Winter 2014 Oil & Natural Gas Program Newsletter

NETL

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U.S. DEPARTMENT OF ENERGY

NETL Boasts State-of-the-Art Capabilities for Cement Research

NETL's multiscale CT imaging facility is equipped to investigate cement properties under in situ conditions that replicate downhole cement environments. This allows researchers to examine core samples under pressure, at temperature, and with fluid flow. CT scanning and other capabilities housed at the laboratory are helping researchers answer fundamental questions about how cement, casing, and subsurface formations interact downhole. Several of these are highlighted below. In contrast, coal bed methane wells initially produce a large volume of water, which declines over time. The methane production starts low, builds to a peak, and then decreases.

Multiscale CT Scanning – To gain an unprecedented view of how foamed cement forms at elevated pressures typical in the subsurface, NETL uses industrial, medical, and micro CT scanners (Figure 1) in conjunction with pressure vessels to study in situ cement conditions over a range of pressures and foam qualities. With these capabilities, NETL

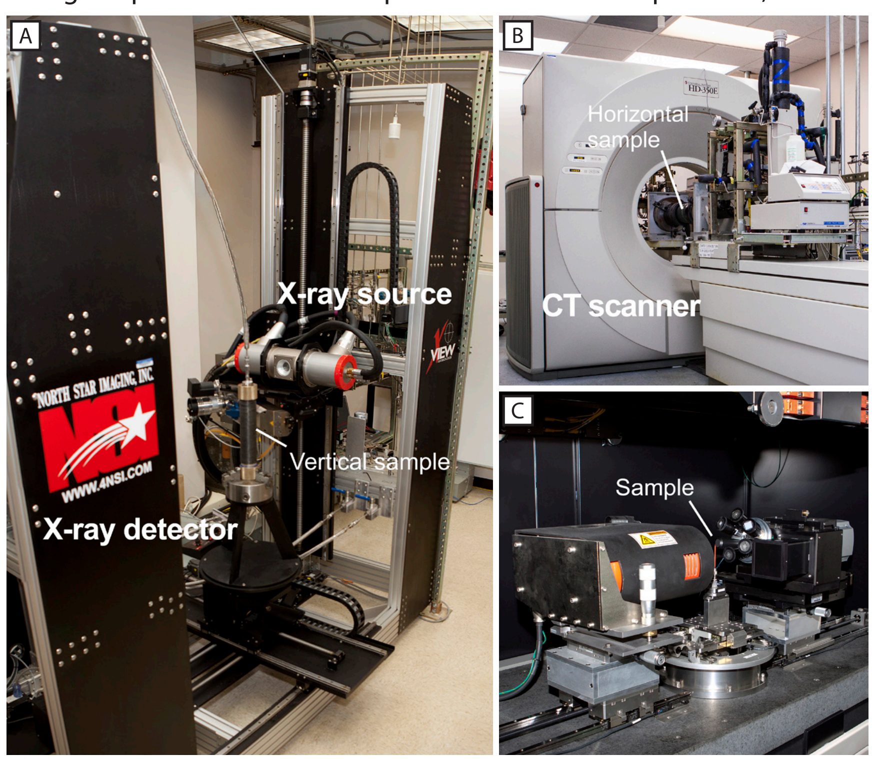

Figure 1. (A) Photograph of the North Star Imaging M-5000 industrial CT scanner and (B) Medical CT scanner installed at NETL in Morgantown, WV. (C) Micro-CT scanner (Xradia Micro-XCT-400) installed at NETL in Pittsburgh, PA.

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Editor's Letter

Cement Integrity Key Driver of NETL Research

Wellbore cement integrity is paramount to safe,successful oil and natural gas drilling. Cement acts as the primary barrier between the wellbore and the environment. An unstable cement job can compromise wellbore control, and research indicates that poor cement integrity is a primary factor contributing to loss of zonal isolation in oil and gas wells. Although cementing designs and placement practices are well established in many operational environments, the extreme subsurface conditions and complicated completion designs found in deepwater oil and unconventional natural gas wells pose new challenges to achieving reliable cement jobs. For more than a decade, NETL (the National Energy Technology Laboratory) has committed personnel and resources, in collaboration with industry and academia, to finding solutions to issues of cement integrity that will ensure safe and reliable oil and gas production.

Collaboration with Academia

NETL and its partners in the NETL Regional University Alliance (The Alliance combines NETL's fossil energy expertise in research, development, and demonstration with the diverse capabilities of industry member URS Corporation and five nationally recognized research universities: Carnegie Mellon University, the Pennsylvania State University, the University of Pittsburgh, Virginia Polytechnic Institute and State University, and West Virginia University) are examining the performance and integrity of key wellbore barrier materials for which performance data in extreme environments are limited. One of those materials is wellbore cement.

Our researchers are working to understand how various cement mixes perform, with emphasis on potential failure pathways and remediation technologies. This work builds on long-standing research conducted by our organizations to understand and develop technologies for drilling systems associated with onshore oil and natural gas development. It also builds on our work in geologic CO_2 storage, which is looking at the effect of stored CO_2, acid gas, and brine solutions on the integrity of cements at high pressure and temperature. As the breadth and scope of cementing evolves and industry drills toward deeper, more complex targets, the initial and long-term integrity of cement barriers, and the protocols for placing them, are critical to safe, productive hydrocarbon recovery.

Outside the NETL program, NETL collaborates with multiple universities across the country on a project-by-project basis developing next-generation cementing technology to ensure well integrity in all operating environments.

Collaboration with Industry

Industry understands the challenges of obtaining reliable cement jobs in deep oil and natural gas production wellbores. Exploration and development companies and the major service organizations that support them continue to expand industry knowledge in this area, and NETL and its partners are complementing their efforts. We are working with drilling and cementing experts to further technology research and development in cement design, placement, and long-term integrity, particularly the American Petroleum Institute's

energy API

Subcommittee on Oil Well Cements. Through experimentation using specialized and standard facilities, we re-create downhole conditions and keep our laboratory research as close to field conditions as possible. By doing so, we can see what happens when cement is transported and pumped in the well, and then determine if current techniques and cement formulations perform as expected.

NETL takes a dual approach to this work: experimental and computational. Traditional lab experiments provide fundamental data from which basic understanding is advanced. The laboratory program also produces data that serve as input for customized computer models. By extrapolating scenarios through computer simulations, research that would normally take years can be conducted in months. This helps our engineers and scientists balance careful research with speed to distribute reliable results more quickly.

The Editor

(continued from page 1) researchers are examining this ubiquitous yet under-studied wellbore material to determine gas bubble stability as cement hardens (Figure 2). Researchers also employ various software applications to derive statistical relationships related to, for example, foamed cement physical structure. The goal is to determine the conditions required for generating stable cement. In addition, injection properties, fluid-gas ratios, and additives are being examined to determine how they, too, affect stability. Because these experiments are non-destructive, difficult-to-obtain cement core samples are preserved for reuse. Digital images are also archived for future investigations.

Subsurface Experimental Facilities - NETL's multifunctional subsurface experimental facilities were originally developed for investigations related to the underground injection of CO_2 for carbon management, particularly with respect to reservoir storage, caprock sealing capacity, and wellbore cement integrity. Researchers are now using these facilities to conduct offshore and unconventional oil and gas wellbore investigations as well. By exposing lab- and field-generated samples to downhole conditions, we are collecting key data on cement stability and performance in various chemical environments. We are studying mechanical properties and behavior of various cement systems, including foamed cement. For example, NETL's tri-axial core flow unit (Figure 3) measures sonic velocity and resistivity to determine the dynamic behavior of foamed cement in situ. We are also using experimental results to build computer models of

