Acoustic Smart Cement for Well Integrity Diagnostics

DE-SC0018836

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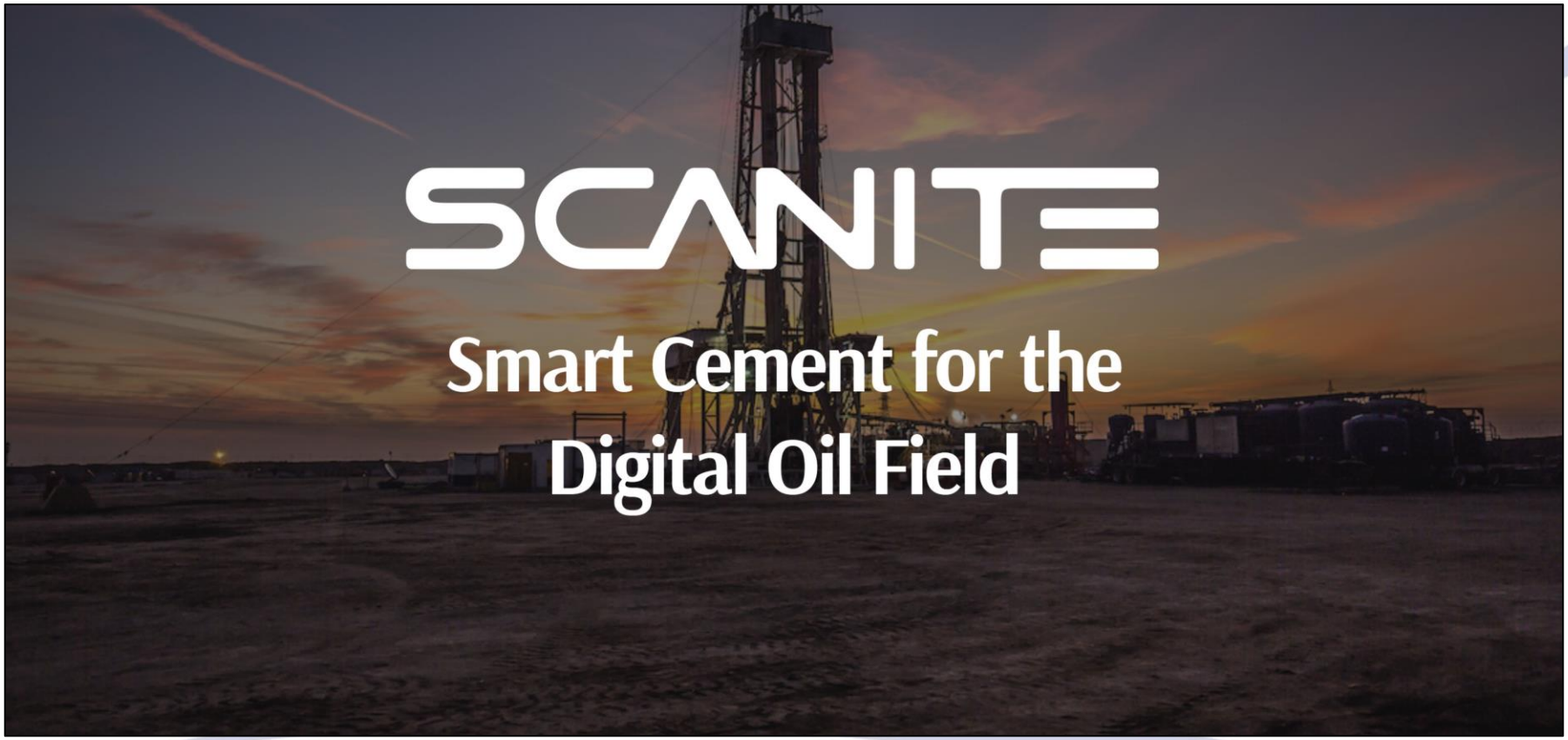
Oceanit Laboratories, Inc.

U.S. Department of Energy

National Energy Technology Laboratory

Oil & Natural Gas

2020 Integrated Review Webinar



https://scanite.io/

https://www.oceanit.com/

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Program Overview

– Funding – DOE SBIR Phases I+II

DOE $1,750,000.00
CS $0.00

– Project Performance Dates

Phase I: July 2, 2018 – April 1, 2019

Phase II: August 19, 2019 – August 18, 2021

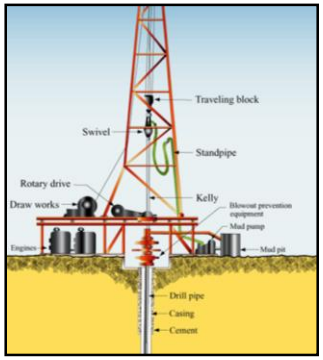
– Project Participants

Oceanit Laboratories, Inc.

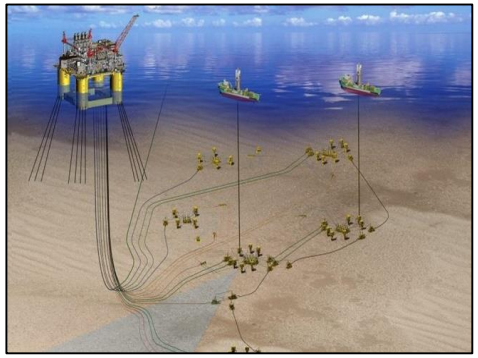
Program Overview

– Overall Project Objectives

Enabling Intelligent Wells

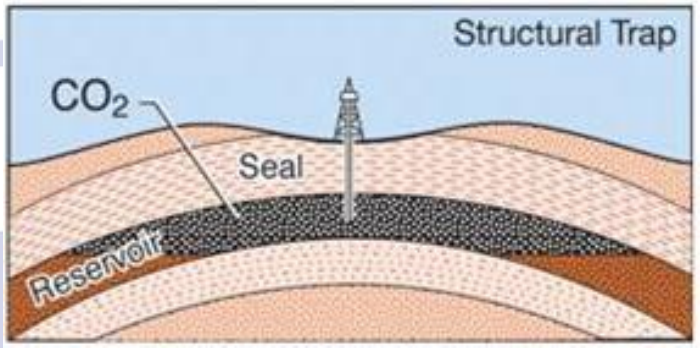


Deepwater Oil Fields



Onshore Unconventional

Carbon Storage Facilities



- **Cement compatibility** - foam, ultra-lite, dry, wet
- **Tool compatiblity** - CBL/VDL, mono-/dipole, EMAT, URS, wellhead low frequency

