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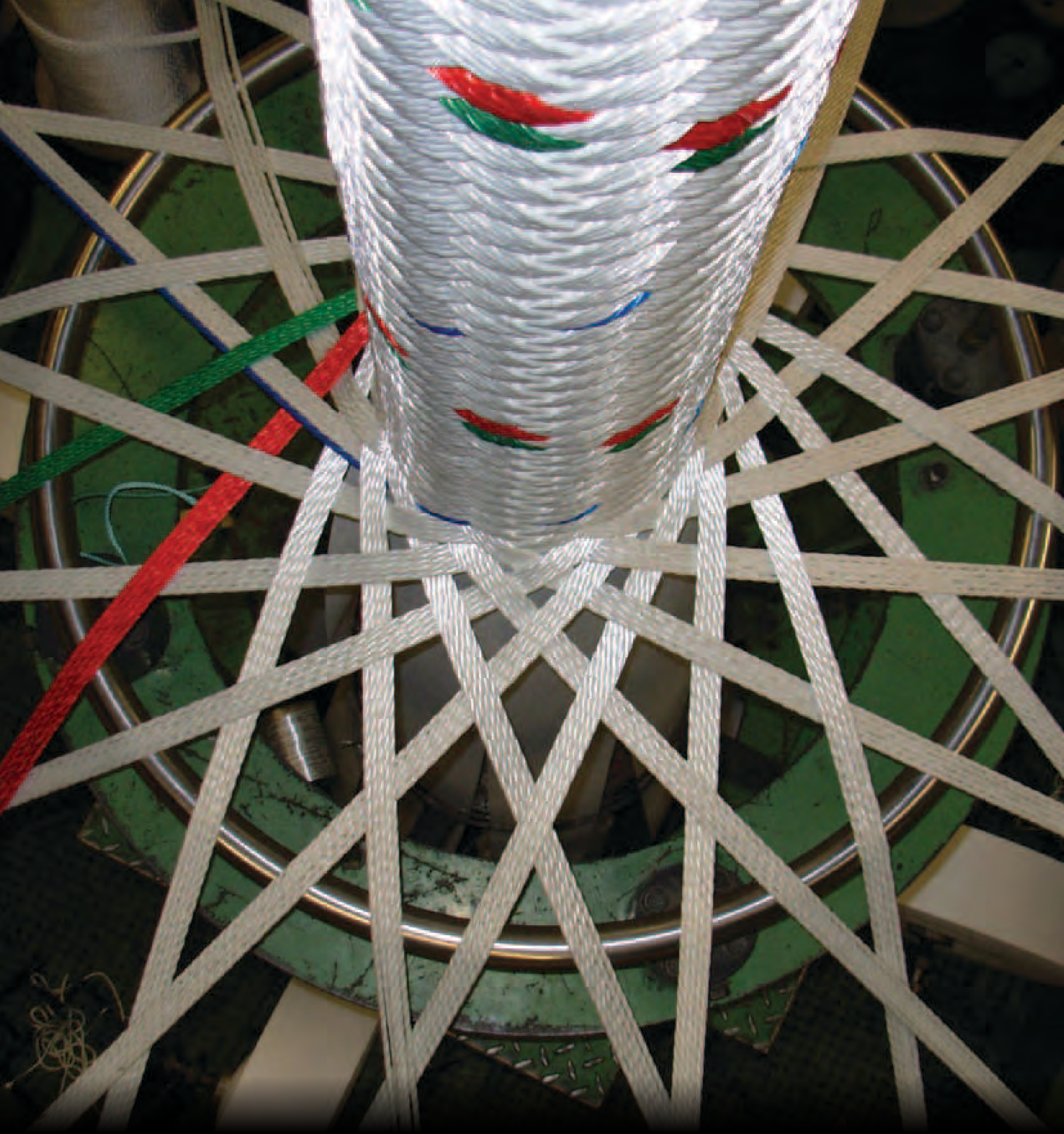

Weaving a High-Tech Web

This look inside the synthetic rope-making process only hints at the technical complexity of modern mooring lines. From materials to weaving to the splicing of sections the synthetic mooring rope is a high-technology product that is constantly evolving to support the demands of oil and gas exploration in ever deeper waters.

ABS OFFSHORE NEWS

COVER:

2H Offshore, a global engineering contractor and member of Research Partnership to Secure Energy for America (RPSEA), specializes in the design, structural analysis and integrity management of riser and conductor systems used in the drilling and production of offshore oil and gas reserves.

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Examining Deepwater Progress

Oil and gas produced from deep water has become a critical energy resource. Therefore, research and development must continue to bridge growing technological gaps, solve increasingly complex dilemmas and help improve the public perception of the oil and gas industry.

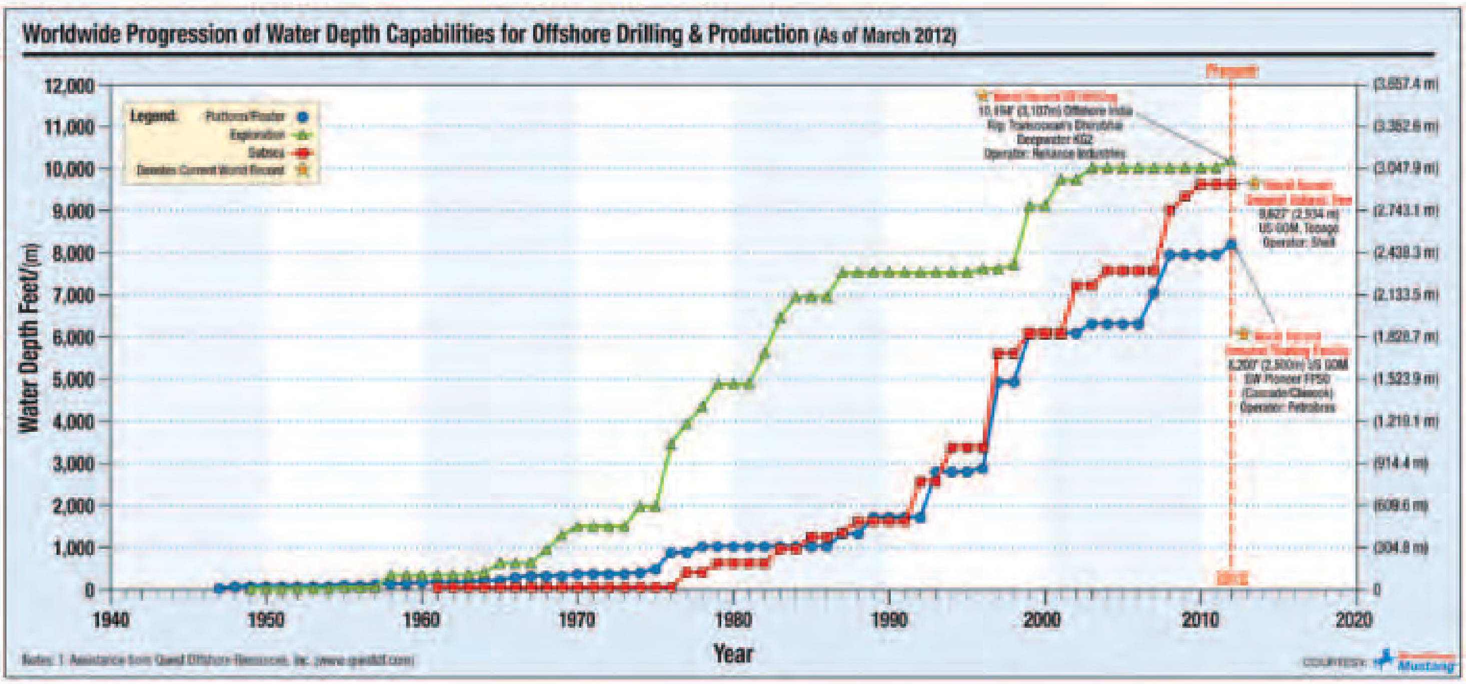
Deepwater exploration and production (E&P) face significant challenges. From rapidly increasing water depths to growing complexities and uncertainties, and with increasing public and governmental scrutiny, the deepwater offshore industry will have many obstacles to overcome in the years ahead.

Despite the fact that energy companies continue to find new, vast reservoirs of oil and gas in deep water (1,500 to 5,000 feet) and ultra deep water (greater than 5,000 feet), delving into the farthest reaches of the oceans increasingly requires accelerated developments in technology. In addition, companies are spending billions on R&D to develop technologies that will solve the long list of deepwater E&P challenges.

Extreme water depths of 10,000 feet, well depths that extend beyond 30,000 feet and well shut-in pressures that surpass 10,000 pounds per square inch (psi) pose enormous challenges. The fact that this work is going on in the middle of the ocean presents problems because complex drilling and production facilities have to fit onto small platforms in open water.

