FIU | Applied Research Center
Florida International University

Project 1: Chemical Process Alternatives for Radioactive Waste

2/25/2014

Worlds Ahead

Outline

- Overview of Tasks
- Task Highlights
  - Development of Alternative Unplugging Technologies
  - Computational Simulation and Evolution of HLW Pipeline Plugs
  - MRT LBM High Density Ratio Multiphase Flows
  - Evaluation of SLIM for Measurement of HLW Solids on Tank Bottoms
  - Development of Inspection Tools for DST Primary Tanks
  - Pipeline Corrosion and Erosion Analysis
- Year 5 Tasks

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 the Lattice Boltzmann method, 3) quantification of residual waste on the floors of staging tanks, 4) development of inspection tools for DST primary tanks, 5) Pipeline integrity analysis

Staff and Students

Project Manager: Dwayne McDaniel

Faculty/Staff: Seckin Gokaltun, Amer Awwad, Tomas Pribanic, Romani Patel, Jairo Crespo, Dave Roelant

Students/DOE Fellows: Gabriela Vazquez, Jennifer Arniella, Sasha Philius, Carmela Vallata, Alex Fleitas, Mike Abbott, Dayron Chigin, Deanna Moya, Adam Manoussakis

Project Tasks and Scope

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

- develop a multiple-relaxation time, lattice Boltzmann model for high-density ratio multiphase flows

Task 18 Technology Development and Instrumentation Evaluation

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

Task 19 Pipeline Integrity and Analysis

– Pipeline corrosion and erosion evaluation (new)

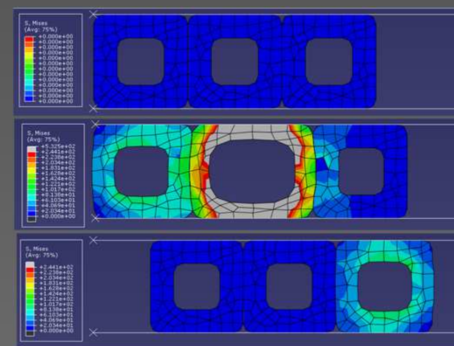
TASK 2.1 DEVELOPMENT OF ALTERNATIVE UNPLUGGING TECHNOLOGIES

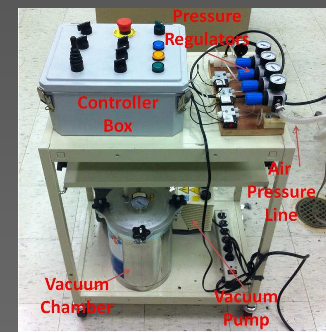
Background

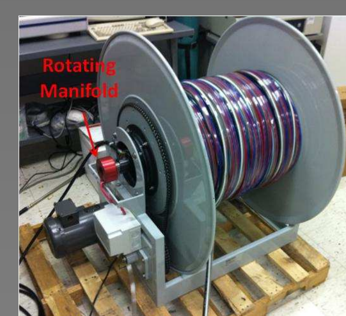
- Approximately 56 million gallons of HLW is currently being stored at Hanford. The transfer of waste to DSTs or the WTP create potential for plugging which can delay project milestones and be hazardous and expensive to repair.
- Industry call (~ 2002) - a number of pipeline unplugging technologies were evaluated. NuVision's Wave Erosion technology and AIMM's Hydrokinetic technology 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

Previous Efforts/Accomplishments

- Proposed concept with a peristaltic crawler and developed/improved various aspects of the design
- Designed and manufactured pneumatic and hydraulic system to power the motion of the unit and the unplugging mechanism
- Added video feedback system to crawler for inspection operations
- Validated modifications at bench scale level and currently are verifying applicability on an engineering scale.



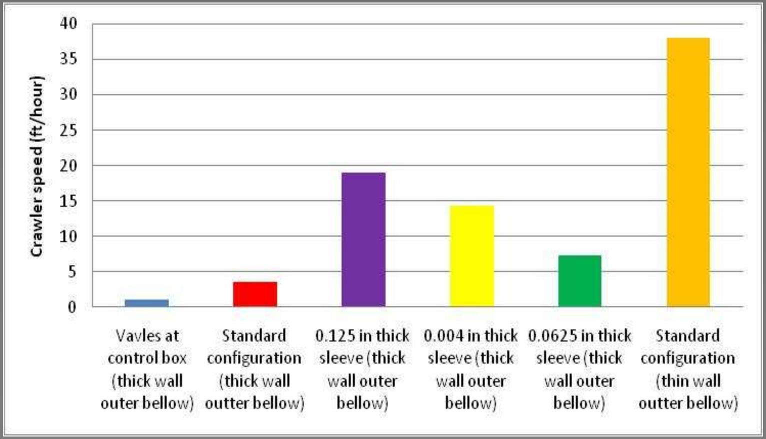


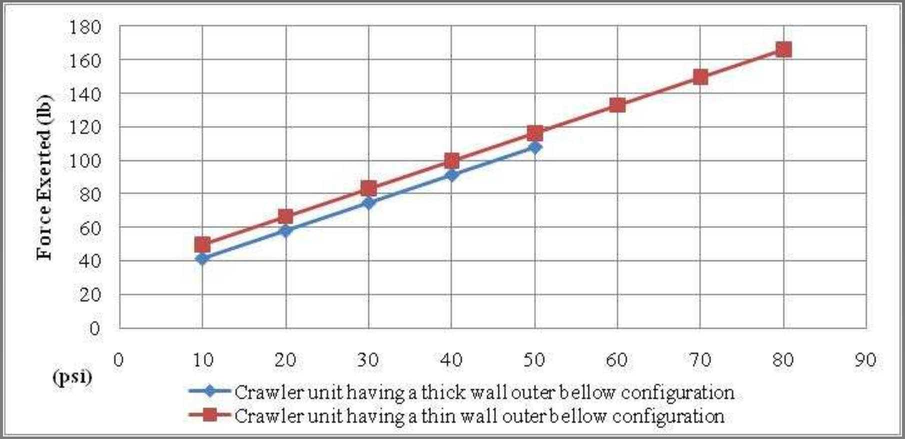


Previous Efforts/Accomplishments

Bench Scale Testing Results

- Demonstrated a navigational speed of 38 ft/hour
- Successfully unplugged bentonite, Kmag, Na-Al-Si plugs
- Generated an axial force of 108 lb

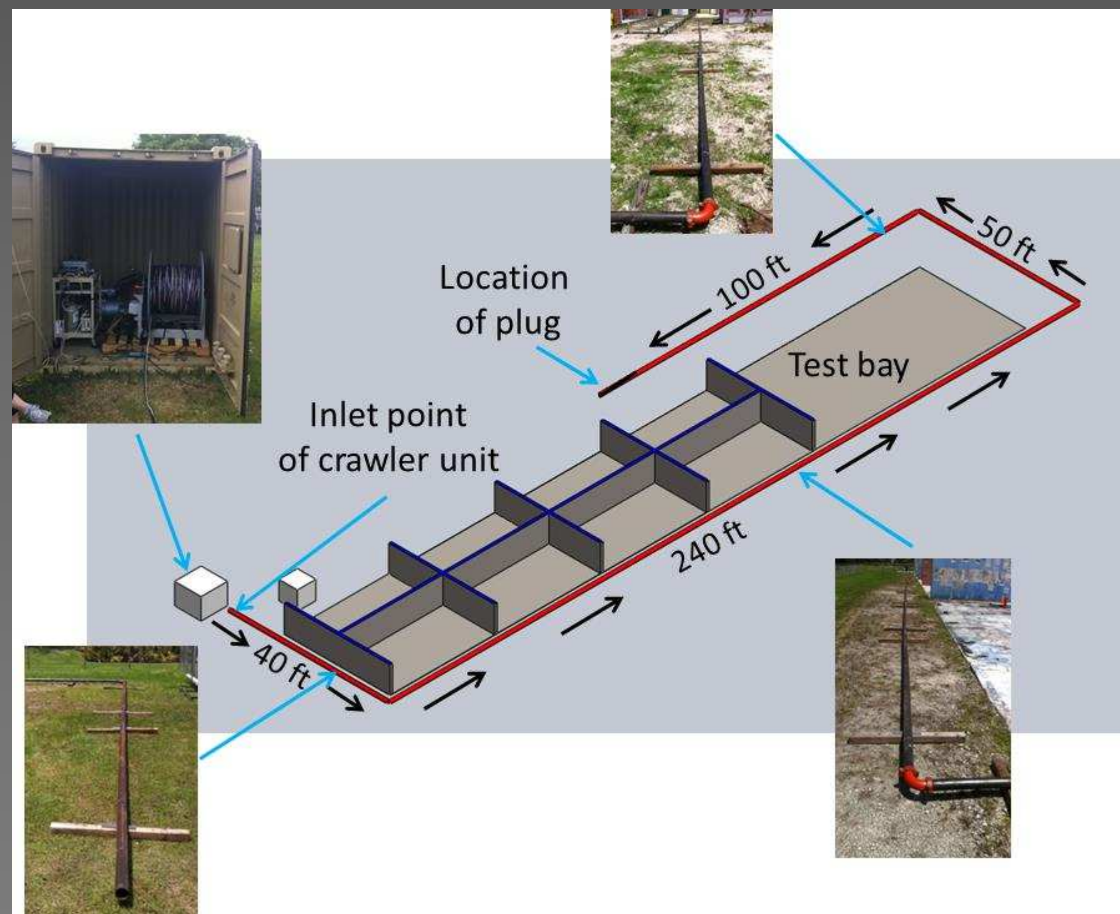




Peristaltic Crawler

Current Effort - focuses on large scale validation of the crawler

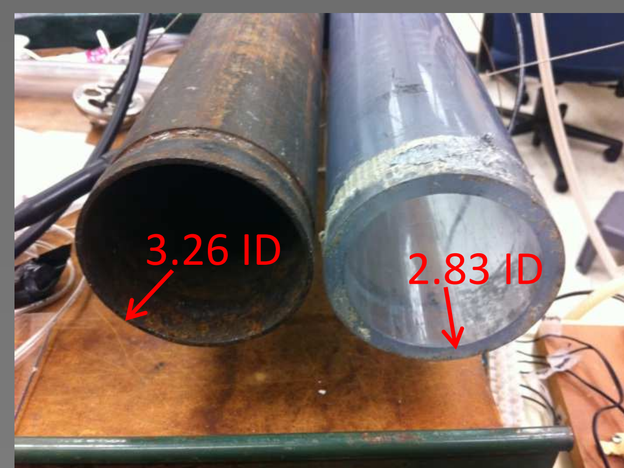
- Fatigue limits of components
- Pull force requirements for dragging the tether inside the pipeline
- Modifications required – changing outer bellow, rims, and expansive materials



Peristaltic Crawler

Engineering Scale Testing

- Testing revealed premature failure of the cavities
- Materials, clamping pressures, and clamp liners were tested
- A difference in diameter between the pipelines of the bench scale testbed and the large tesbed created new expansion requirements
- A total of approximately 3,600 cycles is required to navigate the 430 ft testbed



Peristaltic Crawler

Modification to Design

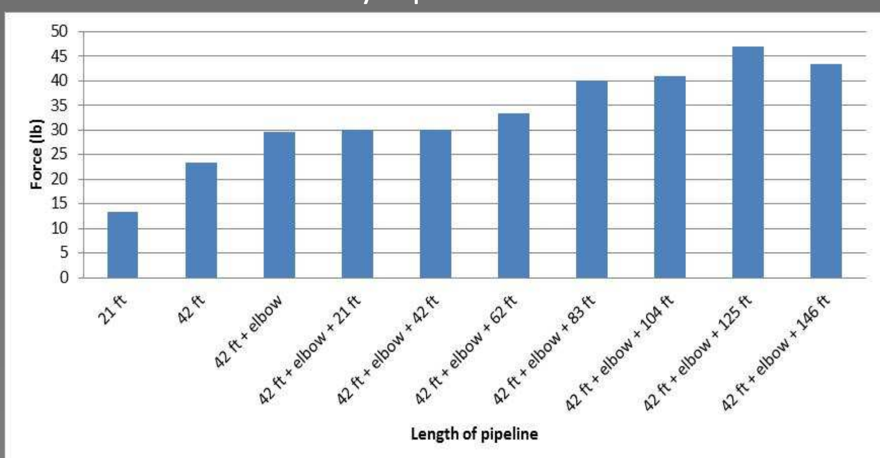
- Increasing the distance between the clamps provides more material for expansion but can affect turning ability
- A fatigue fixture was fabricated to test different camping distances
- A distance of 1.75 in provides no failure on a 14,000 cycle test.
- A distance of 1 in provides a total of 15,000 cycles prior to failure

Peristaltic Crawler

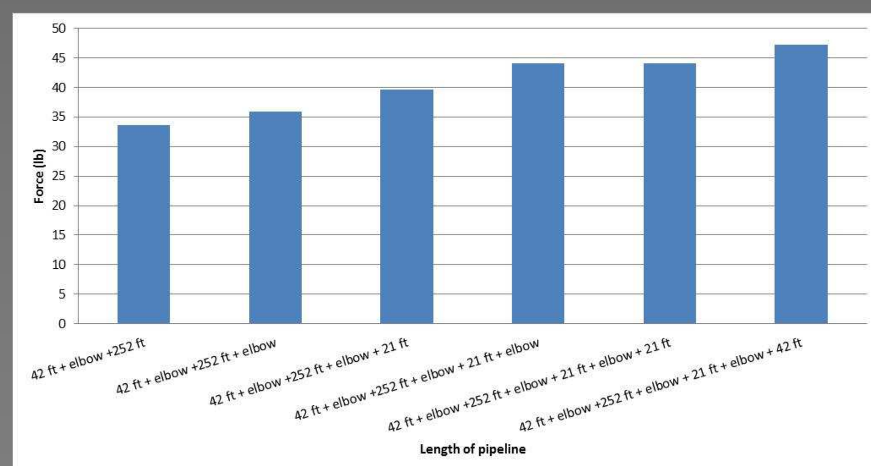
Further Modifications and Testing

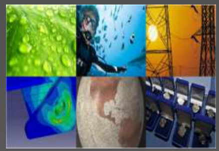
- Friction between tether and pipeline created extreme load requirements
- A 0.051 in diameter stainless steel wire was wounded on the tether
- Elbows significantly increase tether pull force requirements
- Flooding the pipe provides a drastic decrease in the coefficient of friction