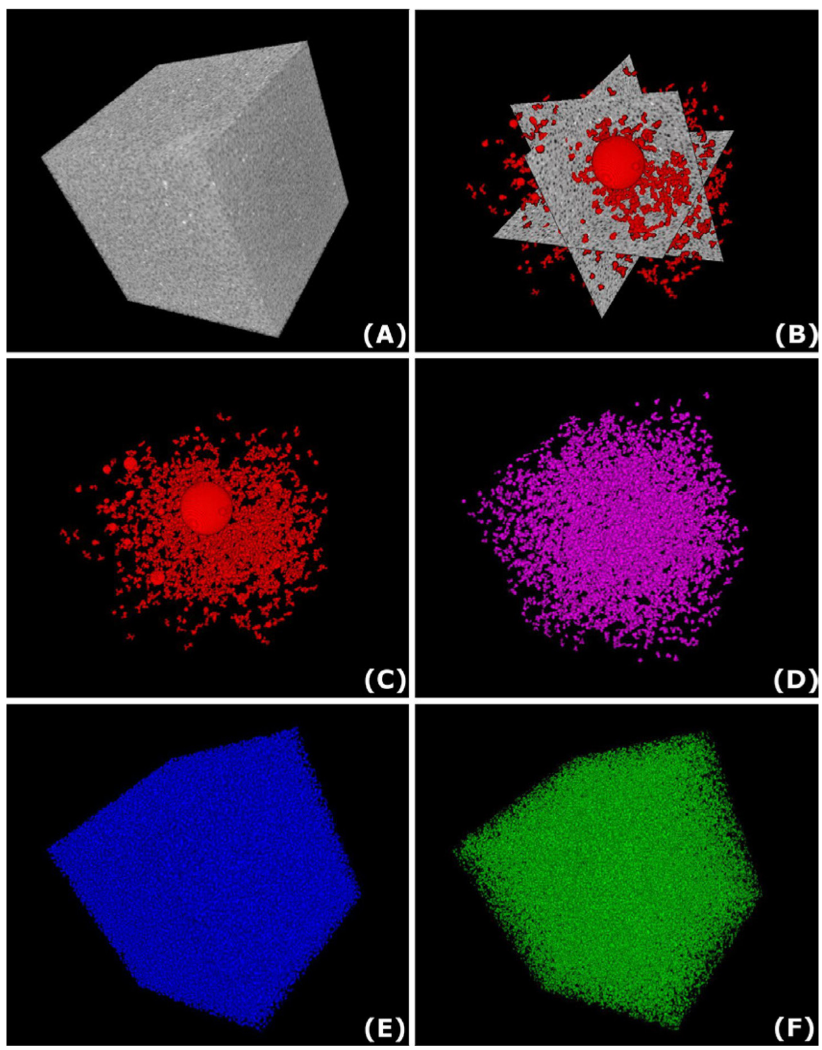


Figure 2. 3-D renderings of a (10.4 mm) digital subsection of a 10% foam quality cement sample. (A) Opaque grayscale cement cube. (B) Orthoslices of solid cube with largestbubbles. (C) Largest bubbles in dataset that sum to 10% of the total void space in the sample. (D) The next largest bubbles, summing again to 10% of the total void volume. (E) The mean bubbles, between the largest and the smallest in the sample set. (F) The smallest half of the bubbles.

Figure 3. Multipurpose Computer-Controlled Servo-Hydraulic Tri-Axial Test System "Autolab-1500".

subsurface phenomena and processes that can increase the speed and lower the cost of ongoing investigations.

Analytical Tools - The NETL laboratory houses a tri-axial multisensor core logger (Figure 4) custom built to measure key geophysical properties like resistivity, gamma-density, and p-wave velocity.

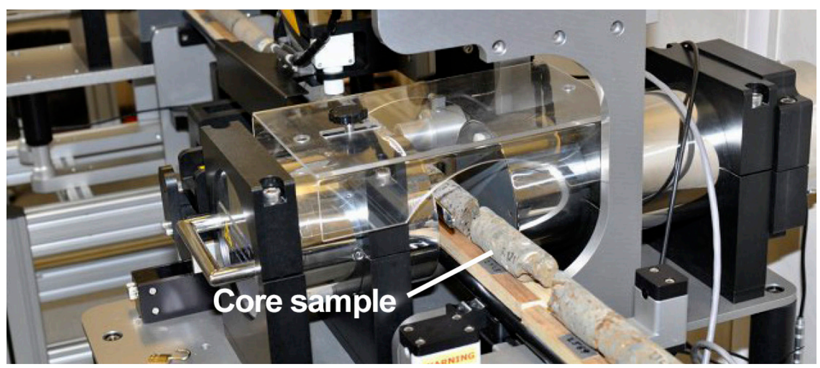


Figure 4. Mobile Tri-Axial Multisensor Core Logger.

As a complement to our CT scanning capabilities, the logger can provide high-resolution 2D graphs scanned down the length of a lab- or field-generated sample, providing data on a greater range of properties. NETL also has the capabilities to analyze and characterize a wide variety of wellbore materials. These include petrography, environmental scanning electron microscopy with energy dispersive spectroscopy, x-ray and micro-x-ray diffraction, permeametry, thermogravimetric analysis, differential scanning calorimetry, and infrared and raman spectroscopy. Analyses are used to characterize the fundamental properties of ultra-deepwater and frontier-region reservoirs, unconventional natural gas and oil reservoirs, and reservoirs that offer potential for CO_2 storage. Information gained helps NETL and its partners better understand field test sites, and it feeds computational models and simulations, risk assessments, and experimental studies investigations.

Five Challenges: NETL Cementing Research Foci

To ensure that the cementing R&D undertaken addresses practical problems in cement integrity, NETL polled the industry to determine those cementing issues that had the greatest impact on cement integrity. Basically, the polling asked two questions: What is the current state of wellbore cementing; and where can we best direct R&D efforts to improve current technologies and develop new approaches? To answer these questions, NETL surveyed industry experts with strategic knowledge, intimate insight, and significant experience in drilling and cementing. Among them were representatives from major oil and gas service companies, the American Petroleum Institute, the International Association of Drilling Contractors, the Drilling Engineering Association, and the American Association of Drilling Engineers. Collectively they characterized five primary research challenges related to borehole design, placement, and long-term integrity and suggested R&D pathways that could lead to safer, more efficient operations. The survey was taken in response to major questions about cement integrity in the wake of the Macondo incident and has guided NETL cementing research since 2011.

Challenge 1: Developing new monitoring for wellbore integrity

The mechanisms associated with cement failure are inadequately understood, partly because industry lacks appropriate or cost-effective monitoring options. How does cement set across zones? Is it properly emplaced? Does it maintain integrity over time? Immediate and long-term monitoring technologies—particularly tools and techniques that accurately monitor and confirm zonal isolation—can help to answer questions critical to emplacing wellbore casings in a manner that operators can trust.

Challenge 2: Understanding cement stability under field conditions

To more accurately assess risk associated with cement placement and well operation, we must improve our general understanding of cement stability under extreme field conditions. Placement concerns include fluid loss, contamination, and dynamic settling. Concerns post placement and beyond include cement expansion and shrinkage, free water development, temperature and pressure stability, hydration, gas and fluid migration, and cement-formation interactions. By identifying key elements for cement job design, we can help inform new and updated standards and best practices to improve risk assessment and ensure safe operations.

The deepwater continental shelf is one of the last remaining areas where undiscovered oil and natural gas resources remain. Exploration and production in these remote, high-risk regions pose unique operational challenges and distinct environmental impact risk concerns. We must better understand the behavior differences between laboratory and field mixers, and other production factors. Industry also seeks a suitable technique for scaling up free water measurements from lab to job.

Challenge 3: Ensuring quality control

Job-site conditions are difficult to replicate in a laboratory and the condition of bulk cement changes during transfer, shipment, and mixing. What are the effects of settling during transportation? Does particle shear influence the cement as it is blown and pumped? How do laboratory prepared cements behave differently from cement that is mixed and pumped in a well? The job modeled in a lab is often not the job pumped. Finding answers to these and other cement-quality questions will help us bridge the potential disconnects between lab and job site.

Challenge 4: Understanding the impact of temperature- and pressure-induced stress

Reliable cement slurry designs depend on temperature measurements. Wells are large heat exchangers, and unknowns surround emplacement temperature cycles as cement slurry travels to the bottom of a well, and then moves back up the annulus and cools. Post-placement pressure and temperature cycles can also cause mechanical failures, potential flowpaths, or loss of zonal isolation as the slurry gels. R&D associated with alternative cements and well isolation technologies will help operators better understand and respond to high-risk, high-stress-cycle environments.

Challenge 5: Improving standard calculations

Tests for cement characteristics and properties are available, but many are considered nonstandard because of the inconsistencies prevalent among them. These include tests for static gel strength and gas migration, which are important in determining which cement system should be used in a specific well environment. They also include stress calculations for set cement. While lower-temperature models calculate induced stress values in compression and tensile components, many higher-temperature tests for mechanical properties only include components that address flexural strength. Properly focused research can help us develop a set of industry standard tests of cement properties for the writing and updating of standards and recommended practices.

