Exploring the Petroleum Frontier

by John C. Barratt
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Exploration associated with ultradeep petroleum wells and deepwater fields is providing a number of exciting and high-value markets for ceramics.

Above: An artist's rendering of typical deepwater fields. Courtesy of FMC Technologies Inc.

As existing supplies of oil and gas are depleted, the petroleum industry is forced to explore in ever deeper and more challenging environments. Certain characteristics of ceramics, including their light weight, heat tolerance, and resistance to both corrosion and erosion, make them attractive alternatives to metal components in several of these emerging exploration applications.

Some 70 miles off the shore of Louisiana, ExxonMobil and several partners are drilling a well intended to achieve depths previously unattainable in the Gulf Coast region of the U.S. This well may ultimately reach 33,000 ft below the surface, over six miles underground, at an anticipated cost exceeding $60 million. Bottomhole temperatures and pressures will exceed 400¼F and 25,000 psi, respectively. While certainly noteworthy, this well is not the exception. In the near future, a number of these ultradeep wells are planned in the area.

Over 100 miles further offshore, BP is completing the installation of a floating production facility for the largest oil field ever located in the Gulf of Mexico. Thousands of feet below the platform, steel structures are being installed on the seabed to control the recovery of an estimated one billion barrels of oil. Dozens of these deepwater fields are already producing and many more are planned for the Gulf of Mexico, offshore Brazil, West Africa and elsewhere.

High risk/high reward exploration associated with ultradeep wells and deepwater fields opens up a number of exciting and high value markets for ceramics. While numerous challenges are associated with entering these markets, substantial funding is available to support the development and field testing of ceramics and other new materials.

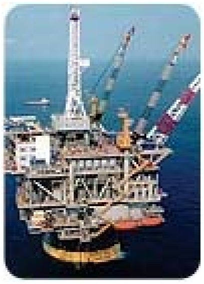
Existing Applications

Ceramics are already being used in the petroleum industry. Zeolite catalysts enable the worldwide refining industry to recover a higher percentage of gasoline and diesel per barrel of crude oil, and spherical ceramic pellets are used in oil and gas wells to increase productivity. Additionally, silicon nitride thermocouples are used in certain refining processes because they can withstand elevated temperatures and provide wear resistance.

Even the ubiquitous pump jacks dotting the landscape in areas such as West Texas and around Bakersfield, Calif., routinely have silicon nitride check balls in their underground mechanical pumps. In all of these instances, the unique characteristics of ceramics provide value to the petroleum industry.

New Drilling Opportunities

The ultradeep ExxonMobil well cited earlier is the first of what promises to be a number of extremely deep wells drilled along the U.S. Gulf Coast region. Their objectives are potential gas reserves rivaling anything found so far in the continental U.S. Oil and gas wells drilled to depths exceeding 18,000 ft are relatively commonplace in many parts of the world. However, only a small percentage of wells have exceeded 25,000 ft. At those depths, there are often high concentrations of carbon dioxide and hydrogen sulfide, and highly corrosive fluids are also frequently encountered. In addition, sand particles in the produced oil and gas move under extreme pressures and therefore tend to erode all but the hardest materials.



Wells drilled to these depths test the limits of metallurgy, and ceramics-with their high tolerance for heat, corrosion and erosion-have numerous applications. During the drilling process, hot drilling fluids circulate through the drill pipe and back to the surface. Ceramic seals and surface assemblies will become an integral part of these high-pressure, high-temperature drilling systems.

Once the drilling stops, wells are evaluated through electrical devices lowered into the well bore and then slowly removed. These logging tools are exposed to the full brunt of the downhole environment. The inclusion of ceramic structural elements, gears and valves makes these devices more reliable and better able to withstand such harsh environments.

Ultradeep wells are always expensive. To achieve a satisfactory return on investment, the wells must produce large volumes of hydrocarbons for years, perhaps even decades. To accomplish these economic objectives, well operators are implementing intelligent completion systems, which transfer some portion of the well's surface control valves underground, thereby allowing the well to simultaneously produce hydrocarbons from multiple zones with widely different pressures and fluid concentrations.

These systems accelerate the recovery of the well's hydrocarbons and are therefore economically attractive; however, they are technically complex. Typically, they include a myriad of sliding surfaces, valves and gears that must work for years under challenging physical conditions. Ceramic components are a natural choice for many of these key subcomponents.

Exploration Applications

In the world's oceans, the petroleum industry is drilling exploratory wells in water depths exceeding 10,000 ft and establishing production from fields found in 7000 ft of water. Many of these deepwater wells reach substantial depths below the seabed and are subject to extreme temperatures, pressures and corrosive environments, much like their onshore equivalents.

In addition, many deepwater wells suffer from another problem commonly referred to as flow assurance. Oil and gas produced from deepwater wells flow for miles or tens of miles through pipelines on the seabed. The surrounding ocean water is very cold, and the hydrocarbons in these pipelines frequently cool to a point where waxes, hydrates and related compounds begin to come out of solution. If left unchecked, these precipitates restrict and eventually block the pipelines.

To counteract this problem, various chemicals called hydrate inhibitors are injected into the pipelines. The inhibitors effectively prevent the formation of hydrates; however, they are also highly corrosive. Some manufacturers of this subsea equipment are already using ceramics in key assemblies exposed to the inhibitors. This represents an emerging high-value market for ceramics, particularly given the high cost of these wells and the myriad problems associated with repairing corroded components inside a deepwater production system.

Overcoming Barriers

While the exploration challenges faced by the petroleum industry create a number of intriguing new market opportunities for ceramics, ceramic manufacturers face multiple hurdles in this marketplace. For starters, steel and specialty alloys are still the overwhelming choice for most applications. Ceramics are perceived as too expensive, prone to brittleness and still largely unproven under the petroleum industry's field conditions. Education and field experience will allay these concerns.

The major oil companies have largely disbanded their R&D groups, as have many of the leading companies providing products and services to this industry. Consequently, a concerted effort is required to identify not only potential commercial partners within this industry, but also the new product champions within these commercial partners.

Ceramics also face a geographic challenge in this industry. Virtually the entire U.S. petroleum industry is concentrated in or around Houston, Texas. The leading petroleum industry trade shows in the U.S., such as the Offshore Technology Conference, are also usually held in Texas. Interestingly, these industry events attract limited participation from the ceramic industry. Ceramic manufacturers pursuing new opportunities in this industry will need to attend and actively participate in these key networking events.

Available Funding

The Energy Policy Act signed by President Bush in August 2005 directs and authorizes the U.S. Department of Energy (DOE) to spend up to $150 million per year over a 10-year period on new petroleum exploration technologies. Of this amount, approximately $50 million per year will be allocated to technology development for ultradeep drilling and deepwater exploration. These funds will not be used to drill wells, but to foster innovation. New materials, such as ceramics, will be direct beneficiaries.

The DOE is currently in the process of selecting a non-profit industry consortium to manage the program specified in the Energy Policy Act. This consortium will work closely with the DOE to delineate technology requirements, issue requests for research proposals and administer proposal awards. Winning these competitive solicitations will require collaboration. Ceramic manufacturers seeking to participate in this process will need to develop strong ties with the existing suppliers of the key systems used in both ultradeep drilling and deepwater exploration.

Pushing the Limits

Frontier exploration occurs because the potential rewards exceed the substantial costs. This exploration inevitably pushes the limits of current technology, thereby creating opportunities for new materials and practices. By responding to these challenges, ceramic manufacturers stand to gain new and high-value markets in the worldwide petroleum industry.

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