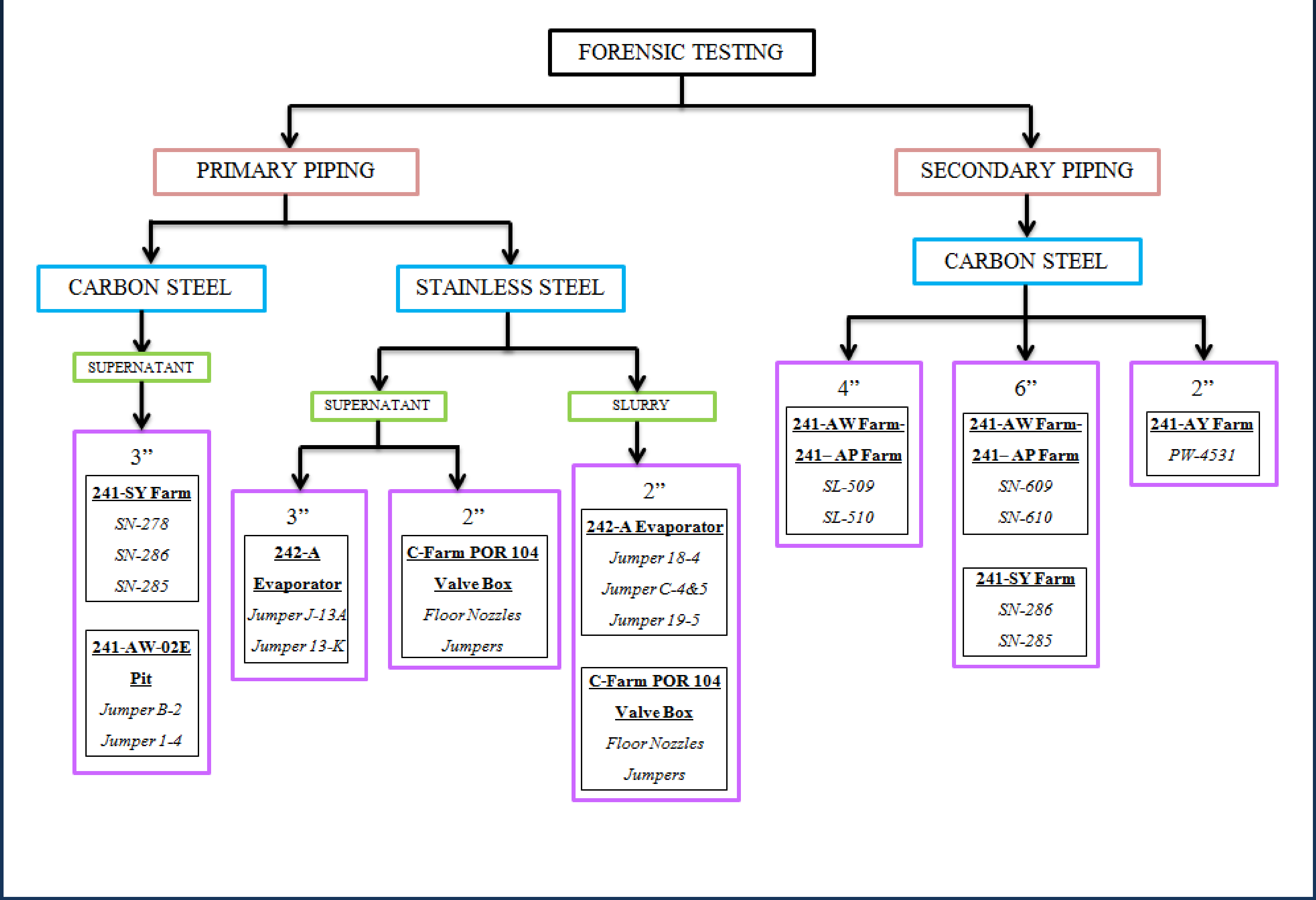
Background

- 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.
- It was recommended that 5% of the buried carbon steel DST's waste transfer line encasements (of the 128 select list lines) be inspected. Seven carbon steel encasement pipelines selected to be exhumed were SN-285, SN-286, SN-278, SL-509, SL-510, SL-609, SL-610 and PW-4531. Primary lines were also inspected including SN-278, SN-286, SN-285.
- Several jumpers in the 242-A Evaporator (18 to 4, C to 4 & 5, J to 13A, 13 to K and 19 to 5) and in the 241-AW-02E Evaporator Feed Pump Pit (B to 2 and 1 to 4) were selected for analysis.