These are the R&D challenges that DOE is focusing on in an effort to advance industry's ability to carry out safer, more efficient cementing operations. Partnering with university and industry researchers, NETL is continuing to develop initiatives that address all of these challenges.

Past NETL Well Integrity Research: Special Cements for Special Conditions

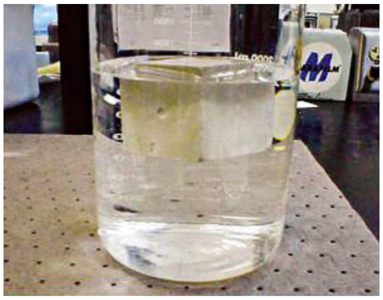


Figure 1. Ultra-lightweight hollow glass sphere slurries exhibit densities less than water

NETL research into cement integrity and performance spans more than a decade. Over that period, R&D has been directed toward improved cements that are specifically suited to downhole conditions and that offer maximum efficiencies in mixing and placement and that ensure wellbore integrity over the life of a well. The projects detailed below are illustrative of both the foci of the program and its achievements.

Many deepwater operations, especially in the Gulf of Mexico (GOM), are characterized by unique conditions that require high-strength, lightweight cements capable of withstanding cycling stresses for extended periods of time. An industry survey conducted in 1997 revealed that the average failure rate of cementing jobs was 15 percent, that industry spends an estimated $470 million per year to repair cementing failures, and that one third to one half of these failures could be prevented with an effective lightweight cementing system.

Data also indicated a continuing problem in maintaining a long-term seal with the use of conventional cementing systems. The U.S. Minerals Management Services estimated that 11,000 out of 14,000 producing wells in the GOM had gas pressure on one of the casing annuli indicative of a cement seal failure. The use of ultra-lightweight cementing systems could improve well performance by enhancing zone isolation and reducing cementing failures. NETL, together with partners Cementing Solutions, Inc. (CSI), ExxonMobil Corporation, Shell Oil Company , BJ Services, Halliburton Energy Services, Schlumberger Inc., 3M Corporation, TXIand Chandler Engineering Company, LLC, undertook an R&D program in 2004 to develop ultra-lightweight cement to mitigate these problems.

Conventional lightweight cements typically use water to decrease density, and include materials that absorb the water and keep the slurry and cement homogenous. These cements, though low in cost, exhibit very low compressive strengths and have difficulty providing long-term zone isolation under severe stress conditions. In addition, they have a minimum density limit of 11.5 lb/gal.

Other options also have their drawbacks. Conventional hollow glass spheres have been used to achieve densities as low as 9.5 lb/gal; however, they are limited in application because of the low crush strength of the beads under pressure. Foamed cements (using nitrogen) can be employed to prevent lost circulation in low-pressure reservoirs, but exhibit both high permeability and low strength, resulting in cementing failures. Additional limitations with foam cements include higher friction in the well during pumping (which can lead to lost circulation), difficulty in maintaining control during the cementing job, and the inability to measure bond strengths with sonic and ultrasonic evaluation tools.

Despite these problems, foam cement slurries are the industry preference for attaining acceptable densities during critical cementing operations. Although lightweight hollow spheres have been used in the industry for some time, the technology advanced by this NETL project allowed the hollow spheres to be ultra-lightweight, while simultaneously exhibiting superior crush strengths of 3,000 to 10,000 psi. These ultra lightweight hollow spheres (ULHS) can attain specific gravities as low as 0.32 to 0.46 while resisting wellbore pressures as high as 6,000 psi.

The results of this project have provided a significant impact on the oil and gas industry. The use of ULHS provides operators the ability to reduce the weight of the cement, increase its strength and make it easy to pump and set the cement in place, in turn providing a much better seal in the annulus. This helps to reduce the safety and environmental hazards associated with cementing failures. The development of this ultra-lightweight cement will also provide significant benefit to drillers in low-pressure or depleted gas and oil fields as the reduced weight will help to avoid fracturing of the formations during cementing, which can lead to lost circulation and failure of the cementing job. ULHS systems are also beneficial in the sealing off of shallow water flows, which is a major challenge in deep water drilling.

The DOE research project accomplished four important objectives that advanced ULHS technology. These are:

- Demonstrated that ultra-lightweight cement slurries using ultra-lightweight hollow spheres (ULHS) provide higher compressive strengths at lower densities and outperform conventional lightweight cement slurries in long-term durability,
- Demonstrated that ULHS cement slurries can be blended and pumped in the field without problems,
- Transferred ULHS technology to industry through publications, meetings and workshops, and
- Developed an electronic decision support tool, SmartCement to help operators choose the most cost efficient low-density cement system.

Tests were designed based on conditions drawn from more than 5,000 data points from field jobs in the U.S. supplied to CSI by service companies. CSI used these data to determine the conditions under which lightweight cements are most commonly used, as well as to define the type of operations currently being performed in deepwater wells.

In addition to standard testing of cementing slurries containing ULHS, CSI performed a unique combination of tests to measure a given cement mixture's ability to withstand formation stresses over long periods of time. Although the mechanical properties of formations are commonly tested, the same mechanical properties tests are not commonly used to test cement. Triaxial load was applied to the samples to simulate wellbore conditions, and the samples were also tested for Young's modulus and tensile strength.

Stress cycling tests were also performed to ensure that the ultra-lightweight cement slurry could withstand the changes in temperature that occur within deepwater wells. Stress cycling within a well can cause the cement-to-pipe bond, and ultimately the cement seal, to deteriorate.

Test results using the ULHS slurry indicated that the slurry could withstand cycling temperature changes of 135°F. Additionally, special test cells were designed to test the cement's shear bonding capability in both the hard formations typically found on land, as well as in the soft formations common to deepwater wells in the Gulf of Mexico (GOM). In both cases, test results indicated that the ULHS slurry could withstand a differential pressure stress of 5,000 psi.

Two field tests were designed to test the slurry's performance in actual formations. The first field test, performed on a South Texas well operated by Conoco, was designed to ensure that the slurry could be easily blended, mixed, and pumped on location with little trouble. The second field test, performed on a well operated by the Rocky Mountain Oilfield Testing

Center (RMOTC) in Wyoming, was designed to test the slurry's performance in a land-based well that closely resembled deepwater operations. The slurry was easily blended on location, one hundred barrels of the ultra-lightweight cement slurry (using 3M 6K ULHS beads) were pumped with no problems, and the ULHS beads showed no breakage after one hour of conditioning at the surface. Ultrasonic logs performed on the well after the cement operation showed excellent application of the slurry, good bond properties, and good perforating qualities.

Today, Glass Bubbles HGS (hollow glass spheres) Series are offered commercially by 3M in a variety of specifications (http://solutions.3m.com/wps/portal/3M/en_US/Oil-Gas_NA/3M-Oil-and-Gas/oil-and-gas-Solutions/upstream-oil-and-gas-exploration/upstream-oil-and-gas-drilling/upstream-lightweight-cementing/).

For further information on this project, contact Gary Covatch at NETL (gary.covatch@netl.doe.gov or 304-285-4589 or Fred L. Sabins at CSI(fsabins@cementingsolutions.com or 713-957-4210).

Super Cement for Annular Seal and Long-term Integrity in Deep, Hot Wells

While additives in current cement compositions and well-designed placement techniques can enhance zonal isolation in high-temperature, high-pressure wells, industry experts continue to report a high incidence of failure in deep, hot wells, presumably due to inadequate placement and mechanical failure of cements. Even when cement is placed properly, temperature and pressure gradients encountered during production can induce very high stresses in the wellbore, exceeding the resistance capabilities of conventional Portland cement systems. Short-term and long-term fluid migration of water and/or gas can also affect the sealing properties of Portland cement, and mechanical cement failure is exaggerated in wells with narrow annuli because of the stresses imposed by temperature, pressure cycling, and corrosive gases such as CO_2 and H_2S.

