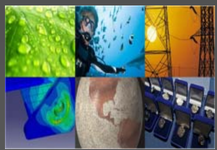
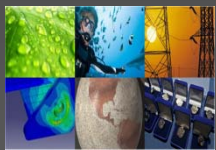
Project 1: Chemical Process Alternatives for Radioactive Waste

Presented to the U.S. Department of Energy
4/29/2013



Outline

- Overview of Tasks
- Pipeline Unplugging
- Computational Fluid Dynamics
- HLW Instrumentation
- FY13 Tasks



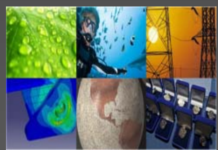
Project Description

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 and 3) evaluation of alternative HLW instrumentation for *in situ* applications



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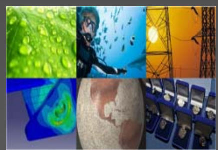


Project Tasks and Scope

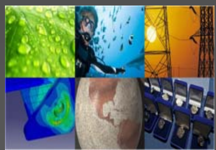
Task 2 Pipeline Unplugging and Plug Prevention – develop novel technologies that can be utilized to remove plugs formed in HLW pipelines.

Task 12 Multiple-Relaxation Time, Lattice Boltzmann Model for High-Density Ratio Multiphase Flows – assist site engineers with computational modeling development and validation that are needed in complex HLW mixing, retrieving and processing.

Task 15 Evaluation of Advanced Instrumentation Needs for HLW Retrieval – evaluate the maturity and effectiveness of commercial and emerging technologies capable of addressing several instrumentation needs for HLW feed mixing and retrieval.

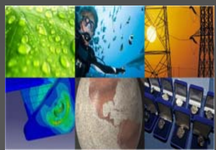
Task 16 Computational Simulation and Evolution of HLW Pipeline Plugs (New Task) – develop computational models describing the build-up and plugging process of retrieval lines.

PIPELINE UNPLUGGING



Outline

- Background/History
  - NuVision and AIMM’s Testing
- Current Tasks
  - Peristaltic Crawler
  - Asynchronous Pulsing
  - Computational Simulation and Evolution of HLW Pipeline Plugs

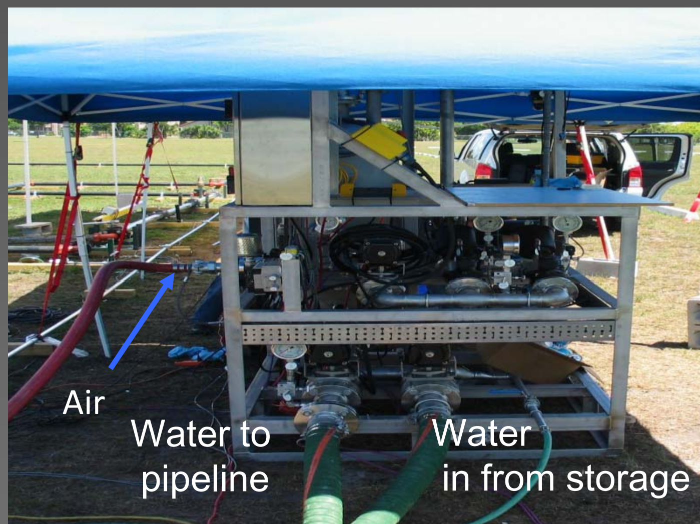


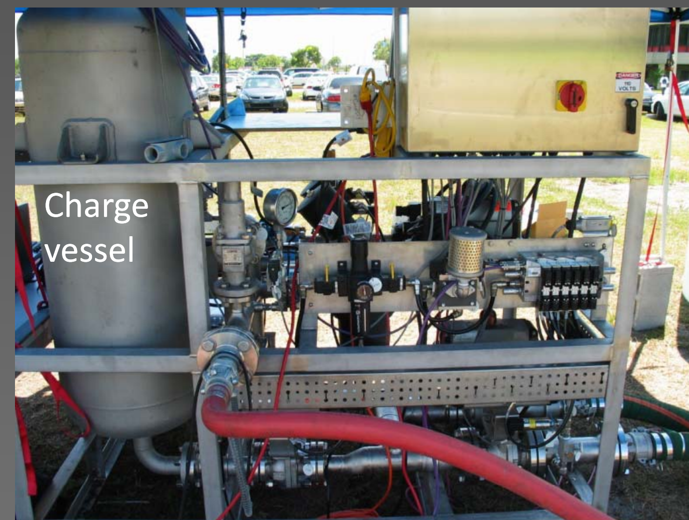
Background/History

- Industry call ~ 2002 – a number of pipeline unplugging technologies were evaluated. Field tests were conducted to determine the viability of the technologies at Hanford.
- NuVision’s Wave Erosion technology and AIMM’s Hydrokinetic technology were identified as having potential and brought back for further evaluation in 2008/2009.
- FIU began developing our own technologies based on lessons learned – 1) Peristaltic Crawler, 2) Asynchronous Pulsing System

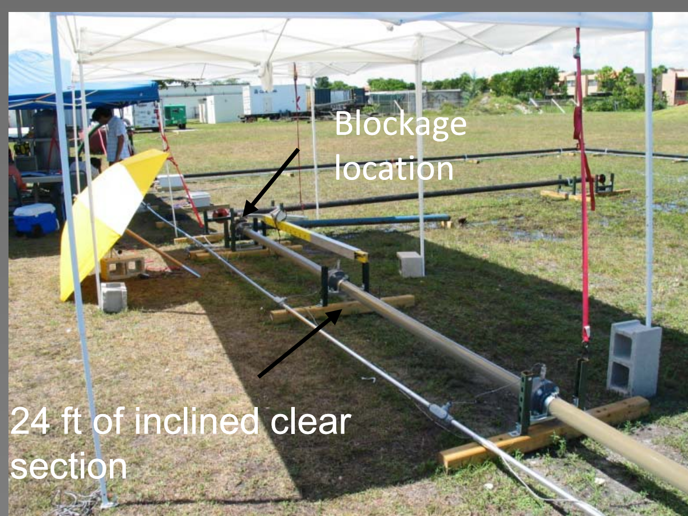
NuVision Testing

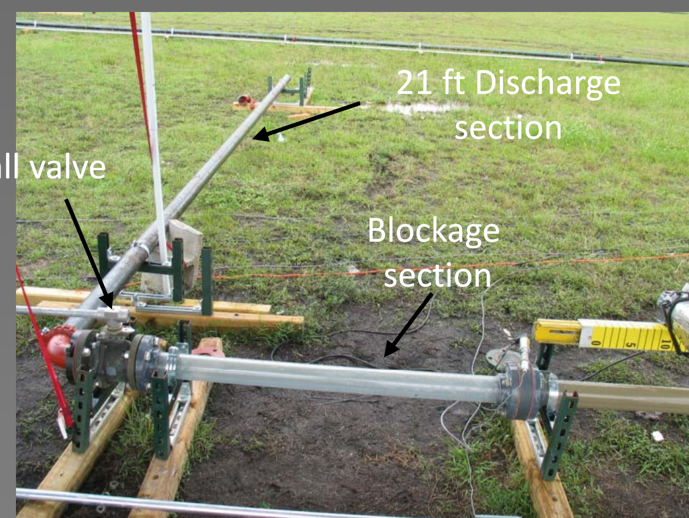
NuVision Equipment





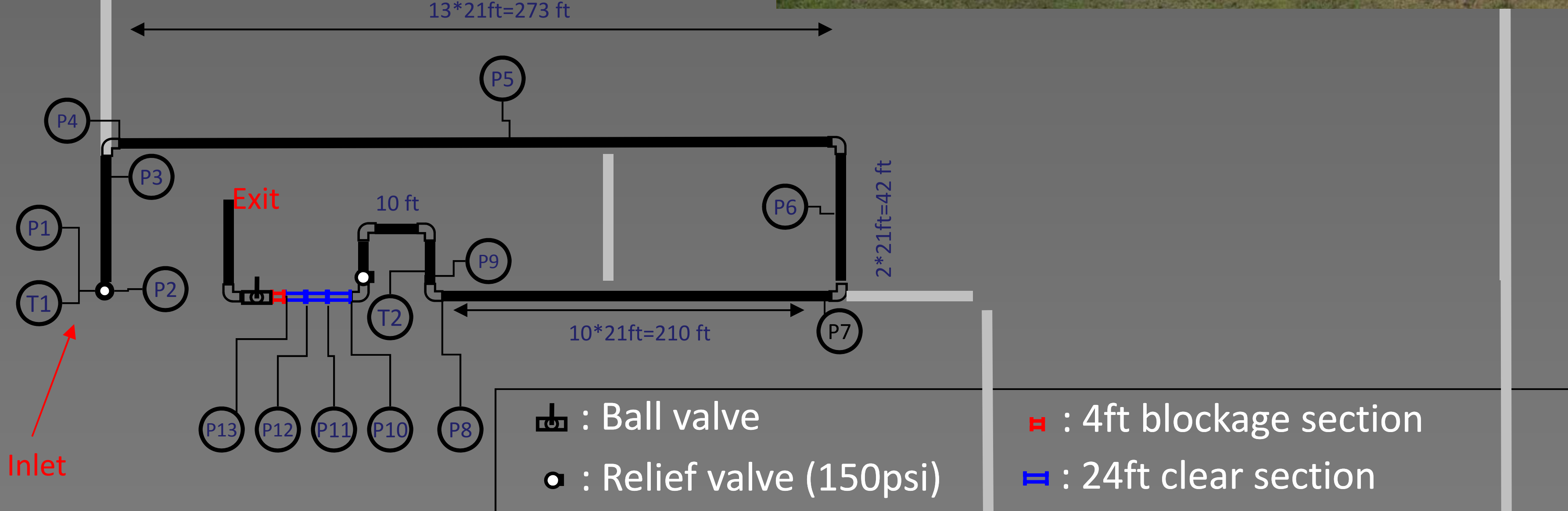
Test-bed Clear section

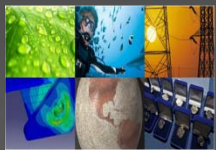




NuVision

Test-bed #2 (621 ft)





AIMM's Testing

AIMMS Hydrokinetics Process

- Patented technology that has successfully been used in petroleum industry to clean fouled pipes
- Pressure pulses and cavitations are primary mechanism that purportedly break bounds between plug and pipe wall

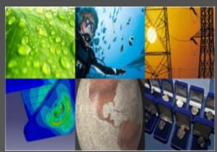
AIMM's Testing

AIMM's Unplugging Results

Trial #	Exp Loop	Distance to Blockage	Blockage	Blockage Length	Max Pressure	Success	Time (min)
1	1	310 ft	Bentonite	8 ft	230 psi	Yes	16
2	1	310 ft	Bentonite	12 ft	290 psi	Yes	30
3	1	310 ft	Kmag	4 ft	280 psi	Partial	40
4	1	310 ft	Na-Al-Si	4 ft	280 psi	No	52
5	0	310 ft	Na-Al-Si	4 ft	285 psi	No	21
6	1	646 ft	Bentonite	8 ft	240 psi	Yes	17
7	1	646 ft	Bentonite	12 ft	270 psi	Yes	18
8	1	646 ft	Kmag	4 ft	285 psi	No	54
9	1	646 ft	Na-Al-Si	4 ft	280 psi	No	41
10	1	1822 ft	Bentonite	8 ft	290 psi	No	115
11	1	1822 ft	Bentonite	12 ft	230 psi	Yes	73
12	1	1822 ft	Kmag	4 ft	305 psi	No	40
13	1	1822 ft	Na-Al-Si	4 ft	280 psi	No	52

8 ft Bentonite

2 ft K-mag

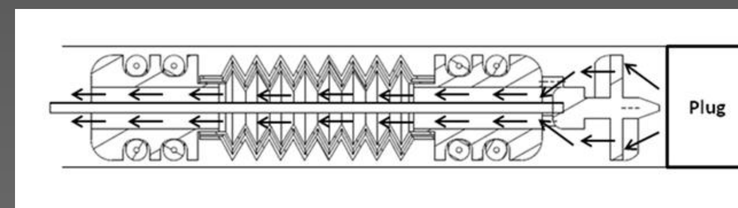


Pipeline Unplugging – Current Tasks

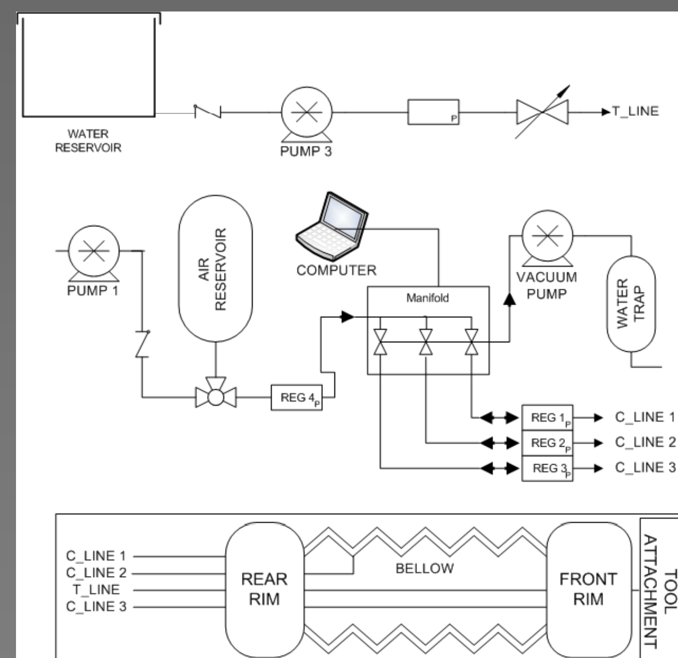
Peristaltic Crawler

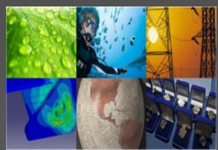
The crawler is a pneumatically powered device that propels itself by a sequence of pressurization/depressurization of cavities (inner tubes). The changes in pressure result in the translation of the vessel by peristaltic movements. The inner tubes are mounted on a flexible skeleton that allows it to turn through elbows.

The advantage of using a device that can successfully navigate inside pipelines is the ability to bring inspection and unplugging technologies closer to areas of interest inside pipelines.



