Pulse Jet Mixer Program

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Pilot Plant Lessons Learned Technical Exchange

Richland Washington

December 5, 2007

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

Battelle

Agenda

- Background
- Lessons learned
  - Project management
  - Design/construct/install
  - Shakedown testing
  - Testing

PJM Project: Background

- The WTP design places several non-Newtonian slurry tanks in permanently closed ‘Black Cells’
- Initial design utilized fluidic pulsed jet mixer pumps (PJMs)
- Traditionally the PJM designs are confirmed using full-scale mock-ups
- A computational fluid dynamics approach to assess the mixing performance was not possible
- Testing required with scaled prototypes

Test Platform Objectives

- Evaluate simulants
- Validate Scaling laws
  - PJM mixing
  - Gas retention and release
- Provide data for design of the air sparge system
- Evaluate prototypic designs @ reduced scale
- Provide a large scale demonstration of WTP operating scenarios

Simulants

- Rheology was key characteristic
  - Bingham plastic rheology model
    - 30 Pa yield stress
    - 30 cP consistency
- Transparent Simulant (Laponite):
  - Assessment of mixing performance in scaled prototypes
  - Initial assessment of mixing scale-up behavior
  - Initial gas release tests
- Particulate Simulant (Kaolin/Bentonite clay):
  - Confirmation of mixing performance
  - Verification of mixing scale-up
  - Gas release and retention behavior
- Simulant representing pretreated sludge from the AZ tanks
  - Used to validate clay mixing behavior

4 PJM Scaled Test Platforms

SRNL: 35 gal. PNNL: 250 gal PNNL: 10,000 gal

1:9 scale 1:4.5 scale 1:1scale

Prototypic Scaled Test Vessels

UFP Test Tank at PNNL

LS Test Tank at PNNL

CRV Test Tank at SRNL

Cone Bottom Tank Used for Large Scale Sparging work

Half-scale Lag Storage PJM Assembly

Types of Tests, duration and staffing

- Mixing tests to determine PJM mixing cavern size
  - Long day
  - Two shifts (sometimes); 4-7 staff
- Air sparge mixing tests to define mixing capabilities
  - Hours
  - 5-6 staff
- Gas retention and release experiments
  - Very long day
  - Two shifts;4-7 staff
- Large-scale demonstration
  - 24/6
  - 3 shifts, 6-7 staff

Project management lessons learned Scope and Approach

- Begin with the end in mind
- Obtain broad agreement on test objectives and approach
  - Document; review periodically and change if needed
  - Momentum of large projects is hard to change quickly
- Resist the temptation to mix demonstrations with tests to quantify an effect
- Have a solid basis for the range of waste properties; particle size/density, rheology, chemistry
- Understand the system impact of options being evaluated
- Keep it simple (especially instruments and data acquisition)
- Identify risks and develop mitigation plans (what ifs?)
  - Use of manual measurements or alternative instruments
  - Functional testing of subsystems
  - Water and simulant shakedown testing
  - Order extra equipment

Budget/schedule

- Provide realistic and achievable budgets and schedules
  - Define scope: easy to underestimate details
  - Multiply initial estimates by some factor >2
    - Overlooked scope
    - Design/equipment/testing issues
  - Too much schedule pressure can easily lead to delays due to errors and rework

Communications

- Steering committee was crucial for PJMs
  - PNNL, WTP R&T, WTP Eng, DOE, Consultant
- Constant communications were crucial
  - Plan of the day meetings
  - Daily status emails
  - Daily (including weekends) steering committee meetings
  - Meeting minutes and document decisions
    - Recommend a full time scribe with a technical background
  - Clear communications of change in directions to testing staff is crucial; explain rationale
- Fully engaged and supportive client
- Problems collect at the interfaces

ES&H

- Recommend a pre-job briefing to address ES&H as well as technical aspects
- Constant emphasis on ES&H
- Client support on safety
- Encourage staff to watch out for each other
- Walkthroughs; include management, Cognizant Space Manager, safety representative
- Beware of any changes to equipment, operating procedures or staff.

