The Development of a Tool and Methods to be used in Flow Path Detection behind Casing for use in the Fayetteville Shale

N. Kyle Combs, Larry T. Watters, Jessica McDaniel, CSI Technologies, Voldi Maki, The Measurement Group, C. R. "Dicky" Hall, Southwestern Energy

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Overview

- Why are these technologies needed?
  - Sustained Casing Pressure (SCP) remediation
  - Behind casing flow detection
- Methods and tools currently in development
- Lab scale conceptual testing results of the methods and tools

Sustained Casing Pressure (SCP)

API STD 65-2 defines SCP as pressure in an annulus of casing strings that is:

- Measurable at the wellhead of a casing annulus that rebuilds to at least the same pressure level when bled down
- Not due solely to temperature fluctuations
- Not a pressure that has been imposed by the operator

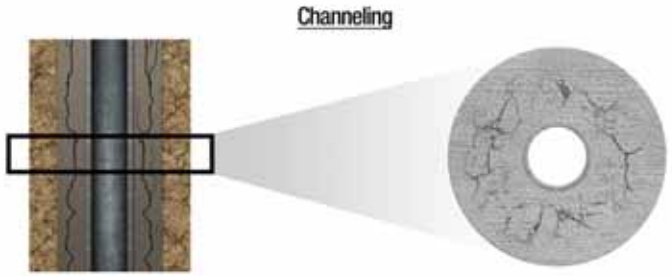
SCP Development Mechanisms

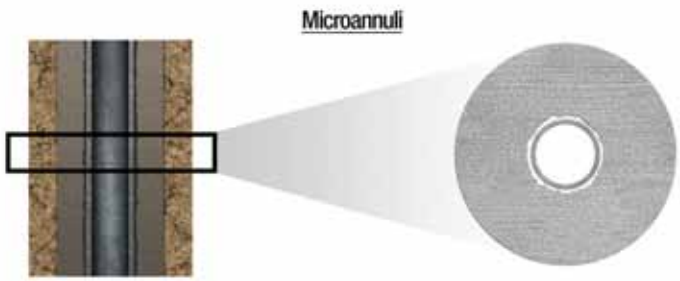
Short Term

- Occurs during setting reaction
  - Hydrostatic pressure reduction due to GST
  - Hydration Volume Reduction
- Channeling

Long Term

- Occurs after cement has set
  - Mechanical failure of cement
  - Poor mud removal
- Microannuli





Fayetteville Shale

Image by Scott Holt, Wild Well Control Inc.

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Current Remediation

- “Perf and Squeeze” only option
- Less than 50% success rate
  - Proper location difficult to determine
  - Proper sealant
  - Proper placement technique

Remediation

- New method in development based on 4 important “needs”:
  - Location of flow pathways
    - Depth
    - Wellbore Orientation
  - Assurance of communication
  - Proper sealant selection
  - Proper sealant placement