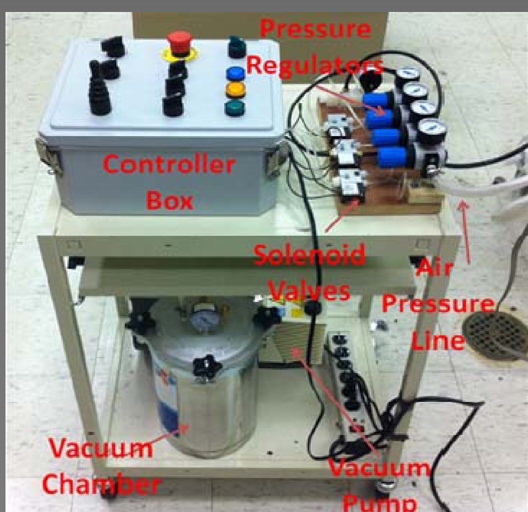
Principle of Operation

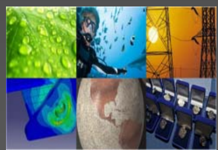




Pipeline Unplugging – Peristaltic Crawler

A number of improvements to the crawler have been implemented since its concept was proposed.





Pipeline Unplugging – Peristaltic Crawler

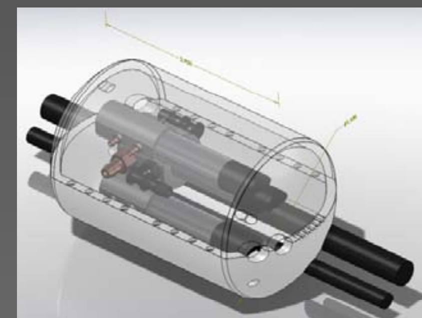
Various types of tests have been conducted

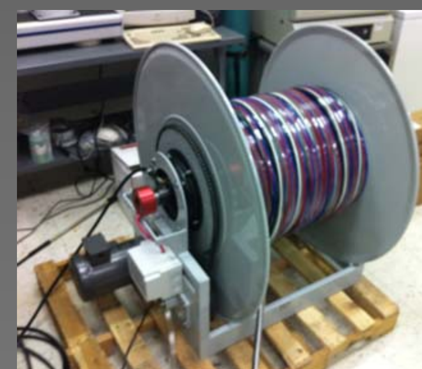
- navigation tests – elbows
- speed tests
- pull strength test
- unplugging tests

Pipeline Unplugging – Peristaltic Crawler

Recent Modifications

- inner and outer hydroformed bellow
- pneumatic valves placed near crawler
- tether and reel system -500 ft
- video feed back for pipeline inspection
- current speed is 30-35 ft/hr



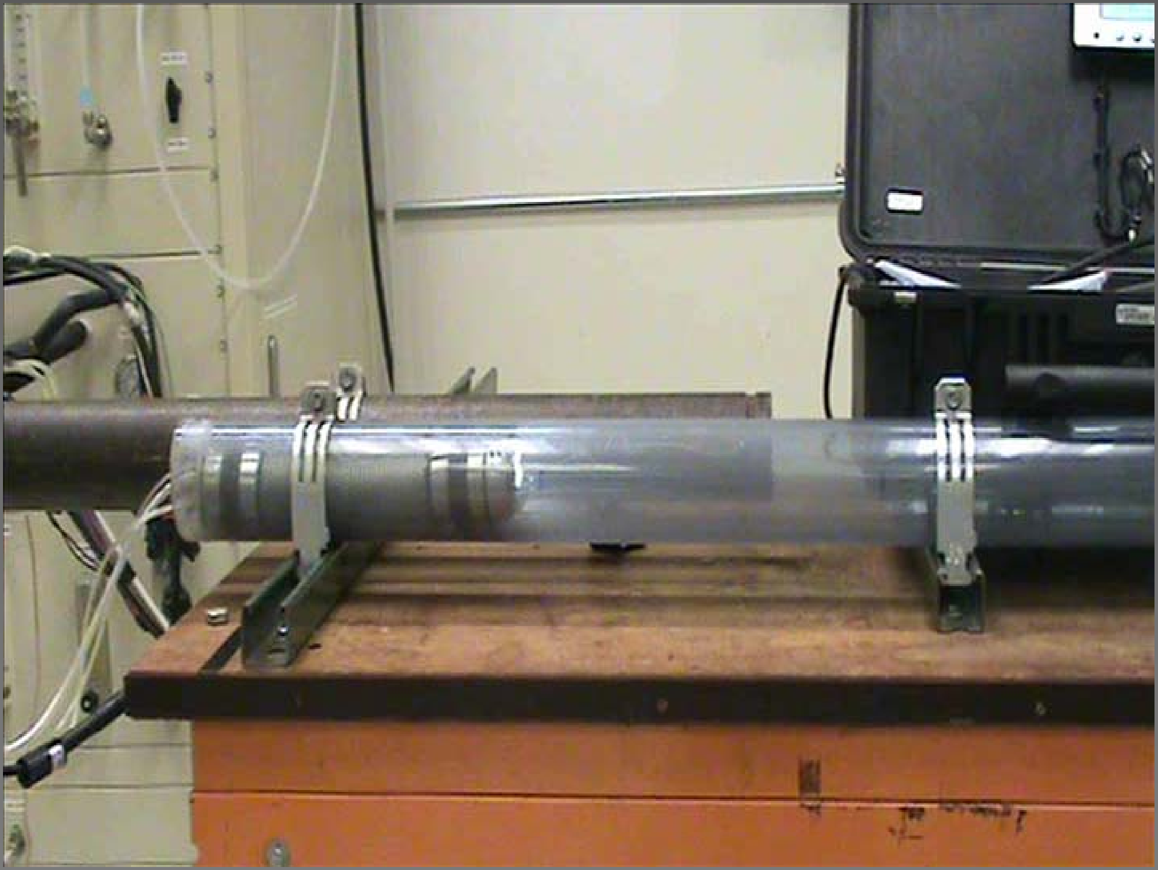


Pipeline Unplugging – Peristaltic Crawler

Current System

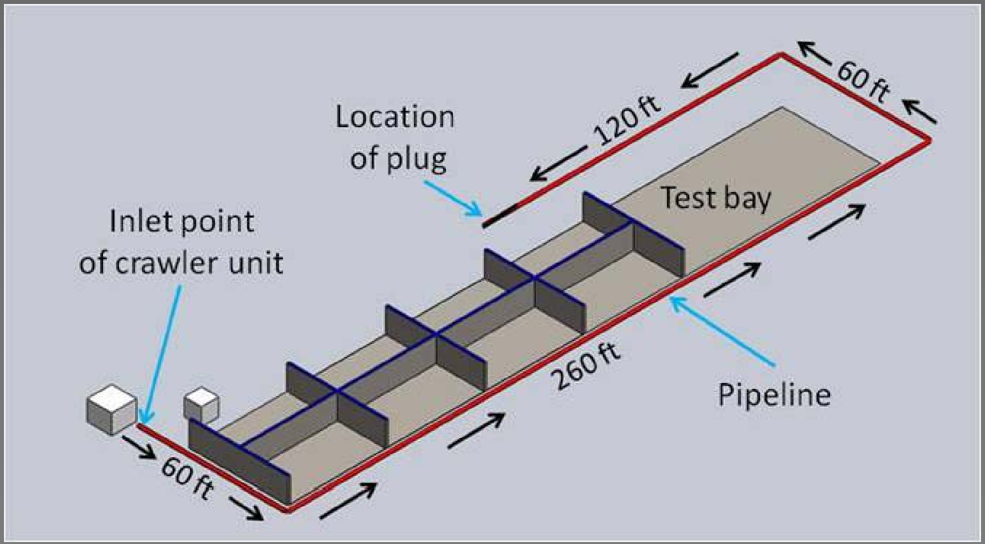
Video Feedback

Pipeline Unplugging – Peristaltic Crawler



Pipeline Unplugging – Peristaltic Crawler

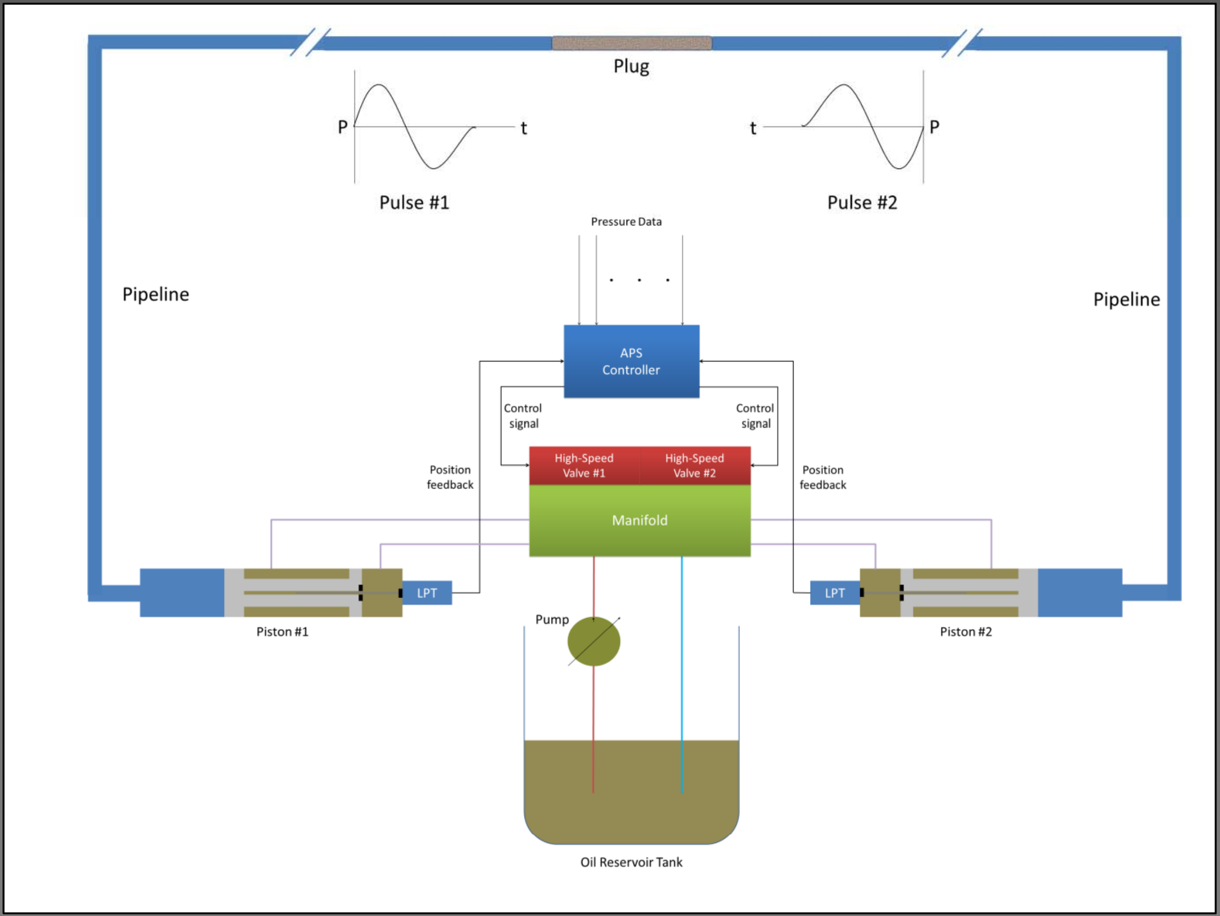
Current Testing – 500 ft test bed



Pipeline Unplugging – Current Tasks

Asynchronous Pulsing

- 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



APS Schematic

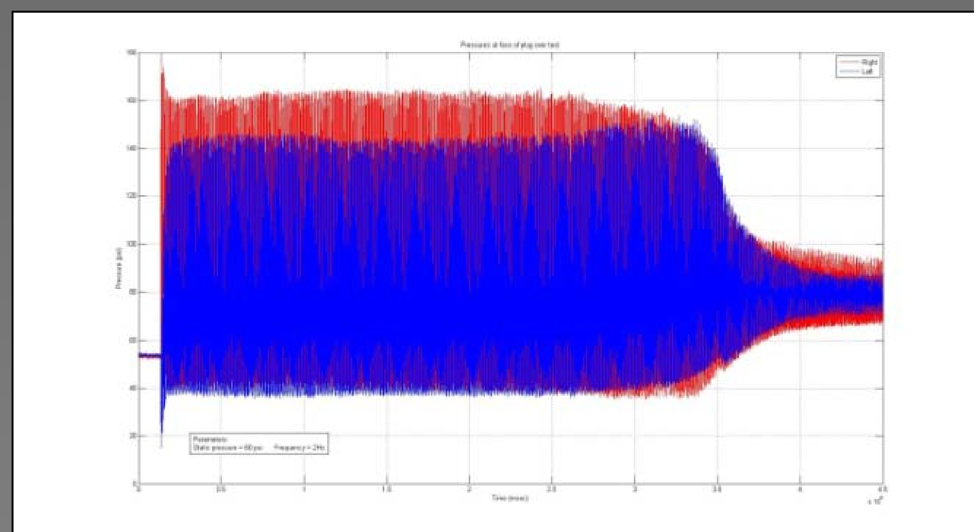
Pipeline Unplugging: Asynchronous Pulsing

Previous Lab Scale Testing

- 2 - 20 ft. systems with 1 elbow
- pressure transducers and accelerometers

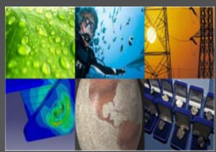
Test Parameters

- System static pressure – 60, 150, 200 psi
- % water – 100% and 85%
- Pulse magnitude
- Pulse frequency – 1, 2, 4, 8, 10, 20 Hz



Testing

- Parametric testing with solid metal plug
- Experimental testing with K-mag plug



Pipeline Unplugging: Asynchronous Pulsing

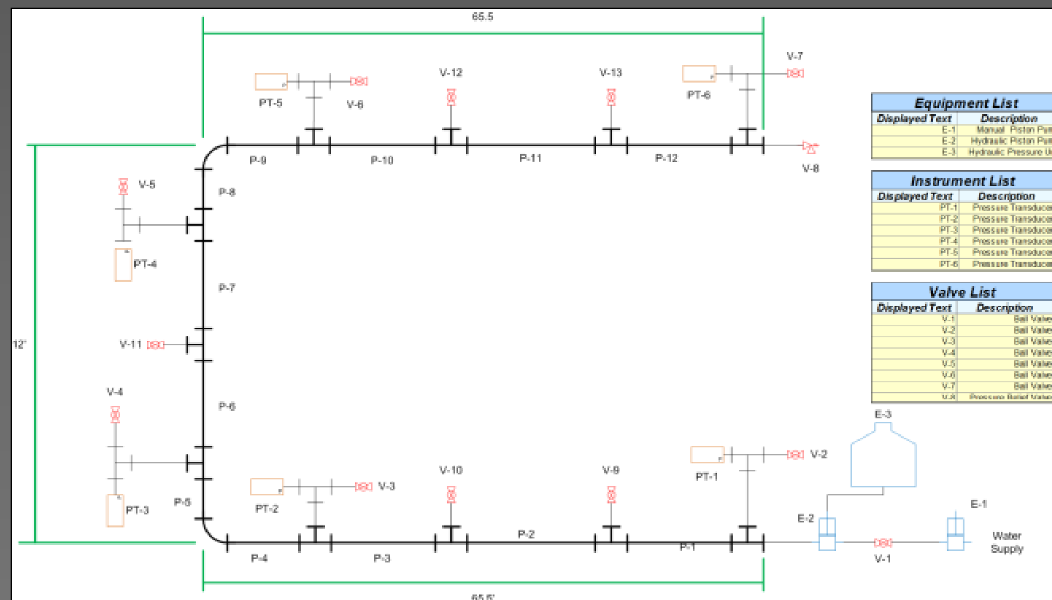
<u>Additional Experimental Set Up</u>

One side of system – 3 loop configurations – 72, 100, and 143 ft

<u>Objectives</u>

Develop systematic process – better estimate system performance at various lengths