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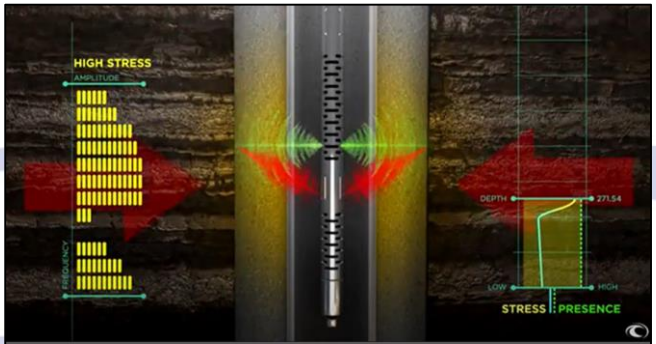
Program Overview

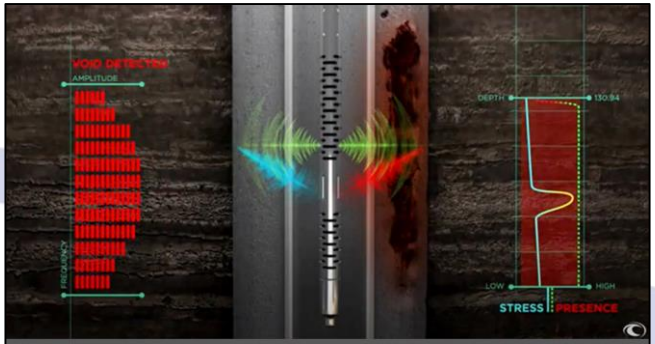
– Overall Project Objectives

- Global and wireline methods of obtaining **cement evaluation measurements**.
- Enhanced **void contrast** and classification.
- Unique **stress dependent** response.

Compatible with existing acoustic log tools



High-stress areas shift the acoustic band gap



Enhanced discrimination of cement defects

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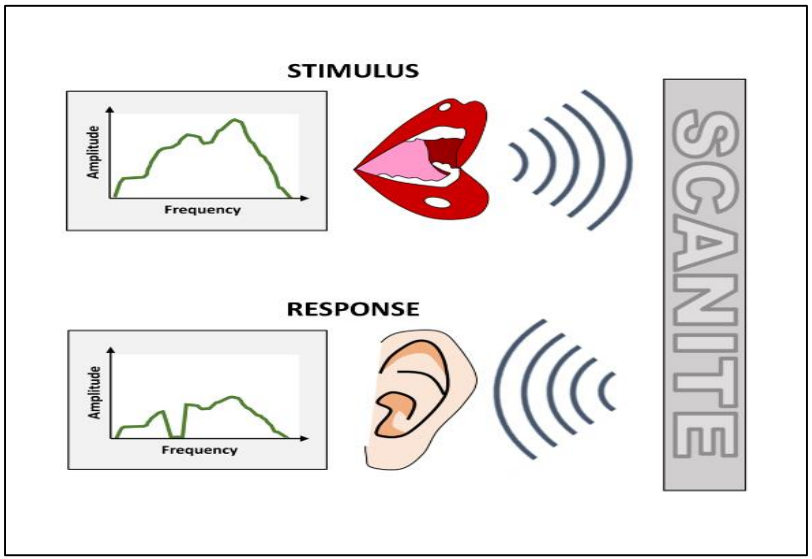
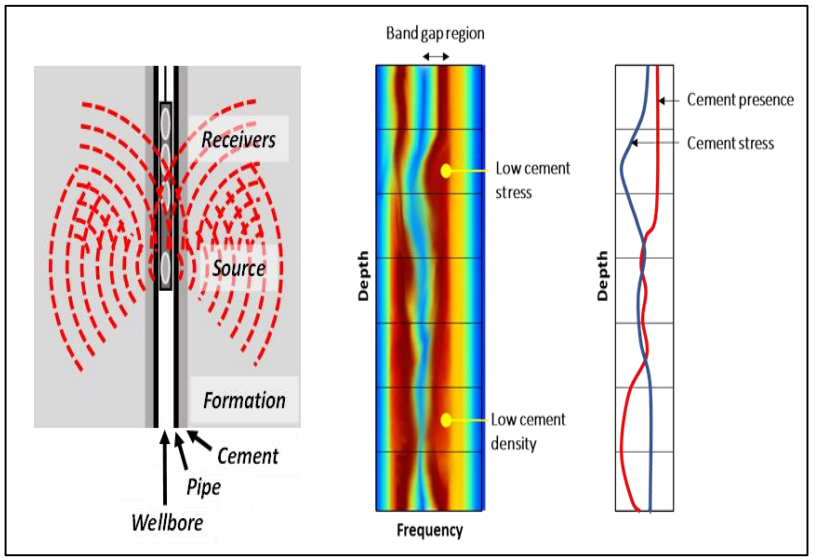
Technology Background

Acoustic Metamaterials – Enable Unique Acoustic Signatures.