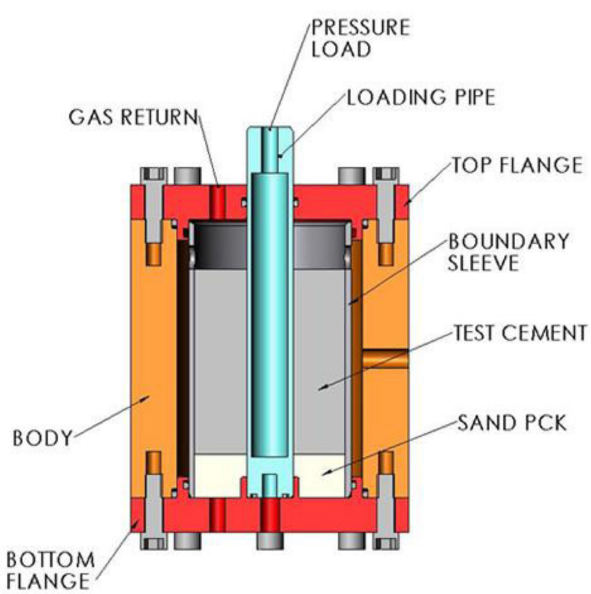


Figure 1. High-temperature, high-pressure annular seal apparatus. Cement is cured and tested for resistance to gas flow across the cement plug at temperature and pressure. The boundary sleeve can be made from a variety of materials to simulate formation competence, from steel to thinwall aluminum or PEEK (polyetheretherketone) plastic.

Failure of the annular seal provided by wellbore cements can be due to a number of factors and be manifested in several ways. The cement can experience a gross matrix integrity failure due to imposed stress, or it can lose its bond to (usually) the inner casing, causing a microannulus flow path between the cement and pipe.

A "super cement" designed to address these problems should possess superior pipe and formation-bonding capabilities to ensure a tight annular seal at depths exceeding 16,000 ft. It will also have the tensile strength, permeability, compressive strength, and expansive properties required for long-term durability, minimizing the potential for mechanical failures at temperatures exceeding 350 °F and pressures exceeding 15,000 psi. The benefits of the proposed super cement discussed below include maximized production and elimination of costly remedial work for improved well economics. In addition, the super cement will be applicable worldwide, both for wells in deep, hot environments and wells in less extreme environments that still require high stress resistance or where gas migration is a known problem.

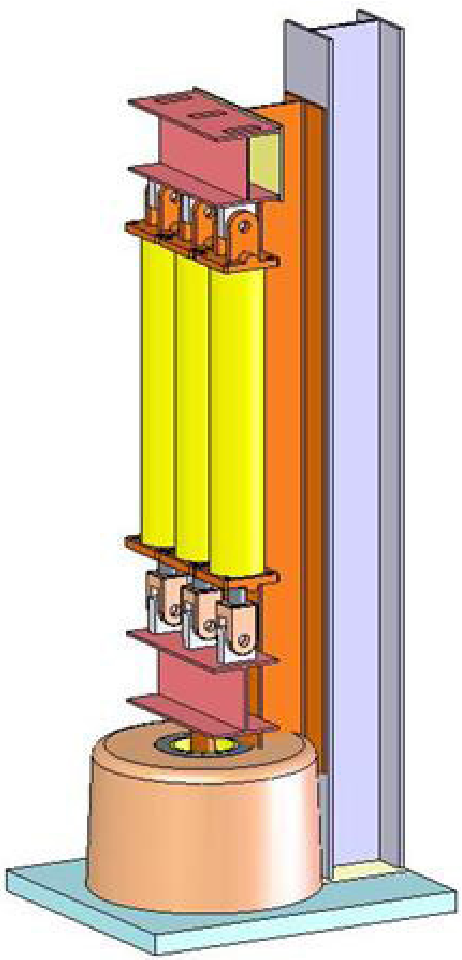


Figure 2. Full radial-scale shearbond test. This apparatus is used to cure pre-stressed cement in a pipe-in-formation simulation, then evaluate the shear bond to determine the limits of formation competence required to allow pre-stressed cement to function properly.

CSI Technologies, LLC and the Argonne National Laboratory conducted a project , beginning in 2004, to develop a super cement capable of sealing the annuli of, and providing long-term integrity in, deep, hot wells. This was in response to the growth in exploration and development activity in HP/HT environments that began to gain momentum in the early 2000s. Laboratory work involved more than 1,100 tests on 169 different formulations of Portland cement systems. An annular seal test fixture was developed to evaluate wellbore performance of cements. This apparatus represents a good approximation of the stresses applied to cement in the wellbore.

Baseline testing established a foundation for comparison. Conventional and unconventional mechanical tests were conducted, and many systems were tested at high temperatures. From this work six candidate systems, comprising some 10 formulas, were recommended for further analysis. These included reduced water systems, magnesium oxide, molybdenum trioxide, fibers, epoxy (resins), and graded particle systems. All of the mechanical testing demonstrated that no single material property is sufficient to determine annular seal effectiveness.

During the second phase of the project, researchers evaluated an epoxy-cement formulation in a gas well in the Gulf of Mexico at a platform operated by Chevron Corp. Prior attempts to use Portland cement to seal the annular area of this well had proved unsuccessful, allowing a gas leak to persist. This leak was successfully sealed using the epoxy cement, which was subsequently applied to other wells on that platform.

Chevron then decided to apply this epoxy cement formulation, now known as ULTRA SEAL®-R(LIQUID BRIDGE PLUG™) to a deeper problem, a leaking packer set at 10,599 feet inside 7-inch casing. This epoxy successfully sealed the leak at a temperature of 205 °F. Per regulations, this seal passed a pressure test with an applied pressure of 1,000 pounds per square inch for 30 minutes. This performance qualified this epoxy cement formulation for further tests at higher temperatures and pressures.

A second Portland cement based super cement formulation was developed that was designed to generate substantial expansion during the curing process. This expansion in the confined wellbore environment develops cement matrix compressive stress during cure, resulting in a compressive pre-load. In practice, the compressive pre-load functions to elevate the effective tensile strength of the material because the compressive stress must be relieved before the material can experience tensile stress. Additionally, the pre-load functions to keep the material tightly bound to the wellbore tubulars, thereby reducing the tendency of repeated stress cycles to form a microannulus.
The third phase of the project involved further evaluation of the super cement in field applications. Various cement jobs were performed with the Ultra Seal ® product at temperatures as high as 295°F which is within the HTHP range envisioned as a primary application for the product. The other super cement formulation, the Portland-cement based ("prestressed") system was test mixed and pumped full scale at an operators facility (Advanced Oil Well Services) in July 2007, but no field demonstrations were carried out.

ULTRA SEAL products are available from M&D Industries of Louisiana (http://drilllab.com/products-applications-case-studies/resin-technology/liquid-bridge-plug%E2%80%A8/).

For further information on this project, contact Eric Smistad at NETL (eric.smistad@netl.doe.gov or 281 525 9416) or Fred Sabins at CSI (fsabins@cementingsolutions.com or 281-784-7902).

Cooperative Agreement on Energy Technologies: Chemically Bonded Phosphate Ceramic Borehole Sealant

One of the basic material requirements in oil and gas well completion operations in Arctic regions where permafrost is present is the use of a suitable insulating cement that will provide both a good seal to prevent gas leakage and at the same time keep the permafrost interval undisturbed during the production of the oil and gas. Conventional Portland cement has difficulty in setting and performing suitably under Arctic conditions. The freezing and expansion of water in the pores and capillaries of the cement slurry leads to the development of cracks in the structure before the cement is set. In addition, conventional cements do not have sufficiently low thermal conductivity, and are thus not good insulators. Ceramicrete, the phosphate bonded ceramic borehole cement developed at ANL (Argonne National Laboratory), may provide an alternative.

Research Objectives

In the mid-2000s, ANL, in partnership with University of Alaska Fairbanks (UAF), proposed to tailor this cement for permafrost regions and demonstrate its application in Alaska. UAF worked with this new material to develop an appropriate "blend" to meet the oil industry's needs. The blend was tested by BJ Services at their Tomball, TX facility. These tests showed positive results for the effective use of Ceramicrete as oilfield cement.

Figure 1. Set Ceramicrete at 40 °F without Portland cement contamination

Figure 2. Set Ceramicrete with Portland cement contamination (5 percent) after 7 hours in 2-inch by 2-inch moulds (API standards)

The goals of the project were to:

• Develop a novel ceramic borehole cement with suitable insulation and binding properties to function as a superior borehole sealant across permafrost intervals in Alaska.

• Test the compatibility of the resulting product (Ceramicrete, see Figure 1) and Portland cement in mixtures.

• Determine the thawed-zone radius around a wellbore that results from the setting of Ceramicrete in the annular volume between wellbore and casing.