Quantifying the effects of air on pulse magnitude and propagation



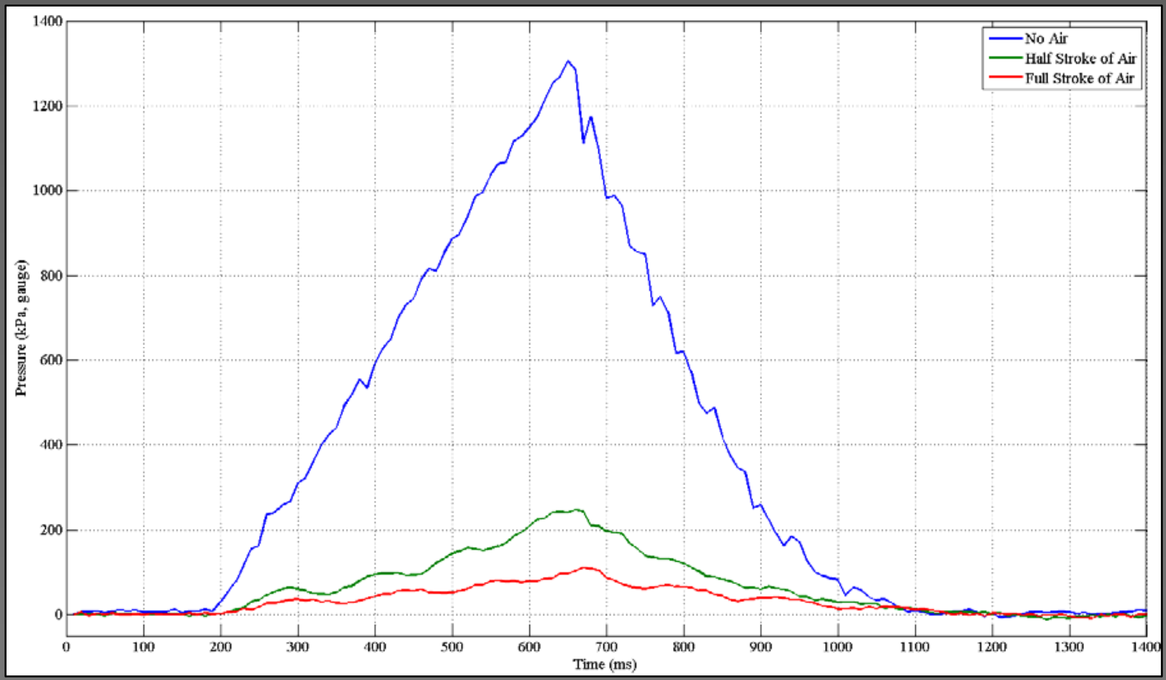
Pipeline Unplugging: Asynchronous Pulsing

Effect of air on 72 ft pipeline system

Significant degradation with a small amount of air

Piston travel is initially used to compress air

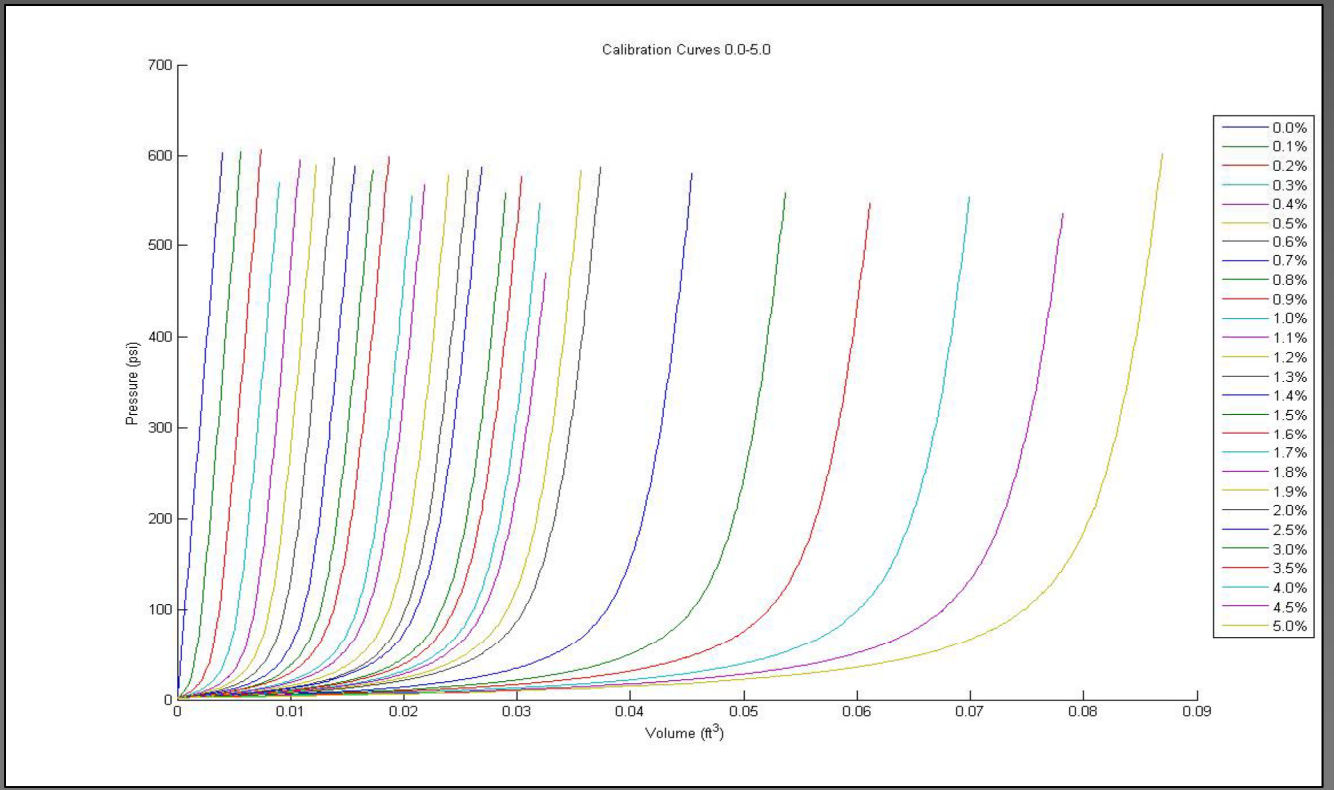
½ stroke – 0.06% volume of air
Full stroke – 0.12% volume of air



Pipeline Unplugging: Asynchronous Pulsing

Compression Tests

- Calibration curves generated for systems with up to 5% air
- Entrained air can be mitigated by increasing static pressure
- The behavior can be exploited to maximize pressure at plug face
- Curves show what static pressure is needed to act as a water only system



Pipeline Unplugging: Asynchronous Pulsing

Current Testing

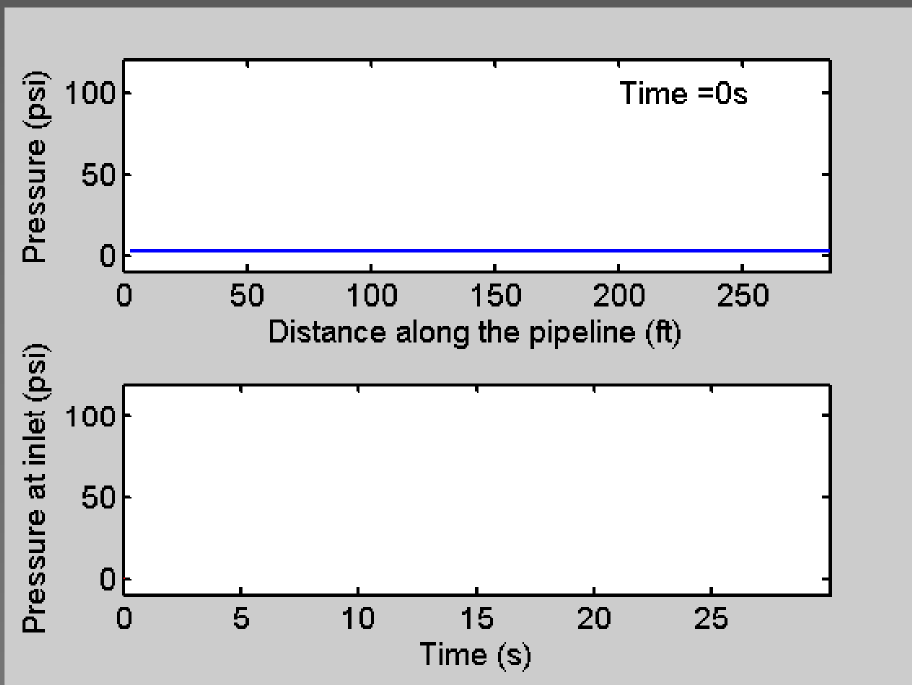
Objective: Evaluate the asynchronous pulsing system on an engineering scale

Testbed:
- 135 ft of threaded sch. 40 carbon steel pipes on each side of plug (0.25% slope) instrumented with pressure transducers, accelerometers and thermocouples

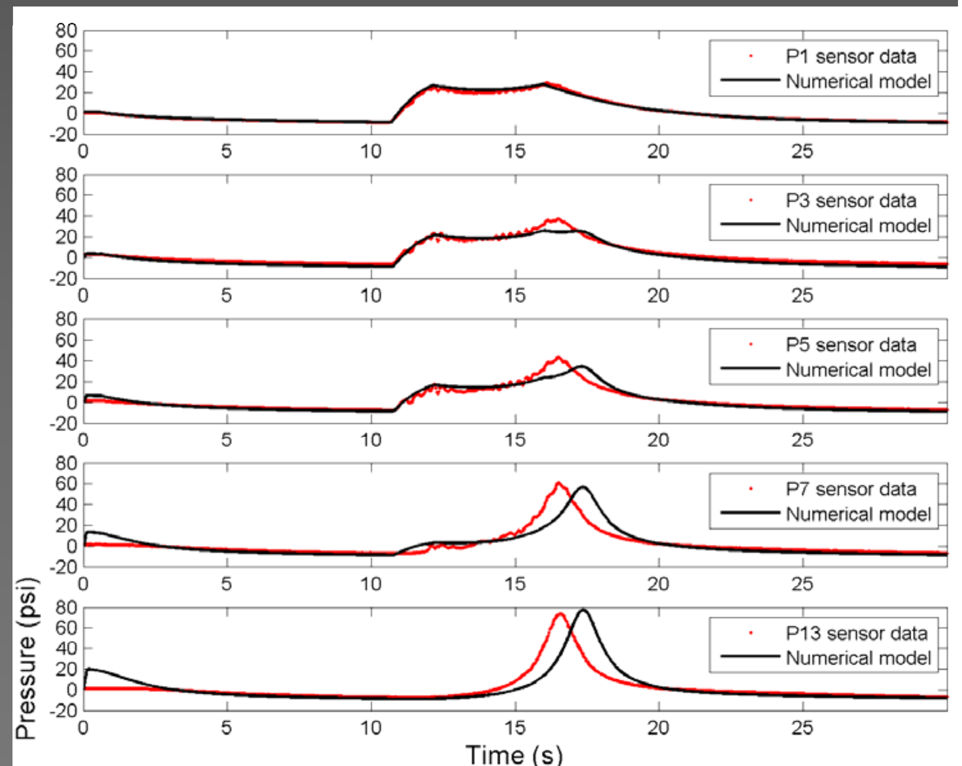
Approach:
- conduct parametric testing – static pressure, pulse frequency and % air

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

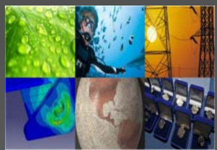
1D Modeling of NuVision



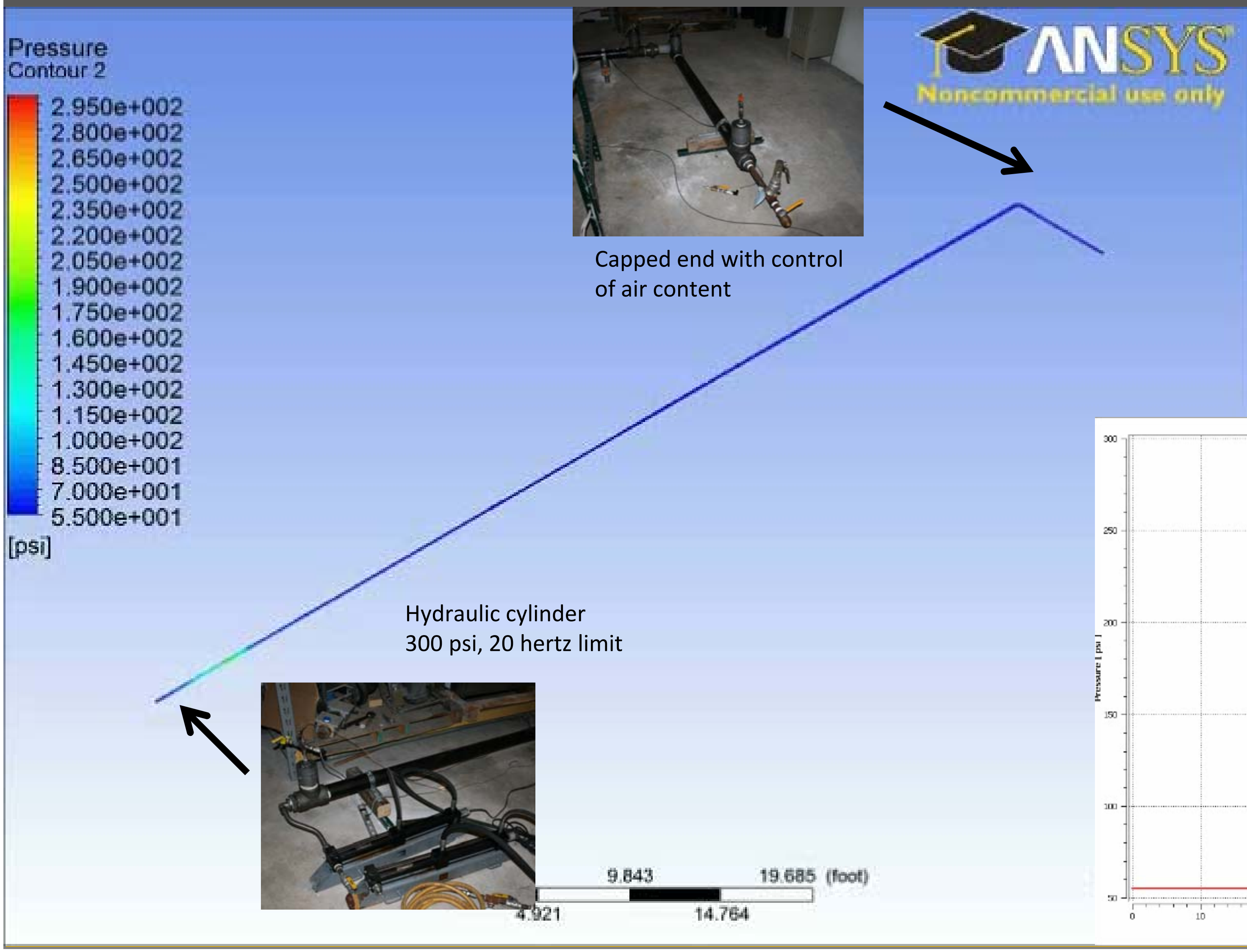
MoC simulation of a pressure pulse translating in a pipe with entrapped air at the end (Bottom picture: Blue: P_inlet, Red: P_end).