Objective

- Analyze the collected data including thickness measurements, location, material , size, service dates, waste transferred. Determine wear rates to predict the existing system's remaining useful life. This will also be used to determine design allowances needed for new piping and pipe jumpers.

Project 1 - Task 19.1 Pipeline Integrity and Analysis



Project 1 - Task 19.1 Pipeline Integrity and Analysis

242-A Evaporator Pump Room

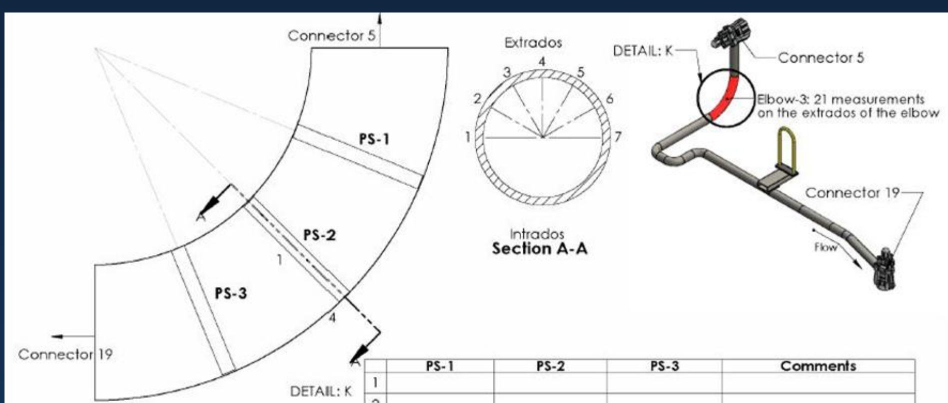
- The jumpers selected were the following: 18-4, C-4&5, J-13A, 13-K, and 19-5.
- The UT measurements collected from jumper 19-5 will assist in future 242-A integrity assessments.

Jumper	Flow Type	Volume (Mgal)	Service Life
19 - 5	Slurry	42	1980 - 2010
C 4 & 5	Slurry	11	Since 1992
18 - 4	Slurry	0	N/A
13 - K	Supernatant	86	Since 1983
J - 13A	Supernatant	29	Since 1983

Project 1 - Task 19.1 Pipeline Integrity and Analysis

242-A Evaporator Pump Room - Jumper 19-5 (Elbow-3)

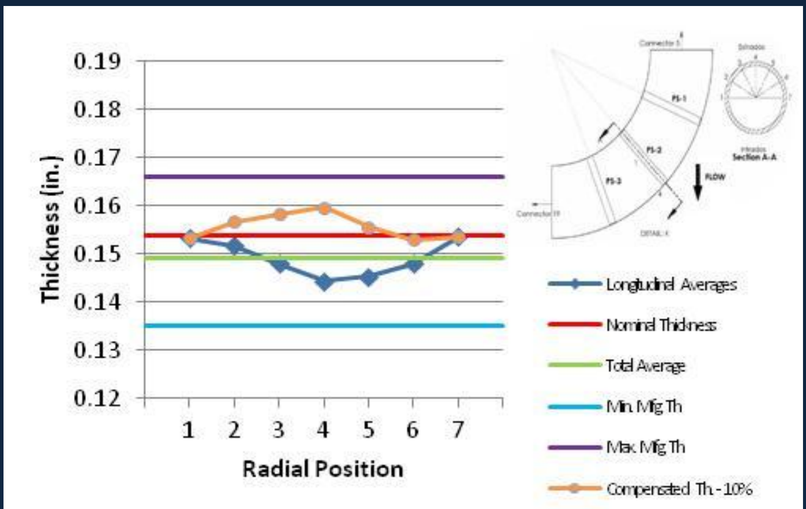
5D bend radius – 2 inch Sch 40 Stainless Steel

