Pressure-Based Inversion and Data Assimilation System for CO_2 Leakage Detection

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National Energy Technology Laboratory

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Transforming Technology through Integration and Collaboration

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- Sandia Technologies LLC: Kirk Delaune

Presentation Outline

- Benefit to the Program
- Project Overview
- Technical Status
- Accomplishments to Date
- Summary

Benefit to the Program

- Major goal being addressed
  - *Develop and validate technologies to ensure 99 percent storage permanence*

- Project benefit
  - The PIDAS project will develop and demonstrate a *pulse testing technology for leakage detection in carbon storage reservoirs*.
  - The technology, when successfully demonstrated, will provide an improvement over current monitoring technologies in both performance and cost.

Project Overview:
Goals and Objectives

- Demonstrate the utility of pulse testing for leakage detection through modeling and experiments

- Develop relevant data assimilation and inversion algorithms

- Design optimal well testing strategies for practitioners

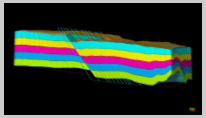
Project Tasks

Modeling

- Forward (Task 2)
- Inverse (Task 4)

Lab Tests (Task 3)

- Single phase
- Multiphase



Field Tests (Task 5)

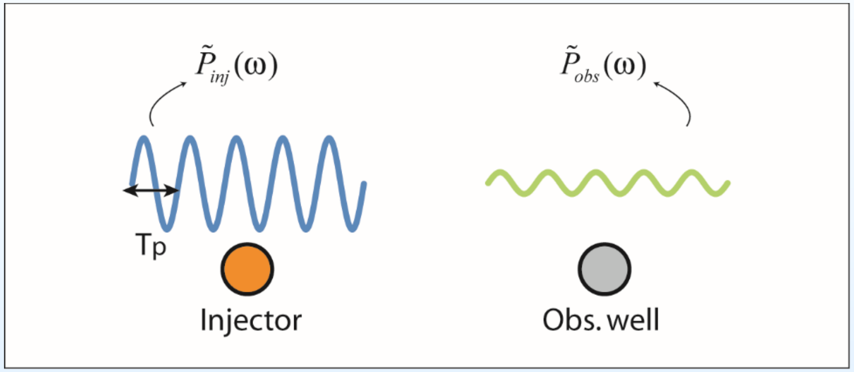
- Baseline
- Leak

Why Pulse Testing

- An established technology
  - Has been used for reservoir characterization since 1960s

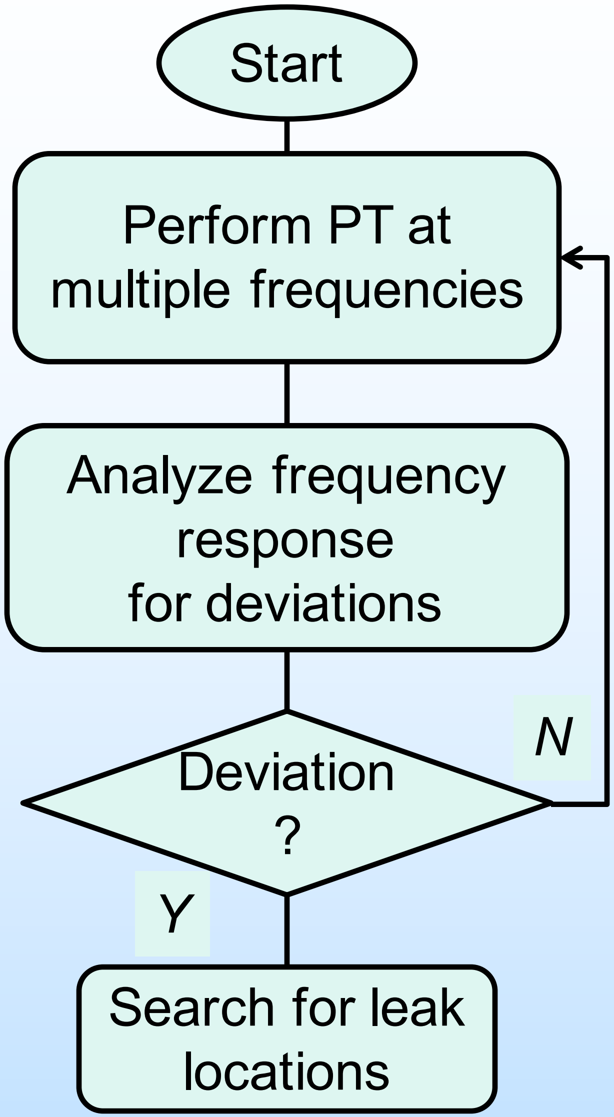
- Investigate pulse testing as an easy-to-implement, leakage detection technology

- Expected advantages over other pressure-based methods
  - An active monitoring method with enhanced signal-to-noise ratio, less prone to reservoir noise interference
  - Pose little interruptions to nominal reservoir operations