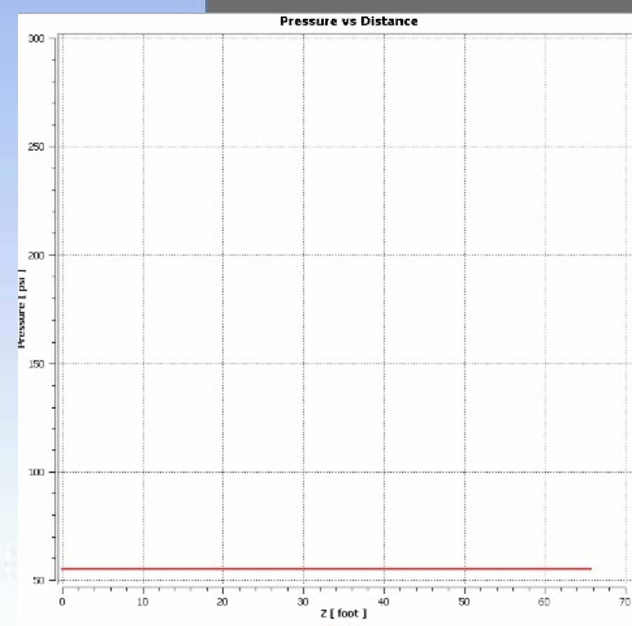
Validation of the MoC results versus the experimental data for pressure profile at various locations in the pipeline.

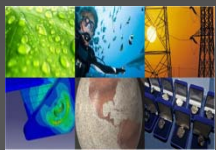


3D Modeling of Fluid Transients



3D Navier Stokes simulation of pressure pulsations created in a pipeline with uniformly distributed air cavity.





Pipeline Unplugging – Current Tasks

Computational Simulation and Evolution of HLW Pipeline Plugs

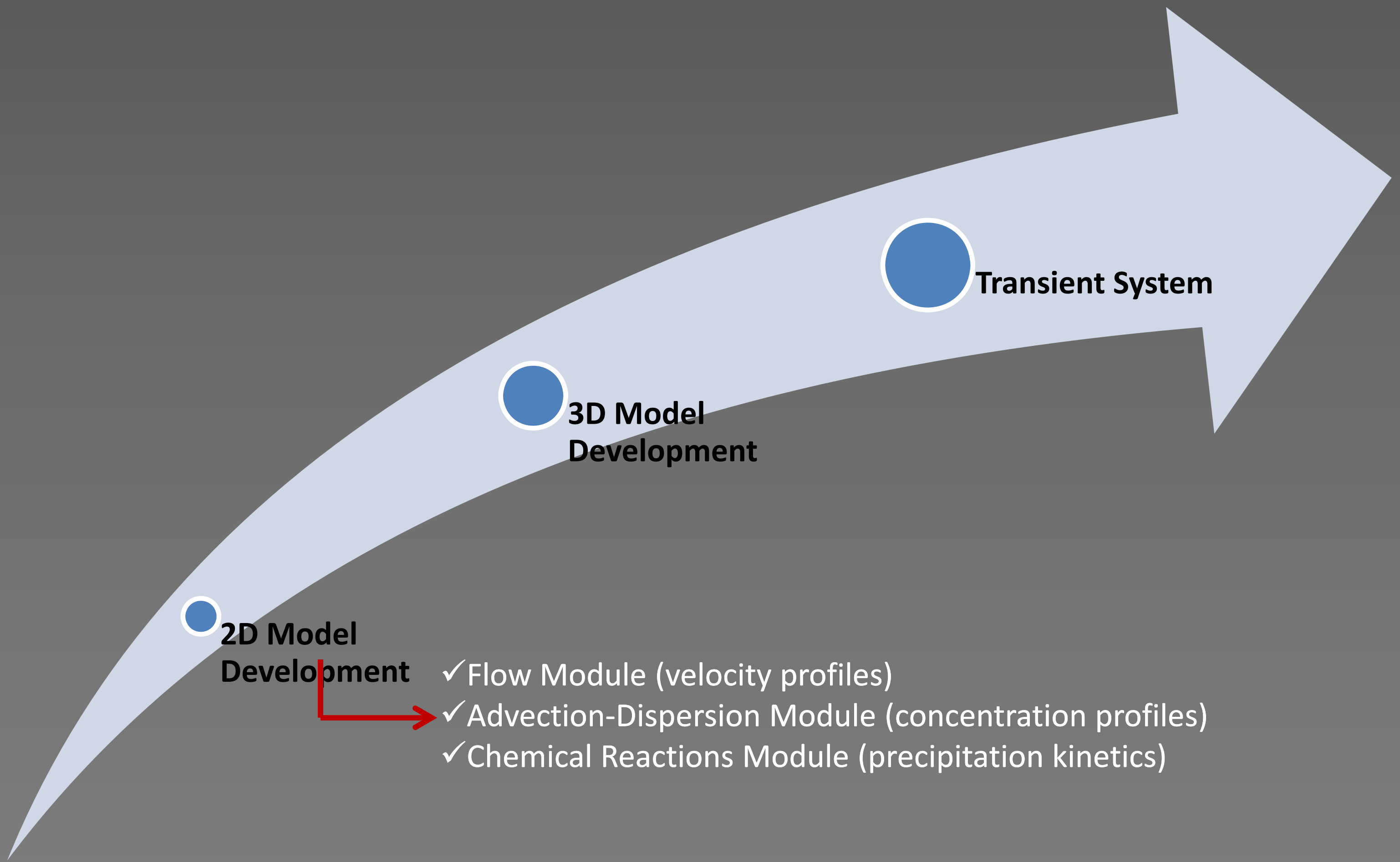
- **<u>Objective:</u>** Create a multi-physical model that simulates the formation of a pipeline plug, and looks at the influence of pipeline geometry/configuration on the plug development process.

- A literature review was carried out to investigate the plugging incidents, plugging mechanisms that caused them and current analysis tools used at Hanford to reduce the risk of plugging.

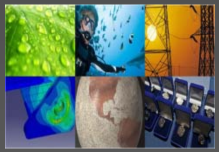
Pipeline Unplugging: Computational Simulation and Evolution of HLW Pipeline Plugs

Current Tools	Capabilities	Notes
Environmental Simulation Program (ESP)	•Chemical equilibrium model used to predict the initial solids fraction of solids and slurry properties •Can Identify precipitation concerns •Evaluate effects of dilution ratios or temperatures	•Does not account for dynamic processes (e.g., breakup of colloidal particles or agglomeration of particles to form particles or gels) •Data for some of the solids in the tank wastes are not in the ESP database
Critical Velocity Correlations	•Calculates the slurry velocity (by Oroskor& Turian Model) that prevents deposition of either a stationary or a moving bed of solids. •Based on *Newtonian* Fluids flowing in a *horizontal piping*	•Estimates one critical velocity for the length of pipe being considered. •The physical properties, transport properties, PSD, and temp are assumed to be the same for length of pipeline. •Little or no information provided about local velocity profile, local solid bed depth, local liquid concentration, solids volume fraction, solids PSD, or temp., along the length of the pipe. •Under predicts velocity for non-Newtonian fluids (WTP-RPT-175)

Pipeline Unplugging: Computational Simulation and Evolution of HLW Pipeline Plugs



- ✓Flow Module (velocity profiles)
- ✓Advection-Dispersion Module (concentration profiles)
- ✓Chemical Reactions Module (precipitation kinetics)



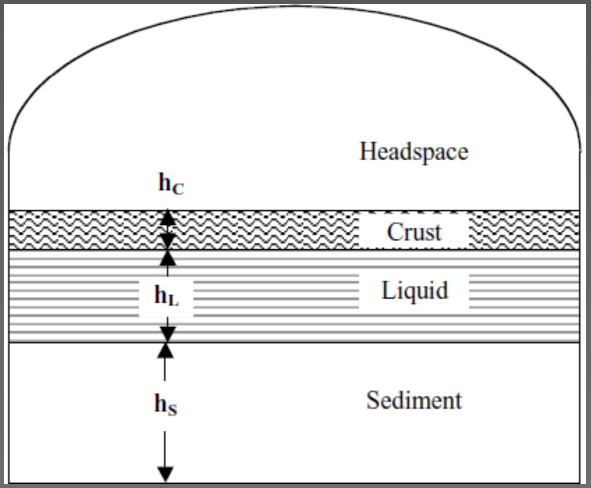
Path Forward

- Complete peristaltic crawler development/testing
  - Fatigue test, Topical report, cold test
- Complete asynchronous pulsing development/testing
  - Topical report, cold test
- Computational Simulation and Evolution of HLW Pipeline Plugs
  - Continue development of computational tools

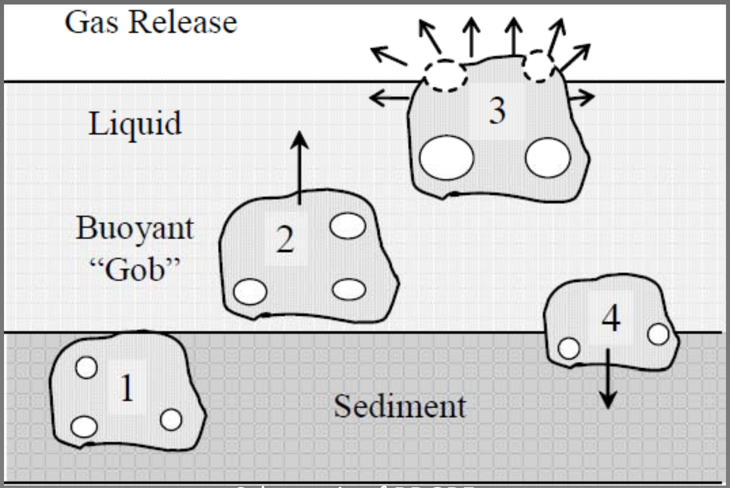
COMPUTATIONAL FLUID DYNAMICS ACTIVITIES

Multiple-Relaxation Time, Lattice Boltzmann Model for High-Density Ratio Multiphase Flows

- Flammable gas generation in DSTs (mainly H2):
  - Radiolysis of water,
  - Radiolytic and chemical oxidation reactions of the organic compounds,
  - Corrosion of the steel tank walls (Stock 2000).
- Retrieval of waste from DSTs:
  - Decanting the supernatant liquid
  - Jet mixer pumps
- Buoyant Displacement Gas Release Events (BDGRE)
  - hydrogen (fuel),
  - nitrous oxide (oxidizer),
  - nitrogen (inert),
  - and small amounts of ammonia, methane,
  - and other hydrocarbons.
- Lower flammability limit (LFL)



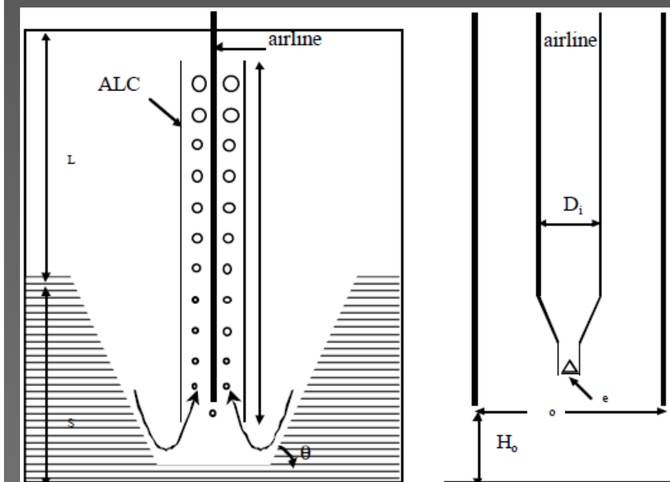
Waste forms existing in a tank.



Schematic of BDGRE.

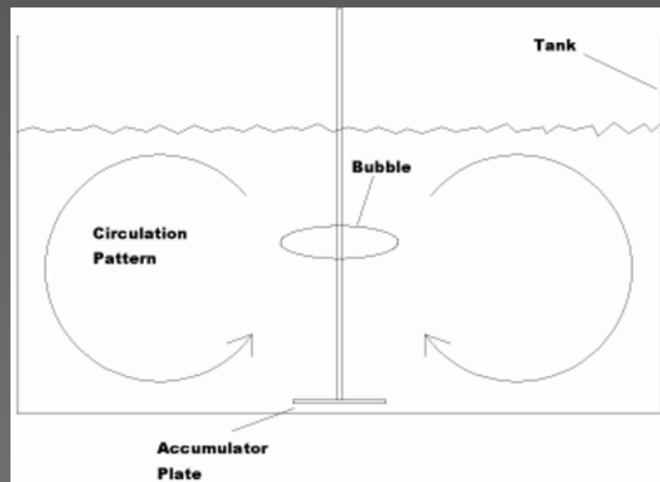
Multiphase Flow in HLW Processing

Airlift Circulators:



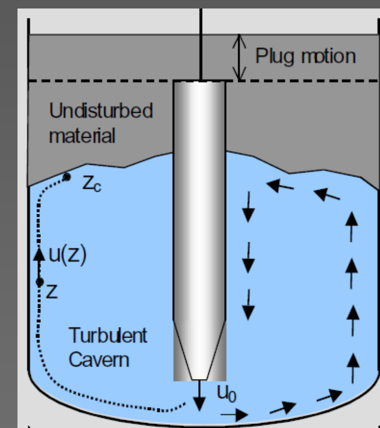
Schematic of Typical Airlift Circulator Operation.