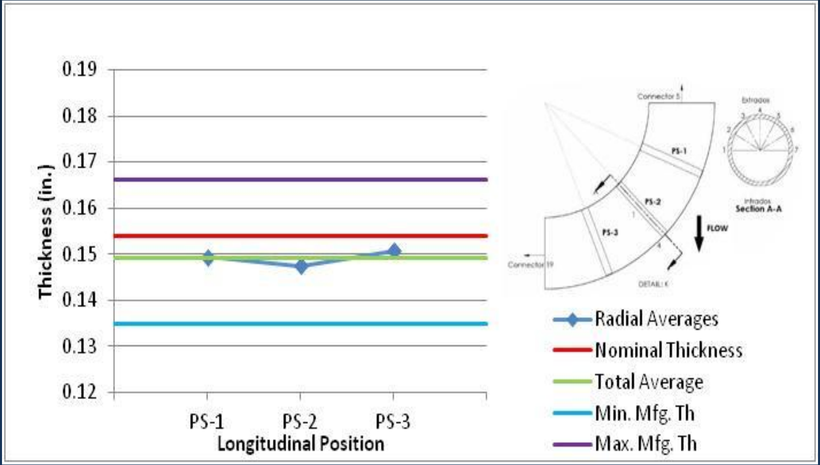


Location	PS -1 (in)	PS-2 (in)	PS-3 (in)
1	0.157	0.143	0.160
2	0.150	0.151	0.154
3	0.147	0.151	0.146
4	0.144	0.145	0.144
5	0.144	0.144	0.148
6	0.148	0.148	0.148
7	0.156	0.150	0.155

Thickness Measurements

Project 1 - Task 19.1 Pipeline Integrity and Analysis





242-A Evaporator Pump Room - Jumper 19-5 (Elbow-3)

- Average longitudinal averages vary symmetrically along the extrados.
- Little variations in longitudinal averages, however average is lower than nominal.
- Based on estimations, the ERUL would be significantly greater than the life required for the estimated volume to be transferred.

	Thickness (in)	Waste (Mgal)
Nominal	0.154	0
Average Measured (2013)	0.149	41.8
Minimum for Operation	0.027	1103.8
Erosion Rate (in/Mgal)	-1.150E-4	

Project 1 - Task 19.1 Pipeline Integrity and Analysis

Summary for 242-A Evaporator Pump Room

Jumper	Section	Average Thickness (in)	Manufacturer's Nominal Thickness (in)	Minimum Manufacturing Thickness (in)
19-5	Elbow-3 (5D Bend Radius)	0.149	0.154*	0.135*
	Elbow-4 (Long Radius)	0.161	0.154*	0.135*
	Straight-3	0.147	0.154	0.135
	Straight-4	0.154	0.154	0.135
18-4	Elbow-1 (5D Bend Radius)	0.154	0.154*	0.135*
	Elbow-2 (Long Radius)	0.172	0.154*	0.135*
	Straight-1	0.155	0.154	0.135
	Straight-2	0.155	0.154	0.135
C-4 & 5	Elbow-5 (Long Radius)	0.161	0.154	0.135*
	Straight-5	0.153	0.154	0.135
	Straight-6	0.155	0.154	0.135
J-13A	Elbow-8 (Long Radius)	0.209	0.216*	0.189*
	Straight-9	0.218	0.216	0.189
	Straight-10	0.228	0.216	0.189
13-K	Elbow-6 (5D Bend Radius)	0.217	0.216*	0.189*
	Elbow-7 (Long Radius)	0.232	0.216*	0.189*
	Straight-7	0.228	0.216	0.189
	Straight-8	0.227	0.216	0.189

Jumper	Flow Type	Volume (Mgal)
19 - 5	Slurry	42
C 4 & 5	Slurry	11
18 - 4	Slurry	0
13 - K	Supernatant	86
J - 13A	Supernatant	29

Jumper	Section	Erosion Rate (in/Mgal)
	Elbow-3	-1.150E-4
19-5	Straight-3	-1.675E-4
	Straight-4	-9.619E-5
C-4 & 5	Straight-5	-9.009E-5
J-13A	Elbow-8	-2.404E-4