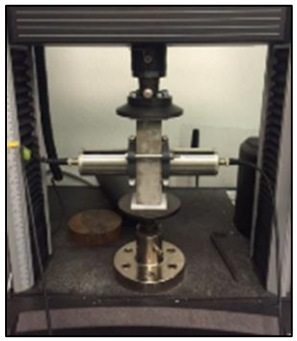


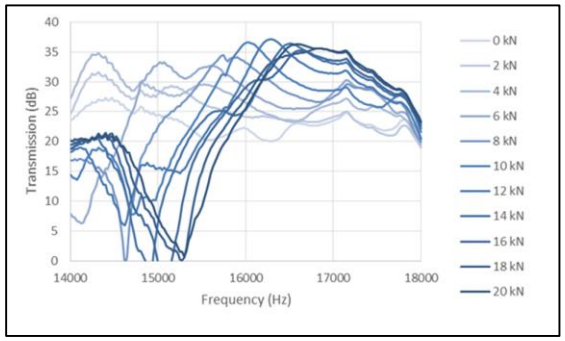


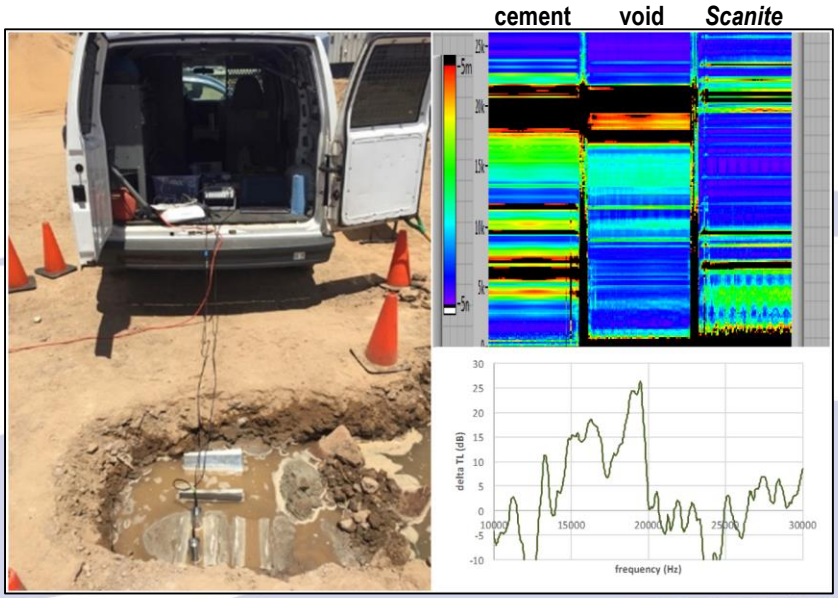
- The smart cement improves measurements of **hydraulic containment**, **casing stress state**, and **cement condition**.
- It can also inform well design and operation through increased understanding of **geomechanical effects**.

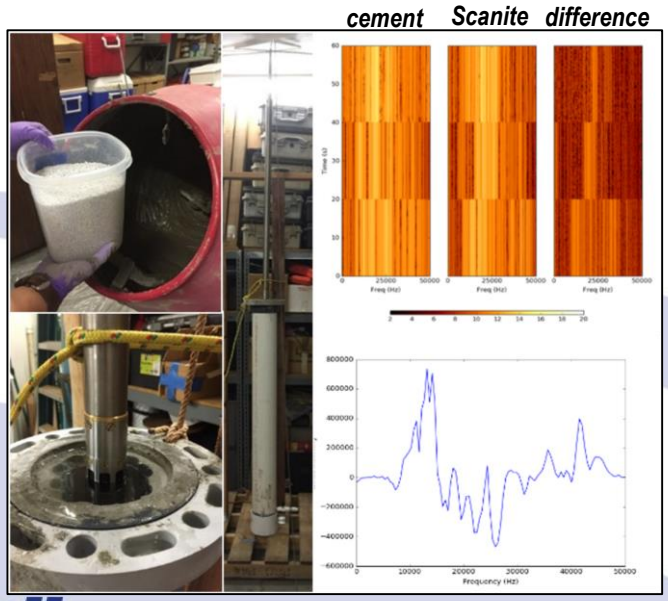
Technology Background

Laboratory and Sub-scale Testing – Acoustic Impedance and Load Response.









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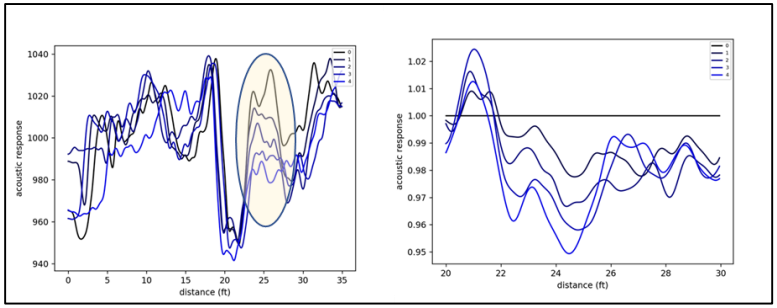
Technology Background

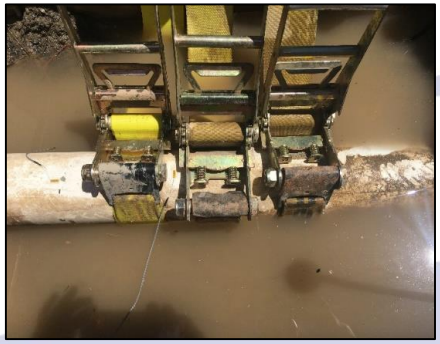
Pilot Scale Mechanical Loading – Flexural, Radial, Through-ground.