Research and development (R&D) will be crucial to the advancement of offshore industry, particularly in light of safety and environmental concerns that came under increased scrutiny following the April 2010 Macondo incident, which caused the second largest oil spill on record in the Gulf of Mexico (GOM). Another significant driver for offshore technology development is the rapidly growing global need for energy.

The US Department of Energy's "2011 Annual Plan" for the Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources Research and Development Program, released in August 2011, says growing energy demand combined with the continued decline of mature domestic onshore oilfields will make deepwater production from the Gulf of Mexico a key contributor to America's oil supply for the foreseeable future. Worldwide, ultra-deepwater oil and gas production is becoming an increasingly important element of the global energy portfolio.



A Backward Glance

Moving the search for oil and gas to increasingly deeper water is a relatively recent pursuit. According to *The History of Offshore Oil and Gas in the United States*, published in January 2011 by the National Commission on the BP *Deepwater Horizon* Oil Spill and Offshore Drilling, as recently as 1970, the average production-weighted depth in the GOM was 100 feet, extending to less than 200 feet by 1980.

In the mid-1980s area-wide leasing in the GOM changed those statistics. In seven lease sales held between 1983 and 1985, 2,653 tracts were leased, more than had been leased in all the federal sales since 1962 combined. About 600 of these tracts lay in water beyond 1,000 feet.

The 1990s brought further advances that opened more of the deepwater for exploration. Average production-weighted depth approached 250 feet in 1990, and by 1998, had moved beyond 1,000 feet. The next decade saw another leap forward. From 2001 to 2004, 11 major fields were discovered in 7,000-ft depths or more. Today, deep water accounts for 80 percent of oil production in the GOM and holds 80 percent of proved reserves.

The deepest GOM field, Shell's Perdido, is being produced from a water depth beyond 8,000 feet, via a spar. Initial production began in 2010 and is expected to reach 100,000 barrels of oil equivalent per day.

Coming of Age

Continued production from challenging deepwater fields will be contingent upon technology development. Realizing the need to expedite progress, the US Government formed the Research Partnership to Secure Energy for America (RPSEA) to facilitate cooperative development of new methods and integrated systems for exploring and producing energy and transporting it to market. The scope includes energy and other derivative products from ultra-deepwater, unconventional natural gas and other petroleum resources. RPSEA brings industry, academia, national laboratories, research organizations and government together to more rapidly achieve R&D advances. Results to date have been significant according to James Pappas, RPSEA Vice President, Ultra-Deepwater Program. "We've gone from the infancy of deepwater to adolescence" Pappas says.

The deepest GOM field, Shell's Perdido, is being produced from a water depth beyond 8,000 feet, via a spar.

Though progress is being made, there are inefficiencies. And all of the uncertainties of deep water have yet to be identified. Failures can and do happen, and industry has to take the lead in risk management.

"What we are beginning to do as an industry is take a proactive stance and start thinking about what may occur, even under the most minuscule circumstances with the smallest chance of occurrence in order to try to foresee what different outcomes we may have," Pappas explains. "Once we determine these outcomes, we are going back and looking at our systems in deep water and the tools that we have and then taking a critical look at them to see how they may be improved or how they may be obsolete in some cases."

James Pappas,
Vice President,
Ultra-Deepwater Program,
RPSEA

Reaching Deeper

Despite the recognized need for new tools and techniques, development of new technology in the upstream oil and gas business traditionally has been slow. Until five years or so ago, Pappas says, "it took us 25 years to get anything to where it was accepted and used by the industry." Beginning around 2007, however, things began to pick up as a result of soaring energy prices.

While some of the larger companies were making efforts to develop technology, most were following a just-in-time crisis mode approach. "In other words, companies wouldn't even pursue technology development until

WORLDWIDE RIG COUNT

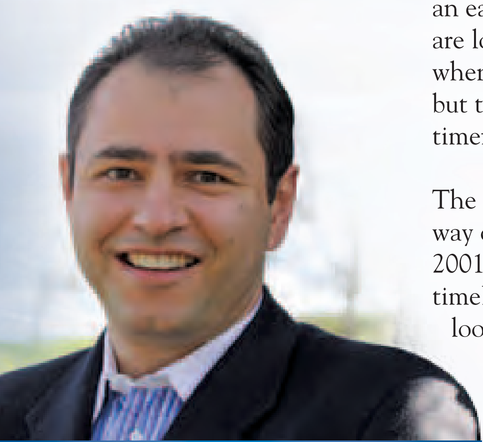
Year	Average Total Worldwide Rig Count
1975	2,722
1980	4,602
1985	3,566
1990	2,052
1995	1,713
2000	1,913
2005	2,746
2010	2,985
2011	3,466

Source: Baker Hughes Inc., April 2012

they recognized they needed the technology pretty quickly," Pappas says. This approach was inefficient. "Plus, it made it more difficult on the people who were developing a particular technology because of internal pressures to get something out that was absolutely necessary with no time to spare."

Not only has the industry realized that this approach is ineffective, it has recognized the value of cooperative development, which expedites technological advancement. That is essential, Pappas says, because the needs are too great for any one company to take on by itself. "We've become smarter in that we've begun to form joint industry partnerships," he says, "and we've developed other novel methods of combining resources to develop results. We've also begun to take an earlier view of these things, whereby we are looking at technology needs not solely when they're absolutely necessary to have, but trying to look at a three- to five-year timeframe."

The short-term result, Pappas says, is a new way of doing business that started around 2001. At that point, the industry began to see timelines cut very significantly. "You're now looking at three to ten years potentially to get them (new technologies) out and commercialized." This is a significant reduction from the 25 years it took previously.



Dr. Greg Kusinski, Director, DeepStar

Developing Solutions

Today's technologies must solve problems that are far more complicated than they were even a few decades ago. According to Dr. Greg Kusinski, Director of DeepStar, these problems often are multidisciplinary and require more of a system engineering approach as opposed to individual component improvement. Because the industry is trying to solve problems that are so complex and they need to operate at such depths and at such high pressures, it is challenging to find the ideal spot to test new innovations, Kusinski says. "So we take a phased approach starting with engineering analysis, then numerical analysis, model testing, systems integration testing and so forth. We don't want to have any unplanned events."

In the 1970s and 1980s, major advances in offshore technologies ranged from digital 3-D seismic imaging to computer workstations, according to the Commission's report. In fact, just 5 percent of the wells drilled in the GOM relied on 3-D imaging in 1989. That number skyrocketed by 80 percent in 1996, to practically industry-wide today. Meanwhile, new generations of subsea vessels took drilling to greater depths, from 5,000 to 10,000 feet to 20,000 or 30,000 feet below the seafloor.

There are many issues that the industry has to deal with. "One that continues to vex us has to do with flow assurance of fluids," Pappas says, explaining that deepwater flow assurance can be exceptionally challenging because of the huge variations in temperatures from the reservoir to the seabed to the surface. In some cases, the fluid can travel 50 miles along the seabed before it moves up the production umbilical, which gives it more time to cool off and more time for hydrate paraffin and/or asphaltenes to form, all of which inhibit production. "All of those are issues that we have to deal with as an industry and that we don't yet totally comprehend," Pappas says. "Work is still going on to try and understand the complexities surrounding how they work and why they work in the ways they do."

DeepStar, for example, is doing significant work in flow assurance as well as subsea processing research, which enables long subsea tiebacks. "While we all hope to find 'elephant fields,' we are also spending direct and supported efforts around safely and profitably developing marginal fields," Kusinski says.

Improving recovery is yet another challenge. According to Art Schroeder, Technology Manager at DeepStar, the industry is expending a great deal of effort to extract more hydrocarbons from the reservoirs. "A lot of the deeper reservoirs that hold a huge resource base, maybe tens of billions of barrels, are challenging us not only because of the cost but also because under natural depletion mechanisms, we might be facing a recovery factor of 10 percent or less," he explains. "Technologies for increased recovery will be a very big piece of the picture going forward."

Yet another challenge is basic maintenance and inspection of components and materials that operate far away from a platform or floating vessel. "How do you do that without human eyes?" Pappas asks, pointing out that maintenance and inspection have to cover every contingency.

Offshore Considerations

As R&D continues into many different areas, there are four key factors that the deepwater industry must bear in mind according to Pappas. First among these is improving safety. The Macondo incident illustrated to the world what happens when a disaster preparedness plan is not present.

Hand-in-glove with safety improvement is risk reduction. "Any time you introduce risk into a system, you introduce the potential for additional cost, lost time, safety issues, environmental issues or other unknowns," Pappas says.

The third key factor is uncertainty – the lack of knowledge of the outcome of a particular scenario. "Anything that can improve the lack of knowledge is going to help me decide if I want to continue on the path that I'm traveling or if I need to change direction," Pappas explains.