Project 1 - Task 19.1 Pipeline Integrity and Analysis

Summary for AW-02E Feed Pit Jumper

Jumper	Section	Average Thickness (in)	Manufacturer's Nominal Thickness (in)	Minimum Manufacturing Thickness (in)
B-2	Elbow-1	0.263	0.216*	0.189 *
	Elbow-2	0.246	0.216*	0.189*
	Straight-1	0.233	0.216	0.189
	Straight-2	0.236	0.216	0.189
	Straight-3	0.231	0.216	0.189
	Connector-B	0.988	0.970	0.940
	Connector-2	0.994	0.970	0.940
1-4	Elbow-1	0.244	0.216*	0.189*
	Straight-1	0.250	0.216	0.189
	Straight-2	0.231	0.216	0.189
	Straight-3	0.234	0.216	0.189
	Straight-4	0.232	0.216	0.189
	Connector-1	0.994	0.970	0.940
	Connector-4	0.994	0.970	0.940

Project 1 - Task 19.1 Pipeline Integrity and Analysis

Summary for the POR104 Valve Box Nozzles

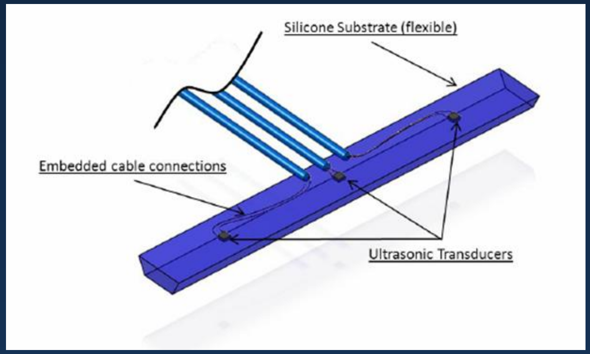
Floor Nozzle	Section	Average Thickness (in)	Manufacturer's Nominal Thickness (in)	Minimum Manufacturing Thickness (in)
B	Elbow	0.169	0.154*	0.135*
	Straight	0.156	0.154	0.135
	Purex Nozzle (Above)	0.275	0.280	0.240
	Purex Nozzle (Below)	0.260	0.263	0.228
C	Elbow	0.163	0.154*	0.135*
	Straight	0.157	0.154	0.135
	Purex Nozzle (Above)	0.271	0.280	0.240
	Purex Nozzle (Below)	0.261	0.263	0.228
E	Elbow	0.165	0.154*	0.135*
	Straight	0.159	0.154	0.135
	Purex Nozzle (Above)	0.278	0.280	0.240
	Purex Nozzle (Below)	0.262	0.263	0.228
F	Elbow	0.168	0.154*	0.135*
	Straight	0.160	0.154	0.135
	Purex Nozzle (Above)	0.277	0.280	0.240
	Purex Nozzle (Below)	0.259	0.263	0.228

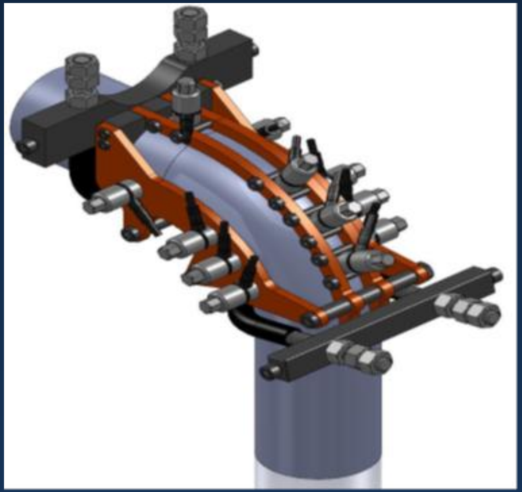
Project 1 - Task 19.1 Pipeline Integrity and Analysis

Path Forward

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





Project 1 – Task 19.2 Evaluation of Nonmetallic Components in the Waste Transfer System

FIU Applied Research Center

Background

- Nonmetallic materials are used in the United States Department of Energy's Hanford Site Tank Farm waste transfer system.
- Materials include the inner primary hoses in the hose-in-hose transfer lines (HIHTLs), Teflon® gaskets, Ethylene Propylene Diene Monomer (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 the nonmetallic components react to each of these stressors individually has been well established. However, simultaneous exposure of these stressors is unknown and is of great concern.