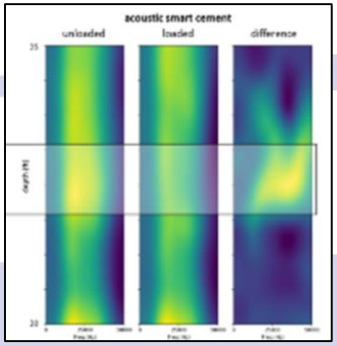
Bending Loading

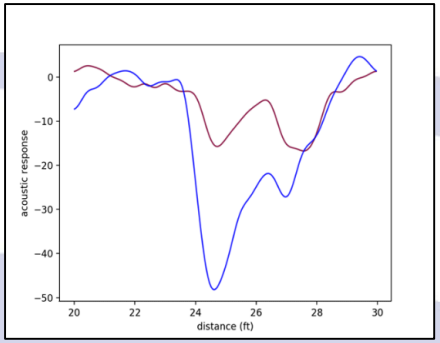


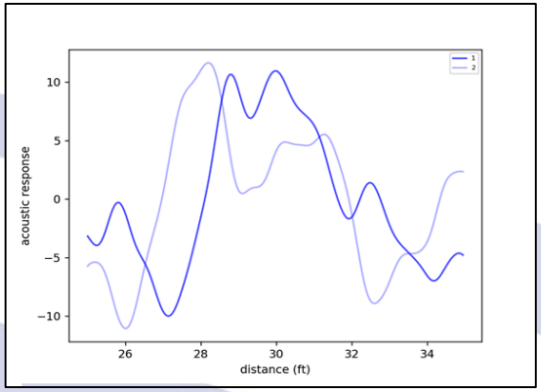
Ground Loading

Compression Loading









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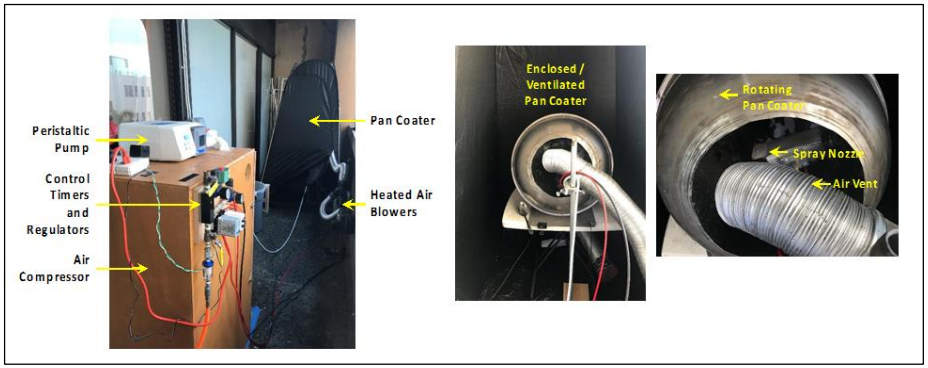
Technology Background

Manufacturing Scale-up – Pan Coating to Fluidized Bed Continuous



Technical Approach/Project Scope

Technical Approach: Acoustic Metamaterials for Well Cement

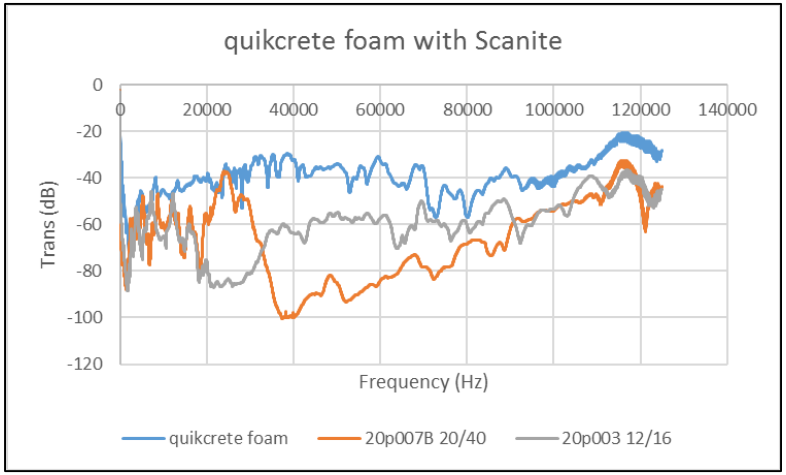
Project Scope: Deployment of acoustic smart cement technology that will provide enhanced information about well cement integrity and formation geomechanics to improve production efficiency and safety

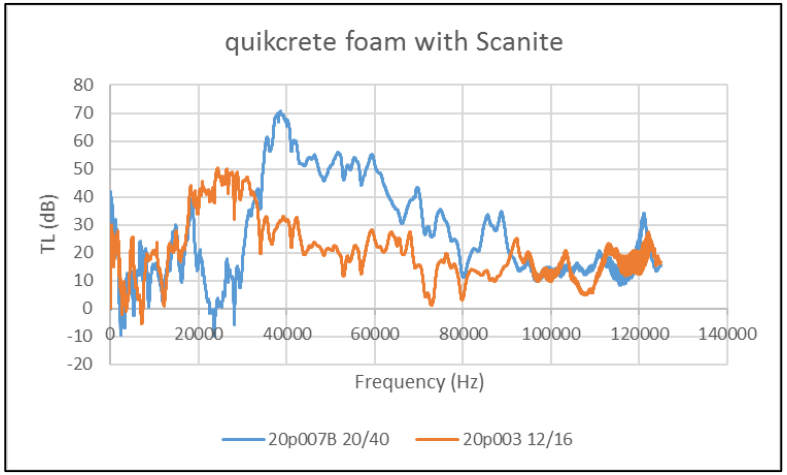
The project has the following milestones:

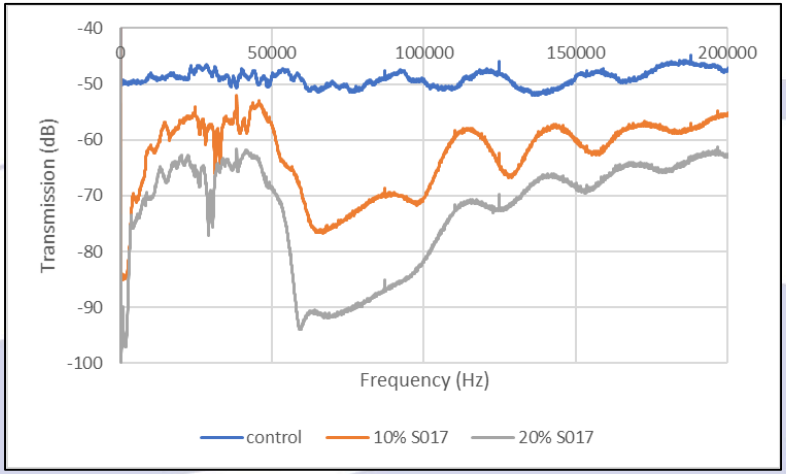
1. Production of 200 lbs. of acoustic metamaterial filler particles. (Month 6)
2. Expanded acoustic characterization of acoustic smart cement. (Month 8)
3. Determination of optimized particle composition and cement formulation. (Month 10)
4. Measurement of API properties of acoustic smart cement. (Month 12)
5. Tool selection and customization of acoustic measurement. (Month 17)
6. Field trial plan, materials, and partnerships. (Month 23)