Dry Pipeline



Flooded Pipeline

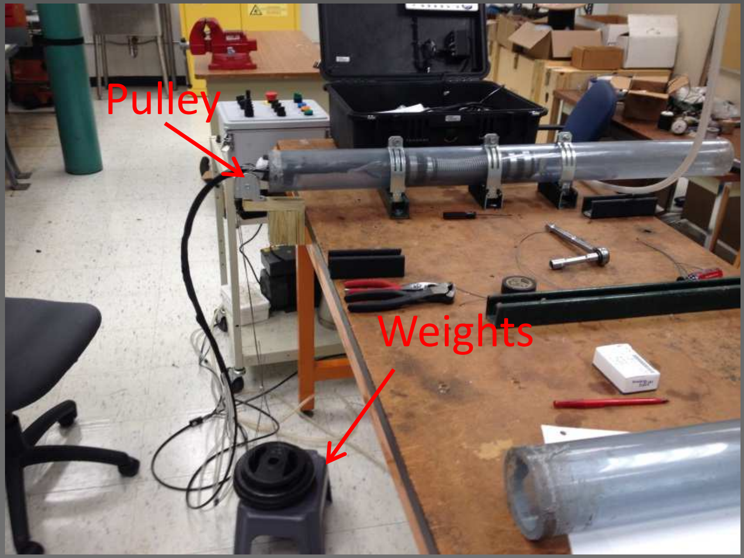




Peristaltic Crawler

Further Testing

- Current efforts include recoding the response of the system to different pull force requirements
- Navigational speed is reduced with increasing pull force requirements
- Current tests include response on elbows



			1st Trial			2nd Trial			3rd Trial			4th Trial		
Pounds	Bellow Pressure (psi)	Rim Pressure (psi)	Time (min/sec)	Inches	Speed (ft/hr)	Time (min/sec)	Inches	Speed (ft/hr)	Time (min/sec)	Inches	Speed (ft/hr)	Time (min/sec)	Inches	Speed (ft/hr)
No load	20	80	2.07	14.69	**35.48**	1.51	13.13	**43.46**						
5	10	80	3.45	12.38	**17.93**									
10	10	80	4.36	16.31	**18.71**									
15	20	80	the bellow. Stopped test at 6.36 because the crawler got stuck at stopped moving at 6.5 inches			6.23	18.13	**14.55**	6.41	18.25	**14.24**	6.40	15.69	**12.26**
20	30	80	the bellow. Stopped test at 4.09 because the crawler got stuck at stopped moving at 0.4375 inches			8.31	14.75	**8.87**	6.28	15.88	**12.64**	6.55	16.75	**12.79**
25	40	80	Would not move more than a quarter of an inch. Bellow Pressure was even increased to 50 and 60 psi.											

Peristaltic Crawler

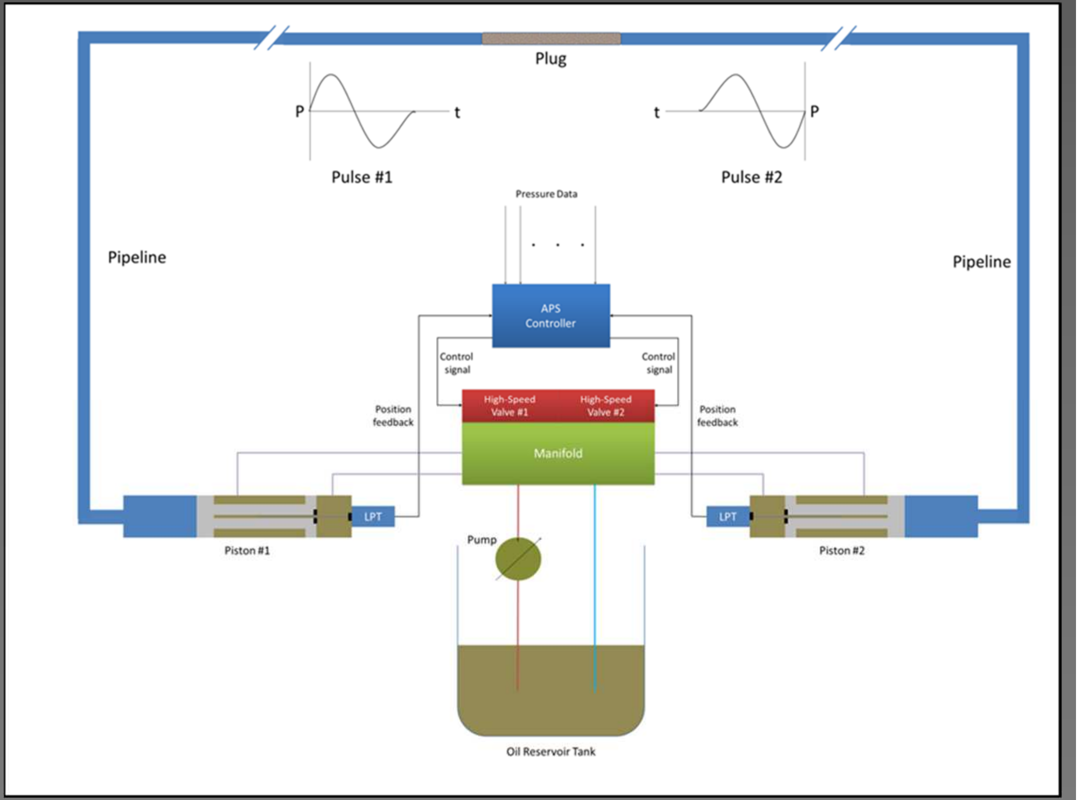
Path Forward:

- Complete engineering scale testing
- Complete topical report
- Investigate opportunities for onsite testing

Asynchronous Pulsing System

System Description:

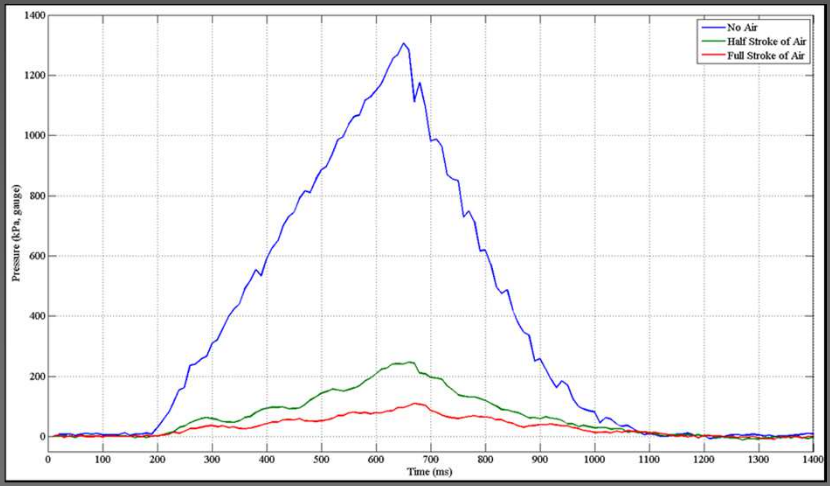
- Principle – pressure pulses created asynchronously from both sides of the plug to capitalize on dynamic loads
- Hydraulic power unit – 7GPM capacity, operating pressure – 200 to 3000 psi
- Hydraulic oil / water tandem pistons, 1.5” diameter bore, 10.0” stroke, operating pressure 2000 psi
- Proportional directional control valves, 250 Hz max frequency

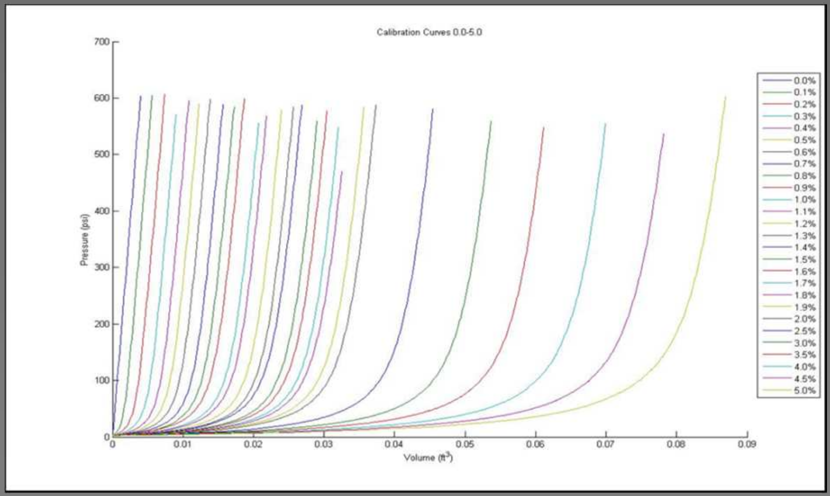


Previous Efforts/Accomplishments

Asynchronous Pulsing System:

- Conducted computational simulations to demonstrate proof of concept
- Developed a bench scale testbed to validate concepts and conduct studies to provide an understanding of various parameter effects
  - Developed systematic process to better estimate system performance at pipeline lengths of 72, 100, and 143 ft.
  - Quantified the effects of air on pulse magnitude and propagation
  - Generated air calibration curves for systems with up to 5% air





Asynchronous Pulsing System

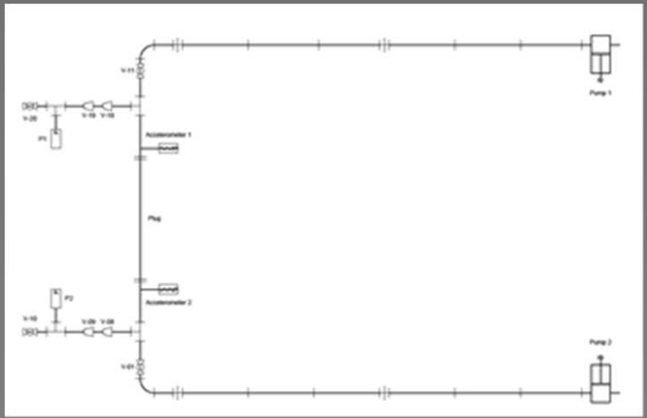
Current Testing:

Objective

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



Asynchronous Pulsing System

Test Plan

- Conduct parametric testing – static pressure, pulse amplitude, pulse frequency, % air

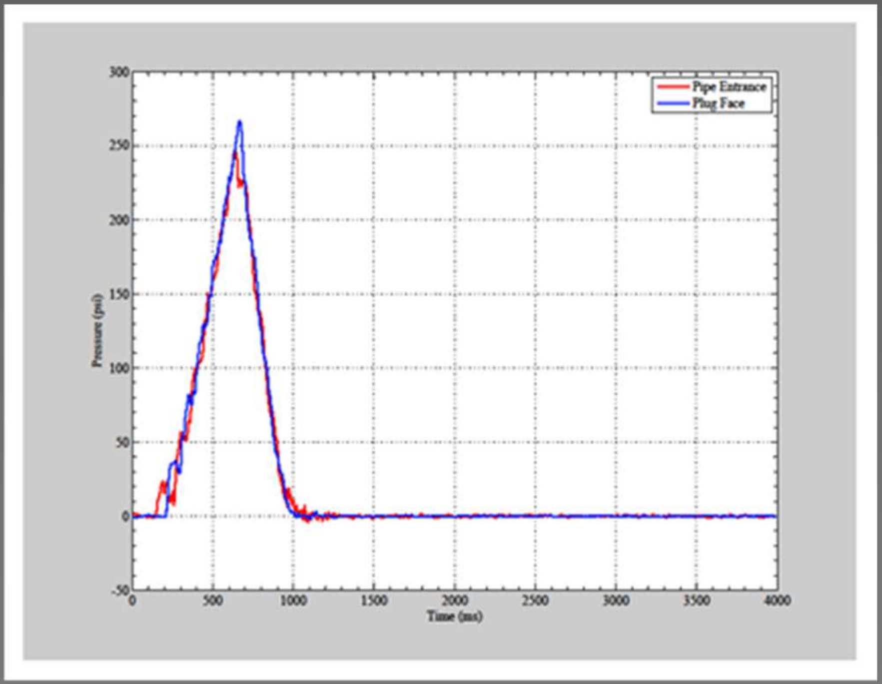
Static Pressure (PSI)	Pulse Frequency (Hz)			
50	0.25	0.50	0.75	1.0
100	0.25	0.50	0.75	1.0
200	0.25	0.50	0.75	1.0
50 (0.5% Air)	0.25	0.50	0.75	1.0
100 (0.5% Air)	0.25	0.50	0.75	1.0
200 (0.5% Air)	0.25	0.50	0.75	1.0

- From parametric testing – use optimal system parameters to unplug 3ft kaolin /plaster of Paris plugs

Asynchronous Pulsing System

Single Pulse Test:

- 0-psi static pressure

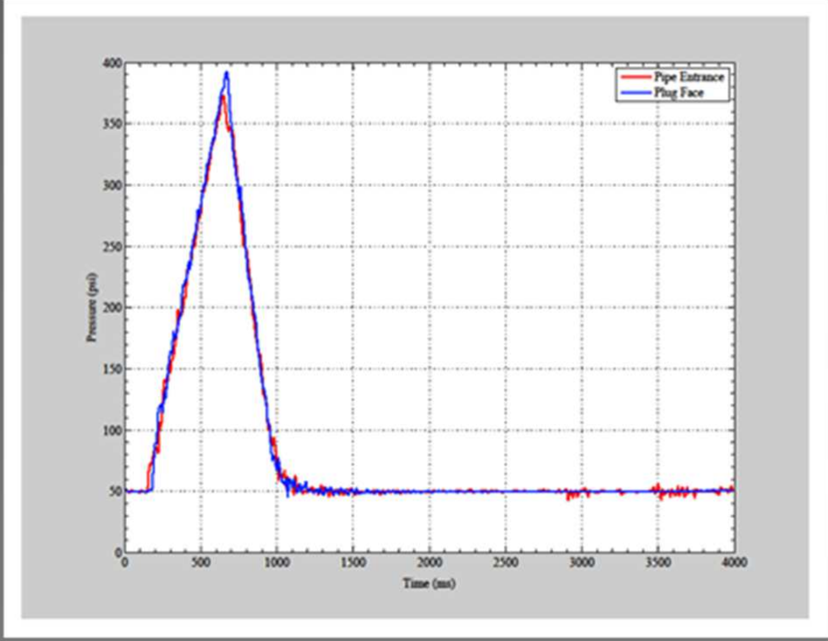


- 30-psi pressure amplification was observed with a 270-psi max pressure

Asynchronous Pulsing System

Single Pulse Test:

- 50-psi static pressure



- 20-psi pressure amplification was observed with a 390-psi max pressure

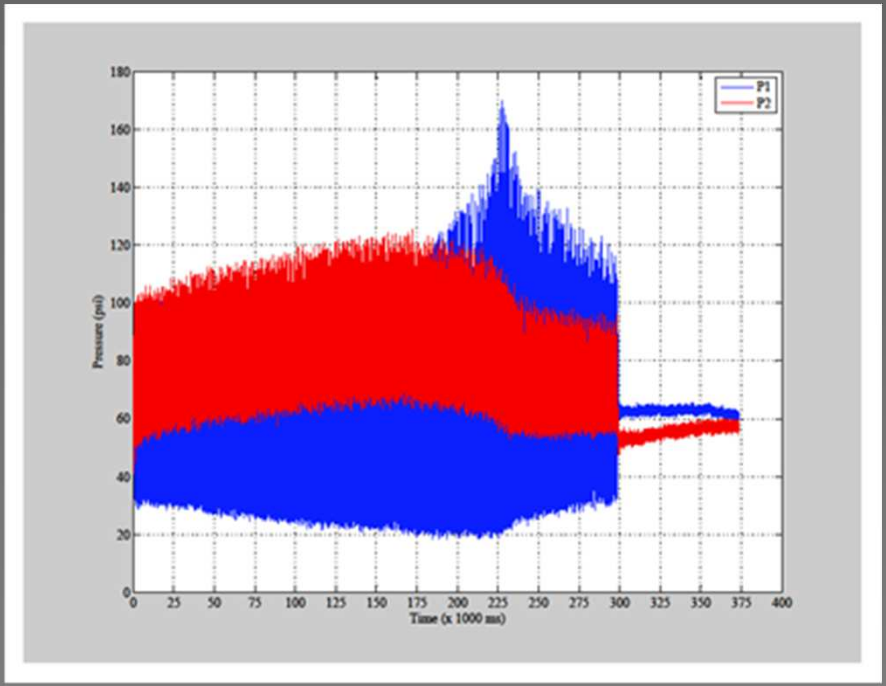
Asynchronous Pulsing System

Unplugging of 3-ft kaolin-plaster plugs:

Asynchronous Pulsing System

Unplugging of 3-ft kaolin-plaster plugs:

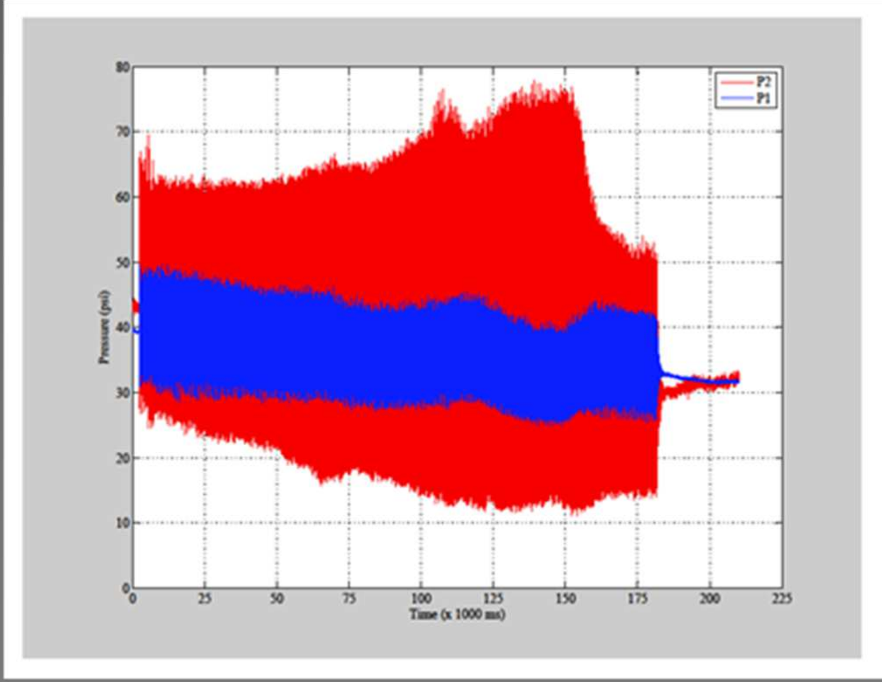
- 1.5 Hz. pulse frequency
- 50 psi static pressure
- P2 had a smaller pressure range than P1 due to the P2 side of the pipe loop containing more air than the P1 side
- Before unplugging occurred P1 started to increase as P2 was decreasing. This is due to water starting to leak past the plug from the P2 side to the P1 side



Asynchronous Pulsing System

Unplugging of 3-ft kaolin-plaster plugs:

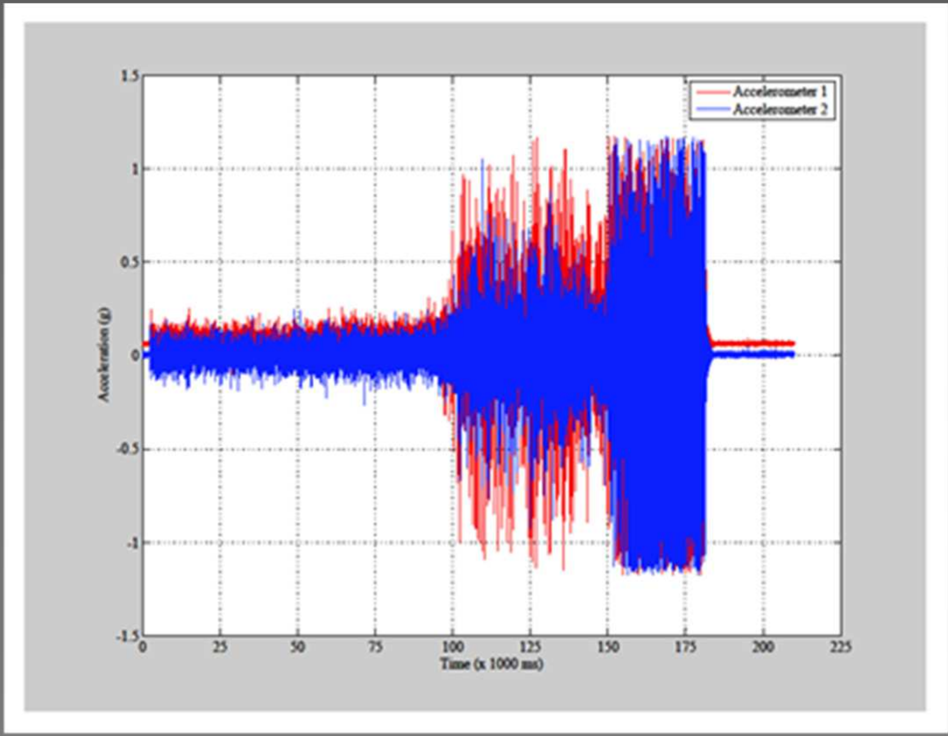
- 0.5 Hz. pulse frequency
- 50 psi static pressure
- P2 had a smaller pressure range than P1 due to the P2 side of the pipe loop containing more air than the P1 side
- Before unplugging occurred P1 started to increase as P2 was decreasing. This is due to water starting to leak past the plug from the P2 side to the P1 side



Asynchronous Pulsing System

Accelerometer Data During Unplugging:

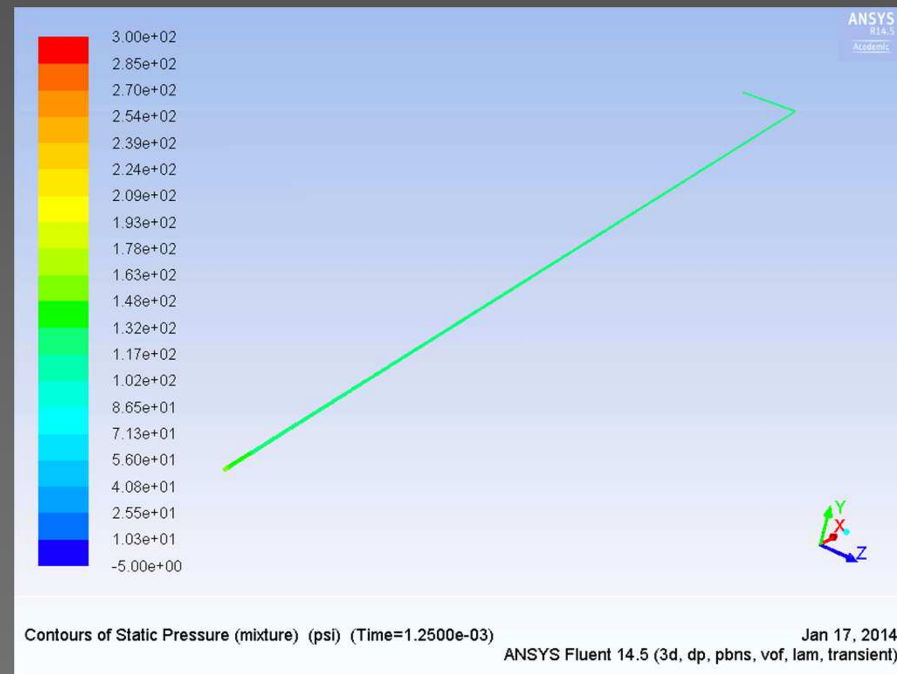
- Pipeline mounted accelerometers on both sides of the plug
- 0.5 Hz. pulse frequency
- 50 psi static pressure

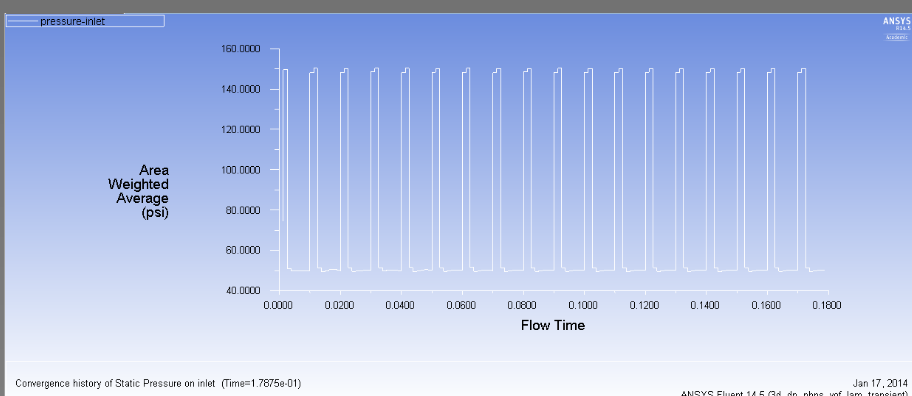


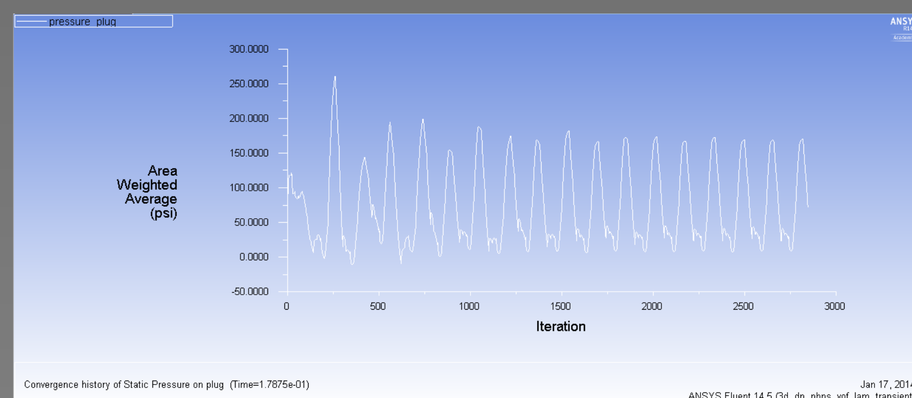
Asynchronous Pulsing System

3D Modeling of Fluid Transients

- Navier Stokes based simulations using Fluent
- 100 Hz pulse frequency
- 100 psi static pressure, 50 psi pulse amplitude
- 0.09 inches of air along length of pipe







Asynchronous Pulsing System

Path Forward:

- Complete engineering scale testing
- Validate CFD simulations with experimental testing
- Complete topical report
- Investigate opportunities for onsite testing

TASK 2.2 COMPUTATIONAL SIMULATION AND EVOLUTION OF HLW PIPELINE PLUGS

Background

- Approximately, 56 million gallons of HLW at Hanford Site
- Transferred via pipelines in slurry form between tanks and from tanks to the processing facilities
- Several lines have plugged during the waste transfer process
- Plugged pipelines are difficult and expensive to repair and delays the waste transfer process

Objective

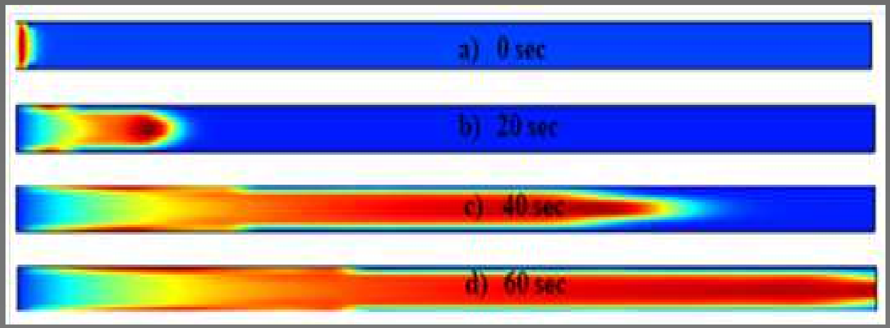
- Current tools used to mitigate the plugging risk include ESP and critical velocity correlations
- The tools do not account for the chemical-flow dynamics
- A need exists to develop computational models with a focus on the multi-physical (chemical, rheological, mechanical) processes that can influence the plug formation process
- The objective is to create a multi-physics model that simulates the formation of a pipeline plug and looks at the influence of pipeline geometry/configuration on the plug development process

Previous Efforts/Accomplishments

- A literature review was conducted to investigate the plugging incidents, plugging mechanisms that caused them and current analysis tools used at Hanford to reduce the risk of plugging.
- The ability of CFD software, COMSOL, to model multi-physics interactions was verified by creating single phase model simulating coupled flow-chemical interactions.