Pulsed-air Mixers:

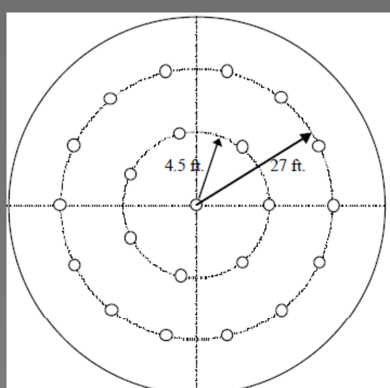


Pulsed-air mixing array in 1=12-scale tank.

Pulsed-Jet Mixers:



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



Location of ALCs in AY and AZ DSTs.
Stewart et al., 2002 , PNNL-13781.


A pulsed-air mixer in action at the ORNL
Gunite and Associated Tanks simulant tank.

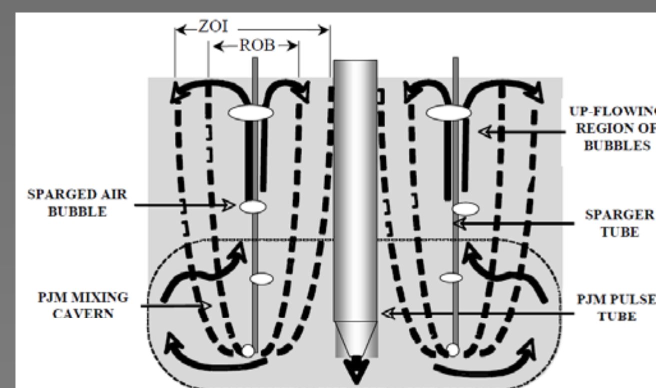
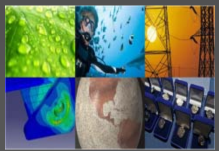


Illustration of Hybrid PJM/Sparger Mixing Concept.
(Stewart et al., 2007, WTP-RTP-156)



Lattice Boltzmann Method – Theory

Continuous Boltzmann equation:

$$\frac{\partial f}{\partial t} + \xi \cdot \nabla f + \mathbf{F} \cdot \nabla_{\xi} f = \Omega.$$

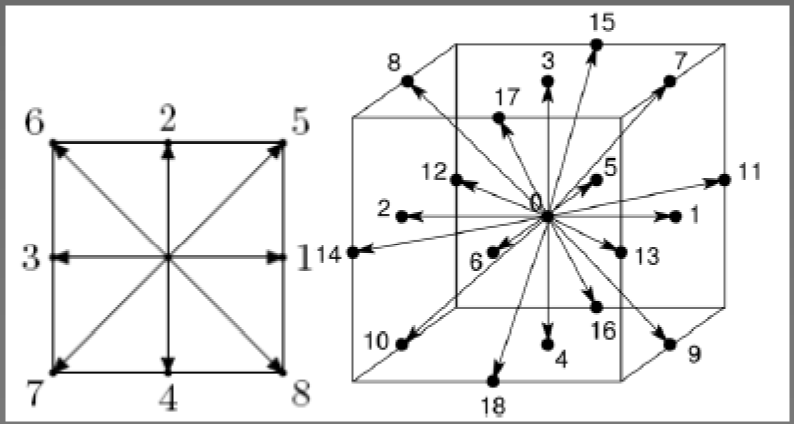
Discrete Boltzmann equation (Discrete Velocity Model):

$$\frac{\partial f_\alpha}{\partial t} + \xi_\alpha \cdot \nabla f_\alpha = \Omega_\alpha + S_\alpha.$$

Lattice Boltzmann equation:

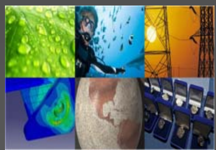
$$f_\alpha(\mathbf{x}+e_\alpha \delta t, t+\delta t) - f_\alpha(\mathbf{x}, t) = \Omega_\alpha + S_\alpha.$$

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



D2Q9 D3Q19

Lattice structures in 2D and 3D.



Lattice Boltzmann Method – Procedure

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

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:

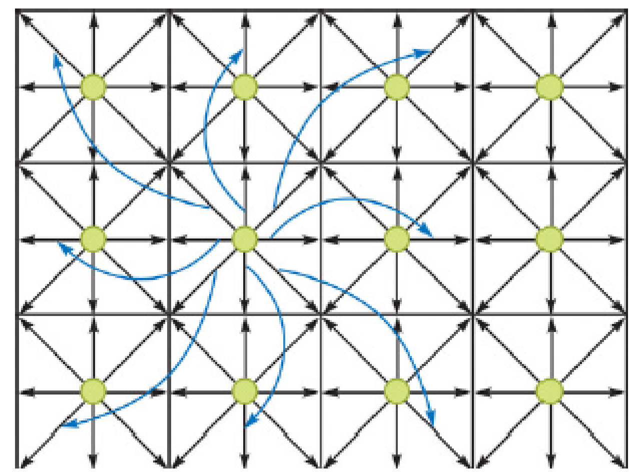
$$f_\alpha^{eq} = w_\alpha \rho \left[1 + \frac{e_{\alpha i} u_i}{c_s^2} + \frac{(e_{\alpha i} e_{\alpha j} - c_s^2 \delta_{ij}) u_i u_j}{2 c_s^4}\right],$$

$$w_\alpha = \begin{cases} 4/9, & \alpha = 0, \\ 1/9, & \alpha = 1-4, \\ 1/36, & \alpha = 5-8, \end{cases} \quad \text{for D2Q9,}$$

$$w_\alpha = \begin{cases} 1/3 & \alpha = 0, \\ 1/18, & \alpha = 2-7, \\ 1/36, & \alpha = 8-18, \end{cases} \quad \text{for D3Q19.}$$

$c_s^2 = 1/3$: speed of sound.

2. *Streaming* **:**



3. *Sampling* **:**

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

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

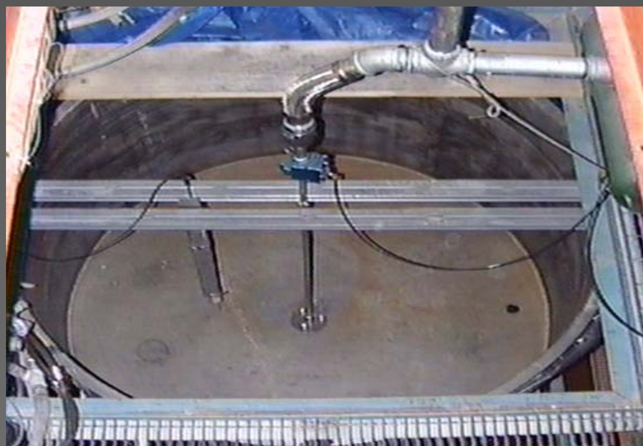
LBM – Highlights

- 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

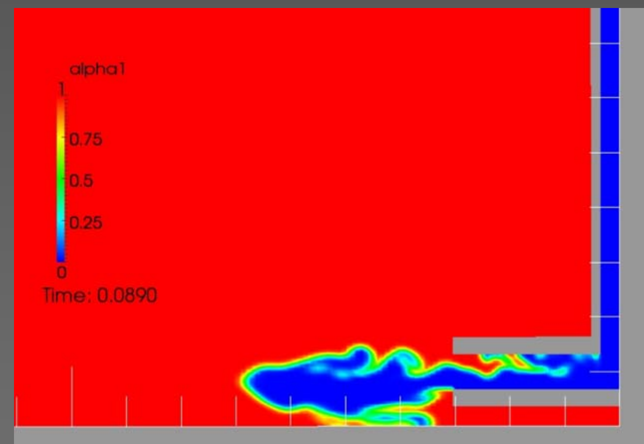
- Multiphase Models:
  - The color method (Gunstensen et al., 1991),
  - the potential method (Shan and Chen, 1993),
  - the free-energy method (Swift et al., 1995),
  - the index function method (He et al., 1999),
  - other methods (hybrid level-set LBM, front tracking LBM etc.)

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

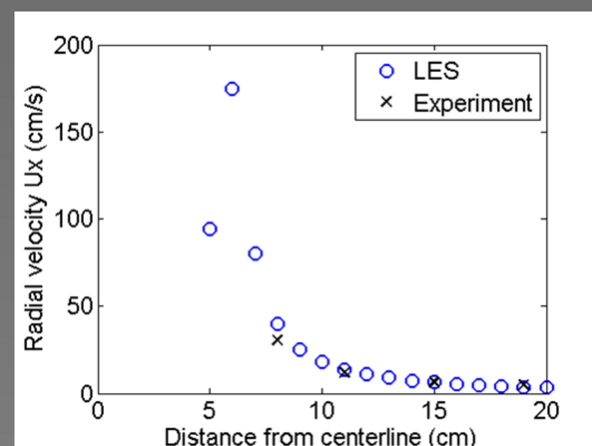
Pulsed-air mixing simulation (OpenFoam – Volume of Fluid)



1/12 scale DST at PNNL (Powell amd Hymas, PNNL-11200, 1996).



Density contours (Galdamez et al., WM2011, Phoenix, AZ, 2011).

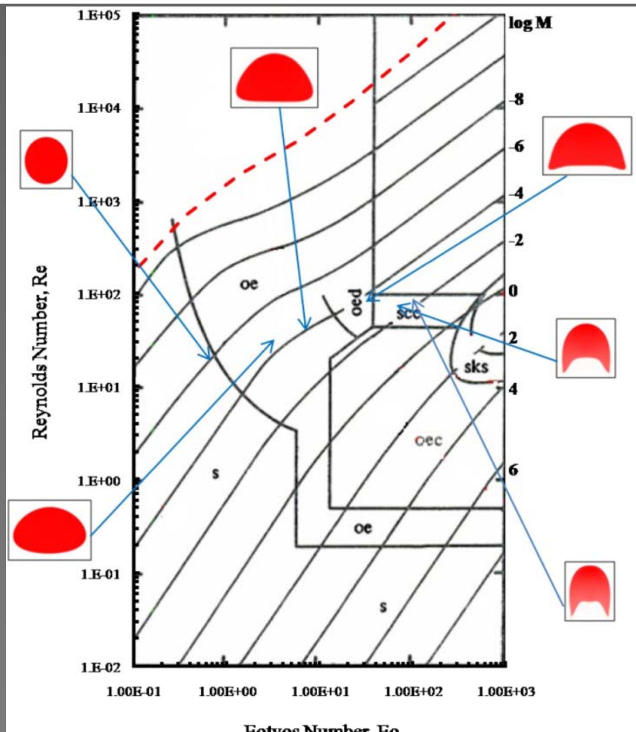


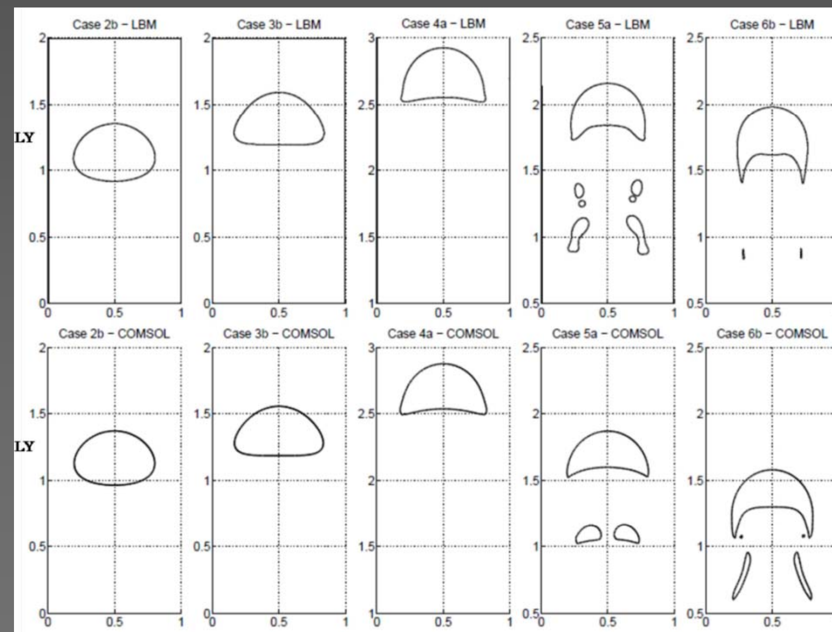
Maximum velocity profile along the nozzle centerline.