The fourth and final factor is direct costs of high dollar items. Improving costs in some cases can mean an entirely new way of doing business. "In some cases it may be a small step-wise improvement," Pappas says. "Companies need to spend time and effort on both of those. The step-wise improvements typically get you to a certain point, but there will be a point in the life of that system when it's going to be too costly to try and save a few more percent, and you may need a whole new 'back of the napkin' idea."

Today, the industry is battling to reach beyond the 10,000-foot mark. The deepest fields today are in 8,000 to 10,000 feet water depth; however if discoveries are made beyond that depth range, current technologies would render those reservoirs inaccessible.

Pappas supplies an example in the form of subsea equipment. Current subsea trees can operate in 15,000 psi, some even close to

A Closer Look at DeepStar

One industry venture pursuing deepwater advances is DeepStar, a deepwater technology development consortium that has been in operation for 20 years. "What is unique about us is that we are an operator-funded, operator-driven technology development consortium," explains Dr. Greg Kusinski, DeepStar Director. "By doing so we represent the pull of the market, as opposed to the push of the market."

Operating in two-year cycles, the consortium comprises 11 operator members (Anadarko, BP, Chevron, ConocoPhillips, Maersk Oil, Marathon Oil, Nexen, Petrobras, Statoil, Total and Woodside Energy) and approximately 80 contributing members (made up of companies such as GE, Baker Hughes, Schlumberger, Halliburton, Technip and Oceaneering). DeepStar operates via nine technical committees: geosciences, regulatory, flow assurance, subsea systems, floating systems, drilling and completion, reservoir engineering, met-ocean and systems engineering.

"DeepStar takes a very structured look at each of its committees as far as understanding the technical needs both from an enabling standpoint – something we can't do now without developing new technology to bridge a gap – and enhancing technology," says Art Schroeder, DeepStar Technology Manager. "DeepStar is very good at identifying and defining specific technology needs, building detailed technology roadmaps, crafting the needs into requests for proposal (RFP); executing the review, vetting and award process; and then managing the project's development. Critical and key to the entire process is the deep and active engagement of more than 1,000 subject matter experts from DeepStar member companies."

DeepStar has delivered about $100 million worth of engineering, reports, presentations, standards and precursors to standards over the last 20 years, Schroeder said. DeepStar has 26 projects already under way for the 2012-2013 operating cycle. ◆

Art Schroeder,
Technology Manager,
DeepStar

20,000 psi," Pappas explains, "but current tree technologies cannot take the industry beyond that point. We cannot just add more steel to it to make it bulkier, because it's to the point that it's so heavy that there are no cranes that can properly place a tree any heavier than what these are now on a wellhead," he says. "We've reached the maximum level of expandability or scale-up, and we also have issues with the reliability of certain valves that are used on these subsea trees – they'll work the first time, but they may not work the third or fourth time because there's so much pressure on one side that it actually deforms the seal." A new tree design is needed, he says, and the industry is going to have to come up with a more effective design if there is any hope of breaking the pressure barrier that limits today's operations. ❖

Deepwater Advances

The Ultra-Deepwater Program at RPSEA is a federally sponsored program that covers the ultra deepwater side of the business for the Gulf of Mexico. "Our charge has been to look at methods to improve recovery and increase safety and environmental compliance within the deepwater," explains James Pappas, Vice President of RPSEA's Ultra-Deepwater Program. The federal government subsidizes some of the research and technology projects, and the remainder of the cost is borne by the subcontractors that include oil and gas companies; service, supply and manufacturing companies; universities; safety and environmental firms; and national labs.

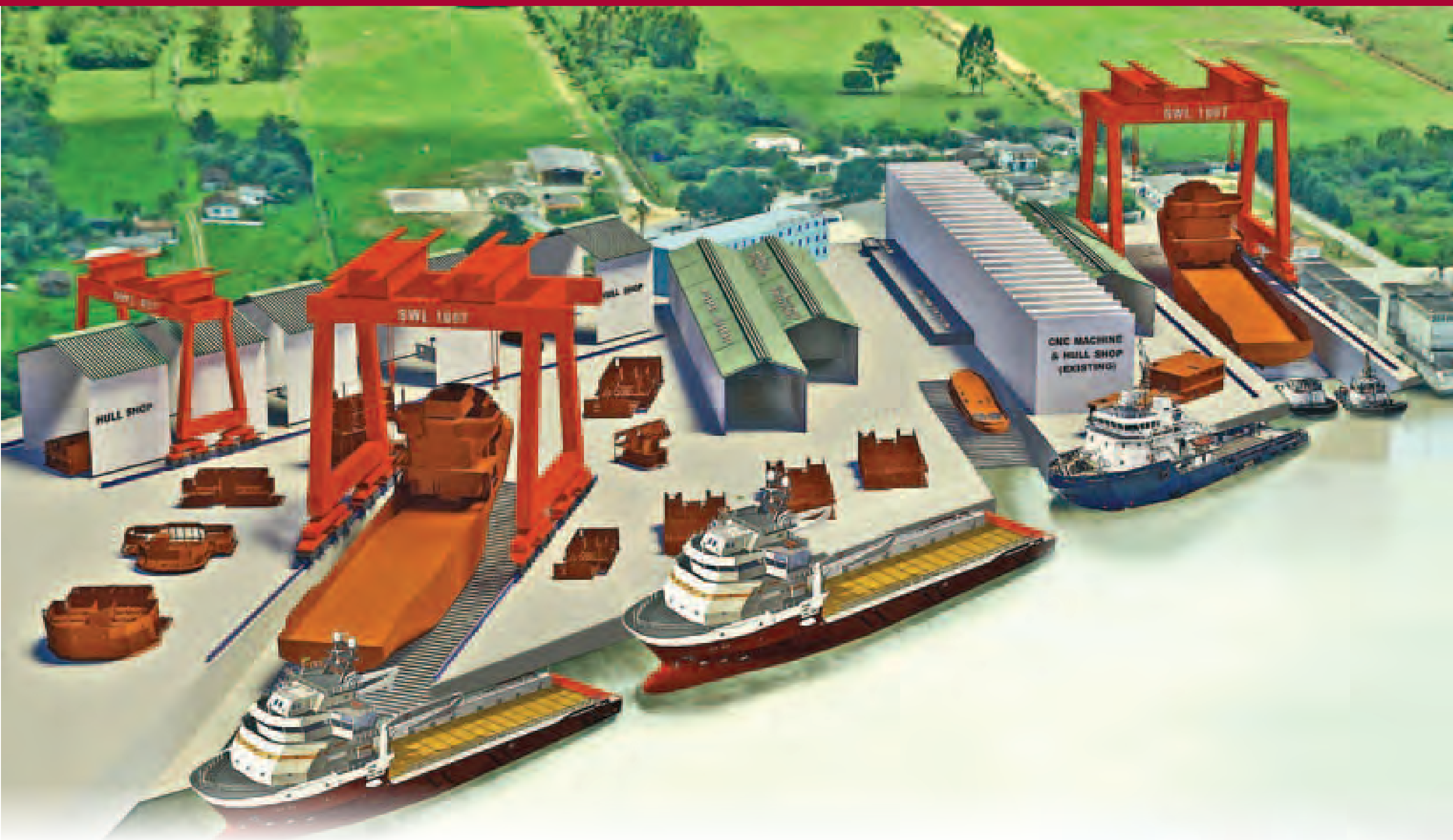
RPSEA has been in existence since 2007 and today boasts more than 40 projects that either are ongoing or have been completed. "We have several others that are in the pipeline right now, awaiting federal approval to pursue," Pappas says.

Together with industry, RPSEA is working to develop a reliable autonomous underwater vehicle (AUV) for deepwater operations and maintenance work. According to Pappas, the AUV could be used in conjunction with LADAR (laser radar) and ultrasonics to look for changes in structures, fluid movement or leaks very quickly and at nearly any depth.

Another project involves developing an umbilical for subsea environments that has high conductivity, using methods such as nanotechnology, which will enable the umbilical to go out up to 100 miles while still maintaining efficiency. RPSEA has one completed project proving the concept and is now aiming to achieve an efficiency equivalent to that of copper cable in the next phase. The goal after that, Pappas says, is to gain efficiency that is 100 times more efficient than copper cable.

RPSEA also is working to develop a hurricane model that does a better job of predicting storms and their strengths. This will provide operators with better information with which to design structures and better warning signals when a storm approaches in the Gulf of Mexico. "This model is not only going to be useful for the offshore oil and gas industry, but it's also going to be able to help forecasters improve hurricane and hurricane land falls predictions throughout the Gulf Coast States," Pappas says.