Flow

+



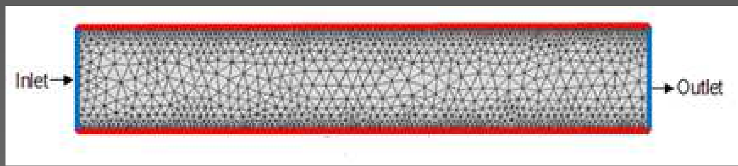
Chemical Reactions

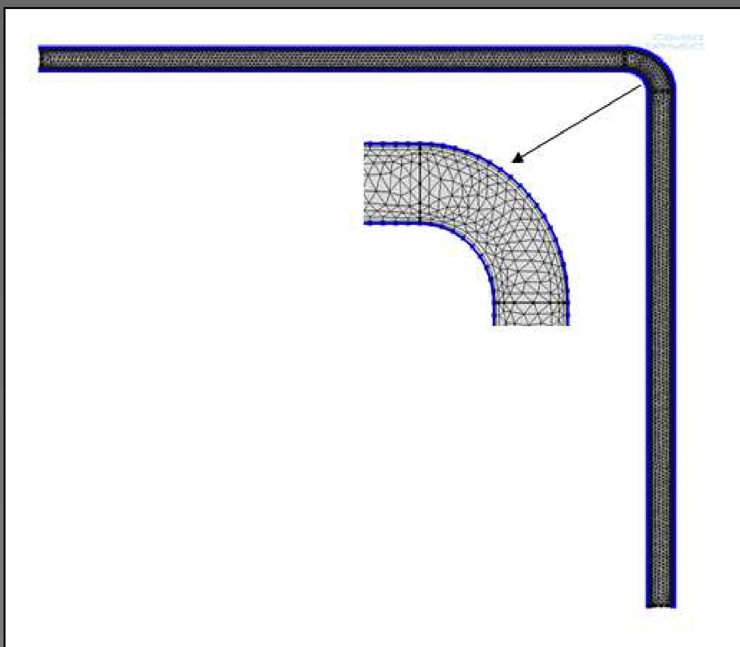
Computational Simulation of HLW Pipeline Plugs

- The single phase simulations were then extended to multi-phase (solid-liquid mixture) simulations. The goal was to create baseline models simulating settling of solids as a function of solids density, solids volume fraction and particle size.
- The models consisted of a horizontal pipe section. The influence of bends on the settling characteristics was investigated by adding a 90° elbow to the geometry.
- Numerical results were compared with experimental results and critical velocity correlations.

Computational Simulation of HLW Pipeline Plugs

Model Geometry



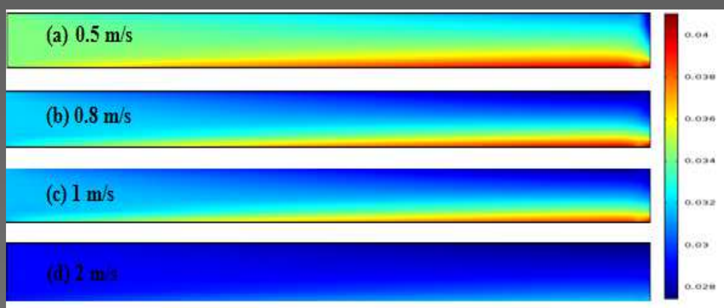


Simulation Matrix

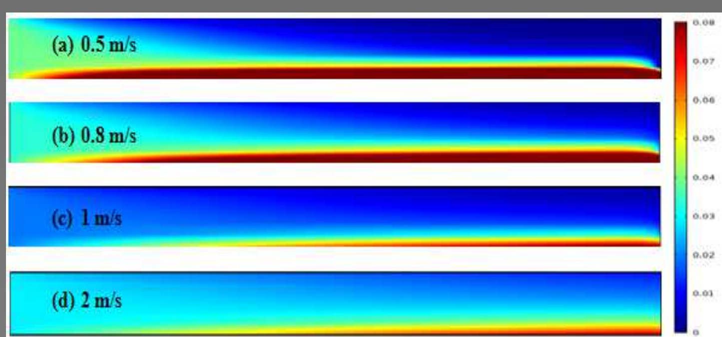
	Simulation Matrix				
Test Configuration	**1**	**2**	**3**	**4**	**5**
Particle diameter (μm)	14.4	37.7	129.5	182.3	203.9
Solids Density (kg/m^3)	2500	7950	3770	2500	7950
Solids volume fraction (%)	9.8	9.3	8.7	7.4	3.0
Liquid density (kg/m^3)	1146	1647	1151	999	1026
Liquid viscosity (cP)	10.2	9.3	4.5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

Computational Simulation of HLW Pipeline Plugs

Particle Size vs Solids Settling



45 µm



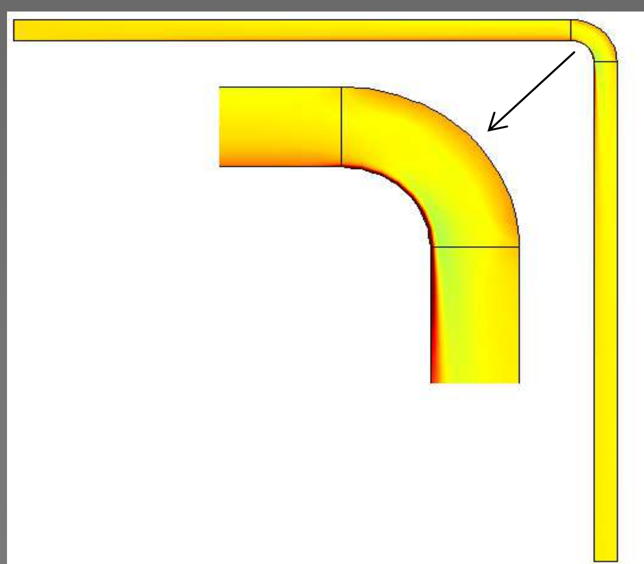
200 µm

Solids Density vs Solids Settling

Computational Simulation of HLW Pipeline Plugs

No Elbow

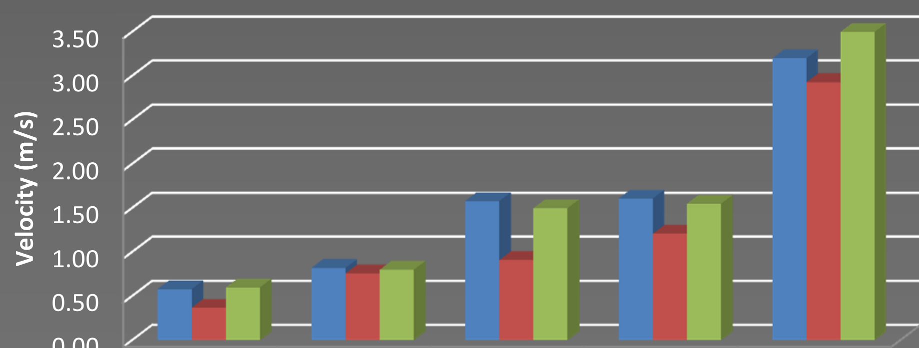
Influence of Elbow



- The critical velocity at which no settling occurs was computed at 2 m/s for a horizontal pipe section.
- The simulations were run at the same velocity and material properties. The geometry was modified to include a 90 ° elbow between two pipe sections.
- The solids were seen deposited at the inner wall of the elbow and thereafter

Computational Simulation of HLW Pipeline Plugs

Comparison of Numerical Versus Experimental and Empirical Results



	1.00	2.00	3.00	4.00	5.00
Empirial Correlations (m/s)	0.58	0.82	1.58	1.61	3.20
PNNL Experimental Values (m/s)	0.37	0.76	0.91	1.21	2.93
COMSOL Results (m/s)	0.60	0.80	1.50	1.55	3.50

- Numerical simulations agree with experimental and empirical results
- Lack chemical kinetics and rheological dynamics

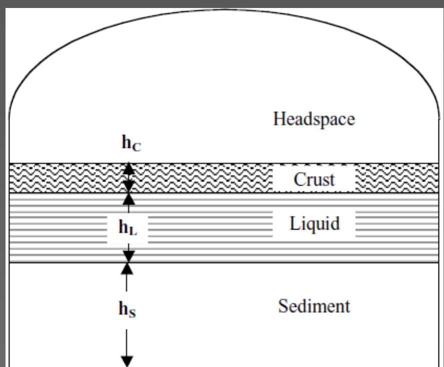
Computational Simulation of HLW Pipeline Plugs

Path Forward:

- The current model assumes that the particle size is static, but, in actual waste transfers the particle size is dynamic due to particle-particle interactions, precipitation, agglomeration, chemical reactions, etc.
- A change in the chemical environment influences the properties and quantity of solids in the waste stream, which in turn influences the slurry viscosity. The slurry viscosity and the solids properties both influence the flow properties. Chemistry affects flow and flow affects chemistry.
- Hence, going forward the mixture model will be expanded to investigate the chemical-flow interactions.

TASK 17.1 MULTIPLE-RELAXATION TIME, LATTICE BOLTZMANN MODEL FOR HIGH-DENSITY RATIO MULTIPHASE FLOWS

Motivation: Gas Generation in DSTs



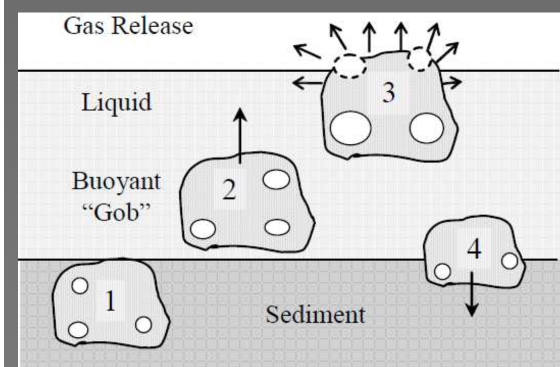
Waste forms existing in a tank.

RECOMMENDATION 2012-2 TO THE SECRETARY OF ENERGY
Hanford Tank Farms Flammable Gas Safety Strategy
Pursuant to 42 U.S.C. § 2286a(a)(5)
Atomic Energy Act of 1954, As Amended

Dated: September 28, 2012

Background

The Defense Nuclear Facilities Safety Board (Board) believes that current operations at the Hanford Tank Farms require safety-significant active ventilation of double-shell tanks (DSTs) to ensure the removal of flammable gas from the tanks' headspace. A significant flammable gas accident would have considerable radiological consequences, endanger personnel, contaminate portions of the Tank Farms, and seriously disrupt the waste cleanup mission. Further, the Board believes that actions are necessary to install real time monitoring to measure tank ventilation flowrates as well as upgrade other indication systems used to perform safety-related functions.



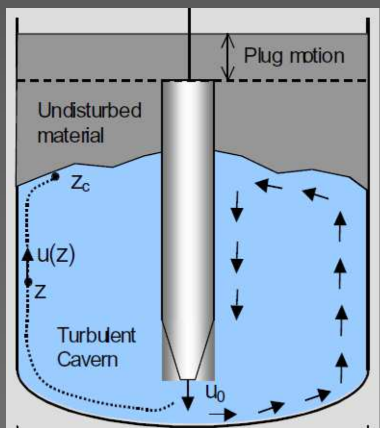
Schematic of BDGRE.

- Buoyant Displacement Gas Release Events (BDGRE) :
  - Radiolysis of water, Radiolytic and chemical oxidation reactions of the organic compounds, Corrosion of the steel tank walls (Stock 2000).
  - Mainly H2, nitrogen etc.
- Can occur during retrieval of waste from DSTs:
  - Decanting the supernatant liquid
  - Jet mixer pumps
- Lower flammability limit (LFL)

Workers replacing headspace vapor sampling with test ports in the tank outlet ventilation lines (source: RPP Facebook page, April 4, 2013)

Motivation: HLW Mixing

Pulsed-Jet Mixers:



Typical Pulse-Jet Mixer System
(Meyer, 2008, PNNL)

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

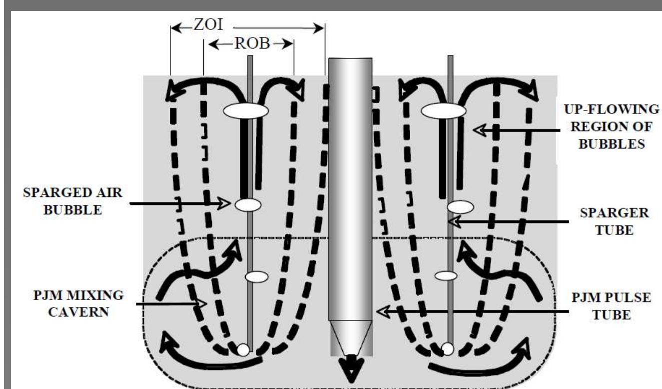
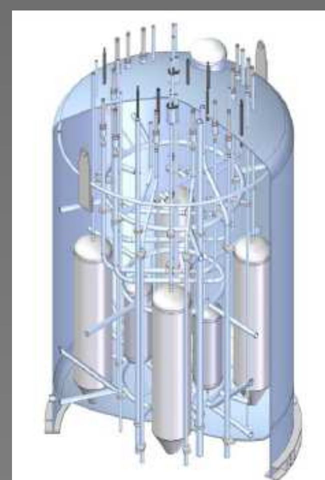
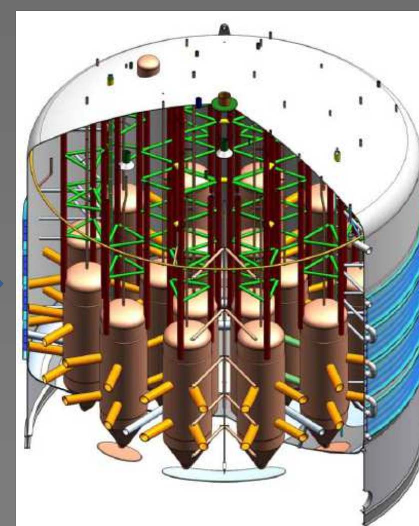


Illustration of Hybrid PJM/Sparger Mixing Concept.
(Stewart et al., 2007, WTP-RTP-156)



Full scale testing



Lattice Boltzmann Method

$$f_\alpha(\mathbf{x} + e_\alpha \delta t, t + \delta t) = f_\alpha(\mathbf{x}, t) + \Omega_\alpha$$

$f(\mathbf{x}, \xi, t)$	:	particle velocity distribution function
ξ	:	particle velocity vector
$\mathbf{x}$	:	spatial position vector
t	:	time
$\mathbf{F}$	:	force vector
Ω	:	collision term

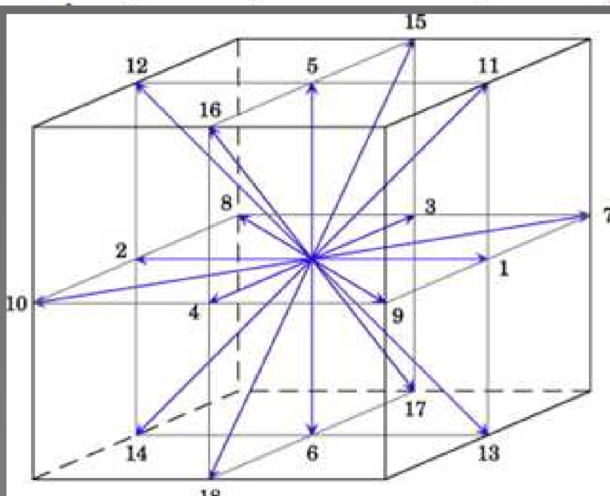
1.Collision :

BGK : $\Omega_\alpha = -\frac{\delta_t}{\tau}\left(f_\alpha - f_\alpha^{eq}\right)$, where $\tau = \lambda/\delta_t$.