Developmental Flow Detection Methods

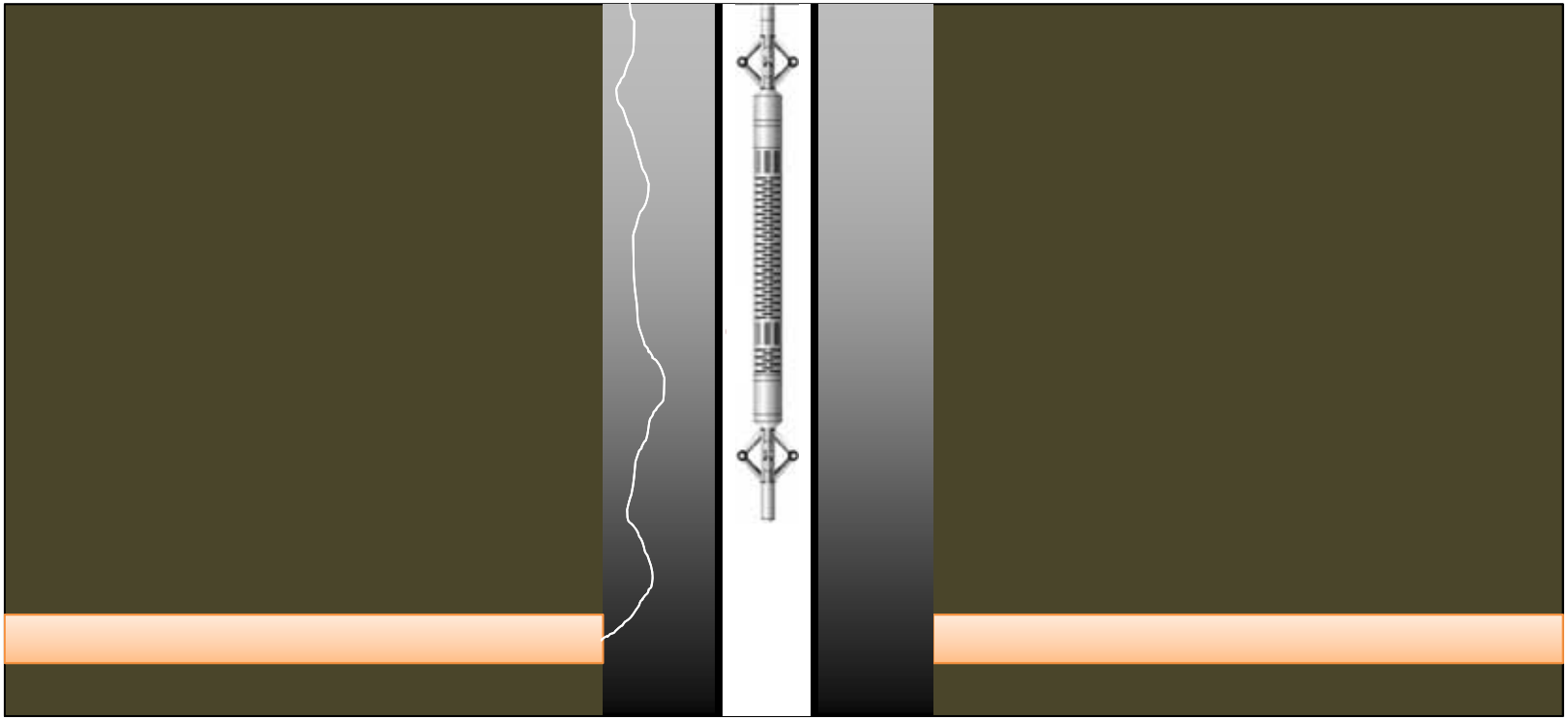
- Two methods in development to satisfy the first "need" of new remediation method

- Active Method
  - Development of an Acoustic Tool
    - Orientation and depth
- Passive Method
  - Standard Low Frequency Noise Log Tool (NLT)
  - Developing signal analysis software
    - Depth and potentially type and magnitude of flow

Active Method

- Based upon concept suggested by Frederick Rambow
  - "Pulse Echo Technique for Detecting Fluid Flow" (US Patent, 1991)
  - Used ultrasonic tool to detect flow
  - Dual pulses from ultrasonic acoustic transducers
    - Bubble detection
- Actively "searches" for flow behind casing