• Develop an economically feasible commercial formulation of Ceramicrete for use as oilfield cement.

• Research and development were undertaken with the following objectives and results:

Project objectives included:

• Formulating and optimizing the ceramic borehole cement for use in permafrost regions.

• Conducting simulated laboratory tests at UAF.

• Collaborating with industry partners to conduct yard tests.

Research Results

Among the project highlights were the following accomplishments and conclusions:

• Simulations were conducted with "ABAQU'S" software to determine the effect of heat generated during the setting of the Ceramicrete in the annulus and its impact on permafrost.

- The setting time and temperature of Ceramicrete slurry in the annular volume between wellbore and casing was determined to be 3.5 hours and 120 °F.
- Sensitivity analyses were conducted over a range of temperatures (90 °F to 120 °F), and results showed that the thawed zone radius around the wellbore was 8.5 cm after 3.5 hours at 90 °F and 9 cm at 120 °F.
- To reduce the heat generated during the setting of the cement slurry, tests were carried out by BJ Services with a new formulation of Ceramicrete. The new formulation showed less heat generation compared with the previous formulation, which in turn will reduce permafrost thawing.
- The new formulation of Ceramicrete was found to be compatible with Portland cement (95 percent of Ceramicrete and 5 percent of California Portland cement "G" grade, see Figure 2), giving it 5 hours of thickening time both with and without Portland cement contamination, which meets API standards.
- Compressive strength tests were carried out by BJ Services with the new formulation of Ceramicrete with and without contamination with Portland cement. These tests showed that the new formulation developed sufficient compressive strength (925 psi after 24 hours for Ceramicrete without contamination) for its use as an oilfield cement.

These efforts were followed by tests regarding freezing point measurement, fluidity, compressive strength, thermal conductivity, heat of hydration, and setting time for a slurry of 95 percent Ceramicrete and 5 percent Portland cement

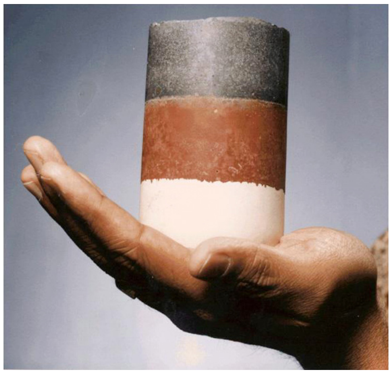


Figure3. Sample of the project's chemically bonded phosphate ceramic borehole cement.

Benefits

The newly developed Ceramicrete is a rapid-setting, strong, pore-free (low-permeability) insulating cement that shows good resistance to corrosion and the effects of freeze-thaw cycles.

If conventional Portland cement is used as oilfield cement on the Alaskan North Slope, it can form water pockets after setting in the annular volume between wellbore and casing. This can lead to loosening of set cement and in turn can affect well integrity.

Ceramicrete tests have shown that its thickening time (with and without contamination from Portland cement) is 5 hours, which meets API standards and avoids the formation of water pockets. Hence, Ceramicrete has an ability to provide improved well integrity.

As well, the amount of heat evolved during the setting of the cement slurry in the case of Ceramicrete is less than that for conventional Portland cement. Thus Ceramicrete can also help to reduce shallow gas migration problems associated with cement-induced thawing of the permafrost around the wellbore.

This lightweight cement is also believed to be more efficient for use in shallow arctic completions. This could mean that Ceramicrete will be quite useful in supporting the development of both shallow heavy oil and gas hydrates resources in the Arctic, while protecting the permafrost.

For further information about this project, contact Shirish Patil at UAF (ffslp@uaf.edu or 907-474-5127)or Arun S. Waghat ANL (wagh@anl.gov or 630-252-4295).

PUBLICATIONS

Wagh, Arun S., Natarajan, Ramkumar, McDaniel, Richard L., and Patil, Shirish, "Ceramicrete Blends Produce Strong, Low-Permeability Cements for Arctic Use," Oil & Gas Journal, May 16, 2005, pp. 48-52.

Banerjee, Sudiptya, "Novel Chemically Bonded Phosphate Ceramic Borehole Sealants for Arctic Permafrost," poster presented at the 2005 American Association of Drilling Engineers Annual Conference, Houston, TX, April 2005. Winner of First Place Award and Sandy Purdy Excellence in Research Award.

Banerjee, Sudiptya, "Novel Chemically Bonded Phosphate Ceramic Borehole Sealants for Arctic Permafrost," paper presented at the 2005 Society of Petroleum Engineers Western Region Student Paper Contest, March 2005. Winner of Third Place Award.

Banerjee, Sudiptya, "Novel Chemically Bonded Phosphate Ceramic Borehole Sealants for Arctic Permafrost," M.S. thesis, University of Alaska-Fairbanks, May 2005.

Ongoing Cementing Research

NETL and its partners in the NETL Regional University Alliance (Carnegie Mellon University, the Pennsylvania State University, the University of Pittsburgh, Virginia Polytechnic Institute and State University, and West Virginia University) have been collaborating on long-standing wellbore cement investigations that span issues related to offshore ultra-deepwater drilling and onshore unconventional gas recovery, as well as CO_2 storage. Recent projects, three of which are highlighted here, are adding to industry's knowledge related to this important well completion material.

Evaluation of Foamed Wellbore Cement StabilityUnder Deepwater Conditions - Cement integrity is fundamental to fulfilling a well's production potential. In foamed cement, inert gas, foaming agents, and stabilizers are added to slurry to improve its mechanical properties and protect problem geologic formations. Integrity, then, is dependent on even gas distribution and density tailored to depth. Gaining a better scientific understanding of foamed cement within the wellbore environment will help ensure the safe construction and maintenance of deep oil and gas wells using this soon-to-be common material. Because our research objectives cut across various industry sectors, our discoveries can globally improve wellbore cementing practices. Specifically, this research initiative seeks to:

- Improve the process - Find consistent, effective operational approaches to obtaining stable cements designed for specific wellbores. To do so may require new technologies, procedures, and/or protocols, as well as improved standards.
- Overcome data-quality limitations - Develop the means to effectively and accurately obtain representative data needed to design, implement, and evaluate a cement job.
- Improve predictive tools - Develop next-generation models that will help us understand the physics of cementing and predict the impact of various designs and operational methods on wellbore integrity.
- Develop additional basic data - Acquire additional fundamental data from laboratory or field testing that can be useful in supporting the above. NETL houses a unique combination of facility capabilities for conducting the research needed to achieve these objectives. Researchers expert in the cement field use these facilities to conduct and oversee projects that will help industry agencies better understand the cementing environment, improve cementing practices, and revise standards for this important operational area.

Foamed cement is produced when nitrogen oranother inert gas is injected into cement slurry to form microscopic bubbles. This produces an ultralow-densitymaterial that can be employed in formations unableto support the annular hydrostatic pressure exerted byconventional cement slurries. In addition to its light-weight application, foamed cement has a unique resistance to the temperature- and pressure-induced stresses found indeep subsurface wellbores. It also exhibits superior fluiddisplacement, gas-migration control, and long-term sealingthrough resistance to cement-sheath stress cracking.

The increased use of foamed cement systems in deepwater environments makes understanding their stability in thewellbore vital, particularly to risk assessment and spillprevention. A stable foam installed properly in the wellbore provides desired zonal isolation and casing support. Unstable foams can result in uncemented sections or channels and failed zonal isolation.

Industry currently faces a number of challenges to obtaining consistently reliable foamed cement jobs that research can help address. For example, foamed cement testing methods need to reflect downhole rather than atmospheric conditions. Researchers also lack significantknowledge regarding the stability and properties of foamed cement during and after placement.

Researchers are working to better understand foamed cement and its interaction with the wellbore environment. To do so, they are evaluating foam stability, bubble size, and channeling (bubble coalescence) as it is affected by pressure, shear, and cement design. They are drawing correlations between atmospheric (in the laboratory) andpressure-generated (in the field) foamed cements and defining materials performance and properties critical to successful cementing. They are also determining foam stability in situ by simulating various depths in the well.

These studies utilize NETL's industrial CT scanner to provide related high-resolution, 3D image datasets of bubble size distribution measuredunder pressure. Ultimately, this research will provide industry with knowledge needed to ensure safe, reliable operations in which foamed cement systems are used.