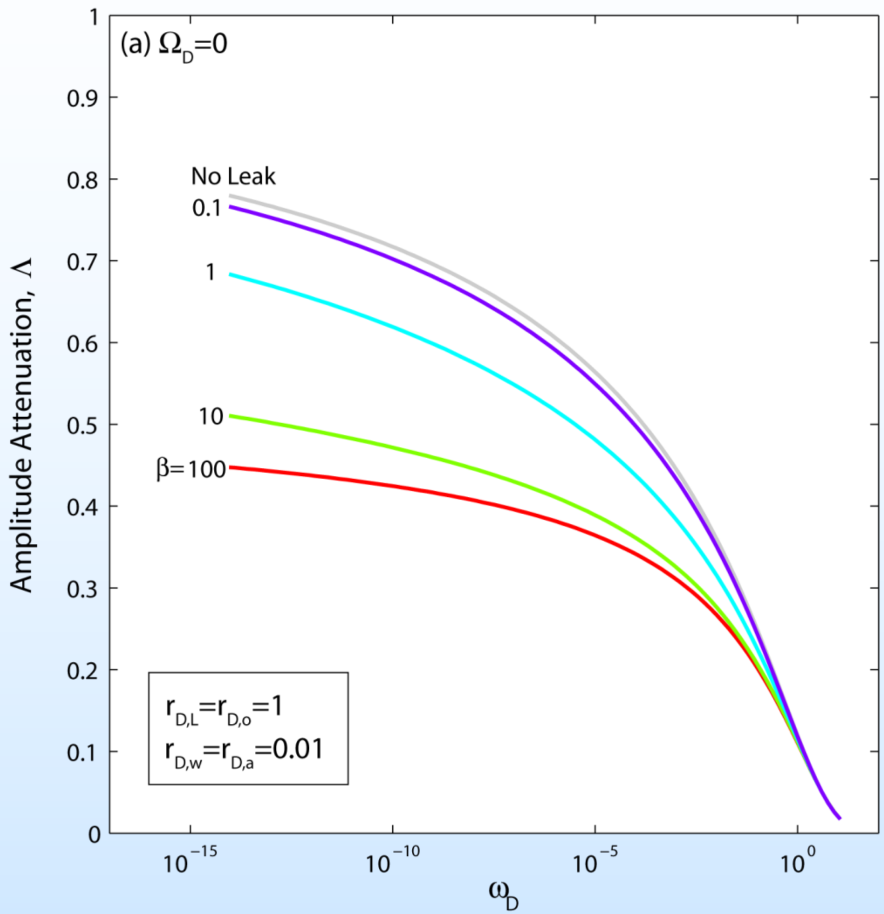


$$\hat{H}(\omega) = \frac{\hat{P}_{obs}(\omega)}{\hat{P}_{inj}(\omega)}$$

Test Procedure



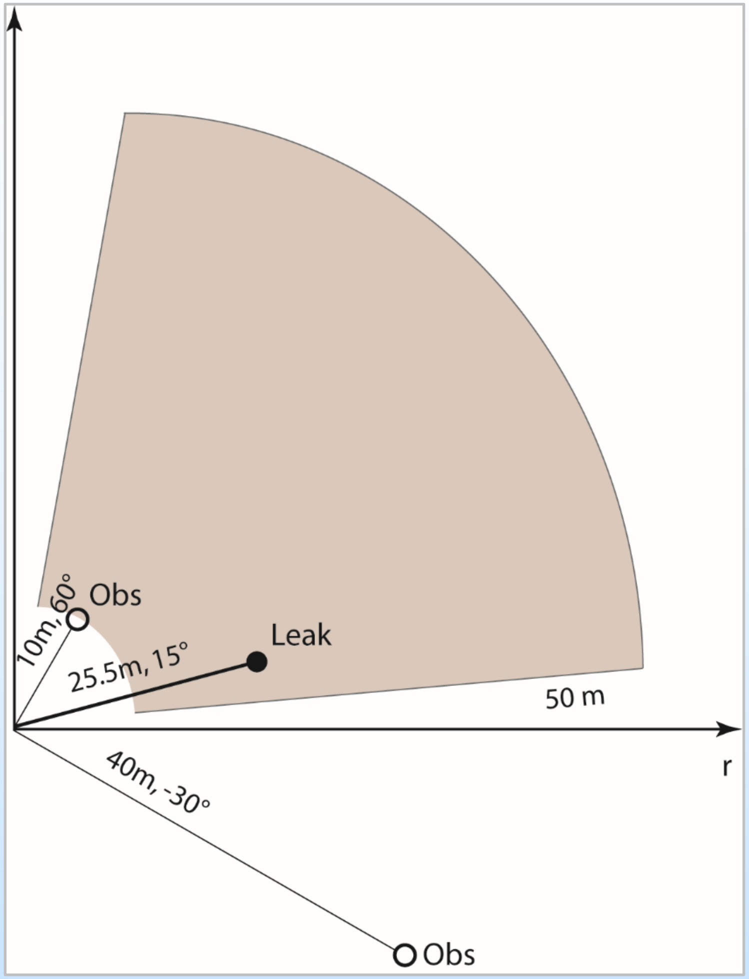
Frequency response



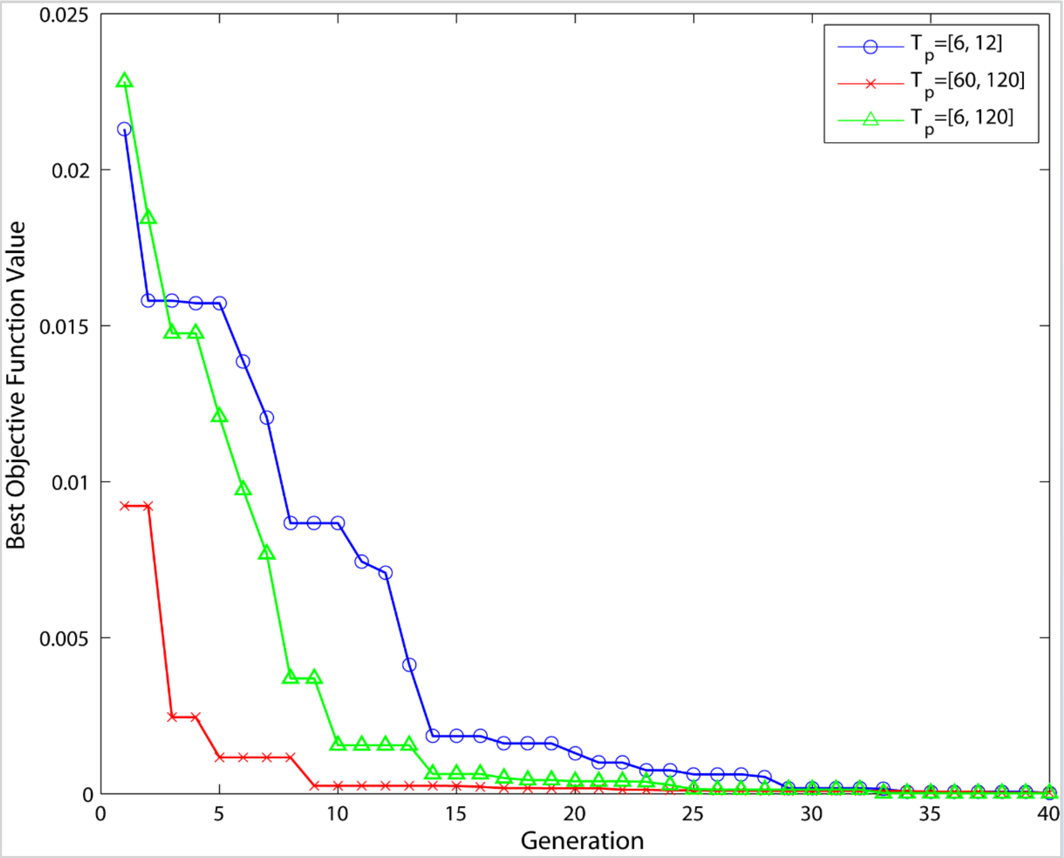
β =Transmissivity ratio between upper and lower aquifer