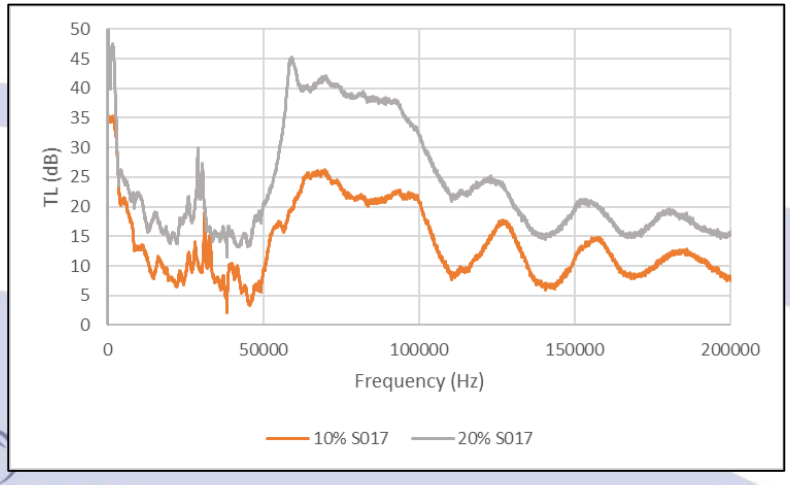
Current Status of Project

Tunable metamaterial filler particles for multiple O&G applications



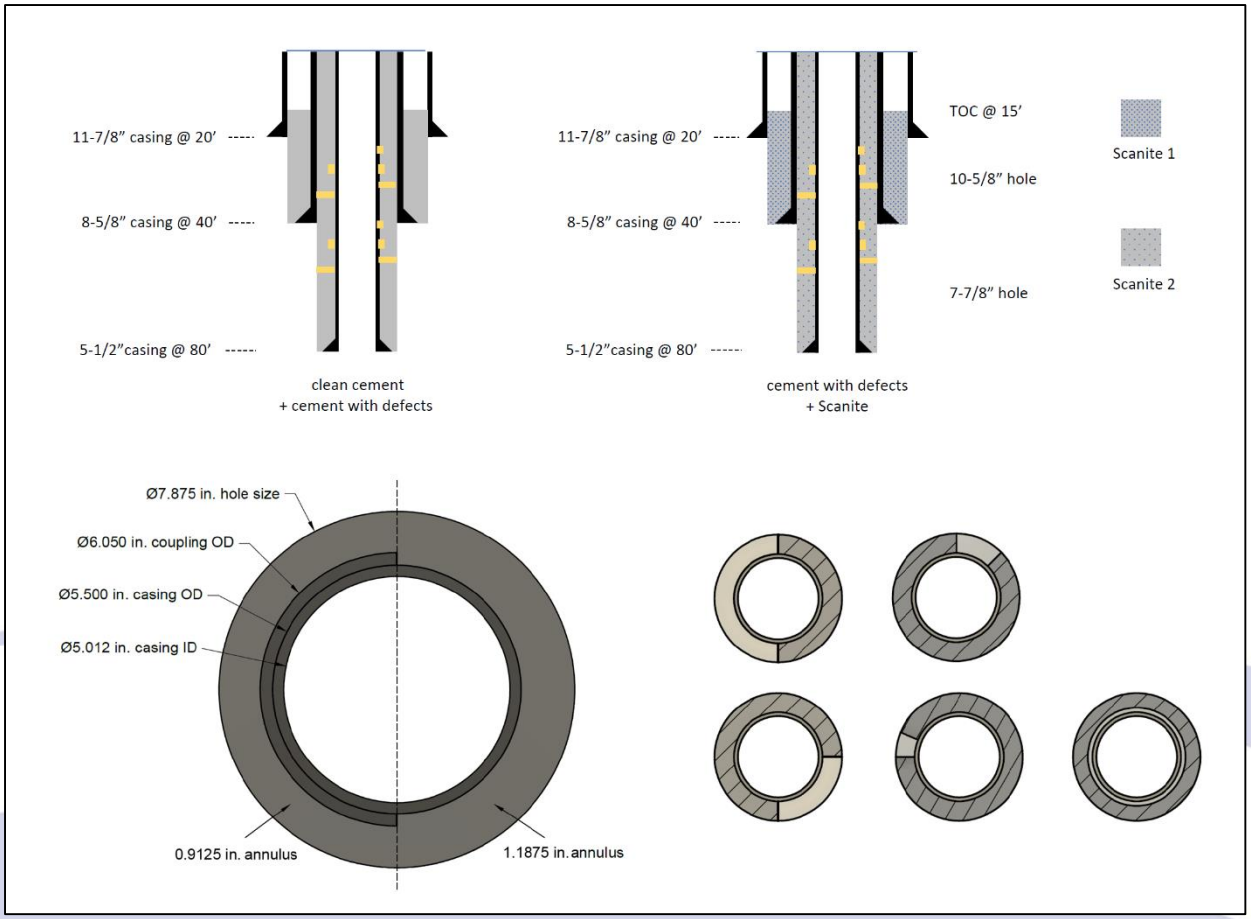






Current Status of Project

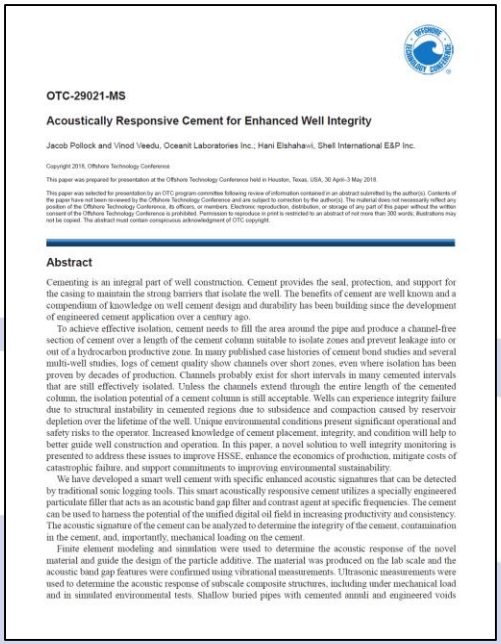
Preparing for field test of Scanite technology



Current Status of Project

Dissemination of technology:

- IPTC 2020 Live Demo
- Scanite SPARK Day Webinar 2020
- Literature and presentations



OTC-29021-MS

Acoustically Responsive Cement for Enhanced Well Integrity

Jacob Pollock and Vinod Veedu, Oceanit Laboratories Inc.; Hani Elshahawi, Shell International E&P Inc.