Quality Assurance

- Reading assignments are a good start but just a start
- Recommend hands on mentoring; especially for staff new to NQA-1 requirements
  - Laboratory record books, test instructions, data entries, calibrations, software V&V, calculations, procurements
  - Recommend periodic surveillances/walkthroughs

Design/Construct/Install Lessons learned

- Don’t cut corners on the design and reviews
- Start procurements as early as possible
  - Lead time can be a big problem
  - Consult with contracts representative to develop a good plan
  - May be hard to find calibration agencies qualified to NQA-1 standards
- Consider hiring dedicated crafts or subcontractor

Equipment

- If testing many variations; incorporate flexibility into design
- Plan ahead and order all possible parts for variations
- Extensive use of available parts + rentals
- Clear vessels and transparent Laponite simulant was very valuable for flow visualization and scoping tests
- Useful to have separate test stands for method development (4PJM system)
- Equipment problems
  - Air supply solenoid valves operating PJMs plugged from time to time requiring cleaning
  - Air supply system design
    - Had to replace PVC pipe with steel pipe
    - Manifold had to be reworked; uneven air distribution
    - Overlooked chokepoints
    - Too much seat of the pants engineering (schedule driven)
    - To much vacuum on PJM refill can cause carryover and plugging of air supply equipment
- Data acquisition system
  - Accessibility of components
  - Try not to use new software

Instruments

- Capacitance level probes
  - OK but not recommended for slurries
- Laser levels
  - Need a reflective surface
  - Aerosols interfere with light beam
- Ultrasonic level device
  - Abandoned because of drift and reflections
- Velocity probes
  - Difficult to calibrate
- Air flow rotameters
  - Understand reference pressure and temperature
- Video tape was useful

Shakedown/acceptance testing-do it

- Component and subsystem testing
  - Instrument and DACS checks
- Shakedown testing with water
  - Equipment
  - Procedures
  - Data acquisition and analysis
  - Staff training
- Shakedown testing with simulant
- Allow sufficient time for shakedown testing and fixing problems
- Data acquisition system and instruments consistently offered the greatest challenges

Testing Lessons Learned
Simulant use and scale-up

- Volume
  - Laponite: 3000-4000 gallons delivered in 275 gallon totes
  - Clay: 20,000 gallons delivered in 275 gallon totes and bottom unloading tanker trucks
  - Order extra if possible
- Makeup issues
  - Water source was very important; ionic content influences particle-particle interactions and rheology
  - Variation between clay batches
    - Order all components from single lots
    - Test recipe in lab ahead of time
  - Aging of clay; clay hydrates with time (~1 month) changing rheology (becomes thin)
    - Order ahead of time and let it age
    - If to thin; makeup and add very thick clay if to thin
    - Evaporation did not work
  - Add a biocide

Staffing

- Consider multiple vendors to avoid overloading staff
- Consider 24/7 or 24/6 for large tests
  - Some instances of tests ending prematurely
- Develop a crew list and backups
  - Cross training is a cost effective approach
  - Especially important for 24/7 experiments
  - Keep teams together and minimize turnover
- If possible, allow a break in between tests
  - Data evaluation
  - Maintenance
  - Staff regeneration
- Write down roles and responsibilities of crew positions

Operator Training

- Briefings
- Reading assignments
- Hands on training and mentoring on subsystems
- Formal laboratory training for hazardous situations; confined space, working at heights
- Full training during shakedown testing with water

Shift turnover

- 30-60 minute overlap of shifts
- Shift turnover documentation using a standardized form

Documentation approach

- Test plan to define scope and how to accomplish it
- Safe operating procedure to cover safety
- Quality covered by QA procedures
- Flexible test instructions that could be modified from test to test

Laboratory analysis

- Conducted at site or on-site
- High priority provided rapid turnaround (1-2 days; if needed)

Data Acquisition

- Data acquisition systems need to be thoroughly Verified and Validated, and then some
  - DASYLAB time slip problem
  - PJM controller data logging problem
- Recommend share drives and/or sharepoint sites
- Warning: data acquisition systems can quickly obtain very large amounts of data; storage, transfer, reviews can be difficult
  - Tailor sample/write rate
  - Only write values that change from previous sampling
  - Average samples are write average
- Take some manual data in case of DACS or instrument failure

Control system

- PJMs: Set time and drive pressures to obtain correct nozzle velocity and stroke length
- PJMs: Did not always shut off on the drive phase leading to overblows
- General: Much to troublesome to do any other type of control; e.g. HSLS