MRT : $\Omega_\alpha = -\Lambda_{\alpha\beta}\left(f_\beta - f_\beta^{eq}\right)$

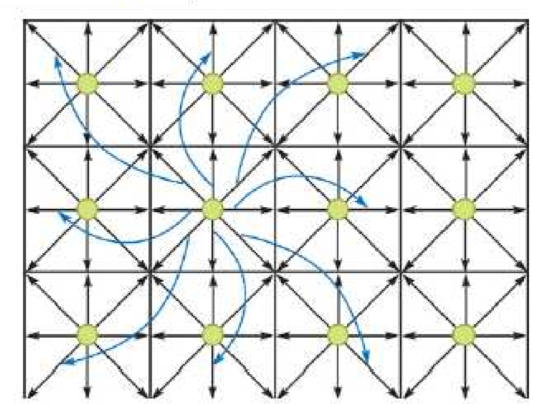
Equilibrium distribution function:

$$f_\alpha^{eq} = w_\alpha \rho \left[1 + \frac{e_{\alpha i} u_i}{c_s^2} + \frac{(e_{\alpha i} e_{\alpha j} - c_s^2 \delta_{ij}) u_i u_j}{2 c_s^4}\right],$$



D3Q19 lattice structure

2.Streaming :



3.Sampling :

$$\rho = \sum_{\alpha=0}^{8} f_\alpha, \quad \rho u = \sum_{\alpha=0}^{8} f_\alpha \mathbf{e}_\alpha,$$

$$\nu = (\tau - 0.5) c_s^2 \delta t.$$

LBM – Highlights

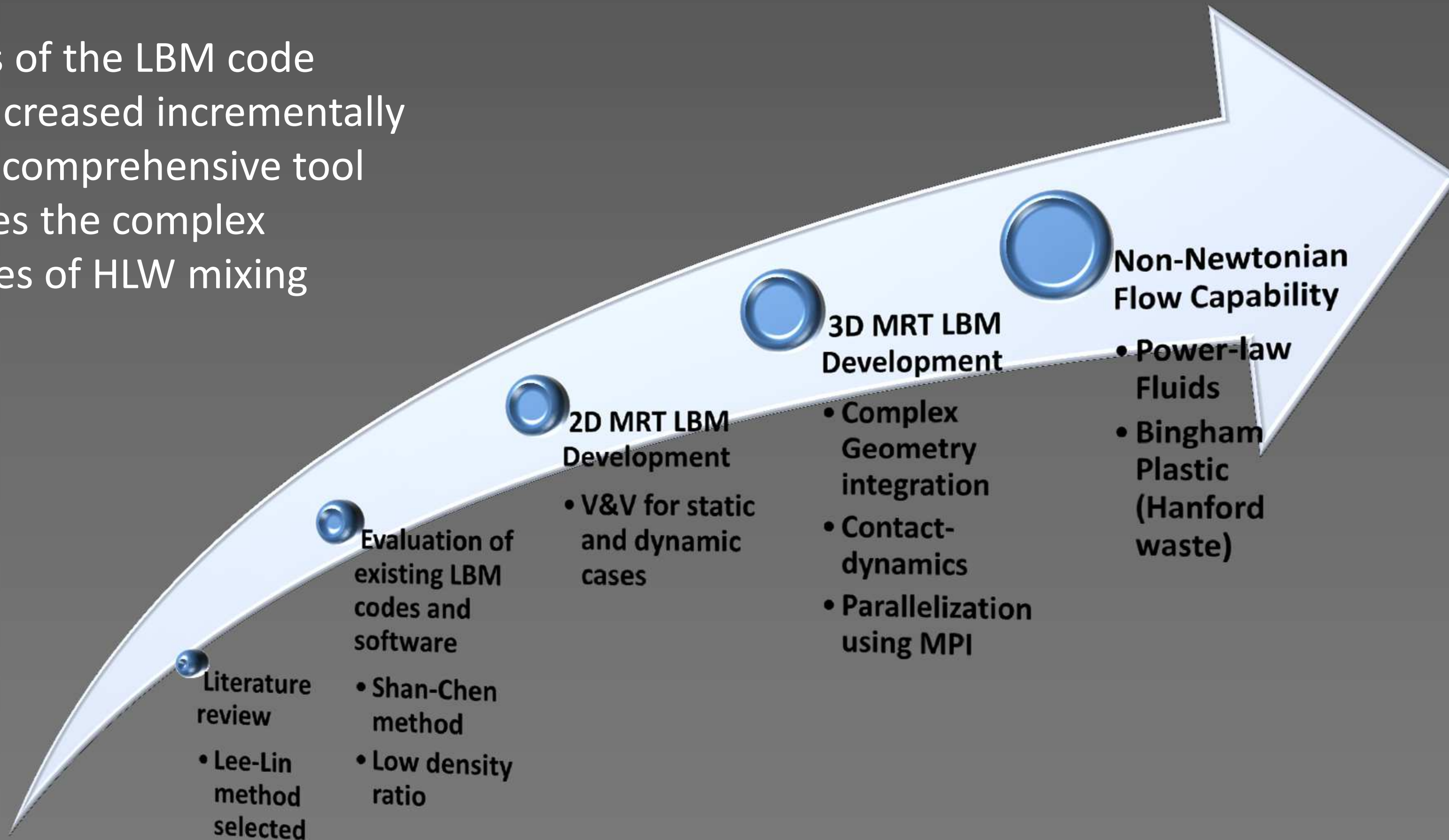
- Pros:
  - inherently capture interfacial flows
  - the intermolecular attraction between different phases can be modeled easily.
  - The interface between two liquids is not required to be determined as in Volume of Fluids approach, but liquid break-up can still be predicted using front capturing methods.
  - Complex geometries can be handles easily (Eg. Flow in porous media)
  - the information is passed on to the neighboring nodes locally that allow the LBM computations to be highly parallelizable.
- Cons:
  - Low Mach number limit (M<0.3) for stable simulations
  - Unitless output - > conversion of units from physical to LBM scale

- Multiphase Models:
  - The color method (Gunstensen et al., 1991),
  - the potential method (Shan and Chen, 1993),
  - the free-energy method (Swift et al., 1995),
  - the index function method (He et al., 1999),
  - other methods (hybrid level-set LBM, front tracking LBM etc.)

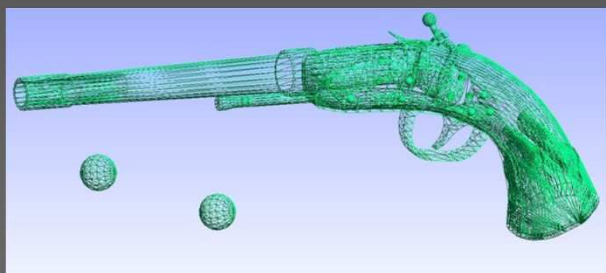
Lee-Lin (2003, 2005)
Updated for high density and viscosity flows

Past, Present and Future Tasks

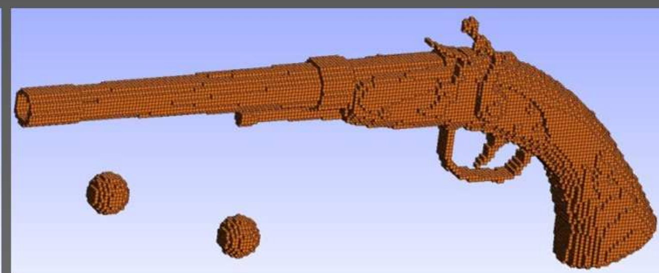
Capabilities of the LBM code has been increased incrementally to obtain a comprehensive tool that includes the complex flow features of HLW mixing



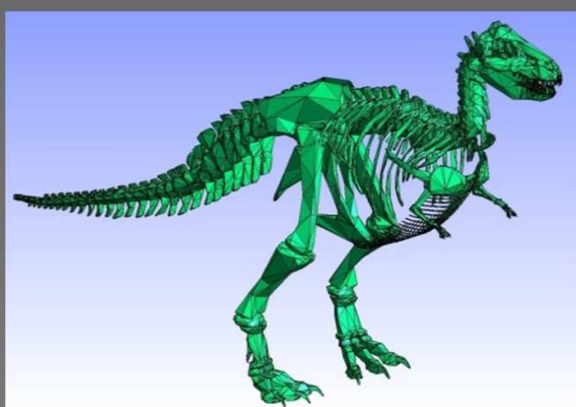
Current capabilities: Complex geometry representation



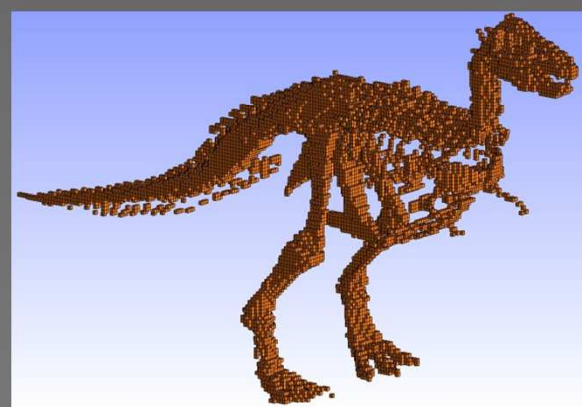
(a) STL file for a pistol.



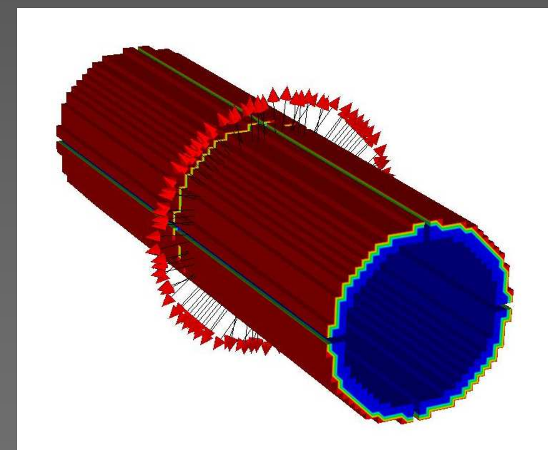
(b) Voxel representation of a pistol.



(c) STL file for a dinosaur.



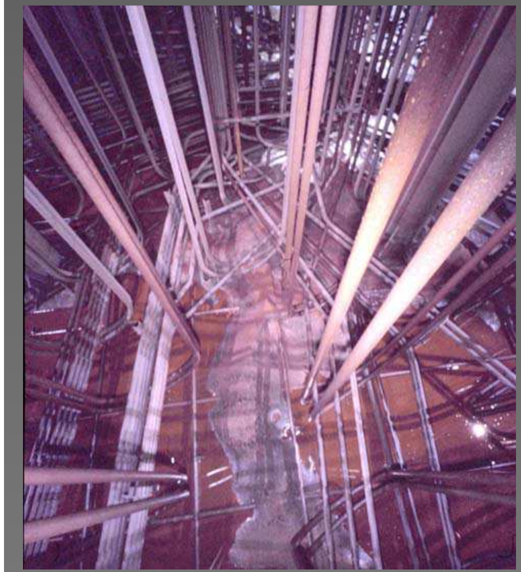
(d) Voxel representation of a dinosaur.



$$\boldsymbol{n} = \left(\sum_i w_i \right)^{-1} \sum_{i=0}^{n_b - 1} \boldsymbol{b_i} \,,$$

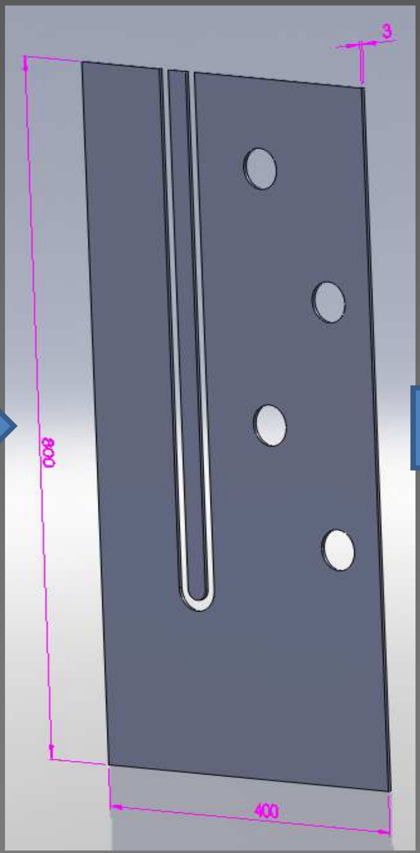
Binvox algorithm (http://www.cs.princeton.edu/~min/binvox/) used to convert STL files obtained from CAD software (Solidworks) into a RAW format which the LBM code were able to integrate.