Objective

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

Project 1 – 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

Project 1 – Task 19.2 Evaluation of Nonmetallic Components in the Waste Transfer System

Phase 1 Test Plan

- This year's efforts (Phase 1) will be limited to EPDM material testing. EPDM was selected for this phase of testing due to its use in multiple applications within the Hanford waste transfer system.
- The EPDM material will consist of EPDM HIHTL inner hoses and EPDM O-rings and EPDM gaskets.
- Material will be simultaneously exposed (aged) to both high temperature 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.
- Post exposure mechanical performance testing will be conducted.

Project 1 – Task 19.2 Evaluation of Nonmetallic Components in the Waste Transfer System

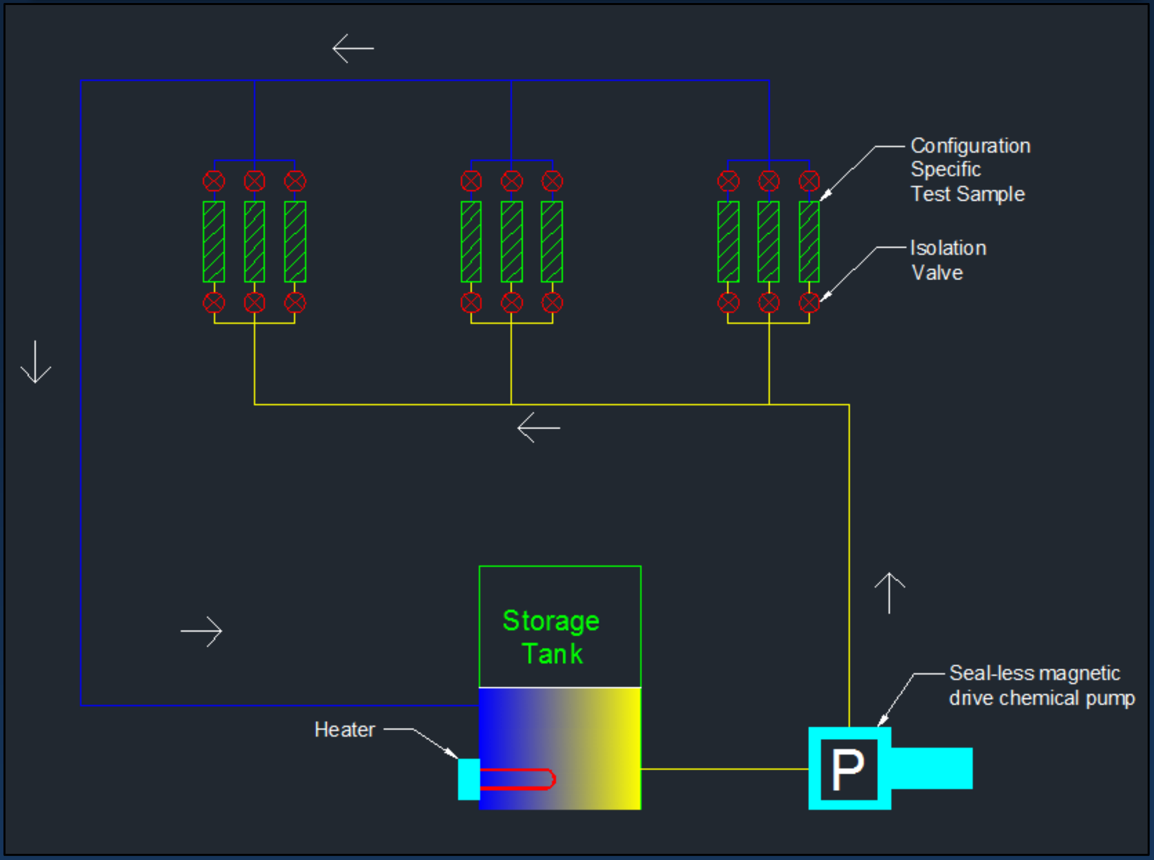
In-Service Configuration Aging

- 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 (70^{o}F), operating (130^{o}F) and design (180^{o}F) temperatures.
- Each manifold section holds three test samples and be used for a corresponding exposure time of 60, 180 and 360 days.
- Test samples will consist of either an EPDM inner hose, EPDM gasket or an EPDM O-ring.