Bubble Detection



Development of a New Tool

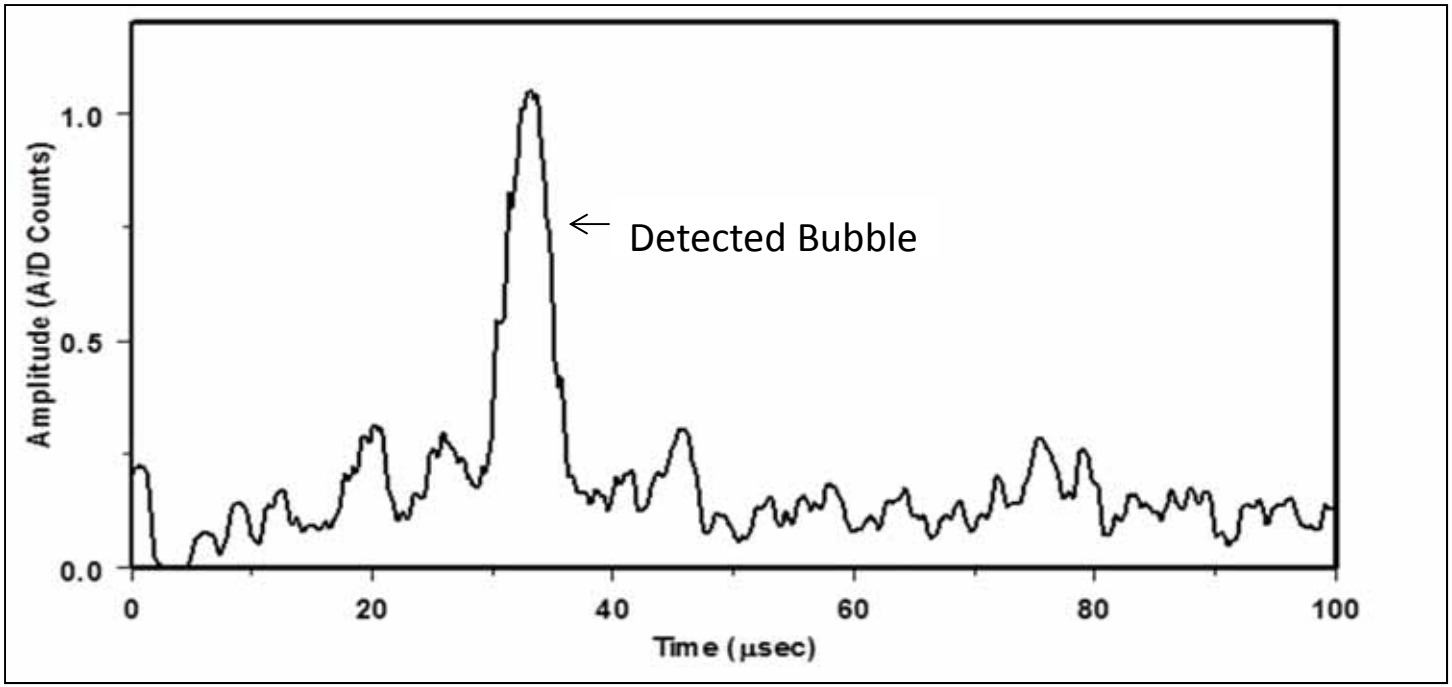
- More sensitive than standard ultrasonic tools to detect flow behind casing
  - Optimizing transducer type and placement on tool
- Still looking at difference between acoustic pulses
  - Bubble detection
- Stipulation - Must have two phases

Transducer Testing Apparatus

- ¼ in steel plate bonded to 2 in of cement
- ¼ in "flow channels"
  - Near casing
    - Microannulus case
  - Far from Casing
    - Channeling case
- Flow gas bubbles through liquid filled "channels"