RPSEA and its 180 members have been awarded $57 million in federal funds toward $90 million in ultra-deepwater projects since 2007. Thus far, 19 ultra-deepwater projects have been completed, 22 projects are in progress, and up to 28 projects are pending approval. ◆



Joint R&D Efforts Expedite Technology Advances

ABS is working in Brazil with Petrobras' research and development (R&D) center CENPES, universities in Rio de Janeiro and other organizations on research and development efforts, local content certification, FPSO life extension and more.

Carlos Tadeu Fraga,
Executive Manager,
Research & Development,
Petrobras

In recent years, Petrobras has consistently ranked among the world's top five investors in energy R&D, investing around 6 percent of its total revenue. According to Carlos Tadeu Fraga, Executive Manager of Research and Development for Petrobras, $2.7 billion was invested in R&D at the company's CENPES technology center between 2009 and 2011. An impressive 59 percent of this amount was allocated to exploration and production.

Approximately 21 percent has gone toward new processing, refining and petrochemical technologies. And although only 2 percent was allocated to biofuels – a small percentage compared to the company's other areas of investment – this represents R$54 million (approximately $29.6 million), which ranks Petrobras among the top ten investors in R&D in biofuels in the world today. Also significant is the amount of research devoted to the environment, which has focused mainly on atmospheric pollution and water resource management.

"For five years in a row, Petrobras has been among the eight biggest investors in research and development in the oil and gas industry worldwide, including oil and service companies," Fraga says. "Our investments added up to approximately $900 million in 2008 and 2009 alone." A significant part of this investment was made up of R&D projects in cooperation with Brazilian universities and foreign R&D centers.

To support Brazilian development and leverage its global R&D resources, ABS established its Brazil Offshore Technology Center (BOTC) in Rio de Janeiro in 2009. As investments continue to increase in the region, ABS is well-placed to work jointly with industry, government and academia to push the limits of deepwater operations.

Christiane Machado,
Principal Engineer,
ABS BOTC

One of the recent contributions made by ABS BOTC was achieved through its participation in a multiyear Torpedo Pile Design Assessment study.

Petrobras plans to invest as much as $4.5 billion in R&D over the next five years, with a focus on advancing technologies for ultra-deepwater oil production. The company's research center is working with Brazilian universities to tackle technical challenges of producing oil buried deep below the ocean's surface under a thick layer of salt (presalt resources).

"To drill through 2 km (1.2 miles) of salt is not a very easy task," Fraga says. "It requires specific technology. The strategy is to have one of the most important research and development centers for oil and gas worldwide."

Government regulations require oil companies to invest 1 percent of gross revenues from high-productivity fields in R&D. Last year, Petrobras inaugurated a $700-million expansion of its CENPES research facility, and the company expects to invest between $800 million and $900 million per year over the next five years in R&D.

Current research projects being funded by Petrobras include developing materials that can resist corrosion under the heavy pressure of ultra-deepwater and new methods for interpreting seismic data needed for the presalt offshore region, which Brazil hopes will transform the country into a major oil exporter.

ABS in Brazil

Many companies recently have announced plans to open research facilities in Brazil to develop technology for the oil and gas industry. Others, such as ABS, have been working in Brazil for decades.

ABS placed its first office in Brazil in June 1948, a local survey office. Since sinking its roots in the region 64 years ago, ABS has created in Brazil an organizational structure that brings together dedicated survey, engineering and project management teams to serve the offshore industry as a whole, including new construction projects, conversions and existing offshore units that are operating in Brazilian waters.

ABS classed the first jackup built in Brazil in 1968 as well as the first very large crude carrier (VLCC) converted to a floating production, storage and offloading (FPSO) unit in Brazil in 1996. In 2000, as activity in Brazil began to increase, the ABS office in Rio de Janerio already was well-established with a solid engineering office to attend to the on-call demand services for shipbuilding and offshore.

Since that time, ABS has been increasing staff, more than doubling its team during the last five years to continue providing services to clients and to support the significantly increasing demands of the offshore oil and gas industry. At the present time, nearly 60 percent of the classed offshore units in operation off-Brazil have been built to or are being maintained to ABS standards.

The creation of the ABS BOTC was an extension of ABS' commitment to one of the world's most dynamic oil and gas regions. According to Christiane Machado, Principal Engineer, ABS BOTC, this center acts as a satellite office of the Offshore Technology department based in Houston. "BOTC interacts daily with local clients, including owners, operators, shipyards, design companies and universities to develop procedures for the verification of the brand new products of the emerging technologies," Machado says.

ABS BOTC was formed as part of a cooperation agreement with COPPE/UFRJ University in 2010. Professor Segen F. Estefen, Director of Technology and Innovation with COPPE/UFRJ addresses an audience.

Since its inception, ABS BOTC has carried out R&D activities on a number of aspects of offshore operations and is augmenting staff to expand its capabilities. In 2011, ABS BOTC increased resources to help meet the needs of industry and to expand opportunities for R&D collaboration in Brazil.

"The focus of BOTC is to be part of the brand new developments of the industry for offshore operation, such as offshore oil and gas drilling and production systems and plants, offshore renewable energy facilities such as wind farms, subsea drilling and production installations for oil and gas and subsea mining," Machado explains.

One of the recent contributions made by ABS BOTC was achieved through its participation in a multiyear Torpedo Pile Design Assessment study, the goal of which was to define a concise and sufficient set of Guidance Notes to review design and installation of these types of anchors. When the study is concluded this year, Machado says, the industry will have a much better understanding of soil interaction with torpedo piles. A report generated from study findings will provide the industry with recommendations for the design and use of dynamically installed multidirectional capacity piles.

There are four projects underway at BOTC today, Machado says, most of which began in late 2010. One of the most interesting is the FPSO Life Extension project, which Machado describes as a multiyear project focusing on investigating the safety and integrity of existing ship-shaped production units. One of the goals of the project is to provide a comprehensive understanding of their performance during their service life, the degradation process and the possibilities for refurbishment during production. A second goal, Machado says, is to provide class requirements for the extension of the owner and operator proposed service lives.

Another ongoing project is one that is assessing the rate of corrosion for assets working offshore Brazil. This project, which is integrated with the FPSO Life Extension project, focuses on the condition and maintenance of FPSOs. The objective of the project is to determine how these production units deteriorate in the course of service on offshore fields under local conditions of temperature and water, chemical and oil compositions.

A project that addresses production riser connectors also is in the works. The goal of this project is to establish recommendations for the safe design of different types of rigid and flexible riser connectors in different environments, which will be determined by studying loads, materials, modes of failure, and survey and maintenance possibilities, Machado explains.

The team at ABS BOTC works in close cooperation with other ABS Offshore and Energy Technology Centers stationed in Singapore, China, Canada and Korea as well as with the team housed at the ABS Technology headquarters in Houston. "This group comprises more than 100 researchers all around the world," Machado says.

ABS BOTC formed as part of a cooperation agreement with COPPE/UFRJ University in 2010 is in the process of seeking funding to begin a project with LabOceano on global performance. "We also put in place a cooperation agreement with IPT (Instituto de Pesquisas Tecnológicas) in late 2011, and we are discussing new topics for study," Machado says.

ABS BOTC has been working in close cooperation with Petrobras/CENPES, sharing knowledge and performing quick

Former Brazilian President Luiz Ignácio Lula da Silva, Petrobras President José Sergio Gabrielli de Azevedo, Chief of Staff Dilma Rousseff and Minister Edison Lobão raised the first small barrel of Jubarte's presalt oil treasure in 2008.

Kjeld Aabo, Manager, Offshore Equipment, MAN Diesel & Turbo

Thereza Moreira, Head of Local Content, ABS Consulting

reviews of portions of different products. "We have already interacted to bring ABS approval in principle (AIP) review and certification to some brand new concepts and modifications of newly created equipment for operation in Brazil's challenging presalt areas," Machado says.

Indications from the Brazilian industry and others around the world imply that the level of demand for natural gas will increase the need for floating liquefied natural gas (FLNG) production plants. This inspired ABS to write two Guides for establishing classification criteria for FLNG concepts that put forward requirements and standards for the design, operation and maintenance of gas carriers and new floating gas transportation concepts, transfer and storage. Also, ABS has introduced new tools and software specially designed to deal with the new applications to handle larger than conventional sized structures for FLNG projects. The key is to identify safety considerations and hazards for affecting the hull, transfer, processing facility and mooring systems, Machado says.

Lula Rules

Petrobras, which operates the largest fleet of production platforms as a single company, plans to triple the number of drilling vessels in its fleet by 2020. The company expects to increase production from approximately 2.7 million barrels of oil per day (bopd) to 6.4 million bopd in 2020, nearly equal to the combined production of OPEC members Angola, Nigeria and Venezuela.