Project 1 – Task 19.2 Evaluation of Nonmetallic Components in the Waste Transfer System

FIU Applied Research Center

In-Service Configuration Aging Loop



Project 1 – Task 19.2 Evaluation of Nonmetallic Components in the Waste Transfer System

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Coupon Aging

- Coupon aging experimental setup will consist of 3 temperature controlled circulating fluid baths maintained at three different temperatures of (70ºF, 130ºF and 180ºF).
- The circulating fluid will be a 25% sodium hydroxide solution.
- Each bath will have three racks with ten coupons suspended on each rack.
- Each rack will be submerged in the bath for a duration of 30, 60 or 180 days.

Project 1 – Task 19.2 Evaluation of Nonmetallic Components in the Waste Transfer System

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Coupon Aging Matrix

Days Exposure	Ambient Temperature (70°F)	Operating Temperature (130°F)	Design Temperature (180°F)	Baseline
0				10 coupon samples
60	10 coupon samples	10 coupon samples	10 coupon samples	
180	10 coupon samples	10 coupon samples	10 coupon samples	
360	10 coupon samples	10 coupon samples	10 coupon samples	

Project 1 – 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 27 aged test samples (9 from each test temperature with 3 at each exposure time).

Project 1 – 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)

Project 1 – Task 19.2 Evaluation of Nonmetallic Components in the Waste Transfer System

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Path Forward

- Fabricate test loop
- Age EPDM materials 60 days
- Conduct tests to quantify material degradation.
- Continue with aging and testing of materials.

- Consider adding pressure as a stressor to the current test matrix.
- Consider other nonmetallic materials for similar testing .

Project 1 – Internships

FIU Applied Research Center

Carmela Vallalta (DOE Fellow - Class of 2013)

- Washington River Protection Solutions (WRPS) under the mentorship of Dennis Washenfelder.
- Prepared waste mitigation and annulus ventilation operating chronologies for DST.

Anthony Fernandez (DOE Fellow – Class of 2014)

- WRPS under the mentorship of Ruben Mendoza.
- Updated SST Enraf's monitoring reference level documentation and baseline change requests.

Sasha Philius (DOE Fellow – Class of 2013)

- WTP (Bechtel) under of mentorship of Joel Peltier.
- Assisted in establishing a new standard vessel design capable of managing challenging waste slurries.

Project 1 – Conferences & Presentations

Waste Management 2015

- Analysis of Erosion/Corrosion Data for High-Level Waste Pipelines at Hanford, Dwayne McDaniel, Jennifer Arniella, Brian Castillo, Dennis Washenfelder (WRPS) and Jason Engeman (WRPS)
- Computational Modeling of Plug Formation in Pipelines, Romani Patel, Deanna Moya, Dwayne McDaniel, Seckin Gokaltun
- Testing of a 3-D Sonar for Future Deployment to Image Solids on the Floor of Hanford HLW Conditioning Tanks, David Roelant, Dayron Chigin

American Nuclear Society (ANS) 2015

- Miniature Motorized Inspection Tool for DOE Hanford Site Tank Bottoms, Ryan Sheffield
- Direct Numerical Simulation of Turbulent Multiphase Bingham Plastic Undergoing Pulse Jet Mixing, Maximiliano Edriei

Project 1 – Conferences & Presentations

FIU Applied Research Center

Student Posters at Waste Management 2015

- Enraf(R) Reference Level Updates for High-Level Nuclear Waste Tanks at Hanford Site - Anthony Fernandez (DOE Fellow)
- Erosion & Corrosion Analysis from POR104 Valve Box at Hanford - Brian Castillo(DOE Fellow)
- Residual Waste Imaging in High Level Waste Mixing Tanks - Dayron Chigin (DOE Fellow)
- Non-Invasive Pipeline Unplugging Technology for Hanford High-Level Waste Asynchronous Pulsing System - John Conley (DOE Fellow)
- Miniature Motorized Inspection Tool for Department of Energy Hanford Site Tank Bottoms - Ryan Sheffield (DOE Fellow)

Journal Publications

S. Gokaltun, D. McDaniel, A. Awwad and J. Varona, “Pipeline unplugging experiments with the fluidic Wave-Action Technology”, *Engineering Science and Technology, an International Journal*, 17 (2014) 73-84.