Ω = Resistance of leaky well to vertical flow

Leak Location Search



Convergence History



Genetic Algorithm

Field Experiments

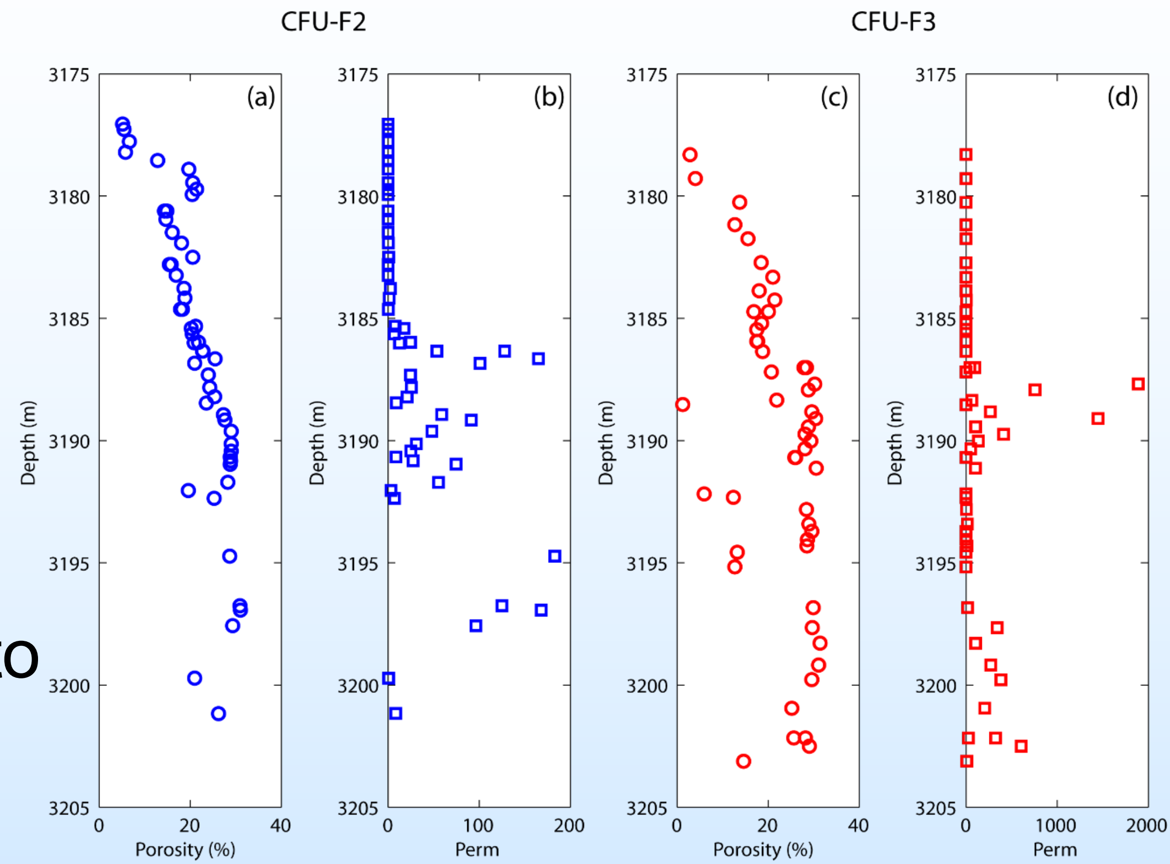
Detailed Area of Study @ Cranfield, MS, January 19-31,2015

Distance between F1 and F2 = 60 m

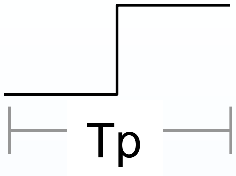
Distance between F1 and F3 = 93 m

DAS Site

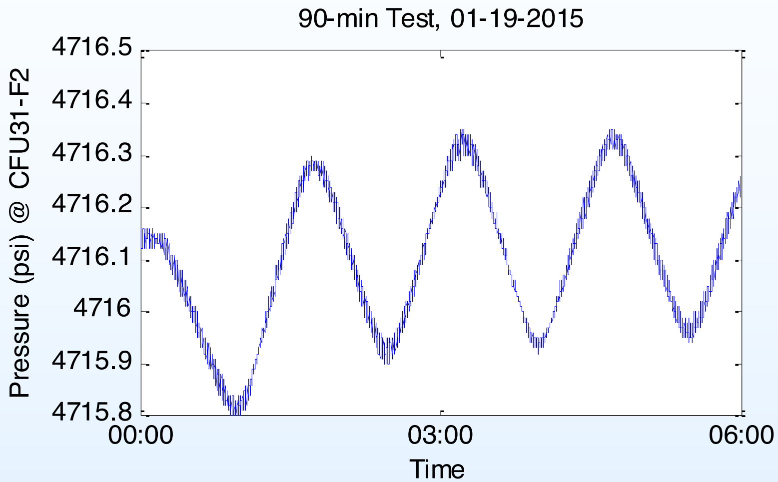
- Lower Tuscaloosa formation
  - Depth 3176 m (10420 ft)
  - Thickness14-24 m (46-80 ft)
- Heterogeneous fluvial strata
  - Permeability: 10^{-3} to 10^{4} mD
  - Porosity: 5-35%