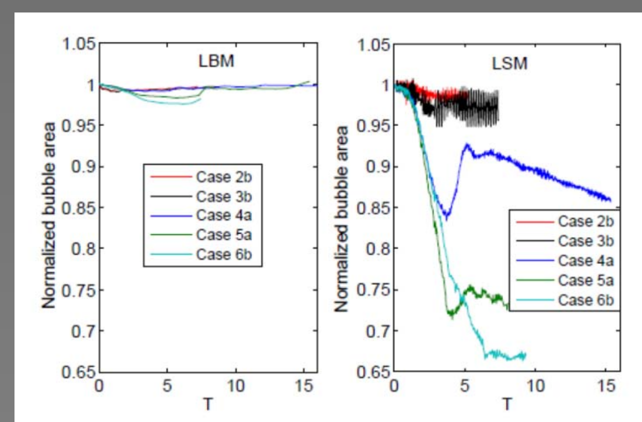
Multiphase LBM (The potential method)

$$R_e = \frac{V_b d_b \rho_L}{\mu_L} \qquad M = \frac{g \Delta\rho \mu_L^4}{\rho_L^2 \sigma^3} \qquad E_o = \frac{g \Delta\rho d_b^2}{\sigma}$$

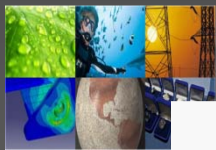
Reynolds Morton Eotvos





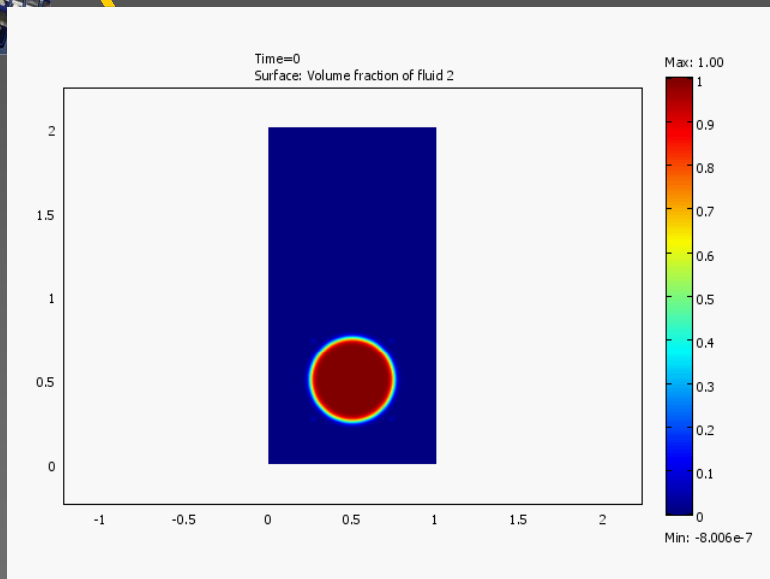


Ngachin, Merlin, Ph.D. Dissertation, FIU, Miami, FL, 2011.
Ngachin, Galdamez, Gokaltun, Sukop, Computers and Fluids, 2013 (under review)

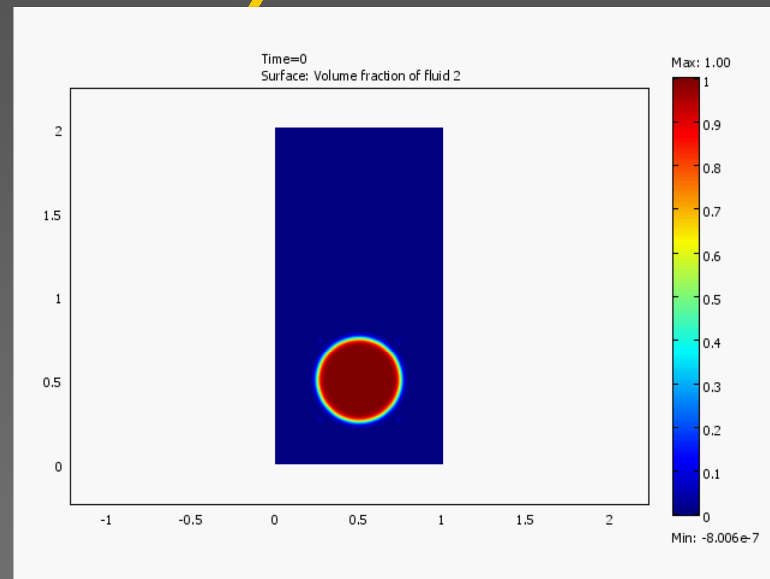


Rising bubble simulation (COMSOL – Level Set Method)

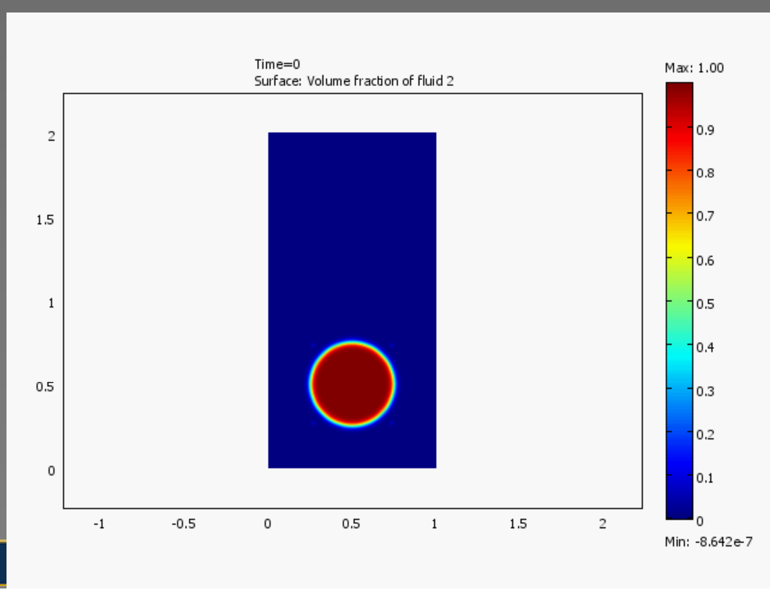
Eo = 5



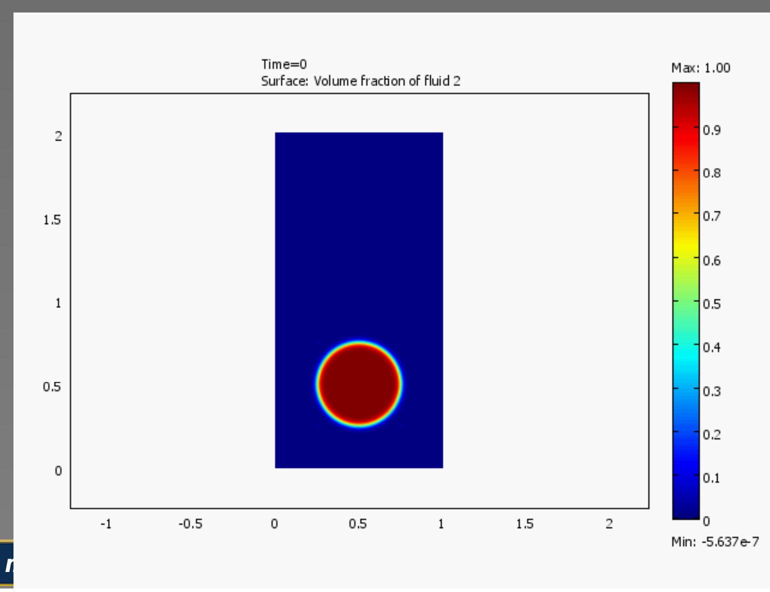
Eo = 10

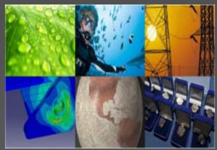


Eo = 30

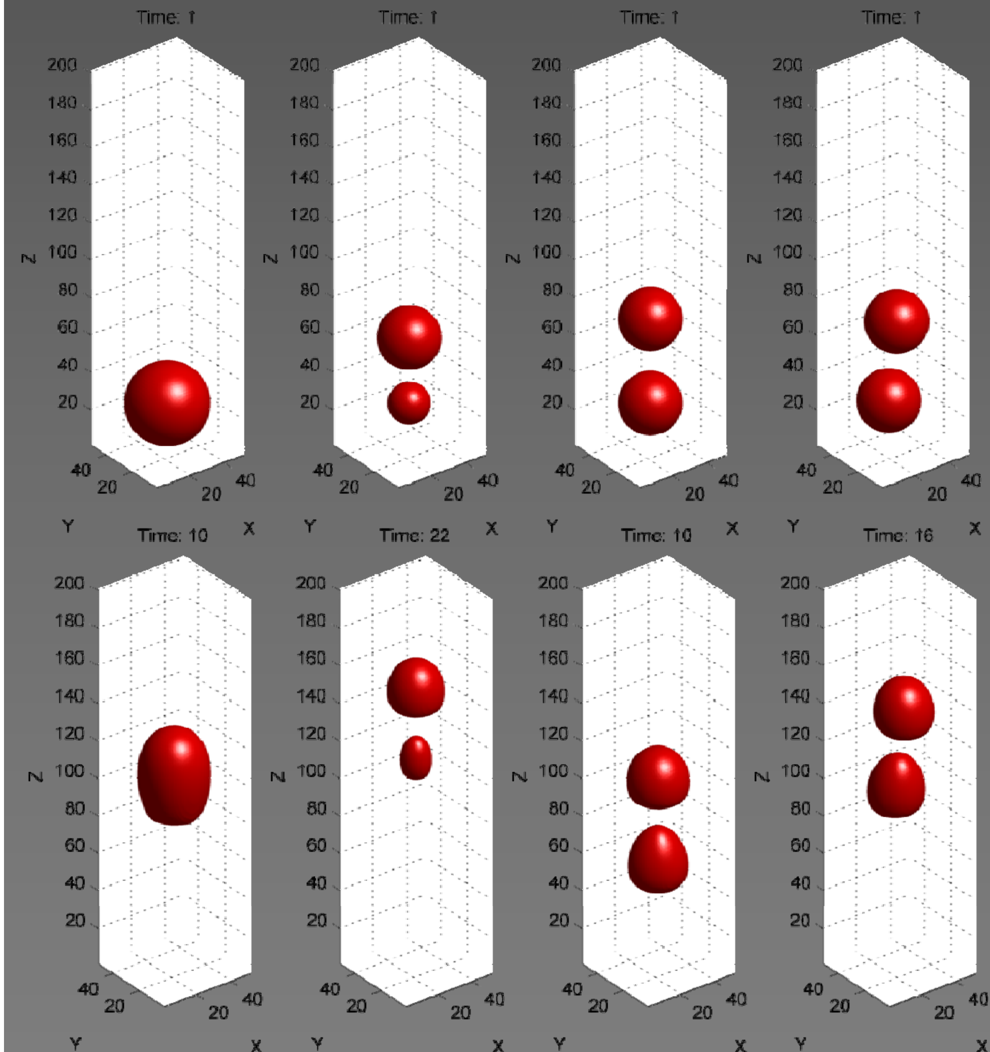


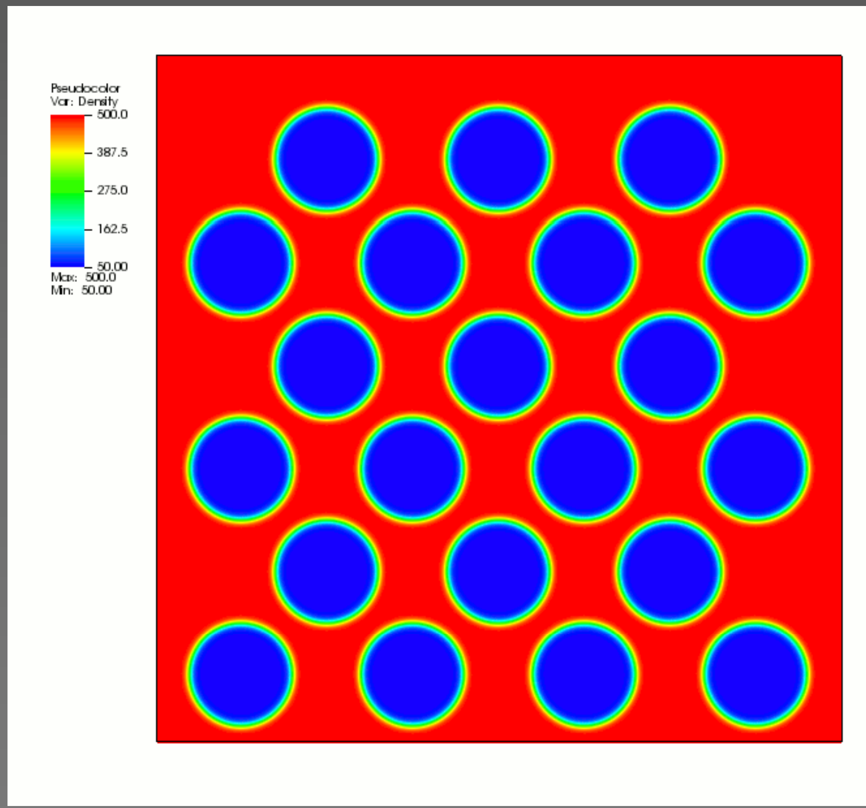
Eo = 75

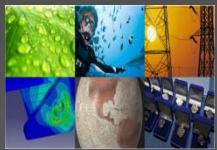




3D Multiphase LBM (The index function method)

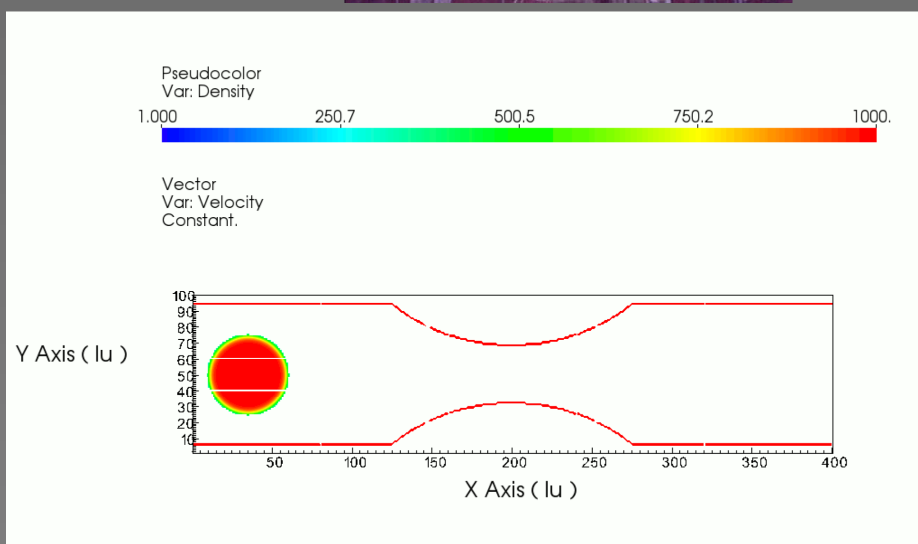


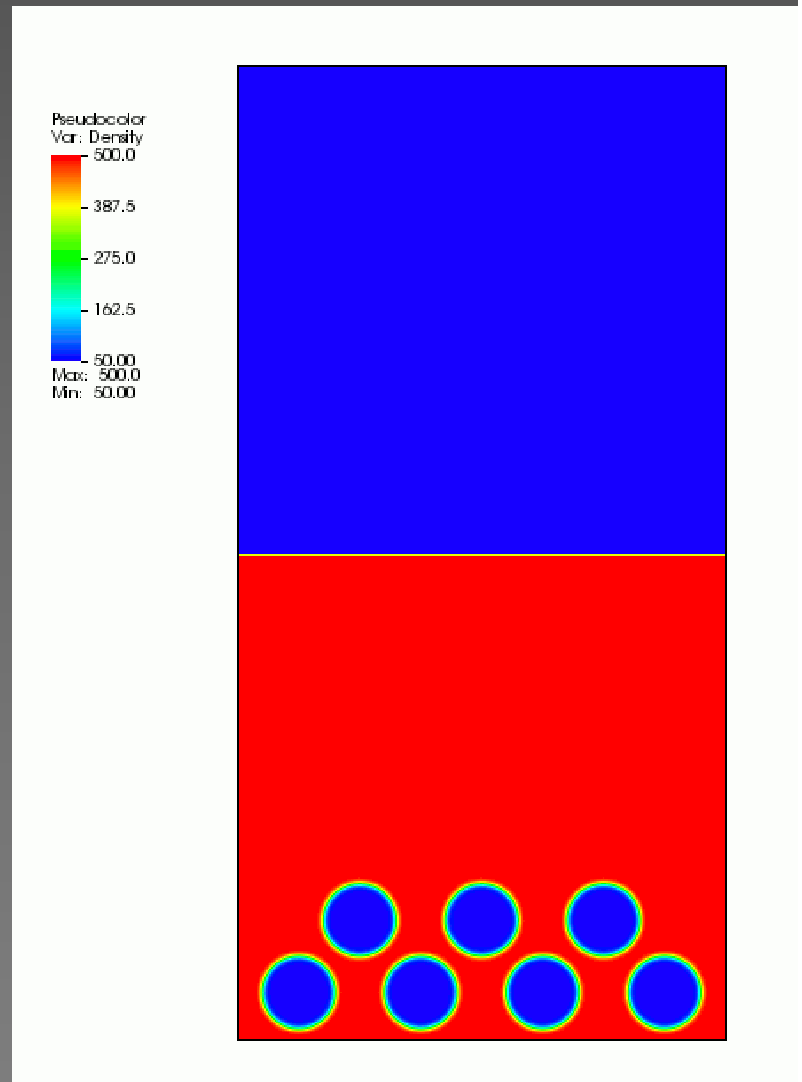


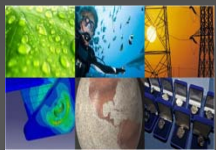


3D Multiphase LBM (Complex geometries)

Cooling coils in Tank 1 in SRNL.