Much of the construction work for the expanding Brazilian fleet that will be required to achieve this ambitious goal will take place in Brazil. A requirement put in place by former President Luiz Inácio Lula da Silva dictates that local content will make up 70 percent of the equipment and work. This means Petrobras and other companies that want to work in Brazil will have to purchase a large percentage of equipment and manpower from domestic suppliers. The goal of this requirement is to promote domestic economic development.

While this is an admirable goal, Brazilian manufacturers will unlikely be able to deliver equipment and as efficiently as suppliers with long-term experince in the market. According to Kjeld Aabo, a Rio de Janeiro-based Manager for Offshore Equipment at MAN Diesel & Turbo, a division of MAN SE, inexperience will be a considerable challeng for many domestic suppliers.

Domestic companies need to quickly develop the capabilities in order to produce the engines and power generators needed for the 33 drillships Petrobras is ordering from domestic yards. "This will be a challenge," Aabo says, "because in Brazil, they're basically starting at the beginning."

Brazil is enthusiastically working toward greater capabilities, and ABS is working hand-in-hand to help the country reach its goals.

ABS Consulting, an affiliated company of ABS, which certifies the amount of local content in Brazilian oil equipment, has expanded its staff fivefold to 25 auditors since opening the department in 2008. According to Thereza Moreira, Head of Local Content, ABS Consulting, existing plans call for continued expansion in the country.

Brazil wants to achieve sustainability and to improve the standard of living for millions of its citizens, Moreira says. Companies that want to take advantage of the tremendous offshore potential realize there will be a steep learning curve. In the end, however, the investment will be worth it. Brazil offers tremendous opportunity for the industry, and there will be a considerable return on local investment. For companies that want a piece of the pie, there is no option. "They need to invest here in Brazil," Moreira says. ❖

Deepwater Moorings Prepare to Go Deeper

How one synthetic rope manufacturer is preparing to help with the offshore sector's advance into ever deeper water.

It is widely acknowledged by industry analysts that, for the foreseeable future, deepwater and ultra-deepwater developments represent the single largest growth area in oil and gas exploration and production for the Gulf of Mexico (GOM), West Africa, Asia, Brazil and now the Arctic regions. Once only a dream, mooring a production platform in water depths of 2,000 meters for a period of up to 30 years is now commonplace. As the offshore industry prepares for ultra-deepwater production in water depths exceeding 3,000 meters, the world's leading mooring rope manufacturers are developing the technologies and systems needed to overcome the significant engineering and installation challenges of deepwater development.

One leading offshore mooring rope manufacturer is Lankhorst Ropes, based in Sneek, Holland, and part of the Royal Lankhorst Euronete group. With more than 200 years of experience in manufacturing maritime rope, the company acquired Portuguese rope maker Quintas & Quintas Offshore in 2009 to form its Offshore Division, supplying permanent deepwater and temporary mobile offshore drilling unit (MODU) moorings and single point mooring (SPM) systems for CALM (Catenary Anchor Leg Mooring System) buoys. Among the company's recent deepwater mooring projects in the GOM are Murphy's *Thunder Hawk* deep draft semisubmersible floating production unit (FPU), Petrobras' *Cascade-Chinook* floating production, storage and offloading (FPSO) vessel, and the award to supply polyester mooring ropes for Anardarko's *Lucius* truss spar, which will be installed in a water depth of 2,165 m (7,100 ft).

Deepwater Mooring Ropes

Deepwater mooring is different from other rope applications. In the taut-leg mooring system, the ropes are installed long term (typically, 30 years) and are kept under constant load. Unlike wire and chain mooring systems at shallower depths, which rely on the weight of the mooring lines to hold the floating unit on station, polyester rope taut-leg mooring systems use the elasticity of the rope to provide the required restoring force. The higher the rope's elasticity, the greater the line stretches and absorbs higher dynamic loads. Generally, polyester rope is preferred by naval architects looking for a 'softer' mooring where the platform motions are more compliant and riser-friendly.

Workers deploy the mooring line offshore.

Deepwater rope tether manufacture is a high-technology engineering business. Lankhorst's GAMA 98 polyester deepwater rope, for example, is typically made of up to 18 sub-ropes, each sub-rope being of a long lay length braided construction to provide a torque-free rope.

As with maritime ropes, the engineering integrity of the eye splice is the determining factor in the overall strength of the mooring rope – in fact, the quality of the splice is critical for deepwater mooring tethers. All eye splices are made by hand. Where a maritime rope may contain between eight and 12 strands and require half an hour to complete an eye splice, a deepwater mooring rope has up to 18 sub-ropes, with an overall diameter of 250 and weight of 43kg/m, and can take one and a half days to splice.

Ensuring the integrity of the deepwater mooring line splice is dependent on allocating each sub-rope a preset position around the eye so the load is shared equally by all of the sub-ropes. In the ideal splice, each sub-rope is exactly the same length. The effect of length variation among sub-ropes is an unequal loading on the shortest sub-rope in the eye, which results in a shorter fatigue life. Failure of the shortest rope initiates a domino effect as the next shortest rope in turn takes an increasing load leading ultimately to catastrophic rope failure.

The differences in maritime and deepwater splicing reflect the mechanical demands on each type of rope. Maritime ropes are subject to dynamic loads at irregular intervals as ships are towed and moored. Deepwater ropes, on the other hand, are subject to constant cycling loads over many years where resistance to mooring line fatigue is an important factor in rope selection. Contracts for deepwater mooring ropes are mostly custom designed and require prototype ropes to be tested in accordance with a variety of industry standards before manufacture can commence.

Deepwater Mooring Systems Evolve

The installation cost of mooring lines in 2,000-m water depths already exceeds the cost of the lines themselves. Naval architects and installation contractors preparing for moorings in depths of 3,000 m and beyond, therefore, face two challenges: how to engineer permanent mooring systems at this depth while at the same time reducing mooring line deployment costs.

One means of cost control is accurate length measurement. Accurate rope length has practical and financial benefits. Overall length accuracy is important in minimizing the length of top chain connecting the end of the mooring rope and the FPU. A 0.5-percent line length 'safety margin' in the top chain can cost millions of dollars. A 50-m savings in top chain length per line on a 12-leg mooring system equates to a savings of approximately $700,000 with R4 chain, and nearly $1 million for Grade 5 chain. Conversely, if the mooring line is too short, the ropes are difficult to install and need higher pre-tensioning, resulting in an extended and more costly offshore installation time.

During deepwater mooring system installation, polyester ropes are routinely tensioned to pre-load the rope, increase its stiffness and set initial bedding in construction stretch. Polyester mooring stiffness and pre-loading have a bearing on platform motions. A low pre-loaded, low stiffness mooring system gives a softer mooring than a high pre-loaded, high-stiffness mooring system. Pre-loading is done using a specialist, heavy lift installation vessel or anchor handling vessel so that 'out-of-the-box' storm offsets are minimized. Alternately, mooring tensioners on the vessel can be used to pre-load the ropes.

When Lankhorst supplied the mooring ropes for Chevron's *Tahiti* spar moored at 1,219 m water depth in the GOM in 2008, it introduced the industry's first Length

Measurement System (LMS) for deepwater ropes. Until the *Tahiti* project, rope length tolerances from more or less 2 percent for deepwater mooring lines were not uncommon. Using the LMS, Lankhorst was able to manufacture the 254-mm diameter, 42.6 kg/m polyester spar mooring rope to within more or less 0.5 percent of the correct length after post-installation tensioning. This significantly reduced the time needed to tension the lines offshore.

Meeting the Challenge of Deeper Moorings

As mooring lines go deeper, the engineering integrity of the fiber ropes and their construction becomes more important. Due largely to the lack of specialist rope test equipment and the very high cost of testing, there has been a shortage of authoritative data on rope properties for a variety of fiber types and rope constructions.

To address this deficit, Lankhorst developed a rope test machine at its Portugal offshore rope production facility for 20-m test pieces, enabling a 3-m stroke up to a maximum breaking load of 1,200 metric tons. The stroke length is greater than for traditional rope testing procedures, so as to compensate for the elasticity of the synthetic fiber ropes. This ensures that there is at least a full 2-m length of rope under tension. The rope test machine also can conduct fatigue testing of ropes to any fatigue regime specified by oil and gas operators and certified verification authorities.

In addition to rope testing, the machine allows investigators to establish project baseline test data and run 'what if' scenarios by simulating storms, hurricanes and loop current events on the mooring lines. Also it is able to undertake a range of proof-loading, break-load and tension-tension fatigue testing of ropes and other strength member components.

Given industry concerns about the rising cost of performing deepwater installations, one outcome of Lankhorst's extensive research into rope performance has been a potential new methodology for mooring rope pre-tensioning during installation.

