the ENERGY lab

R&D FACTS

Natural Gas & Oil R&D

Ultra-deepwater and Frontier Regions Research Program

Assessing Risk and Mitigating Deleterious Events Associated with Drilling and Production

Background

Increasingly, offshore domestic oil and natural gas activities are associated with remote and challenging regions, such as the ultra-deepwater (greater than 5,000 feet) Gulf of Mexico and the offshore Arctic. Development in these areas poses unique technical and operational challenges, as well as distinct environmental and societal concerns. At present, ultra-deepwater resources account for approximately 32 percent of U.S. crude oil production and approximately 13 percent of total dry gas production; however, these contributions are expected to increase in the years ahead as a result of increased development activities.

Domestic resources of natural gas and oil will continue to play an increasingly critical role in meeting U.S. energy needs provided they can be produced with the confidence that environmental concerns (such as air, water, and species protection) are being addressed effectively, as noted in the President's recent executive order on the safe and responsible development of natural gas. The science base necessary to support stakeholder decisions stems from the ability to understand the behavior of engineered-natural systems over a range of often extreme conditions. NETL's Office of Research and Development (ORD) has extensive expertise in characterizing engineered natural systems associated with oil and natural gas development. This expertise is being leveraged for deepwater and ultra-deepwater hydrocarbon systems through NETL-ORD's Complementary Program in support of the Energy Policy Act (EPAct) of 2005 and in coordination with the Research Partnership to Secure Energy for America (RPSEA).

In addition to EPAct, NETL's portfolio aligns with key Federal-scale initiatives including the Ocean Energy Safety Advisory Committee (OESC), chartered February 8, 2011, to advise the Secretary of the Interior, on a variety of issues related to offshore energy safety. In particular, the findings and recommendations of the OESC's Spill Prevention Subcommittee, a multi-entity committee that seeks to address safety and potential impacts of deep offshore hydrocarbon development in the U.S. and adjoining regions, are addressed by aspects of the Complementary Program research. ORD Complementary Program research is also aligned with some of the goals of the Alaska Interagency Working Group (AIWG), led by the Department of the Interior, which brings together state, federal, and tribal government personnel to address energy-related issues and needs in the Alaskan Arctic.

CONTACTS

George Guthrie
Focus Area Lead
Office of Research and Development
National Energy Technology Laboratory
626 Cochrans Mill Road
Pittsburgh, PA 15236-0940
412-386-6571
george.guthrie@netl.doe.gov

Kelly Rose
Technical Coordinator
Office of Research and Development
National Energy Technology Laboratory
1450 Queen Avenue SW
Albany, OR 97321-2152
541-967-5883
kelly.rose@netl.doe.gov

PARTNERS

Carnegie Mellon University
Pittsburgh, PA

Oregon State University
Corvallis, OR

Pennsylvania State University
State College, PA

University of Pittsburgh
Pittsburgh, PA

URS Corporation
Pittsburgh, PA

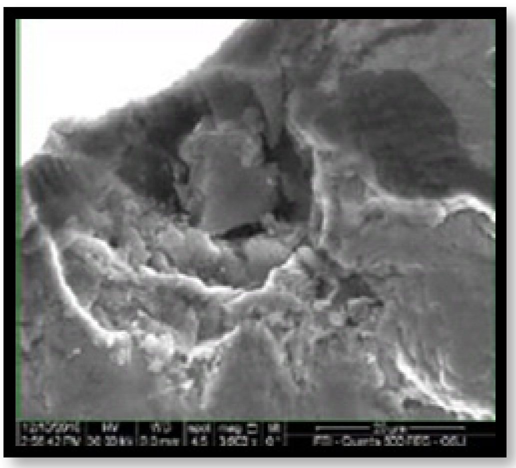
Virginia Tech
Blacksburg, VA

West Virginia University
Morgantown, WV

NETL Complementary Program Ultra-Deepwater/Deepwater Projects:

The objective of NETL's Ultra-deepwater and Frontier Regions research portfolio is 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. The portfolio consists of six research projects that are working to address quantitative prediction of potential deleterious events in extreme offshore drilling and production. Successful implementation of portfolio research objectives will ultimately increase America's domestic oil and gas supply, reduce our nation's dependency foreign imports, and address the environmental and social concerns associated with development.