Current capabilities: Complex geometry integration into Multiphase CFD simulation

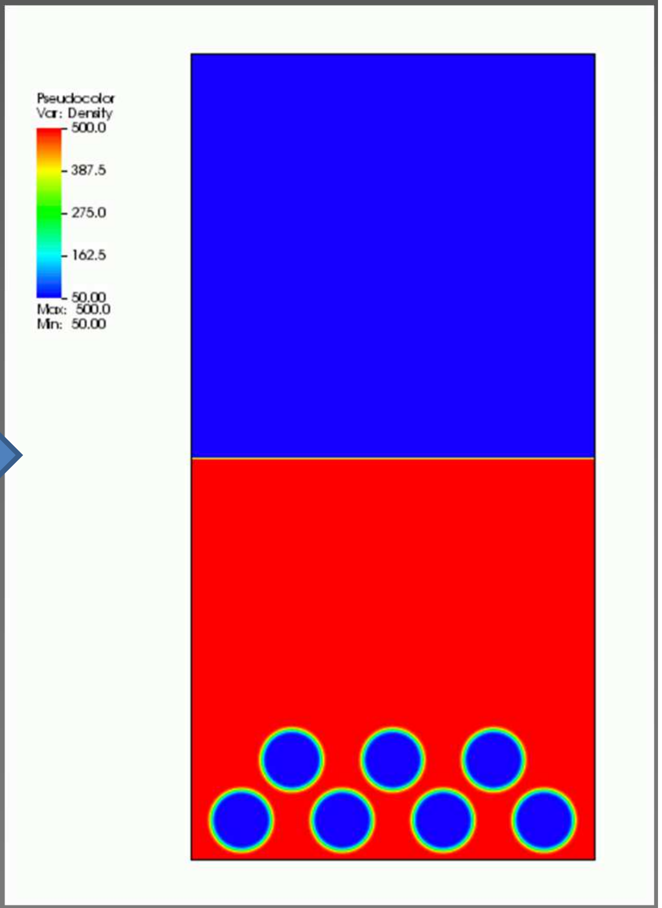


Cooling coils in Tank 1 in SRNL.

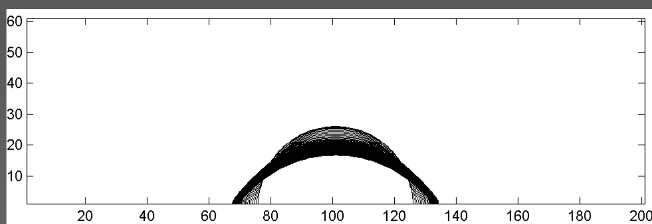
To CAD



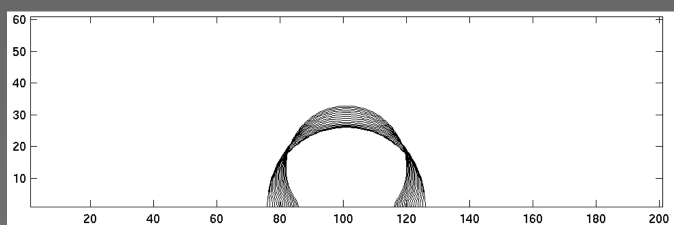
To LBM



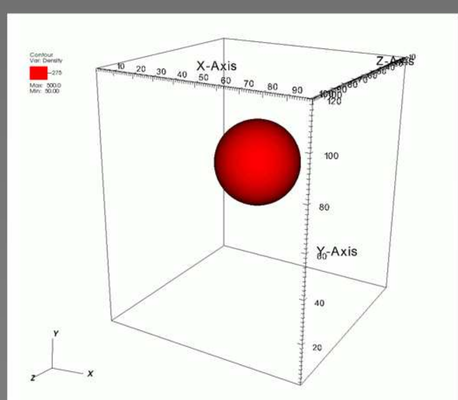
Current capabilities: Contact Dynamics



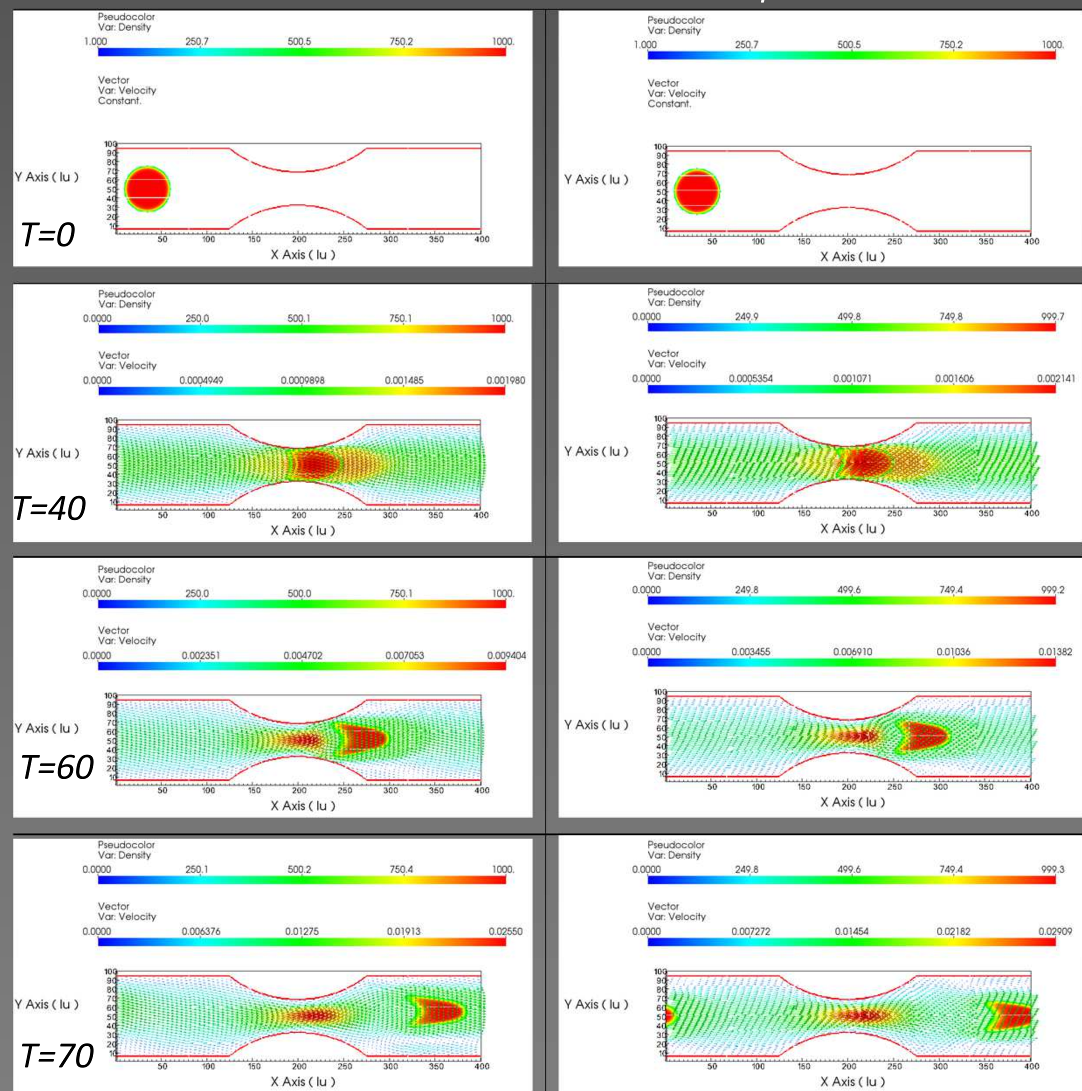
$K_w > 0$ results in good wetting : $\theta < 90°$



$K_w < 0$ results in partial wetting : $\theta > 90°$



Attractive walls *Repulsive walls*



Future Capabilities to be included:

Non-Newtonian Flow Modeling:
In order to simulate the Non-Newtonian behavior of Hanford waste in the LBM simulations, the viscosity definition of the LBM needs to be changed such that the dynamic viscosity becomes a function of the shear rate.

Turbulent Flow Modeling:
Future work will include implementation of a turbulence model in the LBM code to handle large velocities that PJMs create.

1- Initialize the particle distribution functions, f and f^{eq}, at time=0.

2- Obtain the strain rate tensor is obtained :

$$\varepsilon_{\alpha\beta} = -\frac{1}{2\rho c_s^2 \delta t}\sum_{i=1}^{19} \boldsymbol{e}_{i\alpha}\boldsymbol{e}_{i\beta}\sum_{j=1}^{19}\hat{\Lambda}\left[f_j - f_j^{eq}\right]$$

3- Find the effective viscosity:

Power-law: $\mu_{eff} = \mu_P|\dot{\gamma}|^{n-1}$, where $|\dot{\gamma}| = \sqrt{2(\varepsilon:\varepsilon)}$, μ_P is the flow consistency coefficient and n is the Power-law index of the fluid. This gives us a shear stress definition for Power-law fluids as, $\mu = \mu_P|\dot{\gamma}|^{n-1}\dot{\gamma}$.

Bingham plastic: (Hanford sludge)

$$\mu_{eff} = \mu_B + \left(1 - e^{-m|\dot{\gamma}|}\right)\frac{\tau_B}{|\dot{\gamma}|}$$

where μ_B is the plastic viscosity and m is the stress growth exponent. Shear stress definition for Bingham plastics given as,

$$\begin{cases} \tau = \dfrac{\tau_B}{|\dot{\gamma}|} + \mu_B, & |\tau| > \tau_B, \\ \dot{\gamma} = 0, & |\tau| < \tau_B, \end{cases}$$

where τ_B is the Bingham yield stress.

4- Calculate the relaxation factor s_{10} using the relation,
$\nu = \frac{1}{3}\left(\frac{1}{s_{10}}\right)$.

5- Execute the collision step and the streaming step.

6- Calculate the macroscopic quantities such as fluid density and velocity.

TASK 18.1 EVALUATION OF FIU'S SOLID-LIQUID INTERFACE MONITOR FOR RAPID MEASUREMENT OF HLW SOLIDS ON TANK BOTTOMS (NEW)

Technology Need & Proposed Solution

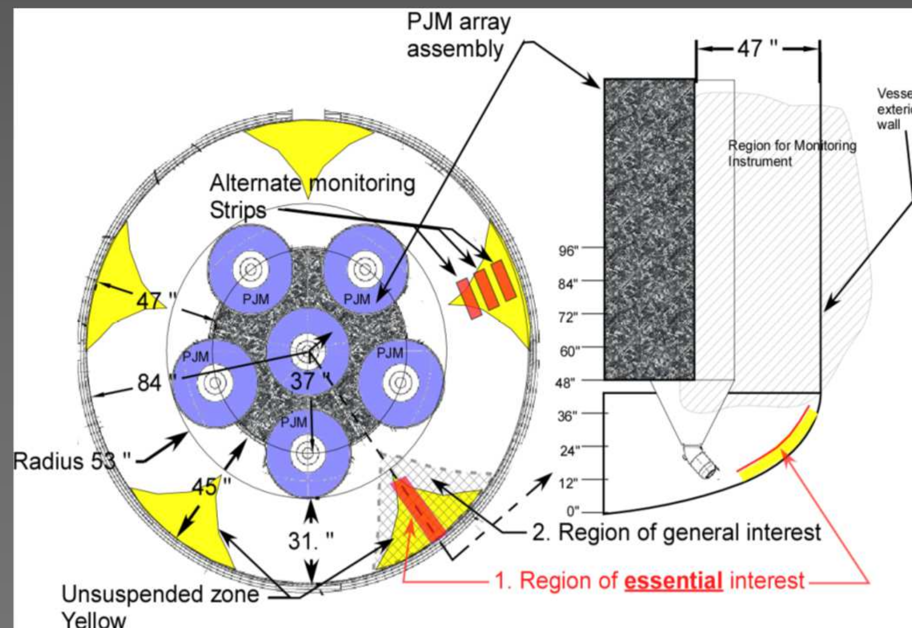
Technology Need: Hanford scientists and engineers have identified a need to rapidly (<20 seconds) image the bottoms of a mixing (conditioning) tanks to estimate the effectiveness of solids suspension by measuring the volume of solids on the tank bottom immediately after suspension of mixing

Proposed Solution: Test FIU's Solid-Liquid Interface Monitor (SLIM) for effectiveness for this new, challenging application in smaller HLW tanks. SLIM is a FIU-designed and built deployment system for a rugged commercial sonar in the large single and double shelled, underground storage tanks at Hanford and Savannah River Site.

Testing SLIM for Measurement of Settled Solids on Conditioning 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.
- Technology is required in order to ensure PJM operations effectively suspending 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

SLIM Accomplishments on a Similar Technology Need

<u>SLIM was successfully tested for:</u>

- 3D Surface map of the settled solids layer on bottom of million gallon tanks
- Deployable to tank floor (50 ft+)
- Custom, commercial sonar is chemically (>pH 14), radiation resistant, able to deploy in HLW
- Resolution of 8 mm at 1 meter
- Remotely operated
- Applicable in tanks being emptied or those being filled

Right: sonar deployed through an 8-inch pipe similar to risers into million gallon HLW tanks

Upper & Lower Left: The sonar deployment mechanism with 3 side walls removed

Testing SLIM for Measurement of Settled Solids on Conditioning Tank Bottoms

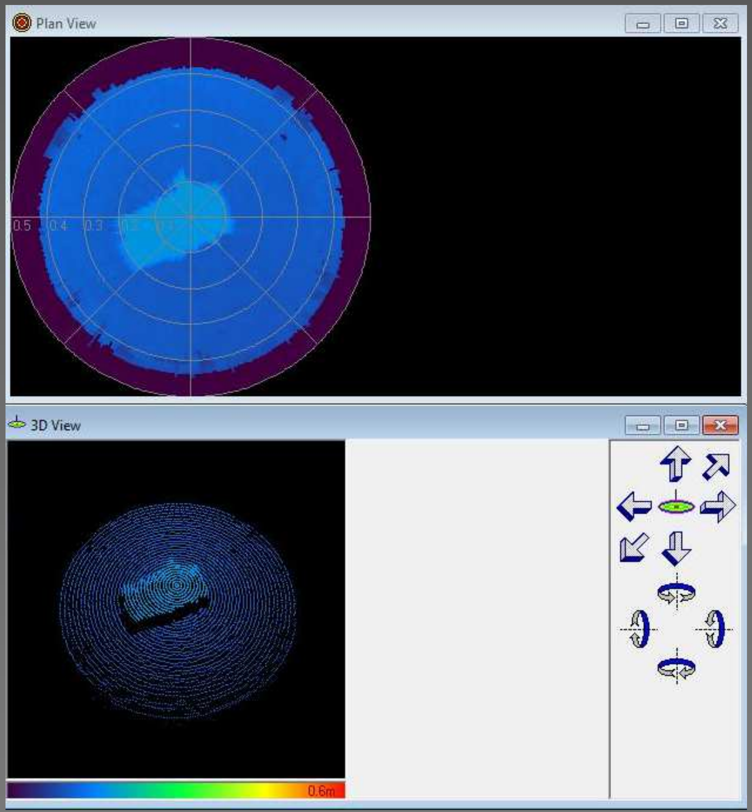
Sonar Description:

- The device consists of an acoustic transducer, rotation motor with gearbox, tilt motor, position reference sensor and pressure balancing mechanisms.
- No semiconductors are incorporated into the device so that it may be deployed in areas of significant radioactivity.
- Titanium shell and polyurethane transducer cover is chemically resistant to high alkalinity pH>14
- It is an oil-filled device with no user serviceable parts within the unit.
- Connected to an electronic processing unit by a 30m underwater umbilical cable.