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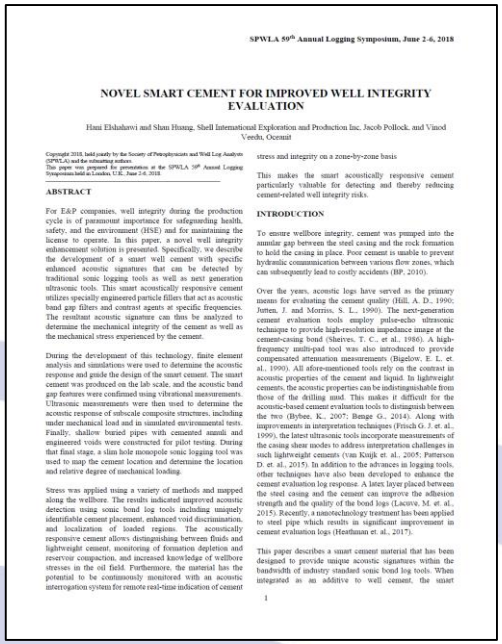
Abstract

Cementing is an integral part of well construction. Cement provides the seal, protection, and support for the casing to maintain the strong barriers that isolate the well. The benefits of cement are well known and a compendium of knowledge on well cement design and durability has been building since the development of engineered cement application over a century ago.

To achieve effective isolation, cement needs to fill the area around the pipe and produce a channel-free section of cement over a length of the cement column suitable to isolate zones and prevent leakage into or out of a hydrocarbon productive zone. In many published case histories of cement bond studies and several multi-well studies, logs of cement quality show channels over short zones, even where isolation has been proven by decades of production. Channels probably exist for short intervals in many cemented intervals that are still effectively isolated. Unless the channels extend through the entire length of the cemented column, the isolation potential of a cement column is still acceptable. Wells can experience integrity failure due to structural instability in cemented regions due to subsidence and compaction caused by reservoir depletion over the lifetime of the well. Unique environmental conditions present significant operational and safety risks to the operator. Increased knowledge of cement placement, integrity, and condition will help to better guide well construction and operation. In this paper, a novel solution to well integrity monitoring is presented to address these issues to improve HSSE, enhance the economics of production, mitigate costs of catastrophic failure, and support commitments to improving environmental sustainability.

We have developed a smart well cement with specific enhanced acoustic signatures that can be detected by traditional sonic logging tools. This smart acoustically responsive cement utilizes a specially engineered particulate filler that acts as an acoustic band gap filter and contrast agent at specific frequencies. The cement can be used to harness the potential of the unified digital oil field in increasing productivity and consistency. The acoustic signature of the cement can be analyzed to determine the integrity of the cement, contamination in the cement, and, importantly, mechanical loading on the cement.

Finite element modeling and simulation were used to determine the acoustic response of the novel material and guide the design of the particle additive. The material was produced on the lab scale and the acoustic band gap features were confirmed using vibrational measurements. Ultrasonic measurements were used to determine the acoustic response of subscale composite structures, including under mechanical load and in simulated environmental tests. Shallow buried pipes with cemented annuli and engineered voids



SPWLA 59th Annual Logging Symposium, June 2-6, 2018

NOVEL SMART CEMENT FOR IMPROVED WELL INTEGRITY EVALUATION

Hani Elshahawi and Shan Huang, Shell International Exploration and Production Inc. Jacob Pollock, and Vinod Veedu, Oceanit

Copyright 2018, held jointly by the Society of Petrophysicists and Well Log Analysts (SPWLA) and the submitting authors.
This paper was prepared for presentation at the SPWLA 59th Annual Logging Symposium held in London, U.K., June 2-6, 2018.

ABSTRACT

For E&P companies, well integrity during the production cycle is of paramount importance for safeguarding health, safety, and the environment (HSE) and for maintaining the license to operate. In this paper, a novel well integrity enhancement solution is presented. Specifically, we describe the development of a smart well cement with specific enhanced acoustic signatures that can be detected by traditional sonic logging tools as well as next generation ultrasonic tools. This smart acoustically responsive cement utilizes specially engineered particle fillers that act as acoustic band gap filters and contrast agents at specific frequencies. The resultant acoustic signature can thus be analyzed to determine the mechanical integrity of the cement as well as the mechanical stress experienced by the cement.

During the development of this technology, finite element analysis and simulations were used to determine the acoustic response and guide the design of the smart cement. The smart cement was produced on the lab scale, and the acoustic band gap features were confirmed using vibrational measurements. Ultrasonic measurements were then used to determine the acoustic response of subscale composite structures, including under mechanical load and in simulated environmental tests. Finally, shallow buried pipes with cemented annuli and engineered voids were constructed for pilot testing. During that final stage, a slim hole monopole sonic logging tool was used to map the cement location and determine the location and relative degree of mechanical loading.

Stress was applied using a variety of methods and mapped along the wellbore. The results indicated improved acoustic detection using sonic bond log tools including uniquely identifiable cement placement, enhanced void discrimination, and localization of loaded regions. The acoustically responsive cement allows distinguishing between fluids and lightweight cement, monitoring of formation depletion and reservoir compaction, and increased knowledge of wellbore stresses in the oil field. Furthermore, the material has the potential to be continuously monitored with an acoustic interrogation system for remote real-time indication of cement stress and integrity on a zone-by-zone basis

This makes the smart acoustically responsive cement particularly valuable for detecting and thereby reducing cement-related well integrity risks.