Material failures account for nearly two thirds of all loss of control events to date (SINTEF 2011), and these almost entirely align with metallic component failures and deepwater cementing issues. Three projects will broaden the Complementary Program's focus on improving the science base for key materials used in extreme drilling environments as barriers and controls, including where these materials interact in the subsurface:



Metal corrosion studies evaluate most commonly used offshore alloys

- **Characterization of Metal-Based Systems Used in Control Devices Subject to Extreme Environmental Conditions:** NETL is evaluating failure mechanisms and rates for critical components based in part on observed/reported behavior in the field augmented with experimental studies on materials behavior under simulated extreme conditions. At present, publically available data about the performance of these materials under extreme offshore conditions is limited. To date this study has successfully evaluated strength/corrosion potential the most common alloys used in extreme offshore drilling at in situ conditions (pressure, temperature, H_2S, etc). Ongoing work will result in a pit/fatigue model tool to allow for the assessment of catastrophic failure potential of these metallic components. NETL is also evaluating new alloys and surface treatments (e.g. hammer peening) for ultra-deep well environments to constrain their behavior under extreme borehole conditions.

- **Determining Physical and Chemical Behavior of Cement Barriers Used in Ultra-deepwater Systems:** NETL is researching the physical and chemical behavior of typical wellbore cements to better understand how various cement formulations perform, with a particular 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 industry standard formulations of foam cements and have obtained the 1st CT images of foamed cement systems. The CT characterization of the samples allows for the quantitative analysis of physical properties and structures within the cement (particularly bubble sizes and distributions). NETL researchers have also developed a reliable methodology to probe 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 and correlate those properties with the current method of atmospheric testing. Phase 1 findings from this project were released in a Technical Report Series (TRS) publication on NETL's website.

- **Characterization & Analysis of the Formation of Cement and Cement Casing Integrity:** A new project initiated by NETL researchers focuses on determining the physical, chemical, and temporal integrity of the formation of cement and cement casing systems used in extreme offshore settings. The project leverages NETL materials and natural systems expertise to evaluate short and long term integrity of the seal/bond between the formation, cement and casing at in situ conditions representative of the range of subsurface conditions associated with deep offshore drilling. Initially this project will focus on shallow subsurface conditions (up to 2000 feet below the seafloor) and will incorporate experimental techniques with analysis of field datasets such as borehole geophysical logs.

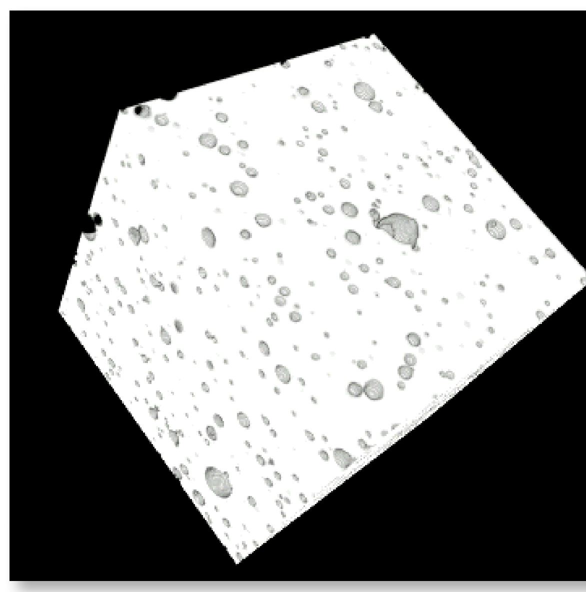
Uncertainties, such as density and viscosity, in hydrocarbon properties under in situ conditions, and behavior, such as hydrate formation and eddies, are key factors impacting the accuracy of predictions of hydrocarbon behavior and volumes both in the subsurface and in the water column during a spill event. Two projects in the offshore portfolio focus on improving the science base for multiphase fluids (like hydrocarbons, CO_2, and brine) at extreme conditions, while the final project seeks to predict, assess, and mitigate risks associated with hydrocarbon development in extreme environments in support of spill prevention and response needs:

- **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 under both controlled and uncontrolled scenarios. Our lack of understanding of these extreme environments inhibits our ability to predict well behavior and develop methods for safely handling fluids under these conditions. To date, NETL researchers have expanded the density and viscosity databases for hydrocarbon compounds to span HPHT conditions. They have integrated their results with existing lower pressure and temperature data, resulting in a comprehensive database. This work is reviewed in a TRS publication on NETL's website, and an interactive database and associated application to interface with the database are under development. These will be released through NETL's Energy Data Exchange (www.edx.netl.doe.gov).

Tubulars used in offshore development

- **Improving Flow Assurance, Expediting Well Control, and Reducing Environmental Impacts Resulting from Blow-Outs in High Temperature/Low Pressure Environments:** In addition to prevention, spill response research at NETL is addressing major issues related to accurately and rapidly assessing how much hydrocarbon is leaking from a well, what is the composition of the mixture, and where does it go in the water column? NETL researchers are conducting experimental and theoretical studies to obtain fundamental, chemical, physical, and hydrodynamic information on the interactions between seawater and fluids that could be released and transported from deep, subsea hydrocarbon reservoirs and inadvertently released into a deepwater environment. This fundamental information will be used in numerical, thermodynamic, and plume models to comprehensively describe potential roles and impacts of gas hydrates. The goal of this program is to develop a comprehensive understanding of the formation and stability of simple and complex hydrates under deepwater conditions, stability of hydrates and their interaction with hydrocarbon, and the impact of dispersants, anti-agglomerants, and other chemicals used to mitigate environmental impacts on the fate and interaction of hydrates. Ultimately, the project seeks to develop a remotely-operated-vehicle (ROV) tool that can be used to rapidly and accurately determine the leak rate, composition, and fate to help guide efficient and effective spill mitigation efforts. This research is currently in the second year of a three-year effort and is on track for completion at the end of FY14.

- **Assessing Risks and the Potential for Environmental Impacts for Deepwater, Ultra-deepwater, and Frontier Regions:** Building on DOE's core competency in simulating and predicting the behavior of engineered-natural systems, NETL researchers are developing a new multi-component model tying the subsurface, wellbore and water column into a single integrated assessment modeling (IAM) tool. To effectively evaluate and reduce risks associated with extreme offshore hydrocarbon development, the IAM tool will be utilized subsurface to shore datasets which are being synthesized and integrated from a combination of existing data sources to new interpretations for the Gulf of Mexico (GOM). The targeted datasets are discussed in the recently released TRS publication on NETL's website, and an interactive database of these data layers will be released through NETL's Energy Data Exchange (www.edx.netl.doe.gov). Ultimately, this project will provide a coordinated platform (GOM IAM and EDXinsight) to allow for the independent, rapid, and science-based prediction of ultra-deepwater hydrocarbon risks and potential impacts. This will allow researchers to conduct predictive assessments of potential social, environmental, and production risk factors, and will provide recommendations on future data and technology needs to support spill prevention. The tool may also serve as a rapid-response platform in the event of future spills or deleterious events.