Gas Flow from Shallow Gas Formations - Gas flow from shallow formations is not a new problem for the petroleum industry, but a somewhat unique deviation is occurring along the Marcellus Shale gas play in the northeastern United States. Sandstone and coal bed formations in the groundwater zone can compromise the integrity of curing cement by introducing natural gas to the wellbore at measureable pressures during the cement slurry's transition from liquid to gel. The specific mechanisms for risks associated with unwanted gas flows have been magnified along the Marcellus via shallow gas-bearing formations that lie within and directly below groundwater aquifers. The primary concern is that naturally occurring formation gas can enter annular pathways and migrate up the wellbore to other formations, causing safety concerns and potentially compromising water supplies.

To better understand this phenomenon, NETL and the Alliance are characterizing in situ conditions that result in nonproduction formation gas invading the annulus during hydration and defining temporal material properties of the slurry. Using a high-pressure chamber at the University of Pittsburgh, Researchers are simulating wellbore exposure to gas flows from shallow formations. Results will be used to develop and validate an analytical simulation of cement annulus hydration in regions where gas sands are present. From this research, guidelines for cementing wellbores that contain formation gas in close proximity to groundwater aquifers can be established.

Effect of CO_2 on the Integrity of Well Cement Under Geologic Storage Conditions - Many locations being considered for large-scale CO_2 injection for carbon management have already seen extensive production of oil, natural gas, and/or coalbed methane. Because annular cement is thermodynamically unstable in a CO_2 environment, existing wells could compromise storage in these areas. To bring carbon storage closer to commercial application, it is important to characterize the chemical interactions between injected CO_2 and existing well cements that may cause leakage.

Researchers first simulated deep underground injectionand wellbore conditions with common wellbore cements, and then examined resulting chemical and microstructural changes using scanning electronmicroscopy, x-ray diffraction, and other techniques. Results indicated that temperature, pressure, cement type, cement additives, and fluid properties play significant roles in the rate of alteration and reaction.

In properly constructed wells with typical cements in good condition, CO_2 reactions were too slow to cause leakage. However, cements in old or abandoned wells were shown to pose potential problems. Further work at the laboratory is being conducted to study situations in which gaps or fractures may be present in the cement column. Researchers are also looking at cement interactions under co-sequestration conditions, particularly with acid gas. The interaction among cement, casing, and geology is fundamental to ensuring wellbore integrity.

"Smart" Cementing Materials and Drilling Muds for Real Time Monitoring of Deepwater Wellbore Enhancement

This ongoing project, undertaken by the University of Houston with partner Baker Hughes and funded by DOE through the Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources Research and Development Program administered by the Research Partnership to Secure Energy for America (RPSEA), seeks to develop technology for real-time monitoring of cement installation and performance during the service life of deepwater wells. In this study, various technologies will be used to develop "smart" drilling mud and cementing slurry with enhanced sensing properties, so that they can be deployed for real time monitoring during installation and the entire service life of a deepwater well.

Advances in materials and grouting technologies will be combined with advancements in surfactant technology to produce drilling mud and cementing materials with enhanced sensing capabilities. With the sensing capabilities installed in the drilling mud and cementing slurry, it will also be possible to monitor the advancement of the drilling mud and cementing slurry front around the casing during the construction phase.

The smart drilling mud and cement slurry will be modified such that its short-term and long-term piezoresistive characteristics reflect the composition, chemical reactions and surrounding environment (temperature and pressure) that influence changes in internal stresses. Changes in stress, strain and/or temperature will cause a change in the electrical resistivity of the smart fluid, reflecting the condition of the cement slurry in the borehole, for example, the length of cement supporting the casing.

The long-term piezoresistive characteristics will be influenced by the stresses induced in the borehole and the condition of the solidified cement materials. The casing will be modified with outside rings at a set spacing to monitor the changes in the electrical resistivity and temperature of the drilling mud and cementing material that are stabilizing the casing and the borehole. This will make it possible to identify the locations that are highly stressed in the cement sheath surrounding the pipe. Also other damages caused by the stresses and temperature conditions in the borehole will be identifiable during the service life of the cemented casing.

The technical study will be completed in three phases over a total of three years. In Phase 1, smart drilling mud (SDM) and smart cementing slurry (SCS) will be developed with conductive fillers (solutions and particles) and fibers that do not affect the flowability characteristics of the drilling mud or cement slurry. The SDM and SCS will be characterized based on filtering, fluid loss, piezoresistivity and rock interaction. In Phase 2, small and large model tests are planned to demonstrate the potential for the new fluids. In the final phase a field demonstration will be carried out jointly by the research partners.

For further information about this project contact Don Richardson at RPSEA (drichardson@RPSEA.org or 281 690 5514) or C. Vipulanandan at the University of Houston (cvipulanandan@uh.edu or 713 743 4278).

Deepwater Reverse-Circulation Primary Cementing

With conventional primary cementing, fluids are pumped down the casing and then up the annulus; while with reverse circulation primary cementing (RCPC), the fluids are pumped down the annulus and up into the casing through the casing shoe (Figure 1). Using RCPC greatly reduces the bottomhole circulating pressure of the fluids as compared to conventional cementing. The primary objective of this project, conducted by Cementing Solutions Inc. (CSI) with partners Weatherford and the University of Houston, is to assess the applicability of RCPC techniques to deepwater wells.

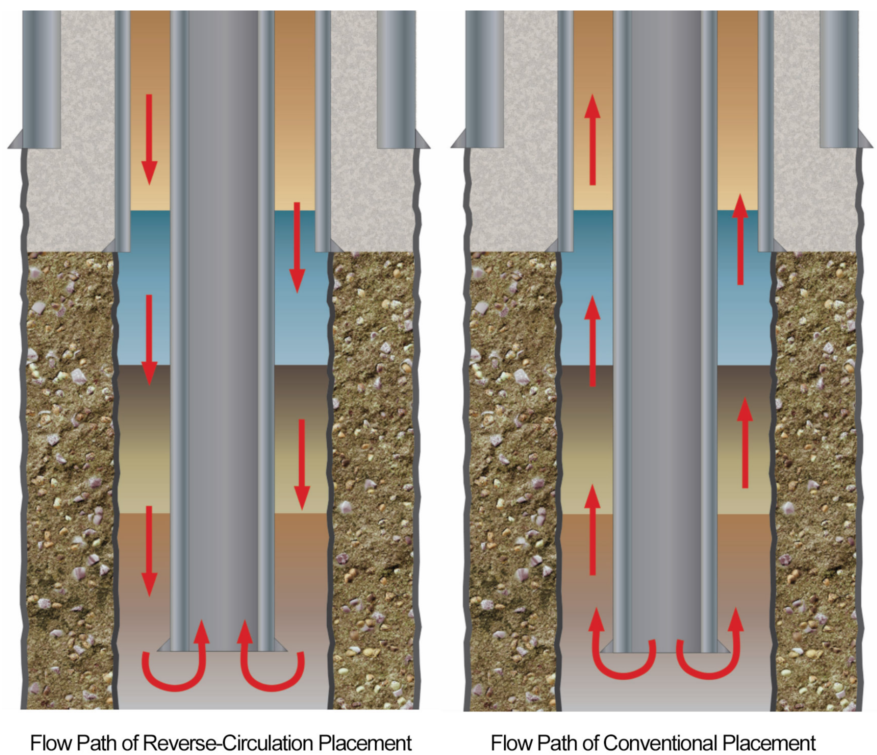


Figure 1: Schematic showing conventional and reverse circulation placement of primary cement job

One major challenge in deepwater cementing is the narrow formation fracture gradient, so the application of RCPC has clear beneficial potential. However, the applicability of RCPC has not been evaluated for use in a challenging deepwater environment. The scope of work includes analysis of the RCPC cementing method, preparation of a development path for technology required to apply RCPC to deepwater wells, and creation of preliminary operational procedures with associated contingency plans. The application of RCPC to deepwater wells is expected to reduce bottom-hole circulating pressures and prevent lost circulation during cementing as well as increase safety, strengthen environmental sustainability, enhance zonal isolation and improve cement seals.

In Phase I of the project, the current state of RCPC technology and practices will be assessed and documented. Analysis will include numerical modeling and simulations, and assessments of mechanical placement controls and cementing materials. A laboratory study will be conducted on the performance of cementing additives spacers and the effect of RCPC on material performance. Based on these findings, potential benefits as well as the technical issues that need to be addressed before RCPC can be used for deepwater applications will be identified.