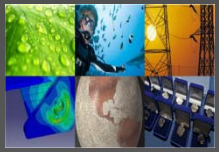




Summary and Future Work

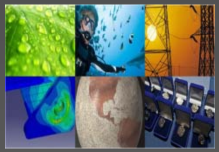
- FIU developed an accurate and efficient computer code for investigation of incompressible, laminar, 3D, multiphase flow in complex geometries.
- Current version of the code allows for moderate Reynolds number flows with bubbles or drops in motion
- To make it more applicable to engineering problems:
    - Turbulence model (turbulent jet flow, PJMs Re=O(10^4)),
    - Non-Newtonian fluids (Bingham Plastic) capability needed.
- Literature review under way
- Graphical Processing Unit(GPU) computing

HLW PROCESSING SUPPORT ACTIVITIES



Background

- Support Mixing, Retrieval & Processing Instrumentation activities
- Utilization of new technologies for process monitoring and characterization
- In-situ or Laboratory

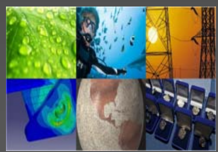


In-Tank Monitoring of WF Mixing

- Instrumented flow loop implementation
- Supplement flow loop data with in-situ monitoring at varying depths
- Target deployment: Tank AY-102
- Limited in-situ instrumentation
- How to measure “consistency” of slurry?
  - Can it be done at different tank depths?

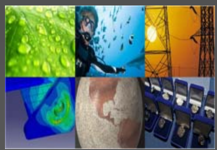
Technology(ies) Need

- Monitor slurry macro/micro characteristics ***in-situ*** (e.g. slurry density, concentration, solid density, PSDD, abrasivity)
- Use of multiple techs an option
- Provide a sensor package for monitoring at various depths
- Provide real-time data
- Be ready for AY-102 deployment



Tech Search Results

- Focused Beam Reflectance Measurement (FBRM)
- Optical Back-Reflectance Measurement (ORM) / Laser Time of Reflection (TOR) Analysis
- Capacitance Profiling
- Ultrasonic Doppler Velocimetry (UDV) / Acoustic Doppler Current Profiling (ADCP)
- Electrical Capacitance Tomography (ECT)
- Energy Dispersive X-ray Diffraction (EDXRD)
- Linear Electrical Resistance Tomography (ERT)
- Lamb (Stoneley) Wave Viscosity Measurement
- Laser Diffraction
- Raman Spectroscopy
- Dynamic Light Scattering
- Ultrasound Spectroscopy (USS)
- Vibration-based Density measurement (Coriolis, Tuning Fork)
- Microwave Phase difference measurement
- Nuclear density measurement



Candidate Technologies

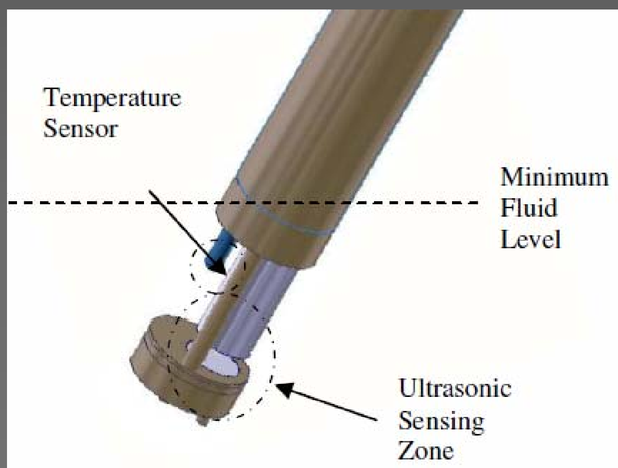
- Focused Beam Reflectance Measurement (FBRM)
- Optical Back-Reflectance Measurement (ORM)
- Ultrasonic Spectroscopy (USS)
- Lamb/Stoneley Wave Measurement
- Vibration-based Density measurement (Tuning Fork)

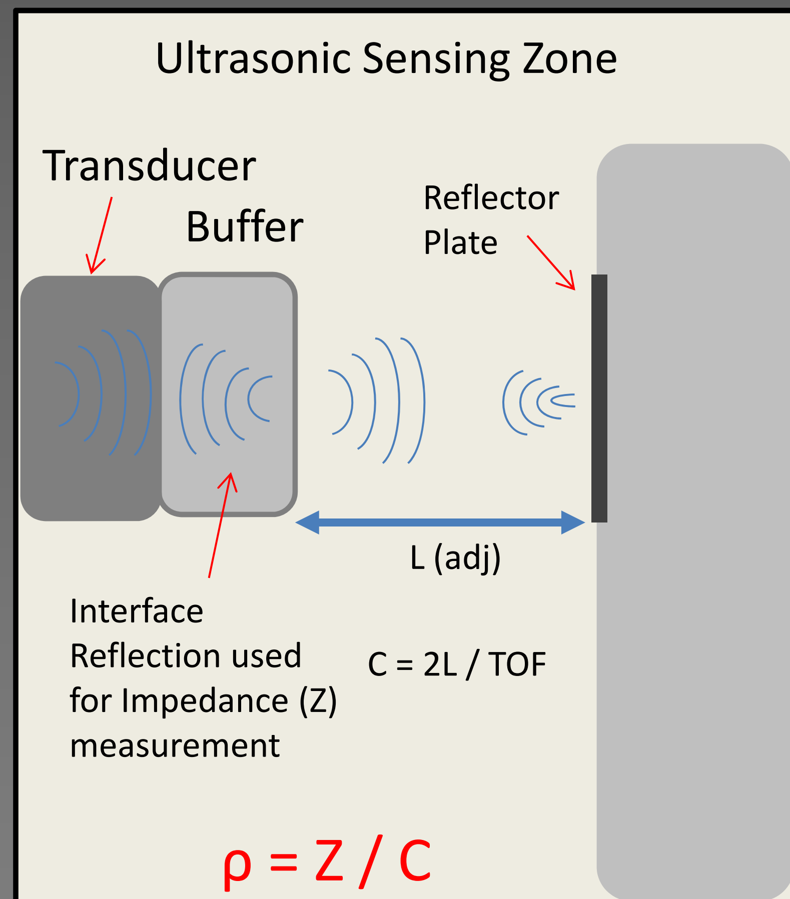
Ultrasonic Spectroscopy (USS)

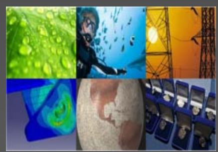
- Spectral analysis of return echo from multiple US pulses; measurement of interface reflection and TOF
- Measures signal attenuation, TOF, reflection at sensor/suspension interface, impedance difference at interface.
- System can be utilized in through-transmission or pulse-echo configuration
- Referencing required to determine attenuation data use (attenuation to slurry UDS concentration)
- Susceptibility to electrical noise

Ultrasonic Spectroscopy (USS)

USS Operating Principle





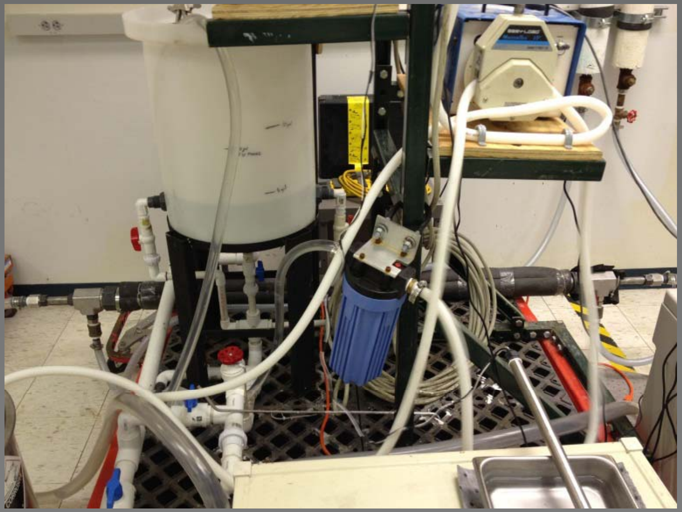


Phase 1 Test Description

- Base and complex slurries
- UDS in mixture
  - Base solid (Aluminum Trihydrate)
  - Complex mixture solids (Aluminum Trihydrate, Zirconium Oxide, Stainless Steel)
- Solution
  - Water
  - NaNO3 solution
- Transient (material addition) and steady-state data collection
- Constant temperature (20 +/- 0.2 ° C)
- Reference Measurement: pycnometer (initial tests), Coriolis Density measurement loop

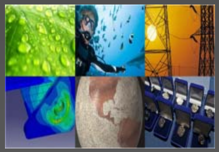
Mixing Loop

- 10-gallon mixing loop
- 1 HP mixing pump
- 1 bottom, 2 angled (45º) jets
- Single-stage filtration for NaNO3 UDS removal
- Solid material loaded manually

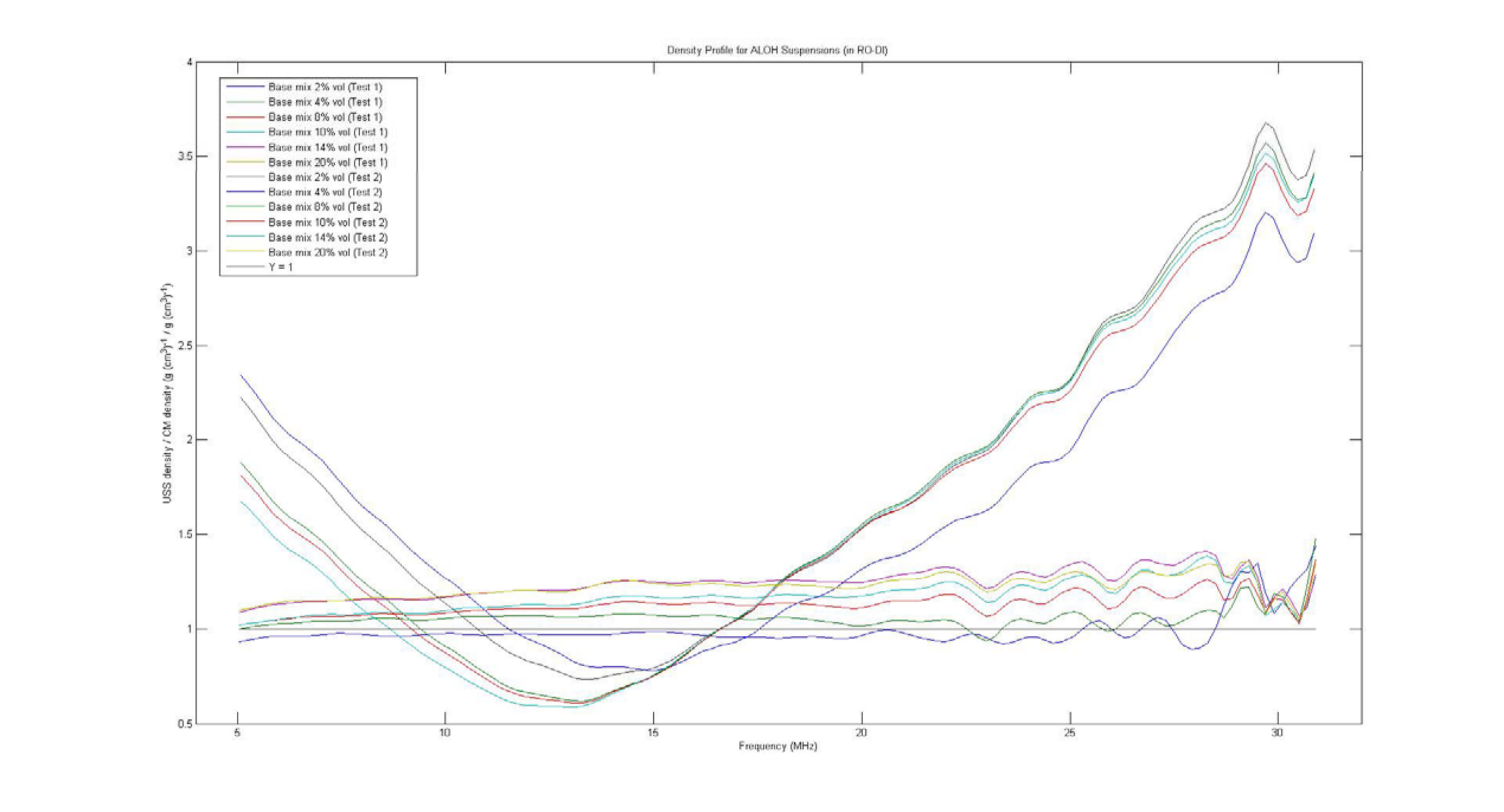


Test Slurries

- Base mixtures
  - Carrier fluid densities (SG): 1.00, 1.16, 1.28
  - UDS concentrations (by VOL%): 2,4,8,10,14,20
- Complex mixtures
  - Carrier fluid densities(SG): 1.00, 1.16
  - UDS concentrations (by VOL%): 2,4,8,10
- Several tests done with NaNO3 solutions to verify speed of sound measurement