Testing SLIM for Measurement of Settled Solids on Conditioning Tank Bottoms

Benchmark SLIM Testing:

- Identification of sonar image resolution and accuracy of estimating volume of settled solids in a select region between 2 adjacent PJMs.
- Operations dictate that the imaging be conducted in less than 20 seconds

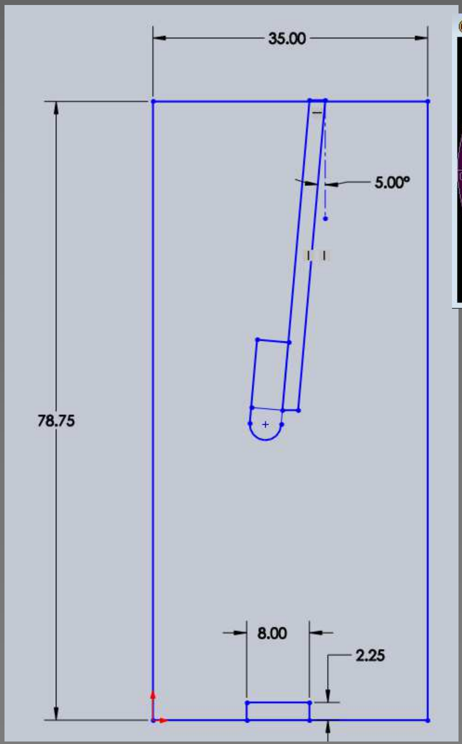


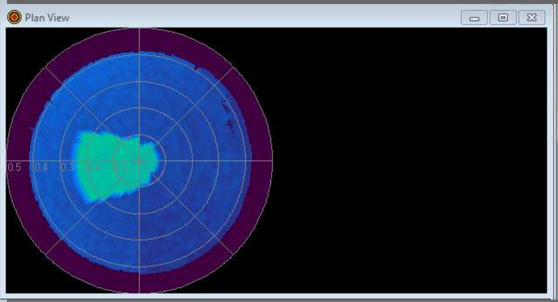
Sonar image of a brick 1.0m below sonar head.

Testing SLIM for Measurement of Settled Solids on Conditioning Tank Bottoms

Vertical alignment of sonar:

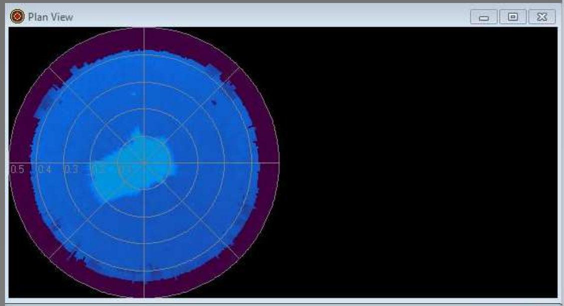
The angle deviation from perpendicular of the deployed sonar with respect to tank bottom has been shown to affect image resolution. ~5° can distort images.

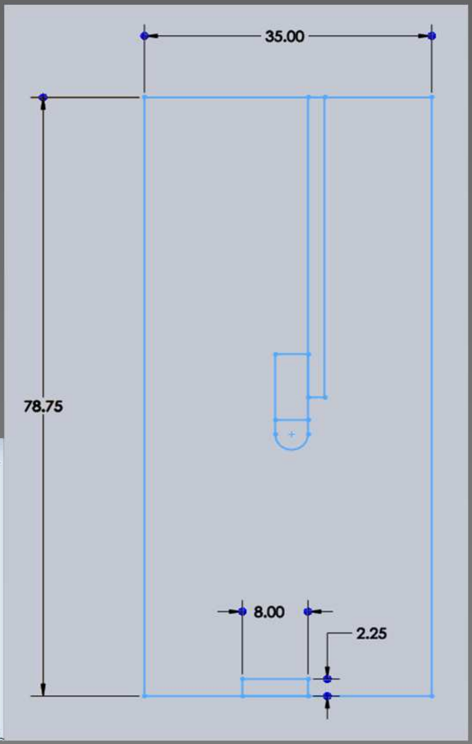




Above: sonar image of brick (5°)
Left: drawing of sonar deployed at 5° from perpendicular

Right: drawing of sonar deployed at 0° from perpendicular
Below: sonar image of brick (0°)





Testing SLIM for Measurement of Settled Solids on Conditioning Tank Bottoms

Primary system parameters:

- Swath arc – 2-D field of view of sonar; for 30° swath arc; images +/- 15° from sonar axis; setting of 30°, 60°, 90°, 120°, 150°, or 180°
- Swath motor step size – angle between sonar pings along the 2-D swath arc; setting varies from 0.9° to 9°
- Rotate motor step size – the rotation angle between consecutive 2-D swaths, setting varies from 0.9° to 9°

Response variables:

- Total time to collect data to image settled solids floor area
- Accuracy of volume of settled solids

Test Plan:

	Swath Arc: 30°, 60°	Swath Step Size: 0.9°, 1.8°, 4.5°, 9°	Rotate Step Size 8.1°, 9°, none (1 swath)
Image Time			
Vol. Accuracy			

Testing SLIM for Measurement of Settled Solids on Conditioning Tank Bottoms

Path Forward:

- Test plan will be conducted using water to allow FIU and Hanford engineers to ascertain the effectiveness of the sonar for quick (<30 sec) imaging and estimation of volume of settled solids
- Given successful testing, a 3D mapping algorithm will be tested by FIU since the commercial sonar imaging system does not provide images when number of points is too low (expected for many short duration sonar images)
- After the volume accuracy is obtained, testing will be conducted with various levels of % solids loading

TASK 18.2 DEVELOPMENT OF INSPECTION TOOLS FOR DST PRIMARY TANKS (NEW)

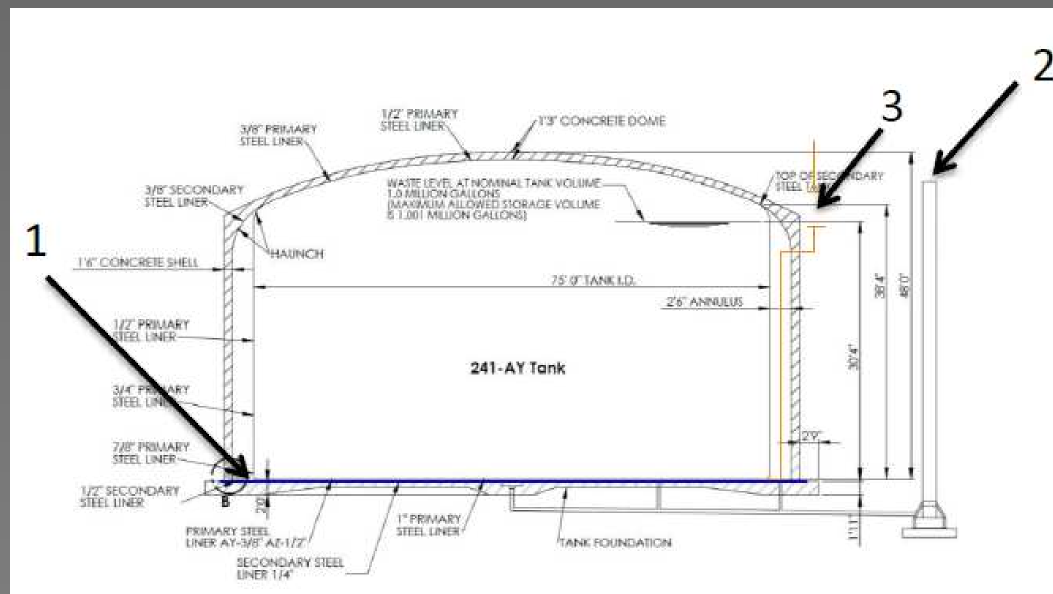
Background

- The waste is believed to have leaked from the tank bottom and flowed through the cooling channels of the refractory pad to the annulus.
- WRPS has contracted commercial companies to modify existing inspection technologies to travel into the piping and/or refractory pad channels to provide visual feedback of the tank bottom.
- FIU has had discussions with engineers at Hanford and will propose alternative designs – specifically for traveling through the cooling channels.

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:

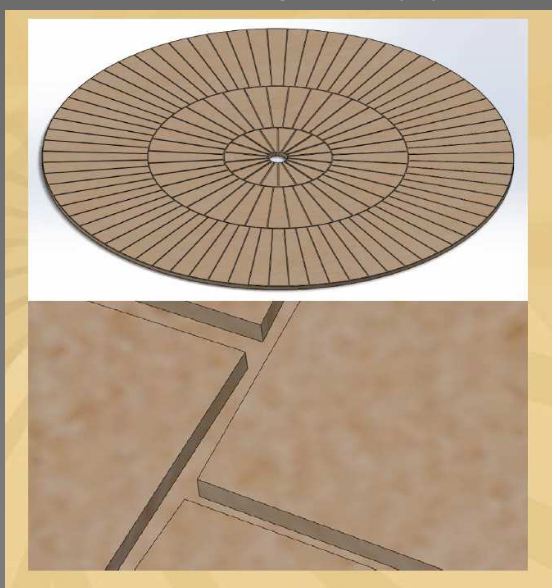
1. Air Channels Under Tank
2. 6” Leak Detection Piping
3. 4” Air Supply Piping

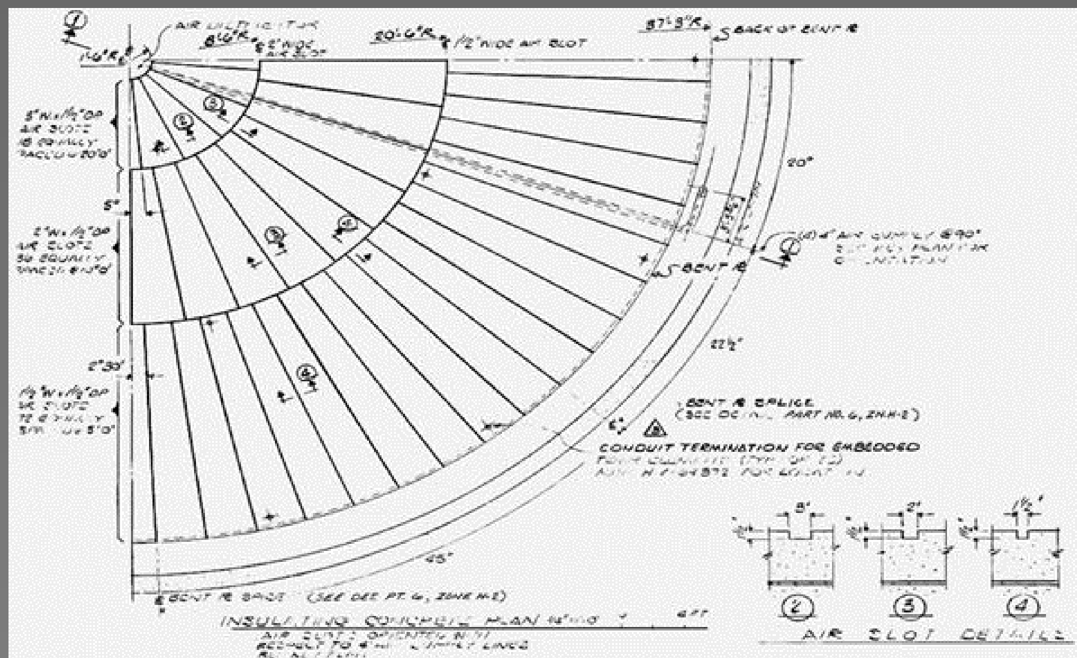


Development of Inspection Tools for DST Primary Tanks

Air Channel Path:

- Channels arranged in 3 sections: (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
- Channels are of small size slots with sharp 90° turns connecting sections
- 72 outer ring entry points





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 tank of the DSTs at Hanford

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 (~ 200 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.