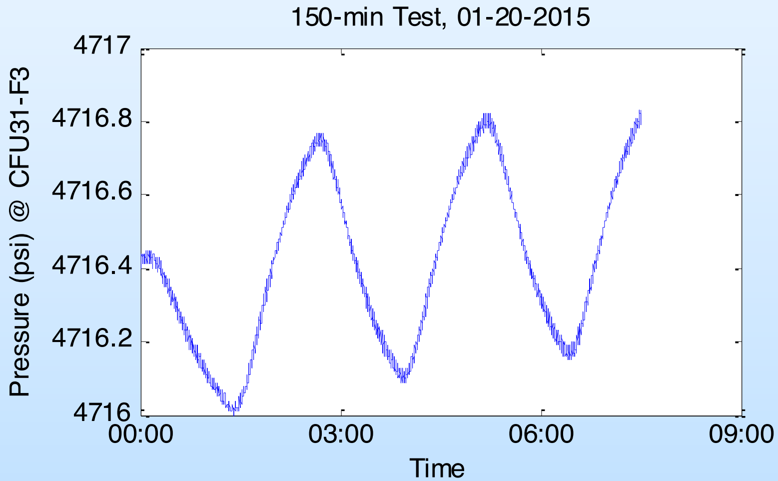


Baseline

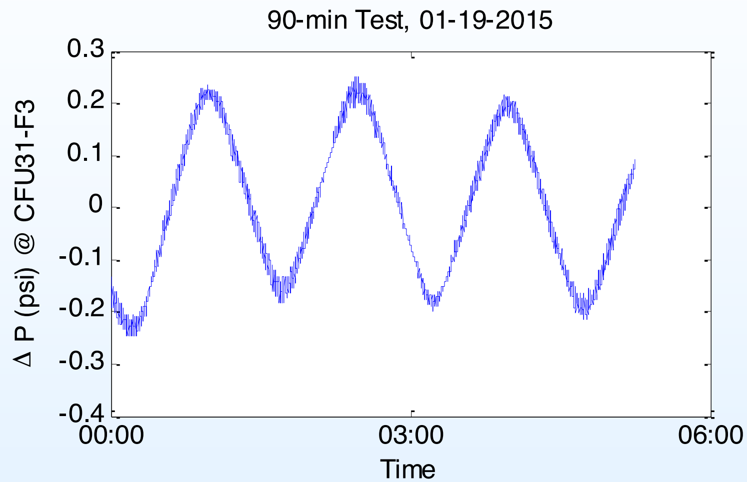


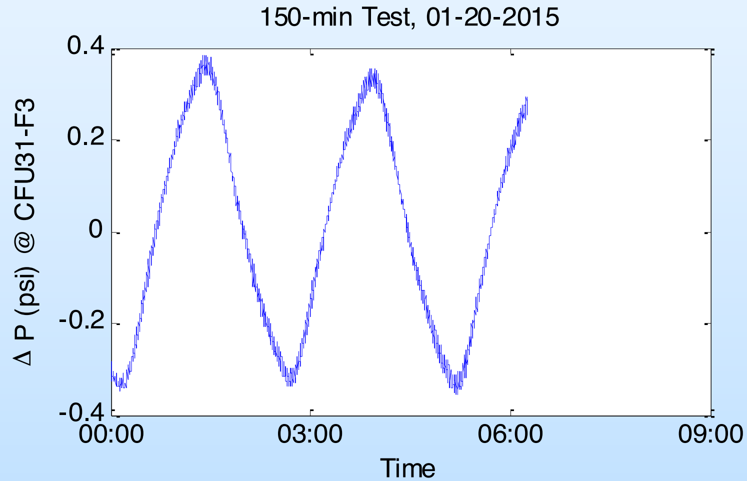
Raw Data





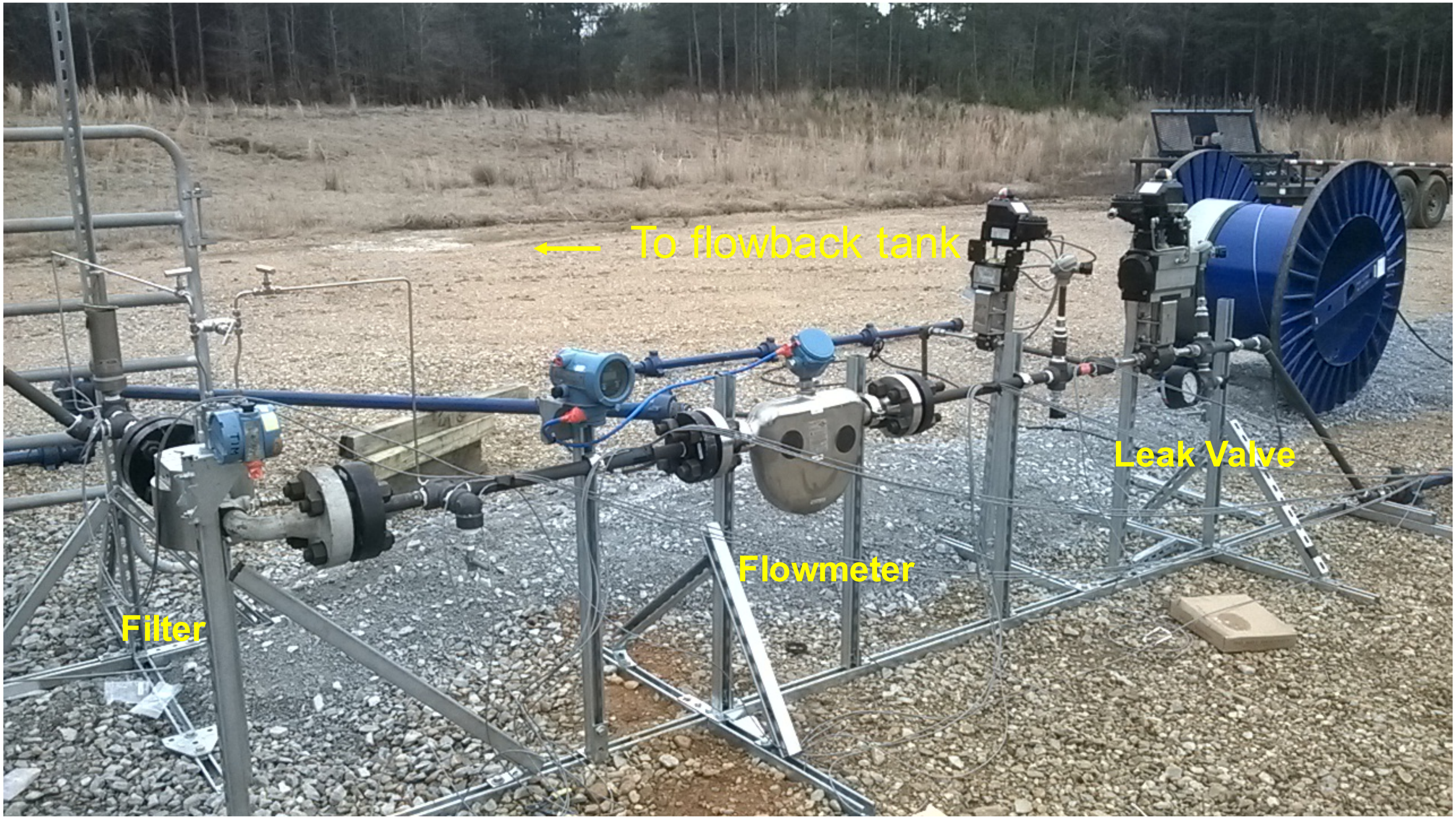
Filtered Time Series





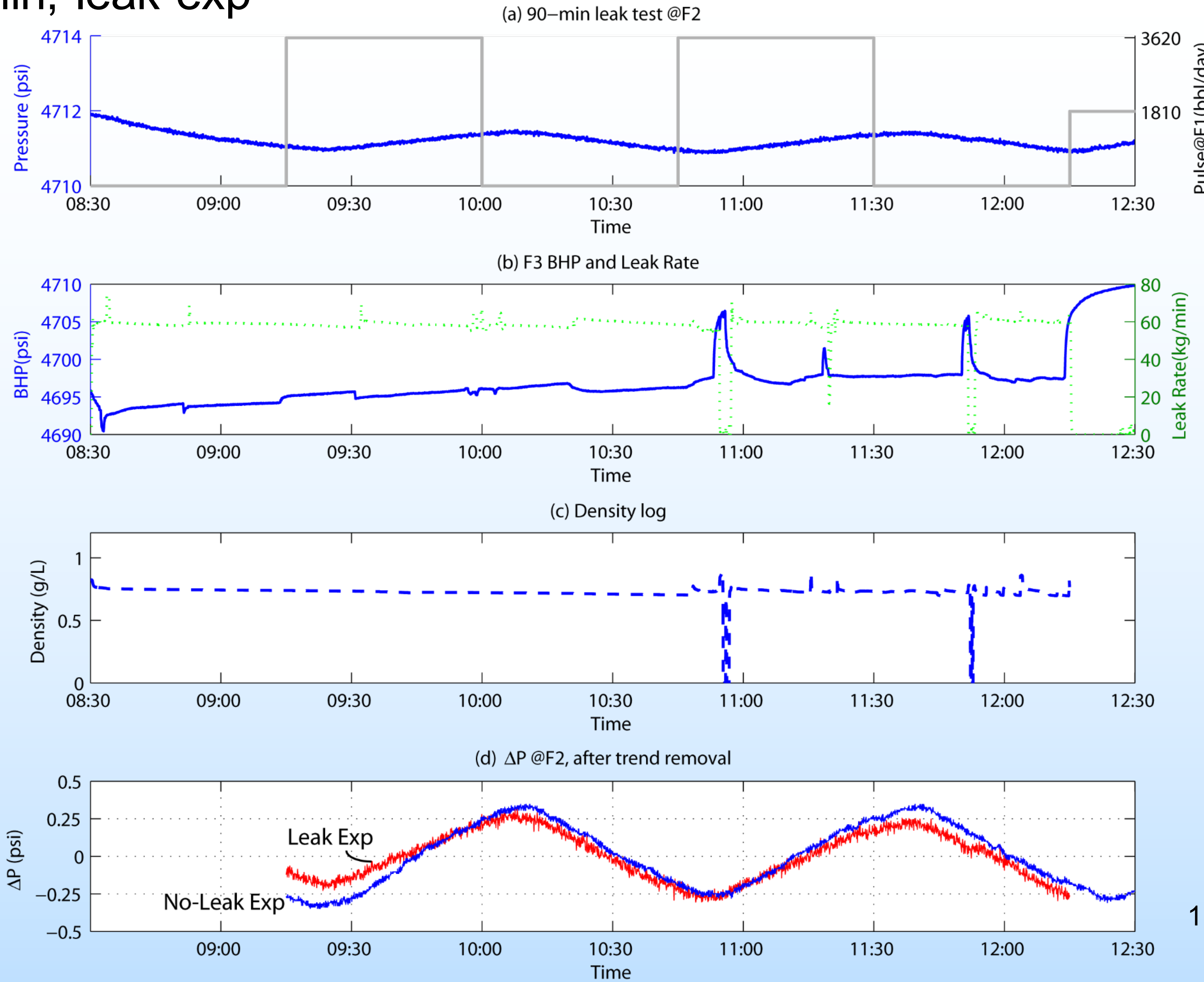
Controlled Leak Experiments

F3

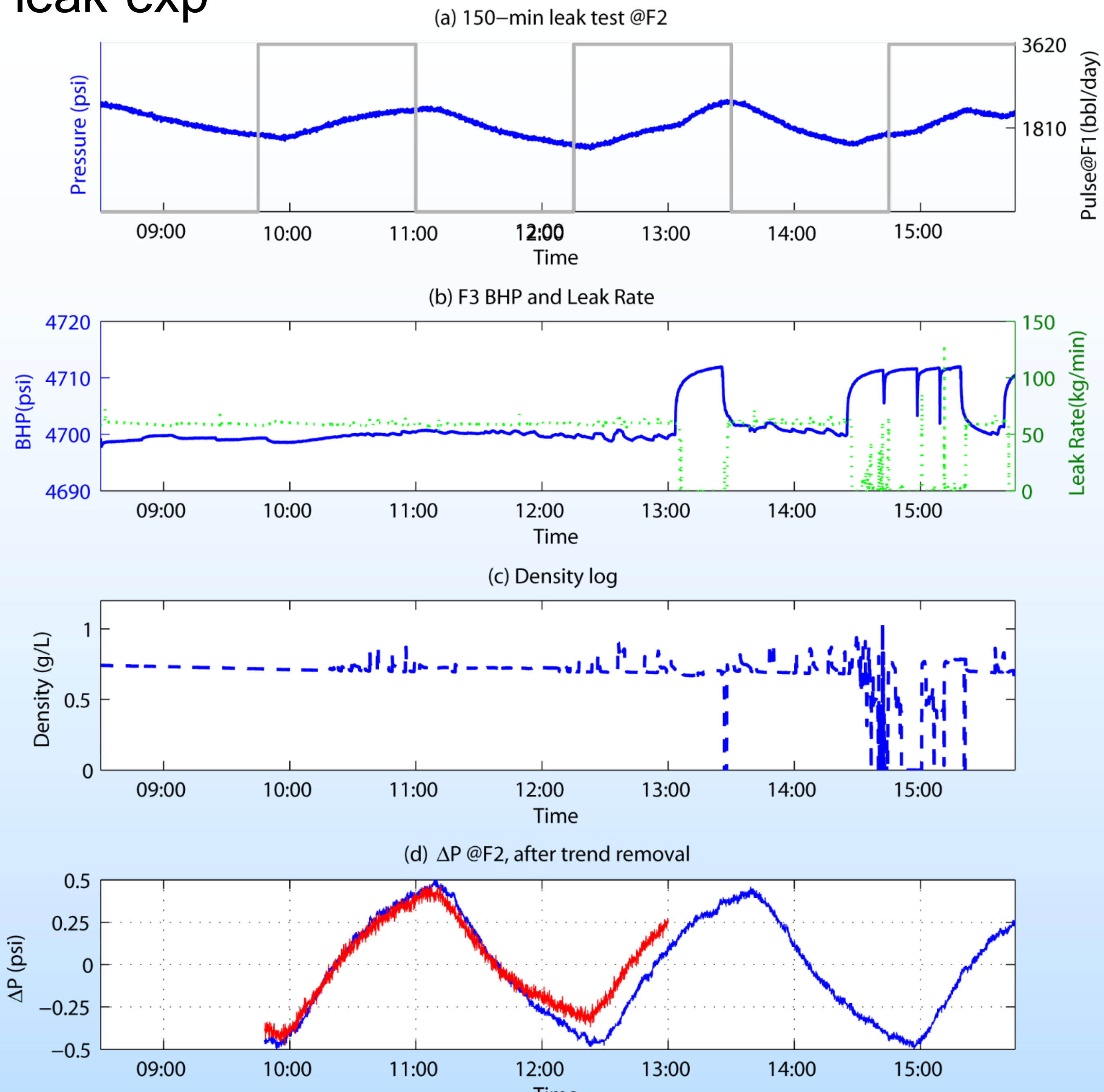


F2 F3

90-min, leak exp

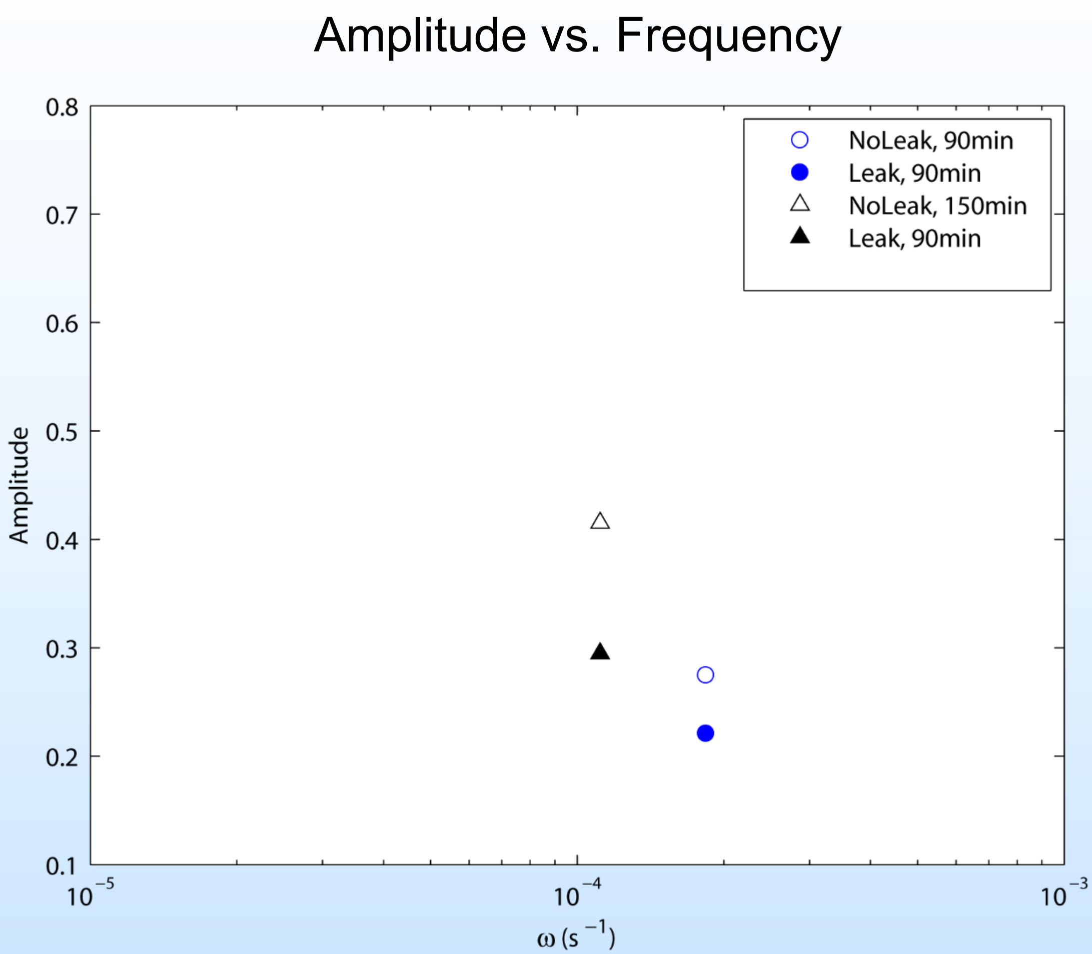


150-min, leak exp



Frequency Domain Diagnosis

Leaks caused deviations in signal amplitudes

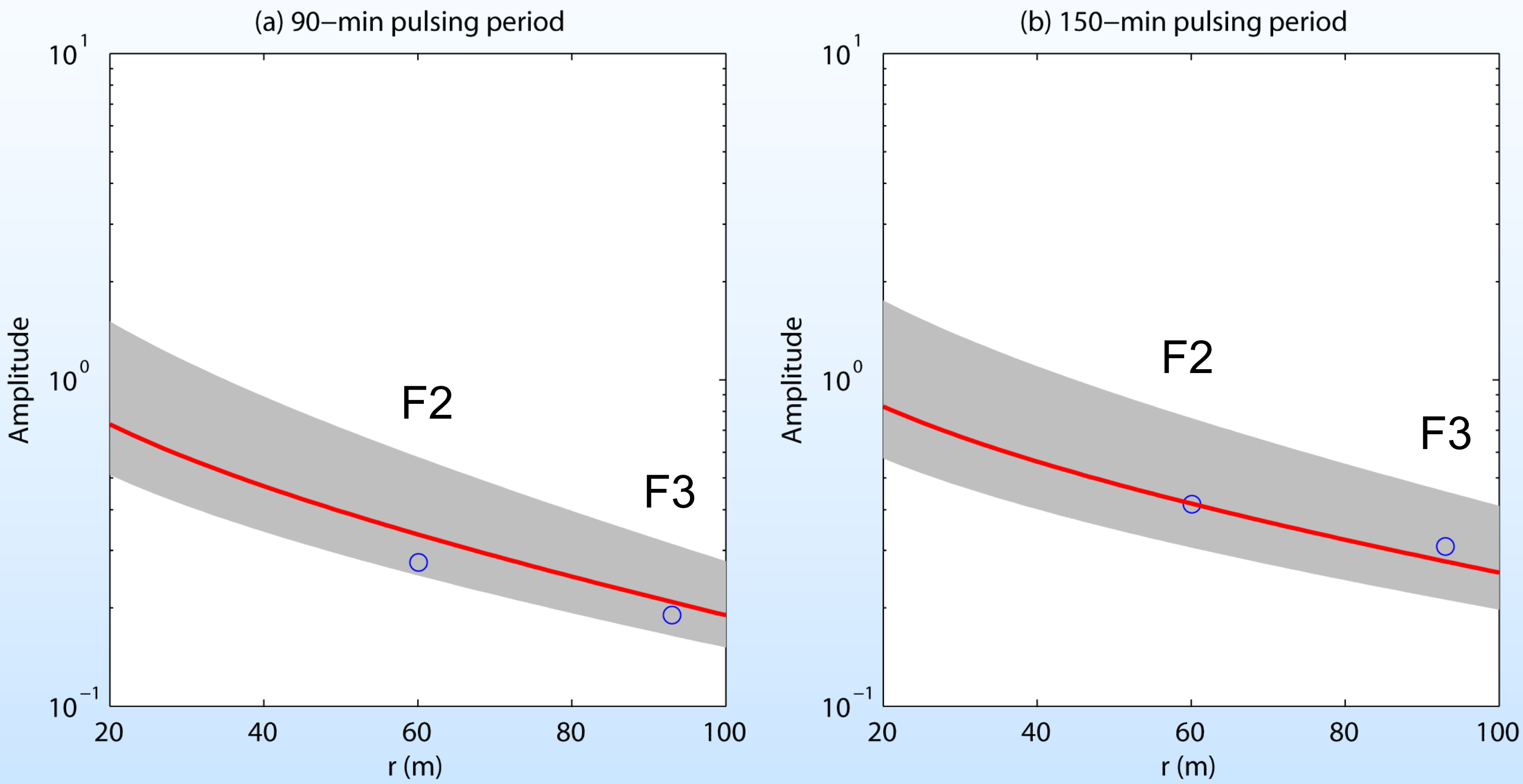


Each experiment yields one data point on the plot

Parameter Estimation