Ultra-deepwater mooring lines will need pre-tensioning to higher loads, making traditional rope pre-tensioning practices unsafe, impractical and uneconomic. Where traditional pre-loading practice is based on the application of fixed loads at variable rope length, the new approach uses variable loads at fixed rope length, which is more representative of the way the rope performs in service. And, although more rope testing is needed at the project outset, this is more than outweighed by the benefits of lower capital costs for mooring equipment and faster installation times. Pre-loading, where required, can be conducted at lower and safer tensions, with the option of using smaller installation vessels.

Specialist Ropes for Ultra-Deepwater Moorings

For ultra-deepwater mooring in water depths beyond 2,500 m, polyester mooring lines lack sufficient stiffness by themselves to maintain a vessel on station. The elasticity of the rope is the issue, as it results in high horizontal offsets of the floating production unit that can exceed riser limits. A better mooring alternative is a stiffer high modulus polyethylene (HMPE) rope. Exhibiting high strength and high modulus, HMPE produces a lighter and smaller diameter, higher stiffness mooring line when compared with polyester.

Until now, however, poor creep performance (the incremental stretching of the rope over time) of HMPE fiber has limited its use in deepwater mooring systems. First tried as mooring rope over ten years ago, HMPE gave promising early results; but subsequent problems with excessive creep prevented its

Lankhorst's GAMA 98 polyester deepwater rope.

use as a deepwater mooring rope. In response, the industry's leading supplier of HMPE, Netherlands-based DSM Dyneema, introduced SK78, an HMPE fiber that reduces creep rate to less than 0.5 percent on five-year moorings – still too much for permanent moorings, but ideal for MODU moorings.

This year, DSM produced an HMPE fiber (DM20) that allowed Lankhorst to manufacture GAMA 98 HMPE ropes, which feature virtually no creep for five-year MODU moorings and less than 0.5 percent for 30-year moorings.

From the mooring systems perspective, the new HMPE rope's ultra-low creep and higher stiffness are expected to provide optimum stationkeeping conditions for permanent moorings at ultra deepwater depths. Moreover, the rope's smaller diameter allows more rope per reel than polyester – 900 m of HMPE per reel compared with 600 m for polyester. This means fewer reels are needed offshore, and these can be more readily handled by an anchor handling vessel. In addition, as permanent moorings go further offshore, it also enables the installation of mooring lines and anchors to be completed in one trip.

DSM Dyneema produced an HMPE fiber (DM20) that allowed Lankhorst to manufacture GAMA 98 HMPE ropes.

New Deepwater Field Development Opportunities

Synthetic ropes are being used more frequently today where steel wire or chain would pass over such subsea infrastructure as pipelines, so as to minimize damage in the event of accidental touchdown. They also are used in semi-taut combinations (steel/polyester mooring systems), particularly in MODU operations.

As the search for offshore oil and gas continues, ever greater water depths will need to be conquered. Advances in mooring systems technology will help make this possible and today are creating new field development opportunities. One area with such new opportunities is the North Atlantic Ocean. Here, field developers can expect to encounter deepwater and ultra-deepwater depths, but of more immediate concern is the damage to mooring lines caused by fishing trawlers. Lankhorst is presently conducting research into development of cut-resistant jackets for mooring ropes in the Norwegian and Barents Seas and is assessing materials needed to reduce the effects of fishing trawler lines on synthetic fiber mooring lines.

In the Norwegian and Barents Seas, for example, moorings in depths beyond 800 m are subject to extreme weather and wave conditions. The mooring ropes for these applications must provide high abrasion resistance and be immune to the effects of external damage arising from trawler activities. The cut-resistant jacket research involves simulating the effect of trawler wires coming into contact with synthetic fiber mooring lies, quantifying the damage and assessing the rope's residual strength after the event. In addition, the limited good weather windows in the area mean the ropes should be capable of being stored on the seabed ahead of mooring deployment.

Technically, deepwater mooring has never been in better shape. Ongoing technology development by the world's leading manufacturers in rope fibers, their construction and manufacture, together with insights offered by dedicated deepwater rope testing facilities, mean that many of today's technical and deployment issues in designing and deploying ultra-deepwater mooring systems are well on the way to resolution. ❖

A History Of Advancing Offshore Oil & Gas Technologies

ABS has been a valued partner to technology development in the offshore oil and gas sector for more than 60 years.

The offshore oil and gas sector has been steadily marching into the unknown for 65 years, conquering challenges in a ceaseless succession of ever harsher environments and ever greater water depths as it pursues the fuels of world industrial growth. ABS has supported technology development in this unique sphere of activity since the earliest days of oil production from 'beyond the horizon.'

Safety regulations were first imposed on offshore equipment in 1961, when the US Coast Guard, noting increased exploration in the Gulf of Mexico (GOM), ruled that rigs that drilled while floating were to be considered vessels and, consequently, had to be assigned a load line. It was soon discovered about such drilling rigs that, due to their unique design characteristics, the amount of study and survey needed to assign a load line was only slightly less than that needed for full classification. This led many designers and operators to have their rigs analyzed and classed by ABS – which, in turn, brought ABS into the heart of the structural evolution of offshore drilling and production. For over half a century, most significant structural or design advances in floating offshore equipment occurred on ABS-classed rigs.

Offshore energy production goes back 125 years to the drilling derricks on wooden piers that began extracting oil from beneath the Santa Barbara Channel at Summerland, California. The offshore oil and gas industry traces its origins to 1947 in the GOM, when drilling contractors Kerr-McGee struck oil with *Kermac Rig 16*, the world's first producing offshore drilling rig installed out of sight of land. Standing in about 20 feet of water approximately 18 miles off the Louisiana coast on an oil field named Ship Shoal Block 32, the rig was a fixed, steel-pile platform carrying only the drilling derrick and drawworks winch, along with downhole pressure control equipment bolted to the top of the well conductor beneath its wooden deck. Everything else for the operation, from the electrical power source to drilling supplies and crew quarters, was aboard its 'support vessel,' a surplus US Navy barge that had been converted into an ABS-classed tender named *Frank Phillips* – the world's first drilling tender.

Using a fixed platform for exploration drilling was recognized as a risky endeavor even in those highly risk-tolerant times; the oil company would have lost a fortune if the well turned out to be dry – but, in fact, the field disgorged more than a million barrels of oil and 300 million cubic feet of natural gas in its nearly 40 years of production. As other early explorations failed, it became clear to the industry that offshore energy production would remain an inshore endeavor unless a less risky exploration solution could be found.

John Hayward, then Vice President of Barnsdall Oil and Refining, proposed that marine oil exploration would best be done using a drilling device that could be moved to a new site should a dry hole be encountered. He got Barnsdall to build such a device in 1949. Designed by pioneering offshore innovator Paul Wolff, *Breton Rig 20* became the world's first mobile offshore drilling unit (MODU); its success inspired an industry and sparked the evolution of floating rigs. That rig (later named *Transworld Rig 40*) is often referred to as a Hayward-Wolff design, but credit must also be given to Wolff's wife Marge, a meticulous mathematician who performed the stability calculations for her husband's designs – and may thus be offshore history's first female technology pioneer.

ABS became involved with assessing offshore structures around this time. Gulf Coast shipyards had played an active role in the World War II shipbuilding effort, and ABS was well known in the region for its experience in assessing steel structural strength and safety in marine applications. For this reason, ABS was being consulted by builders of floating offshore drilling equipment as early as 1950, treating them as kinds of barges and using its Steel Vessel Rules as the primary basis for evaluating their designs. The first drilling barges listed in the ABS *Record* include the submersible *Mr. Charlie* (1954) and the self-elevating drilling units *Mr. Gus II* (built in 1957 and the subject of a seminal technical paper on rig design), *Mr. Cap* (1957) and *Mr. Louie* (1958) – the last two famous for drilling the first wells in the North Sea.


MR. LOUIE

Self-elevating drilling barges have a set of legs that are jacked down to the sea floor in order to raise the vessel's hull out of the water, so that the derrick on deck can drill for oil. These units evolved in size and technology into today's jackup drilling rigs, which, have for 50 years been the backbone of shallow-water exploration and development.