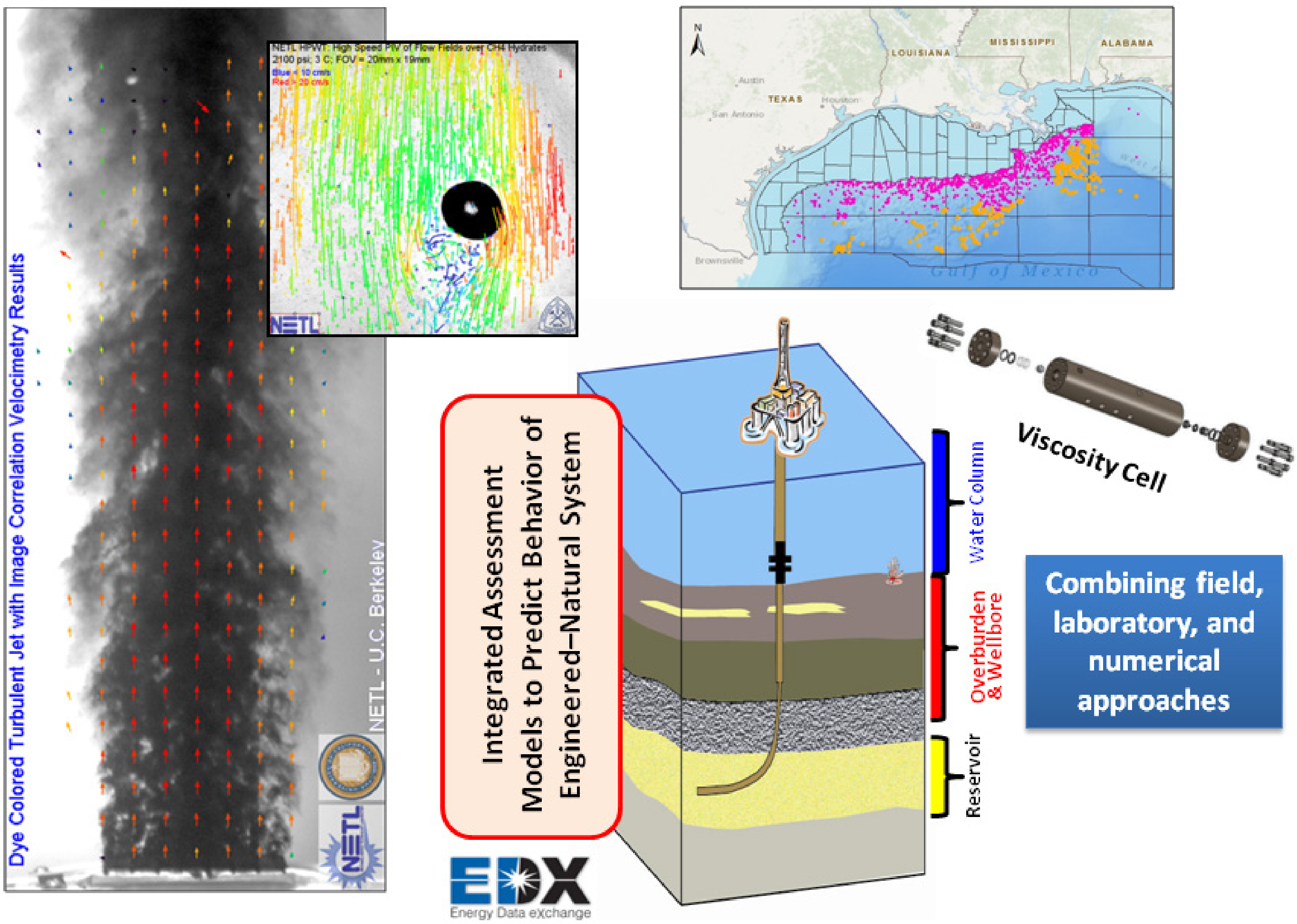


CT-image of a foam cement sample generated at NETL for bubble size distribution analysis

Find NETL TRS Publications associated with this research: www.netl.doe.gov/onsite_research/index.html

Find datasets and data-driven products associated with this research: Energy Data Exchange www.netl.doe.gov

Research to Support Science-Based Decision Making for Spill Prevention & Response



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