Proof of Concept Testing

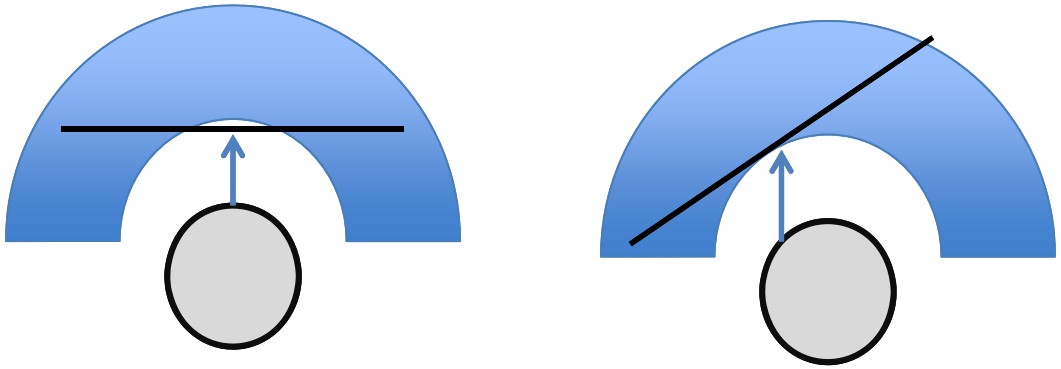
Difference Between Echo Signals



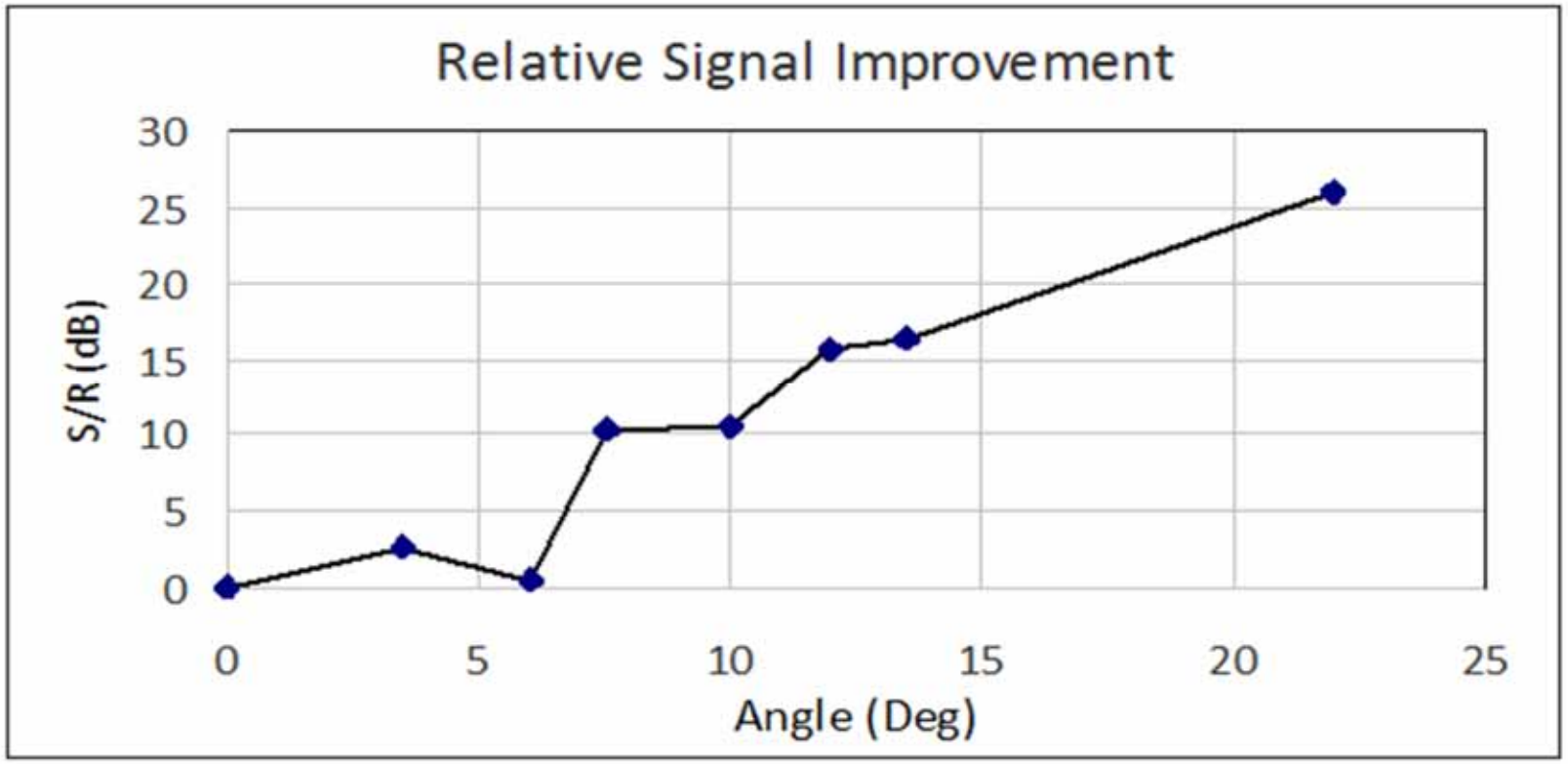
Difference of about 12 dB between the two signals