INTRODUCTION

To ensure wellbore integrity, cement was pumped into the annular gap between the steel casing and the rock formation to hold the casing in place. Poor cement is unable to prevent hydraulic communication between various flow zones, which can subsequently lead to costly accidents (BP, 2010).

Over the years, acoustic logs have served as the primary means for evaluating the cement quality (Hill, A. D., 1990; Jutten, J. and Morriss, S. L., 1990). The next-generation cement evaluation tools employ pulse-echo ultrasonic technique to provide high-resolution impedance image at the cement-casing bond (Sharives, T. C., et al., 1986). A high-frequency multi-pad tool was also introduced to provide compensated attenuation measurements (Bigelow, E. L. et. al., 1990). All afore-mentioned tools rely on the contrast in acoustic properties of the cement and liquid. In lightweight cements, the acoustic properties can be indistinguishable from those of the drilling mud. This makes it difficult for the acoustic-based cement evaluation tools to distinguish between the two (Bybee, K., 2007; Benge G., 2014). Along with improvements in interpretation techniques (Frisch G. J. et. al., 1999), the latest ultrasonic tools incorporate measurements of the casing sheer modes to address interpretation challenges in such lightweight cements (van Kuijk et. al., 2005; Pattersron D. et. al., 2015). In addition to the advances in logging tools, other techniques have also been developed to enhance the cement evaluation log response. A latex layer placed between the steel casing and the cement can improve the adhesion strength and the quality of the bond logs (Lacroix, M. et. al., 2015). Recently, a nanotechnology treatment has been applied to steel pipe which results in significant improvement in cement evaluation logs (Heathman et. al., 2017).

This paper describes a smart cement material that has been designed to provide unique acoustic signatures within the bandwidth of industry standard sonic bond log tools. When integrated as an additive to well cement, the smart

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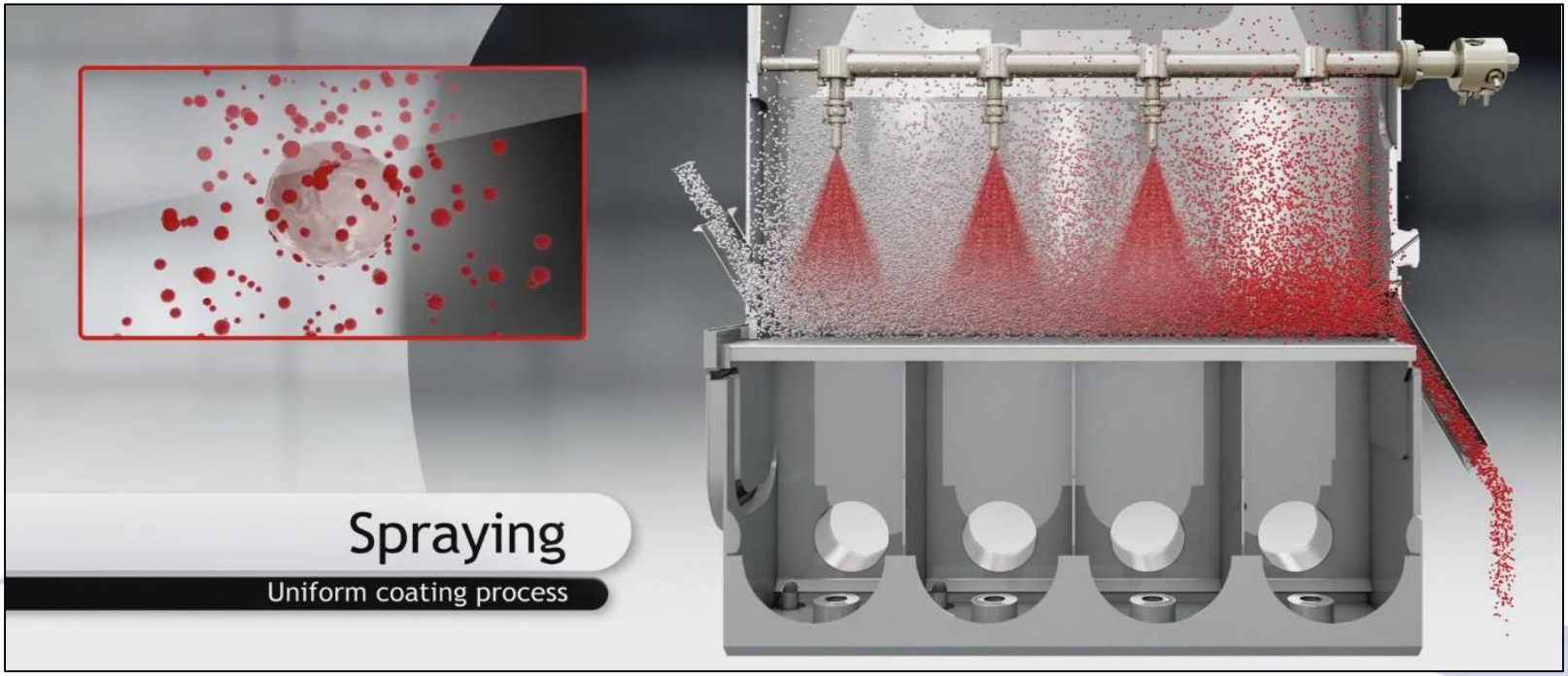
Current Status of Project

Technology Scale-up and Commercialization



Summary

This project will lead to the development of more effective methods for investigating well cement and rock-cement-casing bond integrity and how they are affected by corrosion, thermal cycling, and long term injection of production fluids.

The ultimate result of this enhanced awareness is safer and more economical production techniques and processes that contribute to US energy independence.