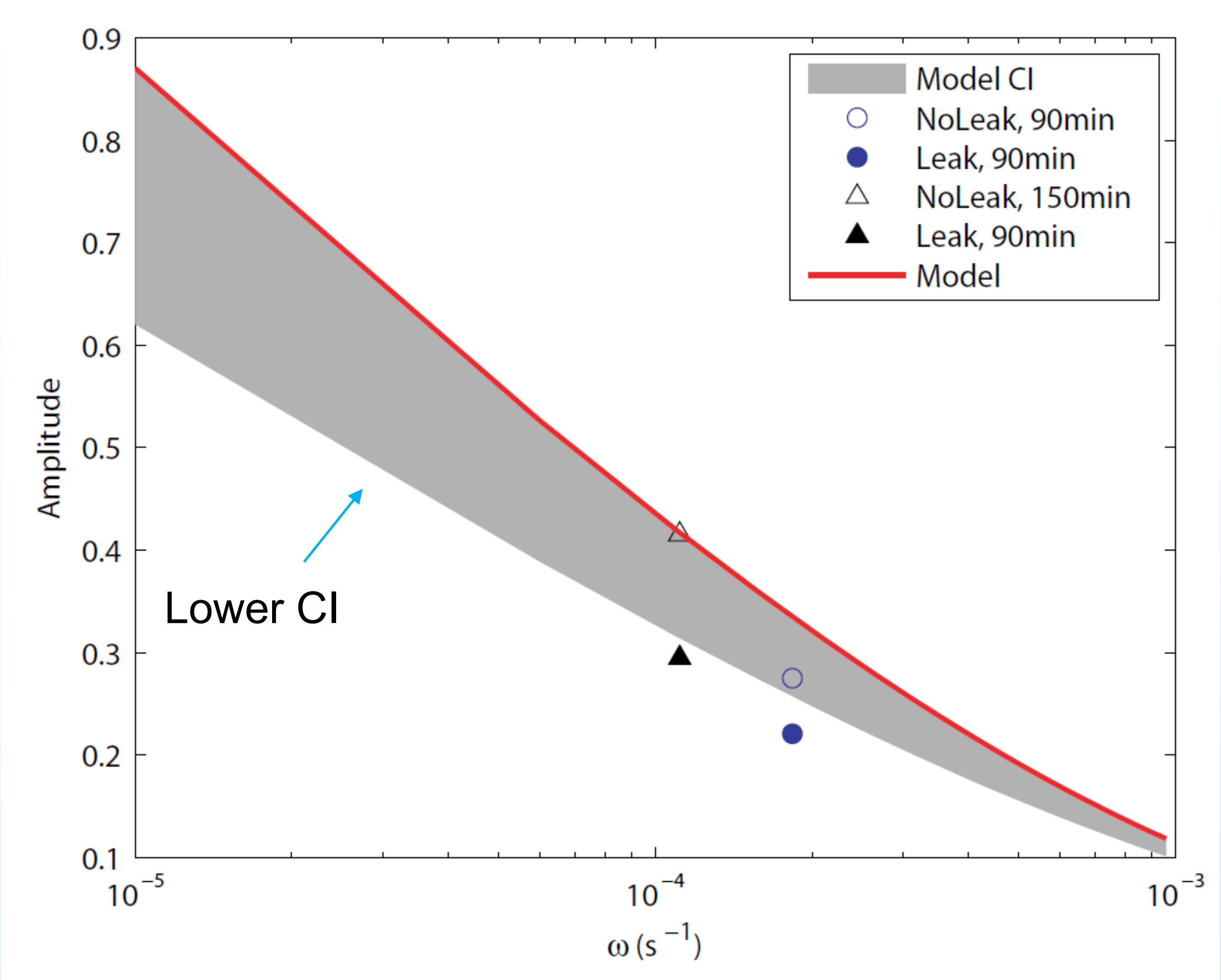
Baseline Experiments

Amplitude vs. Well Distance



Confidence bounds estimated using MCMC

Hypothesis Testing

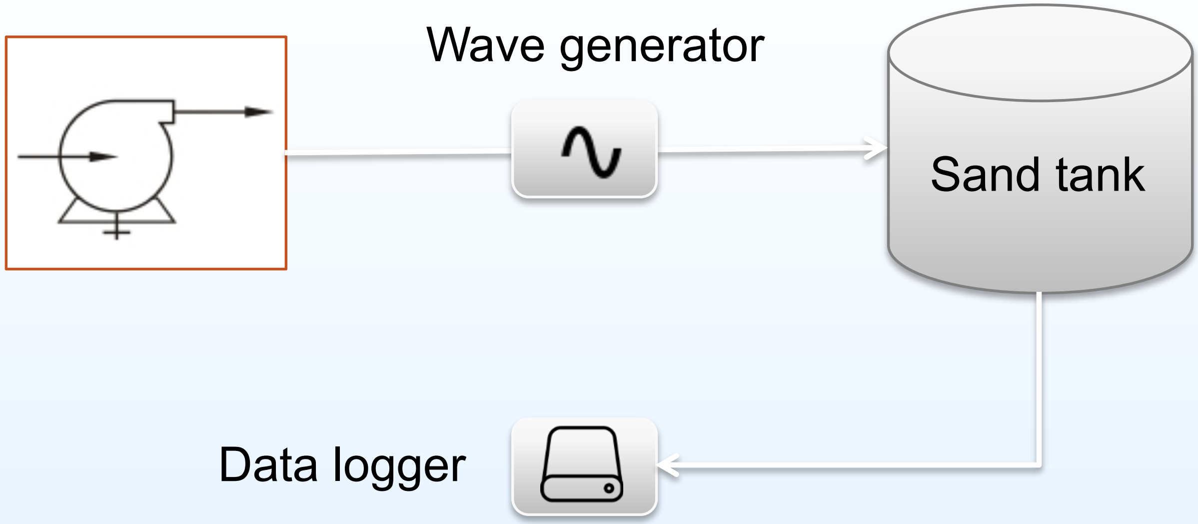


Summary

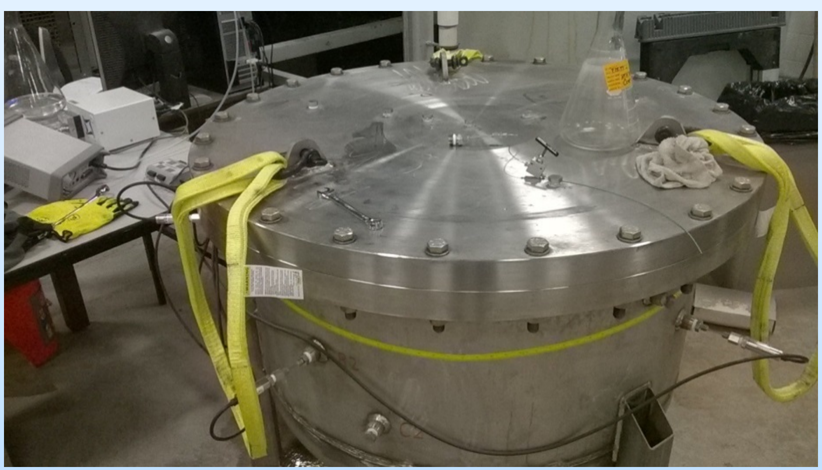
– Field experiments suggest that pulse testing is a cost-effective, continuous monitoring technique

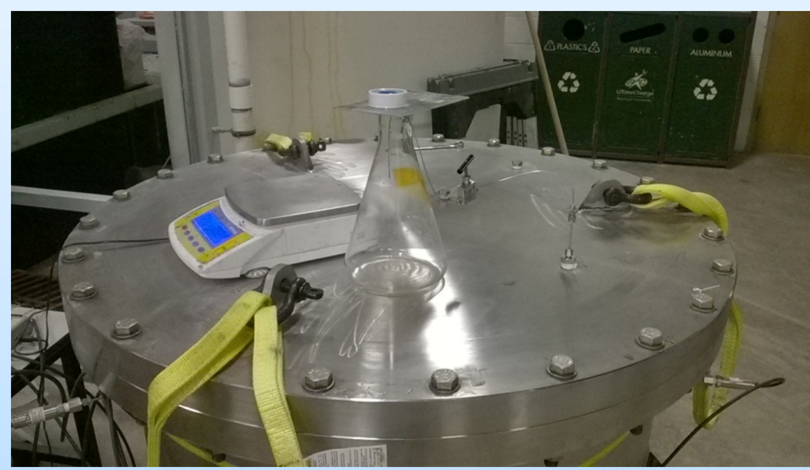
– Additional work is required to assess sensitivity of pulse testing for leakage detection technique in broader settings

Laboratory Experiments



Single-layer setup





Multilayer Setup

Accomplishments to Date