Data Analysis

- Dedicated data review and analysis team, reasonably separate from the testing team
  - Important to keep up with data reviews/QA (memories fade)
  - Concurrent analysis of data for feedback to testing-allows adjustment of testing and catches errors
    - Time slip issue
    - Data logging issue
  - Know how all data will be analyzed and used ahead of time
    - PJM nozzle velocities
    - Conduct shakedown of data analysis during equipment shakedown testing
- Develop consistent data management techniques;
  - File naming conventions, storage locations, backups
  - a data management plan is very useful along with a single person responsible for implementation

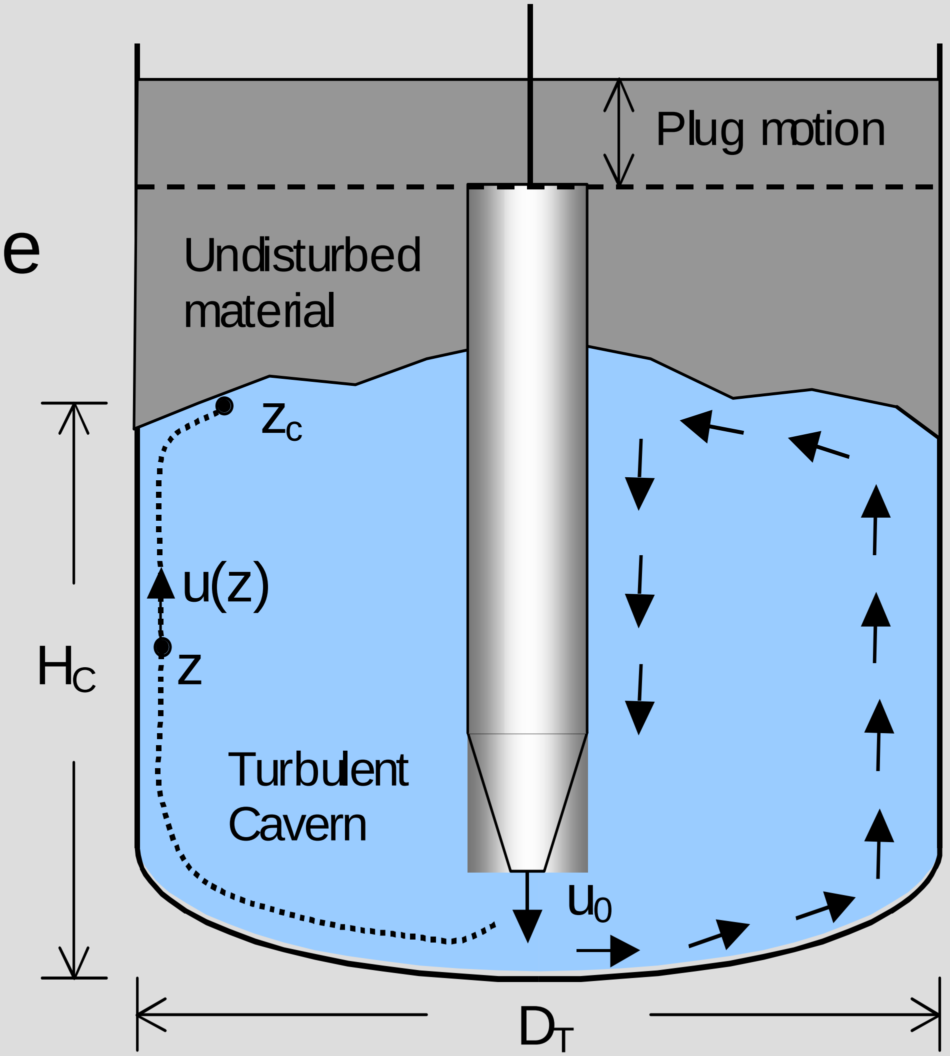
Summary

- Plan for the worst and strive for the best
- Maintain a disciplined approach in all project phases
- Shakedown tests of components and systems
- Communicate
- Stay safe and have fun