Phase II of the project will focus on the operational performance of RCPC and the functional considerations of applying RCPC on a deepwater rig. Phase I results will be used to determine technical issues that need to be addressed before routine deepwater RCPC applications can occur.Further analysis will include RCPC simulations and laboratory analyses under real well conditions and scenarios. Operational plans will include potential contingency situations during the application of RCPC.

For further information about this project contact Don Richardson at RPSEA (drichardson@RPSEA.orgor 281 690 5514) or Jeff Watters at CSI (jwatters@csi-tech.net or 281 784 7906)

Nano Impregnated Cement

Honolulu-based Oceanit Laboratories Inc., supported by DOE funding, is exploring oil and gas well applications for its nanotechnology concrete mix that was created as a means for strengthening material for use in buildings, bridges and roads.

Companies worldwide are working on ways to incorporate so called carbon nanotubes into concrete. In addition to increasing toughness, the nanotubes, which are thousands of times thinner than a human hair, are highly conductive. That means that they could be used to create a kind of nervous system within concrete that could be used to detect cracking and weaknesses in structures (Figure 1).

However, many hurdles remain in the path of the promising technology, including high costs and technical barriers such as how to create a commercial nanoconcrete manufacturing process. Oceanit has worked to solve a key problem — how to homogeneously mix the tiny nanotubes into a thick fluid such as cement. The company is seeking to patent a process in which nanotubes are suspended in a liquid concentrate that is added to the water used to make cement.

The company is developing technology for road and bridge use in coordination with state and county transportation officials. Initially, the nanoconcrete would be tested for durability and strength. Ultimately Oceanit hopes the technology will revolutionize the way the structural integrity of concrete is monitored, though that application could take years to develop.

“The carbon nanotube mixture we’re patenting acts like a spider web

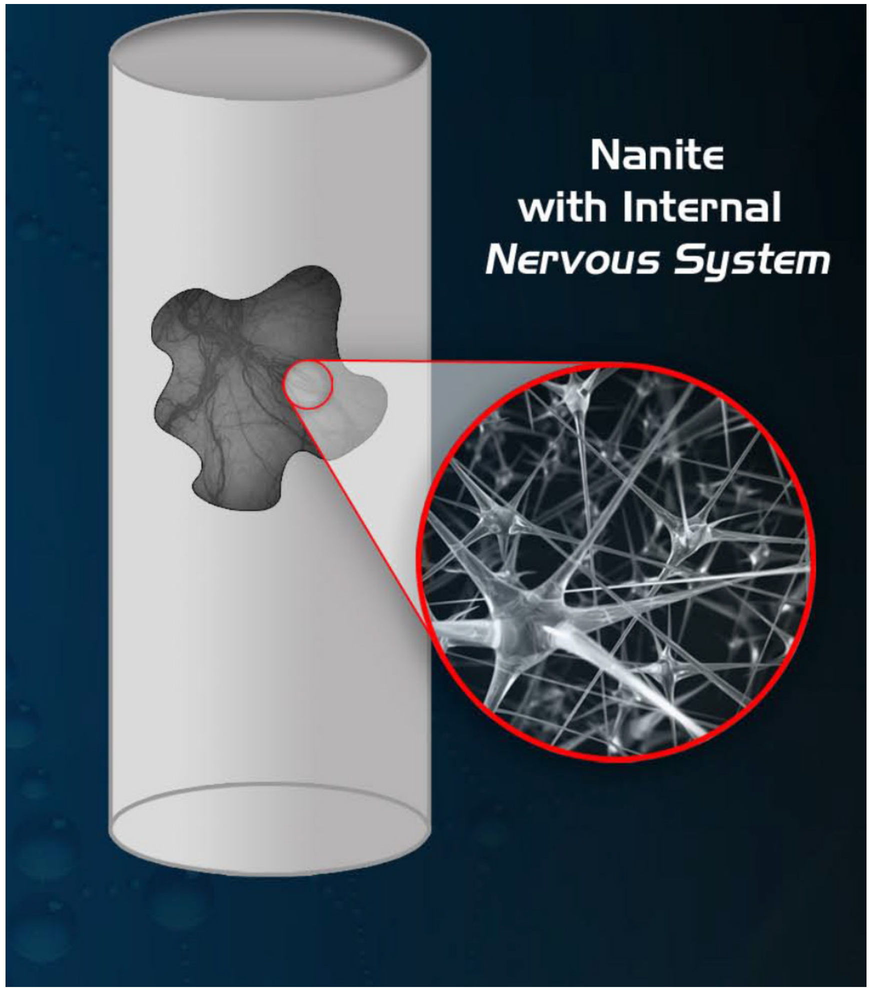


Figure 1. A nano tube matrix within nanite cement imparts exceptional strength and can be interrogated with electrical pulses to determine the structural integrity of the cement.

within the concrete," said Oceanit spokesman Ian Kitajima. "Stresses in the concrete material are sensed by this internal web. Small pulses of electricity are sent through this nano-web within the concrete. Changes in the web reflect changes in cement structure, which affects the return signal that could be used to determine the health of a building."

For now, any use of nanotechnology in cement will be limited to specialized applications because nanotubes cost more than their weight in gold."It is a very expensive material today, but it's being produced in higher and higher quantities every year," Kitajima said.

Potential transportation applications include portions of roadways and bridges that need stronger construction material or require more intensive monitoring, said Barry Fukunaga, director of the Hawaiian Department of Transportation."It's a real innovative kind of a product that they've come up with," he said. "It's the kind of thing where it may be more costly, but in certain applications it could be a good investment because of its durability and sensing qualities."

Through the current DOE partnership, the company is studying deepwater and problematic well cementing applications.

For further information about this project, contact Roy Long at NETL (roy.long@netl.doe.gov or 281 494 2516) or Vinod Veedu at Oceanit (vveedu@oceanit.com or 713 357 9622).

FE's Ultra-Deepwater Program Focuses on Spill Prevention, Safety and Environmental Stewardship

Nearly everyone recognizes that prudent development of domestic oil and natural gas resources will continue to be an important part of U.S. energy strategy for decades to come. How important depends a lot on conducting operations responsibly, ensuring communities are safe and the environment protected as the nation maximizes use of this vital domestic energy resource.

That's where DOE's ultra-deepwater (UDW) research program plays a significant role. Managed by FE's Office of Oil and Natural Gas with the support of NETL, the UDW program's mission is to work toward mitigating the risks and challenges associated with ultra-deepwater drilling and production operations. This includes deepening the collaboration and coordination already established with the Department of the Interior's Bureau of Safety and Environmental Enforcement.

Only 30 years ago, "deepwater" oil and natural gas production referred to offshore wells in water depths of several hundred feet. Today's deepwater operations are generally in the 1,000-to-5,000 foot range, and ultra-deepwater production can occur in water depths of between 5,000-to-10,000 feet or more.

Why are these resources important? Consider these facts:

- U.S. offshore oil and gas resources comprise 25 percent (about 4.6 billion barrels) of total proved crude oil reserves in the lower 48 states. Annually, they account for about 20 percent of total domestic crude production.
- They also make up nearly 6 percent (15 trillion cubic feet) of total U.S. natural gas proved reserves (263 trillion cubic feet) and provide about 10 percent of total annual dry gas production.

The Gulf of Mexico is one of the most important locations of U.S. offshore and deepwater resource production. This area produces 93 percent of all U.S. offshore oil and about 96 percent of offshore natural gas; DOI's Bureau of Ocean Energy Management, Regulation and Enforcement estimates the Central Gulf alone holds more than 30 billion barrels of oil and nearly 134 trillion cubic feet of natural gas yet to be discovered.

Additionally, the Energy Information Administration (EIA) projects the deepwater contribution of domestic oil and natural gas supplies will continue to be significant in the years ahead, assuming ongoing technological solutions to improve production, increase safety and mitigate environmental impacts. By 2040, EIA forecasts crude oil production of 1.75 million barrels a day and 2.85 trillion cubic feet of natural gas from U.S. offshore resources in the lower 48 states.

Obviously, working in environments at UDW depths can pose special complex challenges not only to production, but also to worker safety and the environment, as the tragic Macondo/Deepwater Horizon incident of January 2011 emphasized.

As a result of Macondo, DOE UDW research shifted focus from maximizing value and increasing energy security to spill prevention, safety and environmental protection. This includes additional emphasis not only on improved understanding of systems risk, but also reducing risk through real-time data analysis and the development of advanced technologies.