- Task 2: Theoretical and numerical analyses
  - Year 1: Established theoretical basis and validated the concept of pulse-testing-based leakage detection numerically
  - Sun et al., 2014, 2015
- Task 5: Field experiments
  - Year 2: Demonstrated viability of the pulse testing leakage detection technique in the field
- Task 3: Laboratory experiments
  - Year 2&3: Performing additional validation tests
- Task 4: Data assimilation algorithms
  - Year 2&3: Developing and testing algorithms

Future Work

- Complete laboratory experiments
- Focus on data analyses
- Develop and disseminate a toolbox for interpreting pulse testing results

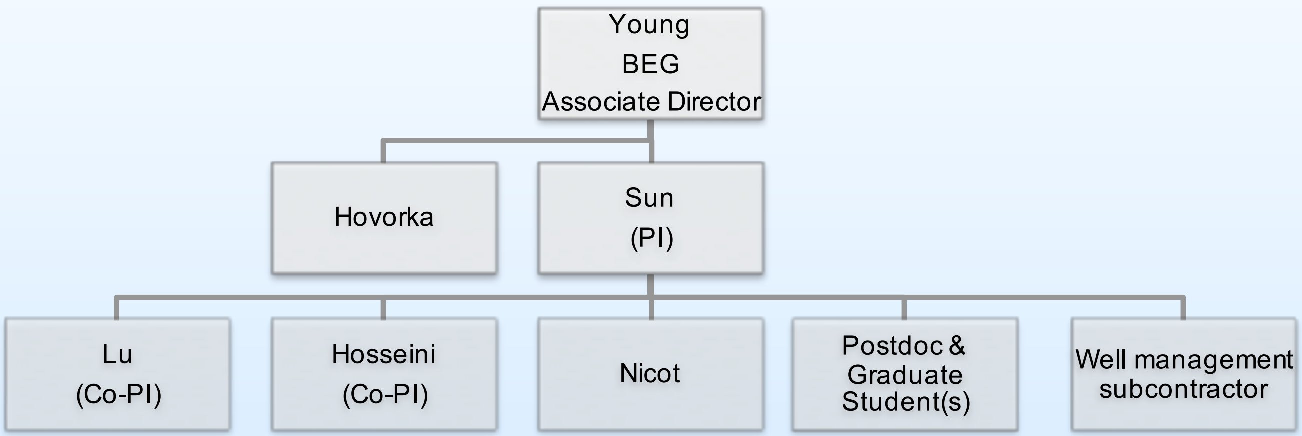
Synergy Opportunities

– The project develops a cost-effective, pressure-based leakage detection technique that can be readily incorporated into operational monitoring plans

Appendix

Organization Chart

Bureau of Economic Geology, UT Austin
Gulf Coast Carbon Center



Gantt Chart

Table 2. Project Gantt chart
(Numbers in table rows indicate milestones).
(Phase I ; Phase II)

Task	Description	Year 1				Year 2				Year 3			
		1	2	3	4	1	2	3	4	1	2	3	4
1	Update project management plan												
2	Modeling of harmonic pulse tests		1										
3	Lab experiment												
3.1	Experiment design and assembling				2								
3.2	Single-phase experiment												
3.3	Multiphase experiment								5				
4	Algorithm development												
4.1	Inversion technique												
4.2	Data assimilation										6		
5	Field demonstration												
5.1	Field site selection												
5.2	Site access & NEPA determination												
5.3	Field experiments						3	4					
6	Synthesis of results												
6.1	Tool user interface development												
6.2	Technology transfer												

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