Nurturing Innovation, Cultivating Technology

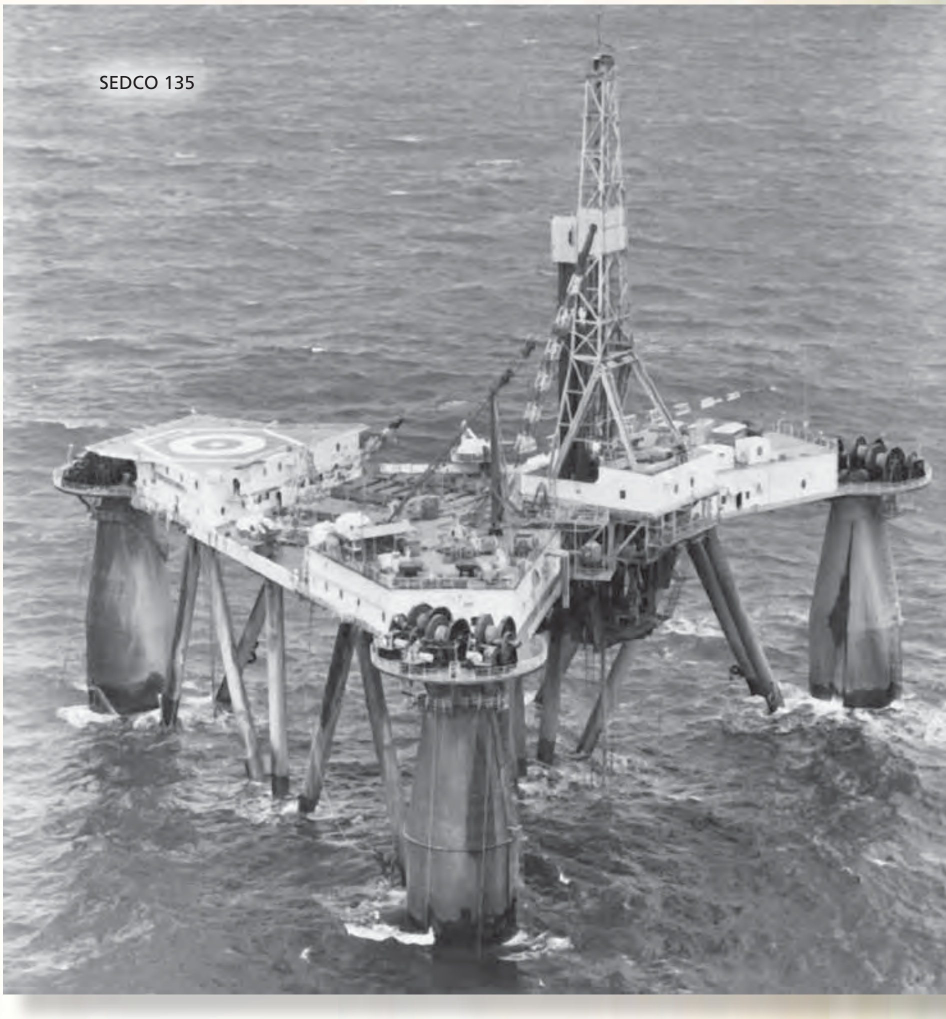
The dawn of offshore drilling was a period of daring innovation, wherein many strange-looking contrivances were floated out into the GOM attempting to access the oil beneath the water. Many failed and are only remembered in technical papers from the period, while the few that succeeded became the ancestors of today's sophisticated floating drilling and production systems. Common to all was that they were designed out of untested theories, built to untried specifications and launched on pure grit and determination.

For example, today's immense, advanced and complex semisubmersible, column-stabilized floating drilling and production units, key elements in the largest offshore oil and gas projects, trace their bloodlines back to early submersible drilling rigs that looked like houses on stilts sitting atop a barge. The barge would be flooded and sunk to the seafloor, leaving the drilling house above water. These barges ballasted unevenly; one end would dip down, followed by the other (many old-timers still call them 'one-end-down' rigs) – a process that became riskier as units grew taller to handle deeper water. In 1956, a new submersible named *Rig No. 46* replaced the supporting barge with four immense columns shaped like milk bottles – a feature that would become an industry standard for nearly 30 years. The structure had that shape because a person known only as 'a man from Florida' – his identity is now lost to history – one day came to Paul Wolff and his partner Emile Brinkmann with an odd but engaging idea. Drawing four milk bottles from his briefcase, he placed them on the table in front of the designers and suggested that a few such structures, fitted appropriately to a drilling platform, might make a drilling rig for which ballasting was a smooth operation.

The idea seemed worthwhile; so when they found an opportunity and a willing client, they tried it. The rig performed so effectively that the owner built a sister unit, which later gave birth to the term semisubmersible when, one day, a head driller decided to see if, instead of standing on the seabed, the thing could be moored in place and drill while floating.

The success of those rigs inspired offshore contractor Sedco to obtain units like that for itself, and in 1963, the company asked a prominent New Orleans naval architectural firm to design one. That firm, Friede and Goldman, produced the first purpose-built semisubmersible drilling unit, the ABS-classed *Sedco 135*. Created by pioneering designer Walter Michel, it became a landmark in the history of offshore drilling rigs, and its milk-bottle legs became a standard element of offshore design for two decades.

Able to drill while afloat or sitting on the bottom in 135 feet of water, Michel's design became internationally popular and inspired many variations that were soon seen in offshore fields around the world. Descendants of this design were built into the early 1980s. Five of those later rigs, constructed for the Transworld Company, were converted by Noble Drilling in the late 1990s into deepwater semisubmersibles capable of working in water depths greater than 6,000 feet. In fact, one of them, the ABS-classed *Noble Paul Wolff*, briefly held the world record drilling depth.


SEDCO 135

Developing Drillships and Dynamic Positioning

Experiments with strange devices for drilling in deep water were not limited to the GOM. In 1953, the Continental, Union, Shell and Superior oil companies formed the CUSS Group, acquired a 174-foot surplus Navy patrol vessel named *Submarex* and converted it into what can be called the world's first drillship. With a cantilever platform holding a 40-foot derrick jutting out from the port side, the unit was indeed peculiar looking, but it worked and inspired a number of variations on the concept. Taking the idea a step further, the CUSS Group acquired a 260-foot Navy barge in 1956 and converted it into *CUSS-I*, a more familiar-looking drilling vessel with the derrick mounted amidships.

CUSS-I became famous as the centerpiece of Project Mohole, a US Government-funded attempt to drill through the earth's crust and into the mantle. Knowing the thinnest part of the crust was under the deepest part of the ocean, the scientists figured they needed a ship-mounted drilling rig that could keep station without anchors, a feat it would accomplish through dynamic positioning – the constant adjustment of rotatable propellers that never stopped churning.

The Mohole team leased the *CUSS-I* and called in as drilling consultant the manager of Shell's Marine Division, W.F. Bates, who returned from the meetings convinced that Shell should have such a ship in its exploration arsenal. Shell soon produced a small drillship named *Eureka*, and in 1961 an important technology debuted at the same time in two independent research projects as the two experimental drillships tried to make dynamic positioning a practical reality. The Mohole team tried manually controlled thrusters, and the Shell team, led by engineer Howard Shatto, succeeded in creating a fully automatic, accurate dynamic positioning (DP) control system. Shatto became a leading developer of DP technology and worked closely with ABS over the years to bring increasingly larger and more reliable DP control systems into service.

The first purpose-built drillship, the ABS-classed *Glomar II*, appeared in 1962, and soon after, drillships became popular exploration tools in the offshore sector. They relied on mooring systems to keep station until 1970, when the first DP drillship, the ABS-classed *Sedco 445*, was launched. Six years later, on board the ABS-classed drillship

Discoverer Seven Seas, Shatto introduced acoustic positioning and, later, satellite-based positioning systems similar to those used today.

Introducing the First Rules for MODUs

Advancing into deeper water and increasingly difficult production scenarios during the 1960s and 1970s, drilling contractors and field developers pushed the limits of current knowledge almost on a daily basis and introduced many of the technologies that are critical elements of today's world energy supply chain. As the numbers and kinds of floating offshore equipment grew, a need for industry standards developed, and in 1968, ABS issued its *Rules for Building and Classing Mobile Offshore Drilling Units* – the first classification Rules specifically for the offshore industry.

The product of three years' work with the Offshore Operator's Committee (a group of representatives from companies that pioneered offshore exploration and development), the MODU Rules embodied two decades of cooperation between ABS and the offshore sector. The 1968 MODU Rules covered floating and bottom-supported units and incorporated the latest knowledge in the field, particularly regarding vessel stability and the wave heights and wind speeds that MODUs should be built to withstand.

The authoritative nature of the MODU Rules was such that the International Maritime Organization (IMO) adopted it as its *Code for the Construction and Equipment of Mobile Offshore Drilling Units* (known as the IMO MODU Code), which the organization first published in 1979. The US Government also recognized ABS' technical authority in the field and, in 1978, asked the classification society to develop its *Requirements for Verifying the Structural Integrity of Outer Continental Shelf Platforms*. These requirements formed the basis of federal rules governing fixed offshore oil and gas platforms.