Transducer Optimization

- Originally used pad-style transducers, but eventually changed to body mounted
  - Pads provide a slightly larger signal than body type , but not enough to overcome the simplicity and robustness of a body mounted transducer tool
- How to optimize body mounted transducers?
  - Change the angle of incidence with the casing



Angle of Incidence Testing



22° is the maximum angle that the current tool body design will allow, S/R is the improvement to the signal to reflection ratio

Active Method – Where are we now?

- Proof of Concept testing shows potential for tool success
- Will provide extreme resolution, even at low flow rates as long as there is multiphase flow
- Will provide orientation if rotated in a stationary position
- Prototype being built
  - About 75% complete

Passive Method

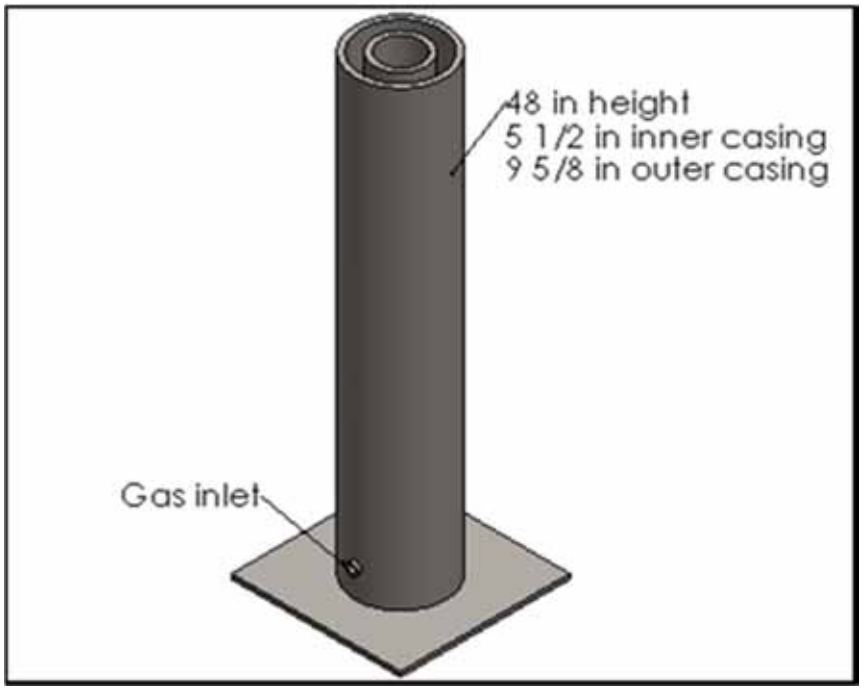
- Utilizes standard low frequency noise log tool (NLT)
  - Preferential to high frequency noise tools
  - Detect small pressure drops over a large area
  - Susceptible to noise up the wellbore
    - clean reference log is required
- Software package in development
  - Analyze the data captured by the NLT, determine flow from difference

Passive Method

- Run the NLT in the well with annulus shut in, (no flow)
  - This provides the reference log
- Run the NLT in the well with annulus open, (flow allowed)
  - This provides the flow log
- Compare the two logs using software developed