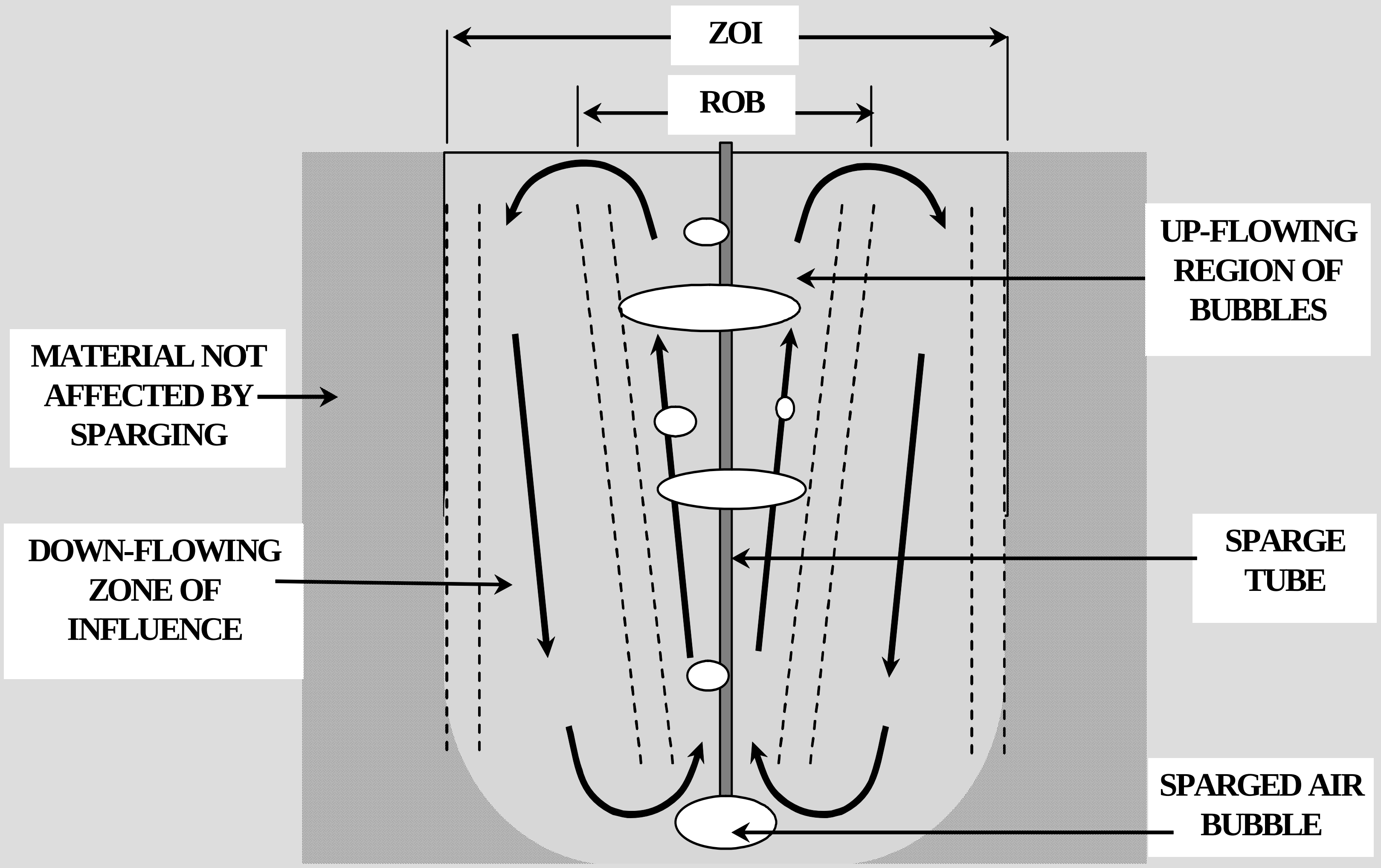
Backup slides

What is a Pulse Jet Mixer?

- Air pressure/vacuum supplies motive force
- Vacuum fills pulse tube
- Pressure discharges fluid at ~12 m/s
- Jet provides turbulent mixing cavern



Sparging in Non-newtonian Slurries



Principles of Gas Retention and Release (GR&R)

- Gas generation due to radiolysis & thermolysis
- Gas species present in dissolved and gas phase (bubbles)
- Gas Release by bubble rise: Non-Newtonian fluid needs to be mobilized to allow bubble rise