System #1 vs #2


Density Profile for ALOH Suspensions (in RO-DI)
Base mix 2% vol (Test 1)
Base mix 4% vol (Test 1)
Base mix 8% vol (Test 1)
Base mix 10% vol (Test 1)
Base mix 14% vol (Test 1)
Base mix 20% vol (Test 1)
Base mix 2% vol (Test 2)
Base mix 4% vol (Test 2)
Base mix 8% vol (Test 2)
Base mix 10% vol (Test 2)
Base mix 14% vol (Test 2)
Base mix 20% vol (Test 2)
Y = 1
4
3.5
3
2.5
2
1.5
1
0.5
5
10
15
20
25
30
Frequency (MHz)

Phase 2 Results

Measured density NaNO3 aq solutions with calculated density

%volume	measured density	calculated density	vol average density	relative error [%]
0.1	1	1001.26	999.26	0.13
0.5	1.01	1006.31	1004.32	0.37
1	1.01	1012.61	1010.63	0.26
2	1.03	1025.22	1023.26	0.47
3	1.04	1037.83	1035.89	0.21
5	1.06	1063.05	1061.15	0.29
7	1.09	1088.27	1086.41	0.16
10	1.13	1126.1	1124.3	0.35
15	1.19	1189.15	1187.45	0.07
20	1.25	1252.2	1250.6	0.18
25	1.32	1315.25	1313.75	0.36
30	1.38	1379.23	1376.9	0.06
37.5	1.47	1474	1471.63	0.27

Phase 2 Results

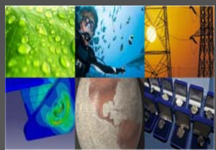
Measured density of aluminum hydroxide in NaNO3 aq solutions with calculated density

% volume	measured density	calculated density	relative error [%]
0.1	1.17	1.17166	0.14
0.5	1.18	1.17831	0.14
1	1.19	1.18661	0.29
2	1.2	1.20323	0.27
3	1.22	1.21984	0.01
5	1.25	1.25307	0.24
7	1.29	1.2863	0.29
10	1.34	1.33614	0.29
15	1.42	1.41921	0.06
20	1.5	1.50228	0.15
25	1.59	1.58535	0.29

Phase 2 Results

Measured density of complex mixture in $NaNO_3$ aq solutions with calculated density

% volume	measured density	calculated density	relative error [%]
1	1.07	1200.398	10.86
2	1.024	1230.81	16.80
4	1.057	1294.207	18.33
6	1.047	1364.286	23.26
8	1.087	1429.074	23.94
10	1.101	1501.173	26.66



Summary

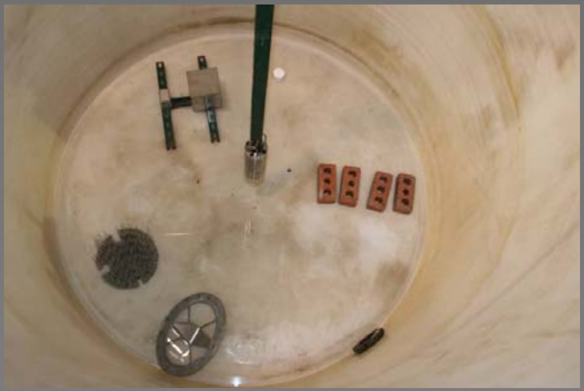
- Reflection measurements were proposed as a means of monitoring the density of the solution
- Density value results were largely dependent on the speed of sound rather than the reflection co-efficient
- Effect of different materials at different concentrations, and different mixtures of materials, was examined to determine the effectiveness of the speed of sound measurement
- Modeling and the measurements both showed that the aluminum hydroxide acoustic velocity increased with concentration, while the zirconium dioxide and stainless steel acoustic velocities decreased with concentration.
- Measurements using mixed samples showed that this resulted in the acoustic velocities of the three samples effectively cancelling each other out with the combined acoustic velocity being less dependent on concentration.
- Future work should concentrate on obtaining high quality attenuation data and velocity data using through transmission measurements and a specialist high concentration measurement system, to enable measurements at the concentrations encountered in the HLW tanks at Hanford.

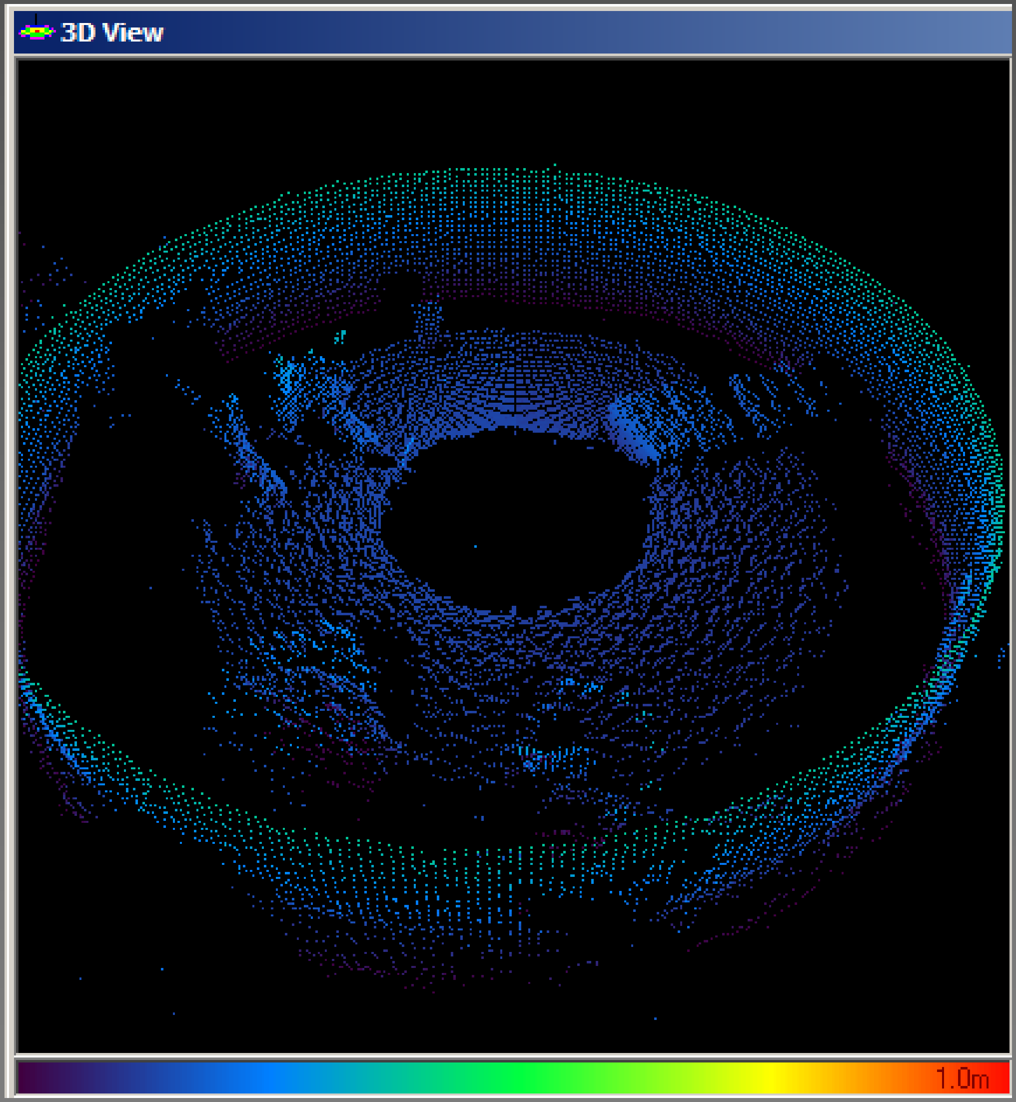
TECHNOLOGY DEVELOPMENT FOR HLW INSTRUMENTATION

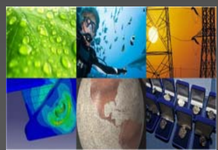
Solid Liquid Interface Monitor (SLIM)

- 3D Surface map of SL interface
- Deployable 50+’ into tank
- Chemical, rad resistant sonar design
- Down to 8 mm resolution (@ 1m)
- Remotely operated and monitored

SLIM Testing

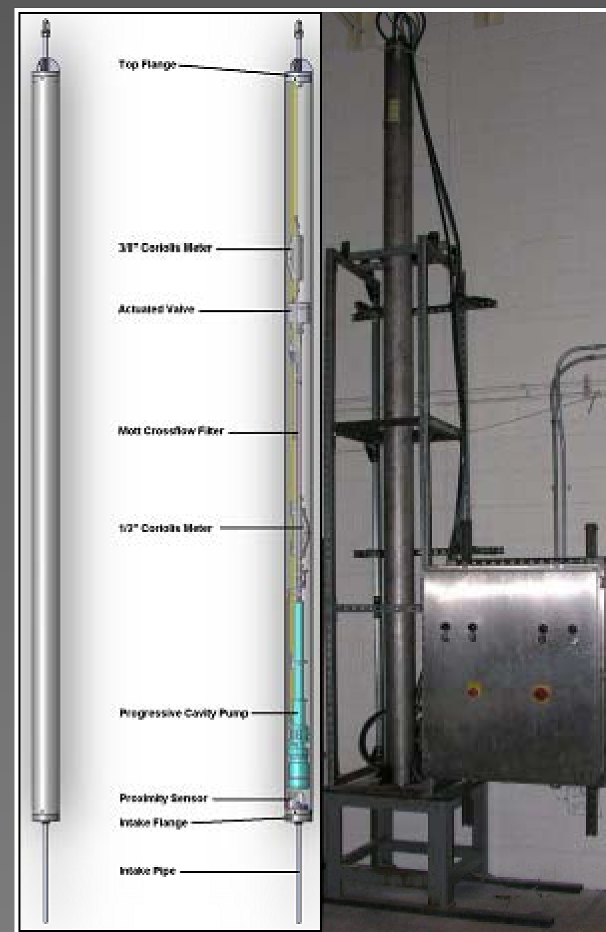


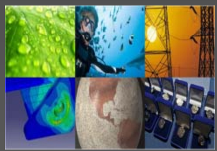




Solids Concentration Monitor

- Solids concentration monitoring (up to 20%)
- Dual Coriolis Meter System
- In-Tank and In-Line versions
- Crossflow filter (0.5 um)
- Back-pulsing for filter fouling prevention
- 17 ft with 1-ft pick-up tube





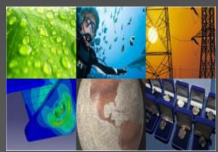
ARC Resources

Equipment/Facilities

- AFM/CFM/ECAFM (w/Environmental Chamber)
- SEM/EDAX
- MTS (5kps)
- Thermatron Environmental Chamber
- American Autoclave (300 psi, 800°F)
- High temperature Kiln (1000°F)
- Machine and fabrication facilities
- 3D FDM System (Rapid Prototyping)
- ICP OES
- Radiation Lab

Analysis/Software

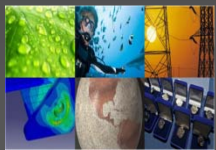
- ABAQUS
- ANSYS
- Fluent
- CATIA
- SPIP
- Matlab
- Comsol
- Labview



Tasks – for FY13

<u>Pipeline Unplugging and Plug Prevention</u>

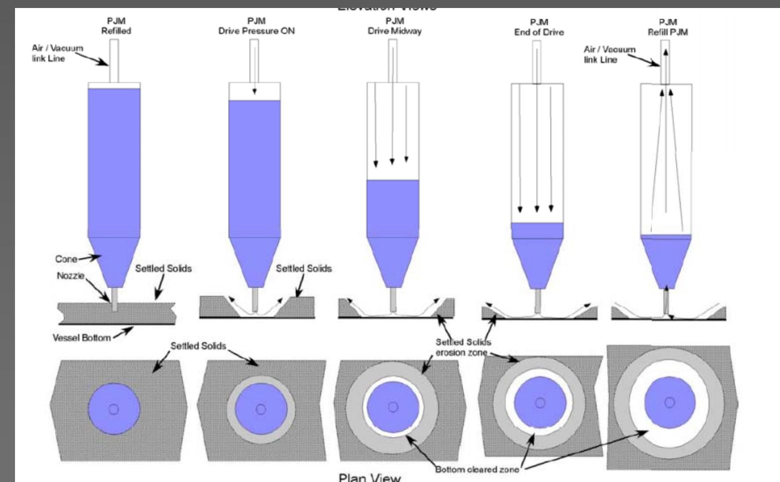
- Development of Alternative Unplugging Technologies
  - Complete testing and validation of the peristaltic crawler and asynchronous pulsing system
- Assessment of AIMM Technology’ Hydrokinetic Process
  - Further evaluate AIMM’s with higher pressure limitations, different plug types and controlled amounts of air entrainment
- Characterization of the Effects of Pulsing Technologies on Pipeline Systems (including waterhammer)
  - Evaluate existing waterhammer codes and develop CFD/FEA models to capture fluid structure interactions of pressure transients with pipeline system
- Computational Simulation and Evolution of HLW Pipeline Plugs
  - Continue the development of a multiphysics model aimed at predicting the formation of plugs with and emphasis on pipeline geometry



Tasks – for FY13

HLW Instrumentation

- Monitoring of Waste in WTP Processing Tanks
  - Evaluate SLIM for ability to determine residual waste



- Stress and Structural Monitoring of HLW Pipeline System
  - Ultrasonics or other NDI techniques to determine effects of pressure transients in HLW lines

Table 1-1: General Ranked Totals

Technology	Total
Pressure Testing	141
Examination of Pipes Taken Out of Service	137
X-Ray	110
Ultrasonic Testing (Secondary Pipe)	92
LRUT (Secondary Pipe)	88
LRUT (Primary Pipe)	66

Tasks – for FY13

<u>Advanced Topics for HLW Mixing and Processing</u>

- Lattice Boltzmann Modeling for Multiphase Flows
  - Improve 3D model by incorporating turbulent flows and non-Newtonian fluids
- Evaluation of Segregation Technologies for HLW Feed Mixing
  - Waste acceptance criteria may require additional waste segregation system/process in order to ensure WTP can process incoming waste feed
  - Review technologies for applicability to monitor PSDD in real time