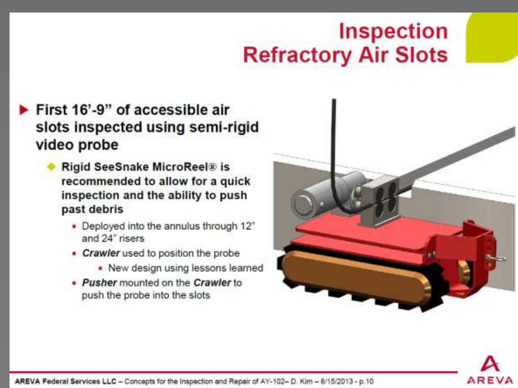
Development of Inspection Tools for DST Primary Tanks

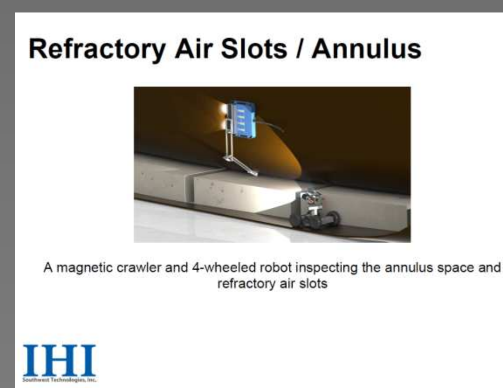
Potential Limitations and Risks:

- Debris in channel may limit travel of inspection tool
- Damaged refractory channels could impact inspection
- 90° turns present a challenging design parameter
- Corrosion on tank bottom
- Equipment failure
- Depending on conditions in channel, the tool could potentially become lodged

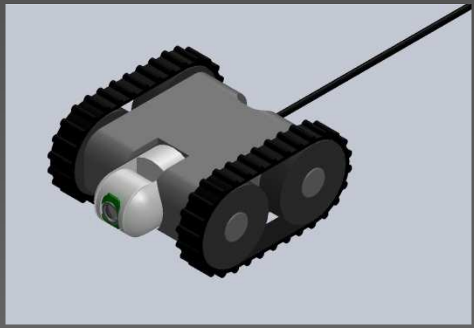
Development of Inspection Tools for DST Primary Tanks

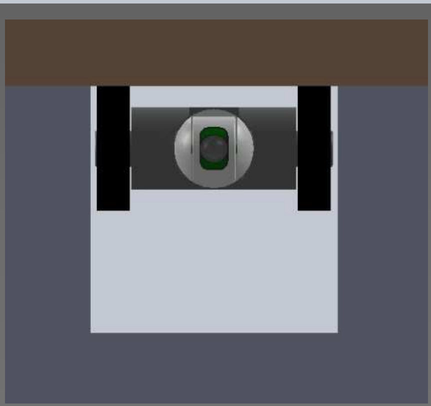
Sample of proposed technologies from companies

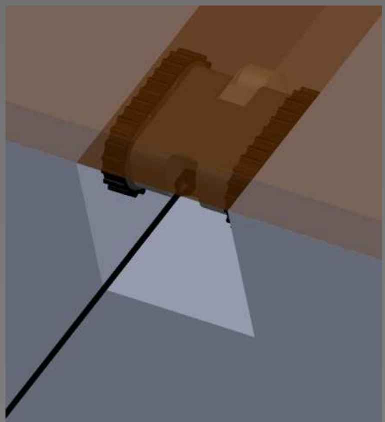




Development of Inspection Tools for DST Primary Tanks







Proposed Concept:

- The body would consist of a camera with attached tether and motors connected to magnetized "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 magnetized wheels so that it can run upside down along the bottom of the tank. The continuous track was favored over wheels so as to increase the surface area along the tank.
- The "tank tread" and its wheels would also be sized larger than the body of the inspection tool so in case it falls from the top, the tool can continue to run on the refractory pad.

Development of Inspection Tools for DST Primary Tanks

Path Forward:

- Complete initial system design
  - Develop proof of concept
    - Simulation validation
    - Initial prototype
- Conduct functional testing
- Make design modifications required as a result of testing
- Build prototype and test in bench scale testbed

TASK 19.1 PIPELINE CORROSION AND EROSION EVALUATION (NEW)

Background

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

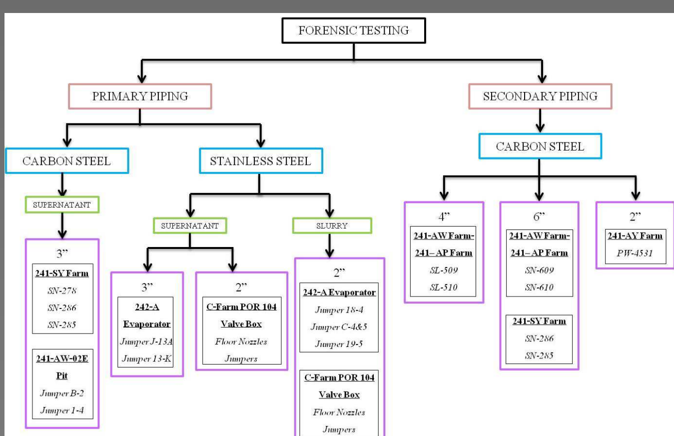
- The eight encasement pipelines selected to be exhumed were SN-285, SN-286, SN-278, SL-509, SL-510, SL-609, SL-610 and PW-4531. The lines are located in various tank farms and differ by diameter and level of protection from soil.

- Several jumpers in the 242-A Evaporator and in the 241-AW-02E Evaporator Feed Pump Pit were selected for analysis: Jumper 18 to 4, Jumper C to 4 & 5, Jumper J to 13A, Jumper 13 to K, and Jumper 19 to 5.

- After data is collected and analyzed, a wear rate will be developed to predict the existing system's remaining useful life. It will also be used to determine design allowances needed for new piping and pipe jumpers.

Previous Research Effort

- DOE Fellow summer internship at Hanford - organize and develop statistical analysis of empirical field and pipeline wall thickness measurements.
- Pipeline wear data was determined and presented showing wear rates for the various lines. Additionally, information on the pipelines was collected (location, material , size, service dates, waste transferred).

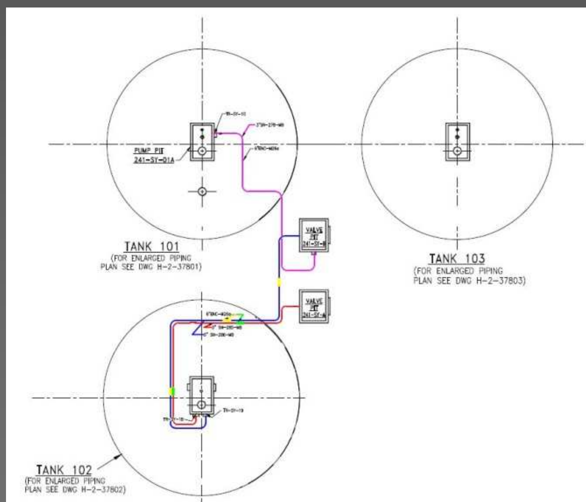


Pipe Tree

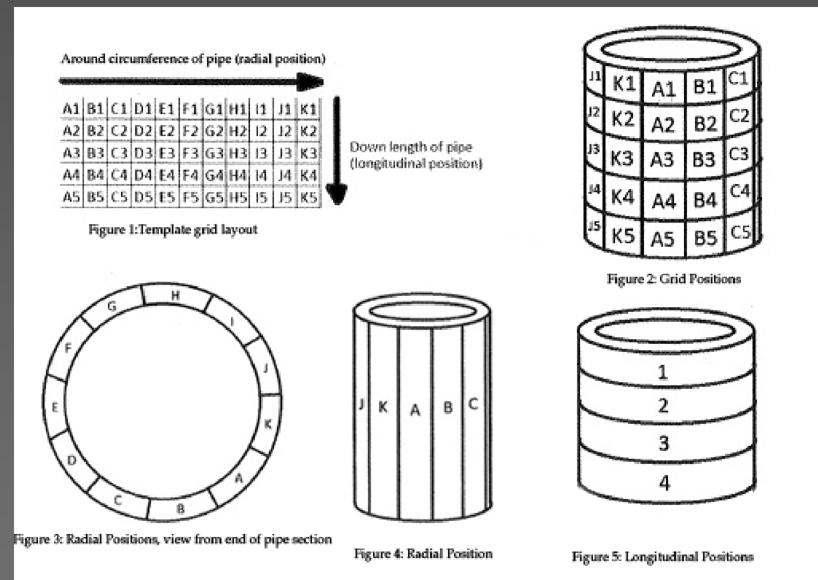
Pipeline Excavation

Photograph of the SN-278 Pipe-in-Pipe Section during sample unpacking.

Pipeline Corrosion and Erosion Evaluation



Tank farm drawing that provides the location of the pipelines inside the tank farm. (241-SY Tank Farm – SN-278, SN-285, SN-278



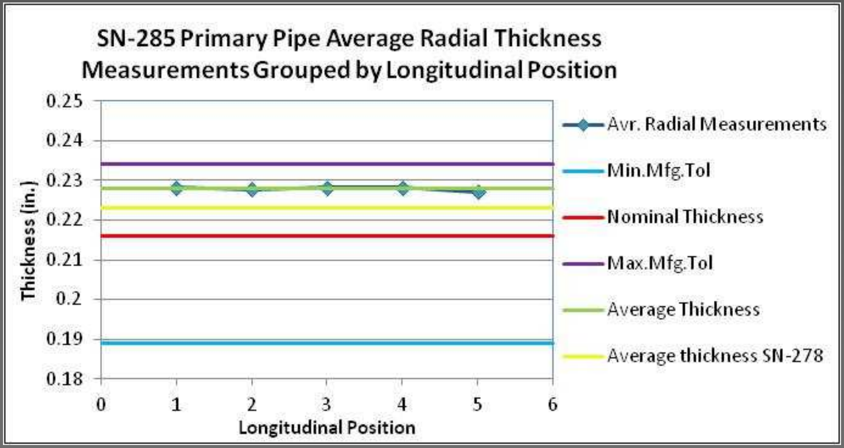
Typical data collection procedure for ultrasonic wall thickness measurements using grid.

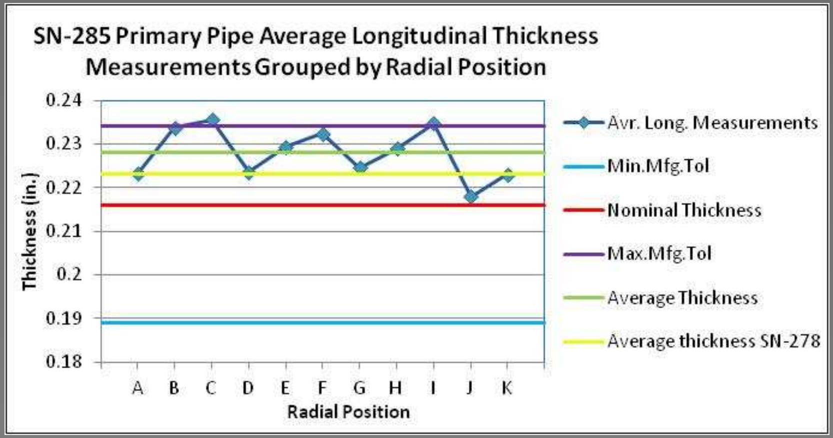
Chart showing all the wall thickness measurements SN-278 primary

	1	2	3	4
A	0.225	0.230	0.224	0.231
B	0.235	0.230	0.231	0.225
C	0.228	0.224	0.225	0.220
D	0.222	0.235	0.223	0.222
E	0.222		0.220	0.229
F	0.215	0.215	0.219	0.219
G	0.224	0.223	0.223	0.225
H	0.216	0.219	0.218	0.220
I	0.219	0.210	0.215	0.216
J	0.227	0.223	0.225	0.222
K	0.223	0.220	0.219	0.219

Pipeline Corrosion and Erosion Evaluation

- Average radial measurements along the longitude of the pipe are similar.
- Average thickness measurements vary in an oscillatory manner around the circumference (likely due to manufacturing process and not wear).
- Average wall thickness is > than nominal thickness, indicating initial thickness was greater than the nominal thickness.
- Results indicate very minimal or no detectable wear - life expectancy analysis is not practical.
- Similar results are seen with SN-285 primary, SN-286 primary, SN-278 primary, SL-509 encasement, SL-510 encasement, SN-609 encasement, SN-610 encasement, PW 4531 encasement.

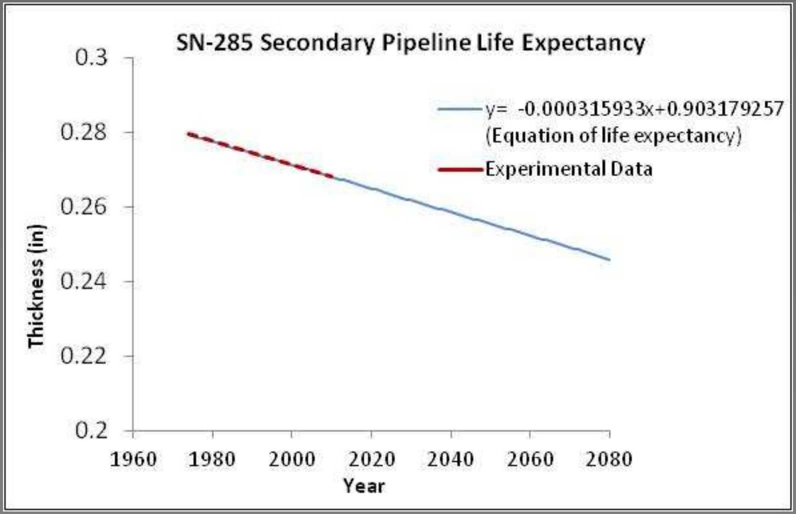




Pipeline Corrosion and Erosion Evaluation

- For pipelines SN-285 secondary and SN-286 secondary the average wall thickness was below the nominal wall thickness and a wear rate analysis was conducted.
- Results showed that these pipelines experienced very minimal corrosion from contact with the soil.
- Based on these projections, it is not likely that other cathodically protected carbon steel encasements with similar designs and service performance will require replacement during the WTP's projected lifetime.

Minimum Thickness for Pipeline to Operate Safely (Carbon Steel, 6" Diameter, (ANSI Schedule 40))		
P (Internal Design Gauge Pressure) (psi)	60	B-101-C3 R01, 1974, Pg. 42, Pipe Code M-26
D (Outside Diameter of pipe) (in)	6.630	ASTM A106-1972a
S (Stress value for materials) (psi)	16000	ASME B31.3 Table A-1
E (Quality factor)	1	ASME B31.3, Table A-1A or A-1B
Y (Coefficient)	0.4	ASME B31.3 Table 304.1.1
W (Weld joint strength reduction factor)	1	ASME B31.3 Paragraph 302.3.5 (e)
t (minimum thickness)= PD/2*(SEW+PY) (in) t (minimum thickness)= 0.012 (in)		



Pipeline Corrosion and Erosion Evaluation

Path Forward:

- The data measurements available from other pipes and jumpers will be analyzed and eventually all of the waste transfer system's materials and materials handling history will be represented.

- Future data will be compiled and analyzed and further comparison between pipelines will be performed to obtain more accurate corrosion/erosion rates.

Year 5 Tasks

Tasks to Continue into Year 5

- Task 2.2 - Computational Simulation and Evolution of HLW Pipeline Plugs
- Task 17.1 - Multiple-Relaxation Time, Lattice Boltzmann Model for High-Density Ratio Multiphase Flows
- Task 18.1 - Evaluation of FIU's Solid-Liquid Interface Monitor for Rapid Measurement of HLW Solids on Tank Bottoms (new this year)
- Task 18.2 - Development of Inspection Tools for DST Primary Tanks (new this year)
- Task 19.1 - Pipeline Corrosion and Erosion Evaluation (new this year)

Expected Tasks to be Completed

- Task 2.1 - Development of Alternative Unplugging Technologies

Year 5 Tasks

Potential New Tasks

- Testing of AIMM's Hydrokinetic system
- Life expectancy testing of non-metallic materials in waste transfer system
- Evaluation of segregation technologies
- Other suggestions???