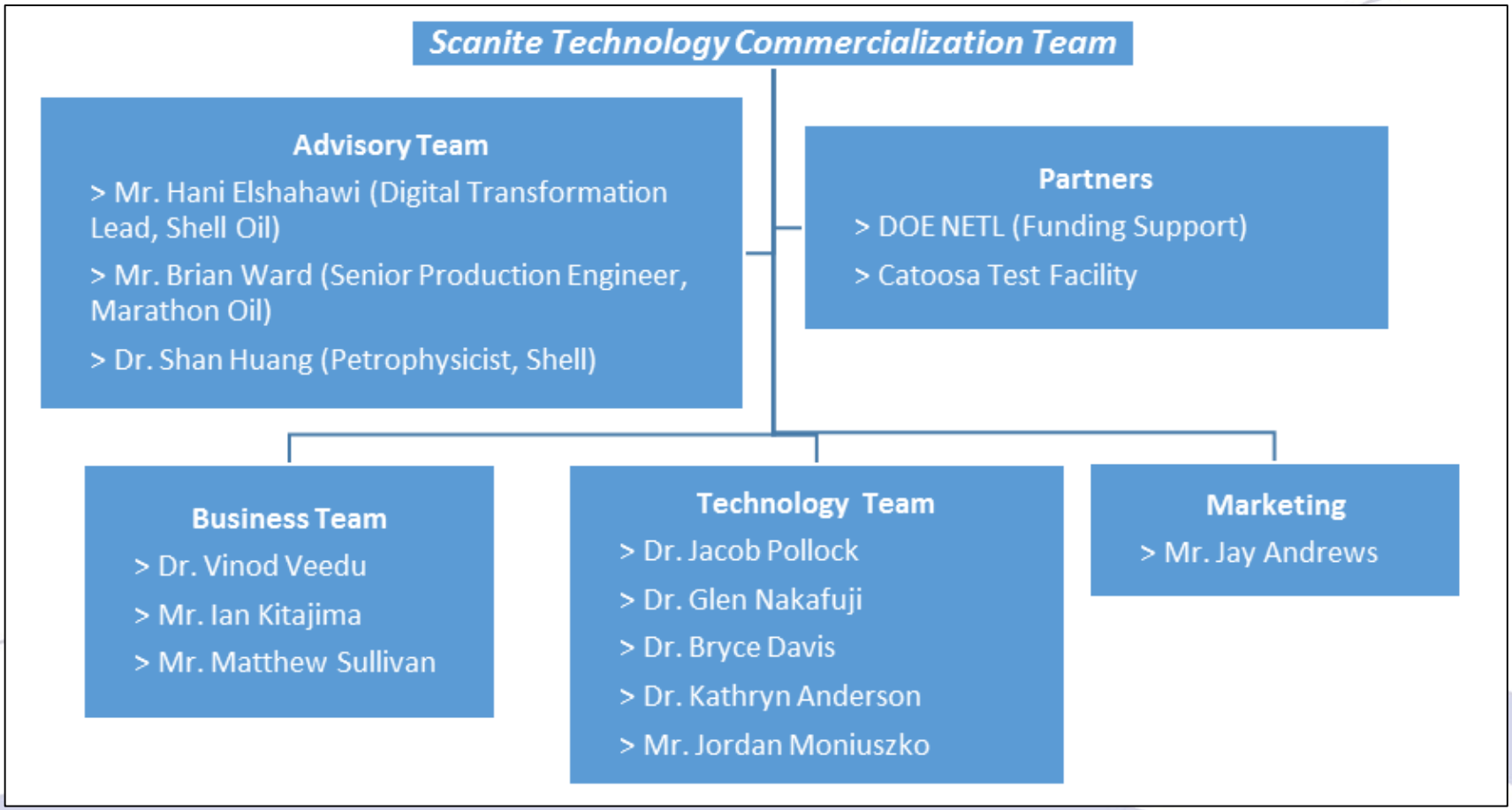
Overall, the project will promote increased human health and environmental safety as well as more efficient production of hydrocarbon fuels and products.

Oceanit's Scanite smart cement technology will incorporate well integrity and geomechanical aspects into the digital oil field.

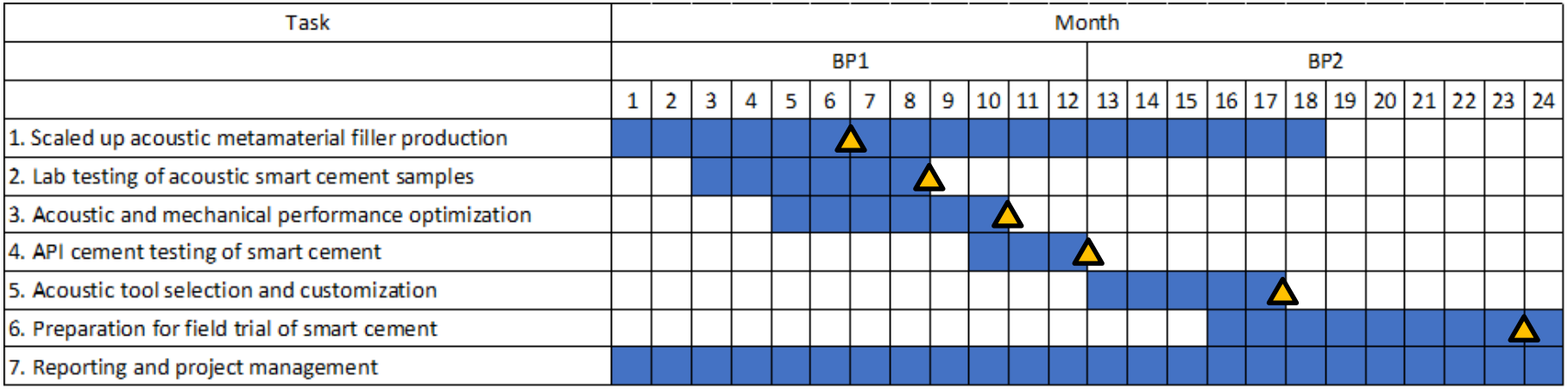
Appendix

– These slides will not be discussed during the presentation, but are mandatory.

Organization Chart



Gantt Chart



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