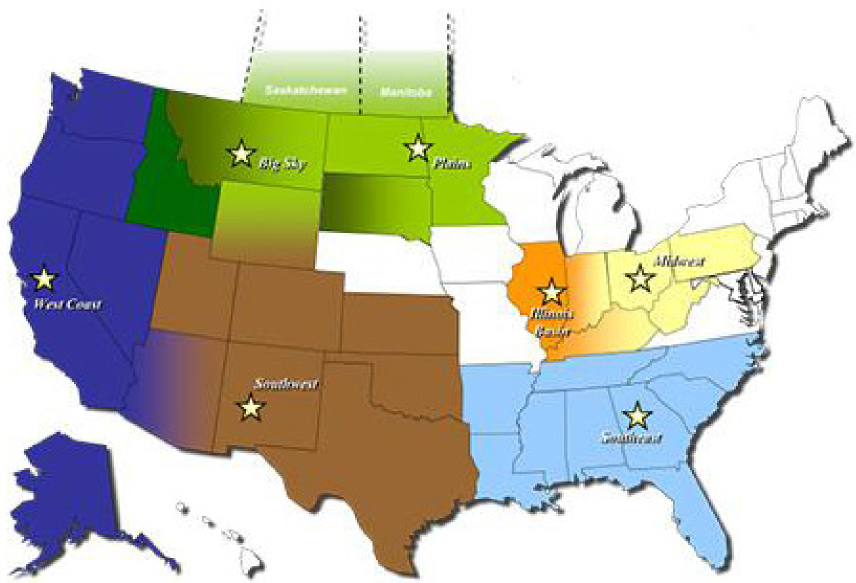
NETL's Ultra-Deepwater and Deepwater research is working to build the scientific understanding and assessment tools necessary to develop confidence in the safe and environmentally sustainable development of domestic oil and gas resources. Some examples of current projects within this portfolio include:

- *Determining Physical and Chemical Behavior of Cement Barriers Used in Ultra-Deepwater Systems:* NETL is researching the behavior of typical wellbore cements to better understand how cement formulations perform, with an emphasis on potential failure pathways and remediation technologies. Currently, there is no information on how foam cements, commonly used in extreme offshore settings, perform and persist under in situ conditions. NETL researchers initiated laboratory characterization studies of commonly used formulations of foam cements, obtained the first CT images of foamed cement systems, and developed a reliable methodology to analyze the microstructure of foamed cements under in situ conditions. Going forward, the team will use this methodology to determine stability of foamed cement systems at various "depths" in the subsurface.
- *Quantifying Complex Fluid-Phase Properties Under High-Pressure/High-Temperature (HPHT) Conditions:* NETL is working to improve the accuracy of thermodynamic models under HPHT conditions, allowing for better characterization of reservoir fluids and the dynamics of these fluids during extraction. Improved models will decrease uncertainty associated with fluid quantity and flow at and near the borehole. Accurate understanding of the reservoir and associated well behavior is an important component of our ability to predict the behavior of wells. NETL researchers have expanded the density and viscosity databases for hydrocarbon compounds in HPHT conditions and integrated these results with existing data, resulting in a comprehensive database.

Additional information on these projects can be found at https://edx.netl.doe.gov/dataset/ultra-deepwater.

Working with its partners in industry and academia, NETL's Strategic Center for Oil and Natural Gas and FE's Oil and Gas Safety and Environmental Sustainability Research Division have collectively amassed wide ranging expertise in areas related to deepwater and UDW resource location, production, safety and environmental protection. While challenges associated with increasingly hard-to-locate-and-produce UDW resources will always be present to some degree, FE's innovative research portfolio is making real progress toward ensuring this important domestic resource will fulfill its potential in a safe and sustainable way in the years ahead.

Celebrating a Decade of Carbon Storage Research Through Partnership



DOE has created a network of seven Regional Carbon Sequestration Partnerships (RCSPs) to help develop the technology, infrastructure, and regulations to implement large-scale CO_2 storage (also called carbon sequestration) in different regions and geologic formations within the Nation.

Government research to mitigate emissions of carbon dioxide (CO_2), a greenhouse gas, would be far less effective without collaboration. Sharing ideas, researchers, and facilities lowers costs and makes novel technologies available for general use much faster than going it alone.

For the past decade, the Office of Fossil Energy's National Energy Technology Laboratory (NETL) has managed a nationwide network of partnerships that team government, industry, academia, and nonprofit organizations to identify the best approaches for permanently storing CO_2 in deep geologic formations. Research performed by the seven Regional Carbon Sequestratio n Partnerships helps validate the most suitable technologies and infrastructure needs for this process, called geologic carbon capture and storage (CCS). From this research, researchers have learned myriad lessons, each leading to more effective ways to contain and monitor CO_2 once it's injected underground.

So what is geologic CCS? The first thing to know is that it's a critical part of national efforts to reduce CO_2 emissions from stationary sources such as power plants, natural gas processing plants, and other industrial sites. It works like this: After gaseous CO_2 is captured from the source, it is compressed and transported to a storage site. At the site, CO_2 the consistency of sea water is injected into porous and permeable rock formations deep underground. These formations, far below any usable groundwater sources, are capped by impermeable rock that keeps the CO_2 from escaping to the surface. Monitoring wells are set up to track the migration of the CO_2 within the storage formations, ensuring that storage is safe and permanent.

Because the United States is a nation of varied emission sources, topography, and geology, the seven partnerships are tailored to address the specific characteristics of their respective regions. Each partnership evaluates potential storage sites in its geographical area and determines the optimal approach for CCS. Testing conducted at the sites prior to, during, and after injection provides insight regarding injectivity, capacity, and containment of CO_2 in the formations. Determining best practices for each region leads the partnerships to identify regulatory and infrastructure requirements for future commercial deployment, making CCS easier and more effective.

True to the collaborative spirit of the partnerships, sharing doesn't end with the completion of a particular project. NETL and the seven partnerships also make available the results of their research and what they have discovered. To augment the information-sharing that occurs through avenues such as research papers, scientific conferences, and technical reports, we will, over the next several weeks, post online a short series of lessons learned from the regional partnerships' carbon storage projects. These "plain English" blog posts will include such topics as site characterization, industry partnerships, public outreach and education, and monitoring, verification, and accounting.

EDX - Share and Share Alike

At NETL, sharing energy technical knowledge and expertise just got a whole lot easier. The Laboratory's Office of Research and Development has recently launched the Energy Data eXchange, or EDX, a knowledge-sharing network built to provide a single source for fossil energy-related datasets and the tools to use them. EDX is designed to make research and other data generated by NETL researchers, other EDX users, and outside agencies available almost instantly through a common portal that features key tools to support analysis and evaluation.

EDX houses primary R&D data. EDX datasets contain results from hundreds of fossil energy research projects. Some datasets are current.

Some are historic. All are made instantly and reliably accessible to increase the speed and reduce the cost of ongoing research, provide transparency to NETL programs, and inform federal, state, and local energy policy.

EDX facilitates connections. Collective workspaces in EDX help researchers collaborate quickly and cost effectively in a secure environment from across the office or across the world. In addition, multi-organizational search capabilities pull from internal energy-related data and link to externally hosted resources. Public features, such as EDX tools and EDX groups, promote information sharing, technology development, and knowledge and technology transfer.

EDX is secure. The system provides three tiers of access, ensuring that information is only shared when it's meant to be. Open-access data is available to the public for download and represents the knowledge-transfer half of EDX. Restricted data is available to registered users as appropriate. Collaborative data is proprietary and securely shared among designated members of identified teams. To further promote a secure environment, open-access and restricted data are quality checked before being made available, and then subject to continuous monitoring by all users.

EDX adapts to user needs. As an evolving platform, EDX is being developed in response to the needs of its users. This user-driven system approach will keep EDX relevant, improve its content and capabilities, and ensure that it is a continuously growing and evolving tool that meets the needs of the energy research community.

Because NETL administers wide-ranging fossil energy research projects and maintains a highly specialized talent base, knowledge management and efficient information transfer are strategic priorities. EDX is dynamically aligning and sharing relevant data to fill immediate needs across our organization. Organizations like NETL understand that the ability to keep researchers connected allows them to create productive relationships and solve today's energy challenges efficiently. EDX meets the growing demand to access, share, and publish data and data-driven products in support of science-based decision making.