Passive Software Testing Apparatus

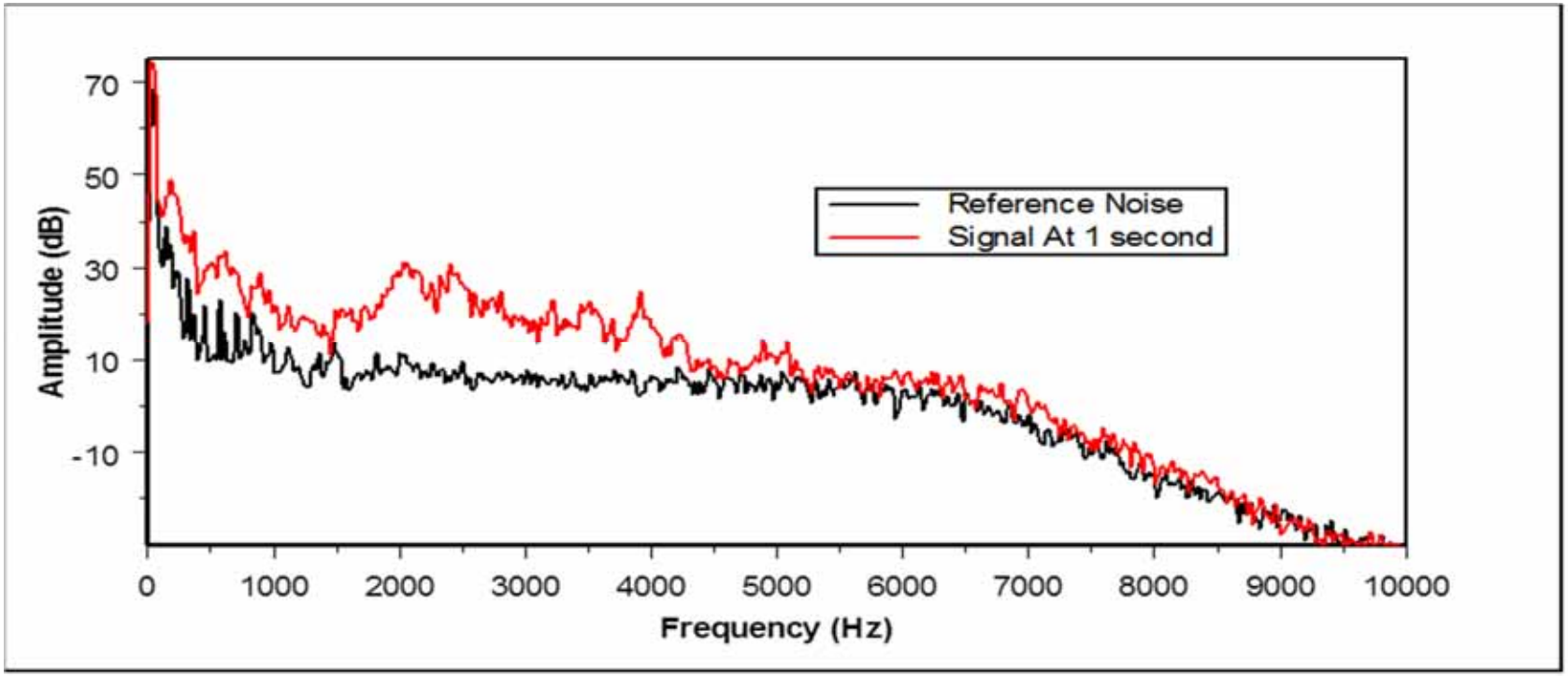
- Used to develop and verify software package
- Actual casing size used
- Two models built
  - Simulated microannulus around inner casing
    - low flow rate
  - Simulated channel through cement
    - high flow rate



Software Development

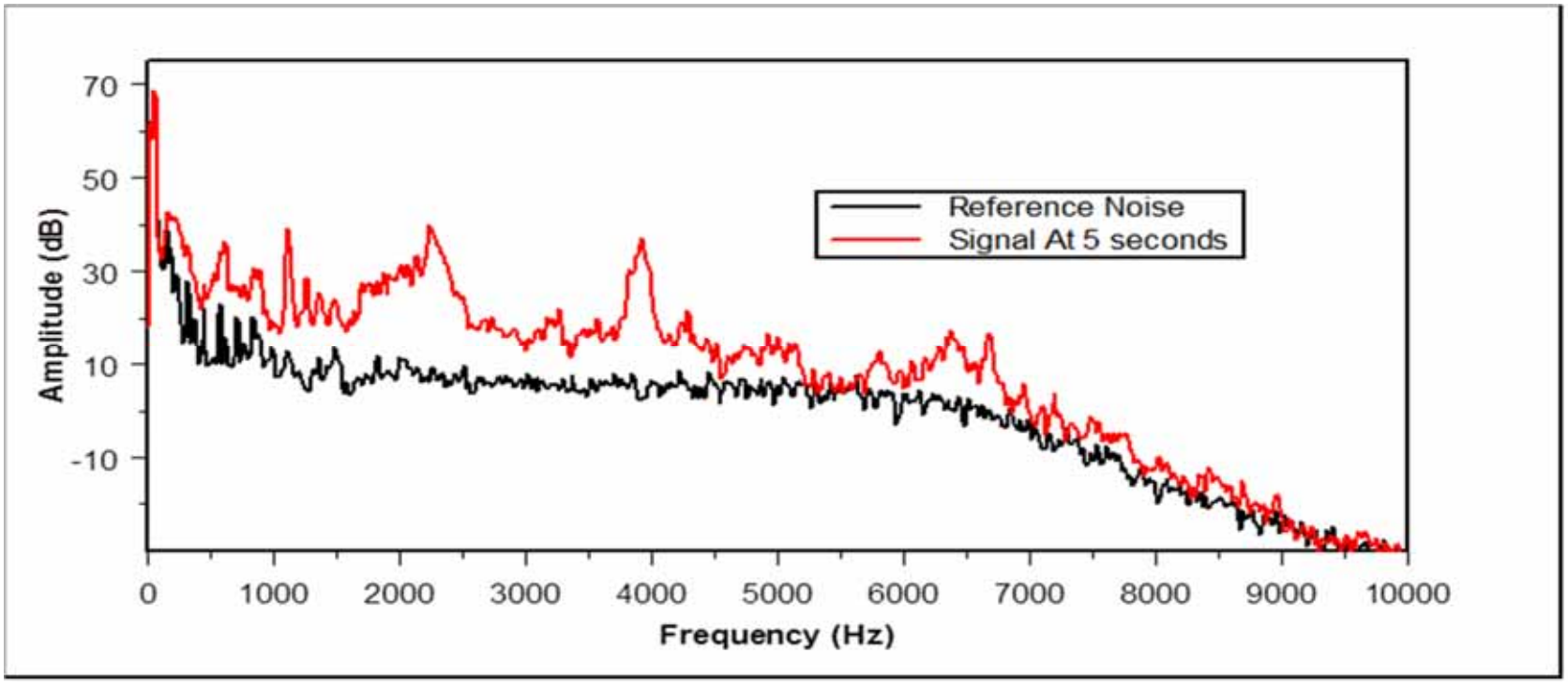
- Used a “transducer on a stick” to obtain noise measurements
- The flow pathways were first filled with liquid
- Gas then injected at bottom

Test Using Microannulus Model – 1sec



Very little gas has entered, so transducer is detecting near pure water flow. Signal differences up to 4 kHz were detected.

Test Using Microannulus Model – 5sec



Gas has completely migrated the length of the apparatus, transducer is detecting a mixture of water and gas. Signal differences up to 7 kHz were detected.

Passive Method – Where are we now?

- Software is being calibrated for different types of:
  - Flow
  - Flow paths
  - Magnitudes of flow

Proposed Field Use of Active and Passive Methods

- Active tool is slow, but very accurate
- Passive method is quick, but not as resolute and provides no orientation
- A combination is proposed
  - Passive method to determine depths of interest, and potentially type of flow
  - Active tool to determine orientation
- Field trials to begin early next year

Conclusions

- Active tool “bubble detection“ capability proven successful at lab scale
- Body mounted transducers placed at a non-normal angle of incidence to the casing provide significantly improved signals
- The concept to accomplish the first step of the developing method of sealing annular flow channels behind pipe to stop SCP, location of the flow path behind pipe, has been successfully demonstrated through laboratory testing
- Design of a field-applicable tool is underway
- Application of tools in concert, passive followed by active

Acknowledgements

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