The MODU Rules have continued to evolve and today include a section addressing the structural maintenance of aging jackup drilling rigs, many of which entered service when the Rules were introduced. The original MODU Rules reflected the industry's first efforts to grapple with the difficult problems of defining the environmental loads the rigs would need to resist. One has to recall the actual strength of a 100-year storm, the true wind and wave conditions of the GOM and even the expected life of a drilling rig were still all unknowns. The latest Rules reflect the evolution of this knowledge, supplemented by the new ABS *Guidance Notes on Dynamic Analysis Procedure for Self-Elevating Drilling Units*, which give owners a way to more fully consider dynamic wave-induced loads on drilling units at the design stage.

The Deepwater Promise Pays Off

After three decades of prosperity, the offshore sector suffered its first depression. Between roughly 1983 and 1993, the US oil and gas industry lost more than 40,000 jobs, about 50 percent of its total employment. All along the GOM, shipyards shut down, design houses went dormant, suppliers closed shops and drilling rigs the size of office towers laid idle. Major oil companies, once symbols of wealth and power, underwent draconian programs with Orwellian names like 'rationalization', 'right-sizing' and 'downsizing' – all euphemisms for the wholesale slashing of staff at all levels.

The turnaround came when, in the early 1990s, the US Government released to the public some of the acoustic technologies used to track Soviet submarines during the Cold War. These technologies revolutionized seismic mapping, the investigative process by which oil companies locate oil and gas reserves buried deep beneath the sea. According to one oil major at the time, the development of 3-D seismic mapping improved the success rate of exploratory drilling from 13 percent to 48 percent – with deepwater wells costing $10 to $20 million each to drill back then, a fourfold improvement in the chance of success moved many new projects from wishful to possible.

By 1996, the hard times were firmly part of the past. Oil companies were pouring billions of dollars into a renewed search for energy reserves in the GOM, concentrating most of their efforts in water depths between 2,500 and 7,500 feet. Soon they had ample proof that an immense amount of oil remained to be recovered from beneath the sea. Industry analysts and other hangers-on, who once referred to the GOM as 'the dead sea,' now began calling it 'the new Alaska' – likening the energy potential in its recently discovered deepwater oil reserves to the more than 10 billion barrels found beneath Prudhoe Bay in 1968.

In fact, during the 1980s the frozen North had remained an area of exploration. In the mid-1980s, ABS worked with offshore industry pioneers to develop a variety of unique mobile submersible drilling units able to endure the severe multiyear ice (ice that survives the summers and grows stronger each year) of the North American Arctic. These insular worlds, known as floating caisson units, were artificial islands of either all-steel or concrete and steel construction.

There developed from this early Arctic research a new type of rig named the Concrete Island Drilling System, an immense reinforced concrete structure mounted atop an impregnable steel base. The first of these, the ABS-classed *Glomar Beaufort Sea 1*, was deployed in 1984. In 2003, the unit was moved offshore Sakhalin Island in Russia. There it joined the ABS-classed steel-encased drilling rig *Moliqpak*, which also had been deployed in 1984 in the Beaufort Sea. The *Moliqpak* had been converted in 1999, under ABS class, to a floating production unit for use on the Sakhalin I field. ABS released new *Rules for Building and Classing Mobile Offshore Drilling Units* in 1985 to account for these and other technology advances to mobile rigs.

Semisubmersible drilling units that had been laid up through the 1980s experienced a rebirth through conversion with the activities in deep water during the 1990s. Units like the ABS-classed *Ocean Quest*, built in the 1970s for drilling in water depths to 2,500 feet, received multimillion-dollar refits making them capable of exploration in depths of 5,000 feet and beyond.

Floating production also saw the introduction of dramatic new technology. The tension leg platform (TLP), fixed to the seabed by tubular tendons, was developed in 1984 as a way to handle great depths without mooring chain and anchors, which presented a number of challenges in deep water. In 1996, the spar platform emerged as a potential solution for producing oil in water depths of 10,000 feet.

Rise of the FPSO

One of the key pieces of equipment in many of today's grand deepwater development projects is the floating production, storage and offloading (FPSO) unit. First devised for marginal oil fields (isolated reserves too small to justify the cost of a pipeline), the FPSO proved to be an economical solution for all sizes of projects during the 1990s. In the beginning, FPSOs were nearly all retired single-hull supertankers converted for production use through the installation of modular refinery equipment topsides. The heavily-built, mild steel hulls of pre-1982 tankers were strong and resilient structures that, after a manageable conversion project, enabled the vessels to be moored in place for decades of continuous service. As the world's leading tanker classification society, ABS became involved with developing FPSO technology from the very beginning.

The first FPSO was installed offshore Spain in 1977. By 1992, there were 28 FPSOs in service around the world with an aggregate production of about one million barrels of oil per day (bopd). During the 1990s, the FPSO became a favored solution for large deepwater fields in remote areas without pipelines or that otherwise were unsuited to shore-based refining. By 2002, the number of units in service tripled to 84, with combined production totaling about 6 million bopd.

OCEAN QUEST

Today, nearly 160 FPSOs are in service worldwide with an aggregate production of about 13 million bopd.

These days, most FPSOs are purpose-built rather than conversions; and individual modern units reach outputs of 250,000 bopd and beyond. Brazilian oil giant Petrobras made a specialty of developing FPSOs for its offshore production projects, in the course of which it introduced many innovations that have broad applications – the synthetic mooring rope and the taut-leg mooring system being just two examples. Following the evolution of this technology, in 2002 ABS classed *Sanha*, the first FPSO for liquefied petroleum gas (LPG) production, and began helping clients explore technologies for the production and storage of liquefied natural gas.

Helping Regulations and Technology Advance

As the leading provider of classification services to the offshore sector since its earliest days, ABS has been approached by many governments seeking help in improving the safety of offshore drilling and production in their waters. One example of this is a joint effort led by ABS Consulting in 2005 on MODU mooring performance. It was initiated after the US Government called for industry action following hurricanes Katrina and Rita, which caused extensive damage to energy production in the GOM. In the first major MODU disaster in five decades of offshore oil and gas production, a dozen units broke free of their moorings and drifted, some for hundreds of miles. Although they caused no pollution or loss of life, their path of devastation energized a strong response from the US Government and, as a result, the offshore industry.

Sponsored by the GOM Offshore Operators Committee, the MODU mooring joint industry project delved into the science underlying MODU mooring criteria and discovered that a major new revision had to be made in the way GOM weather was understood. The 18-month project produced a number of technology advances in industry knowledge and field practice. Most notably, MODUs operating in the GOM were required to be upgraded to a new standard of mooring safety, with most units increasing the number of mooring lines from eight to 12.

In March 2011, ABS released the latest edition of its *Guide for the Classification of Drilling Systems*, which took a comprehensive approach to drilling systems and the associated equipment and well control systems. This publication was particularly welcomed by many national offshore energy safety authorities in the wake of the previous year's oil rig tragedy in the GOM.

On 20 April 2010, the *Deepwater Horizon* semisubmersible drilling rig experienced a well blowout, explosion and fire that resulted in the loss of 11 lives and the sinking of the rig. For three months, the flow of oil from the Macondo field could not be halted.

ABS helped reassess the effectiveness of safety regulations, advised on the development of future spill response plans and assisted in developing improvements in workplace safety. In the wake of the incident, governments with energy exploration and development projects in their waters began reassessing their own regulatory oversight of these activities. From the North Sea to the South China Sea, government investigations brought a variety of changes from new safety standards to new spill response organizations.

With local and international regulations on offshore activity becoming more complex and comprehensive around the world, the oil and gas sector has increasingly turned to the ABS Energy Project Development team for assistance with classification and certification services. These include oil exploration, production and support services from the construction of offshore LNG terminals (floating and gravity-based) and such novel transportation methods as compressed natural gas – several ships and technologies for which already have received ABS approval in principle as novel concepts.

Novel concepts often need to be assessed using novel analytical techniques. One notable evolution in the maritime world of the 21st century has been the steadily increasing incorporation of risk assessment and mitigation technologies into classification. The offshore industry has benefited from advances in risk technologies, which ABS uses to determine the safety and practicality of new hybrid designs as they evolve.

In 2007, these efforts were used in the review of the first multicolumn floater, a cross between a spar and a semisubmersible, as well as the classification of the first spar-built MinDOC design in 2009. A brainchild of eminent MODU designer Bill Bennett, the unique structure includes the elements of a semisubmersible but behaves like a truss spar. The design was in development for more than eight years, as Bennett worked with ABS and a team of designers to develop the unit within the requirements of class.

ABS engineers and surveyors have been the silent partners of progress in the offshore energy sector for 65 years. During that time, offshore energy has become a vital part of the industrial world, and as its challenges grow going forward, ABS and its affiliates will be entwined ever more tightly with its future. By helping advance the technologies and operational safety in the offshore oil and gas sector, the people of ABS have left an indelible imprint on the world energy supply chain. ❖

Is the MODU 150 Years Old?

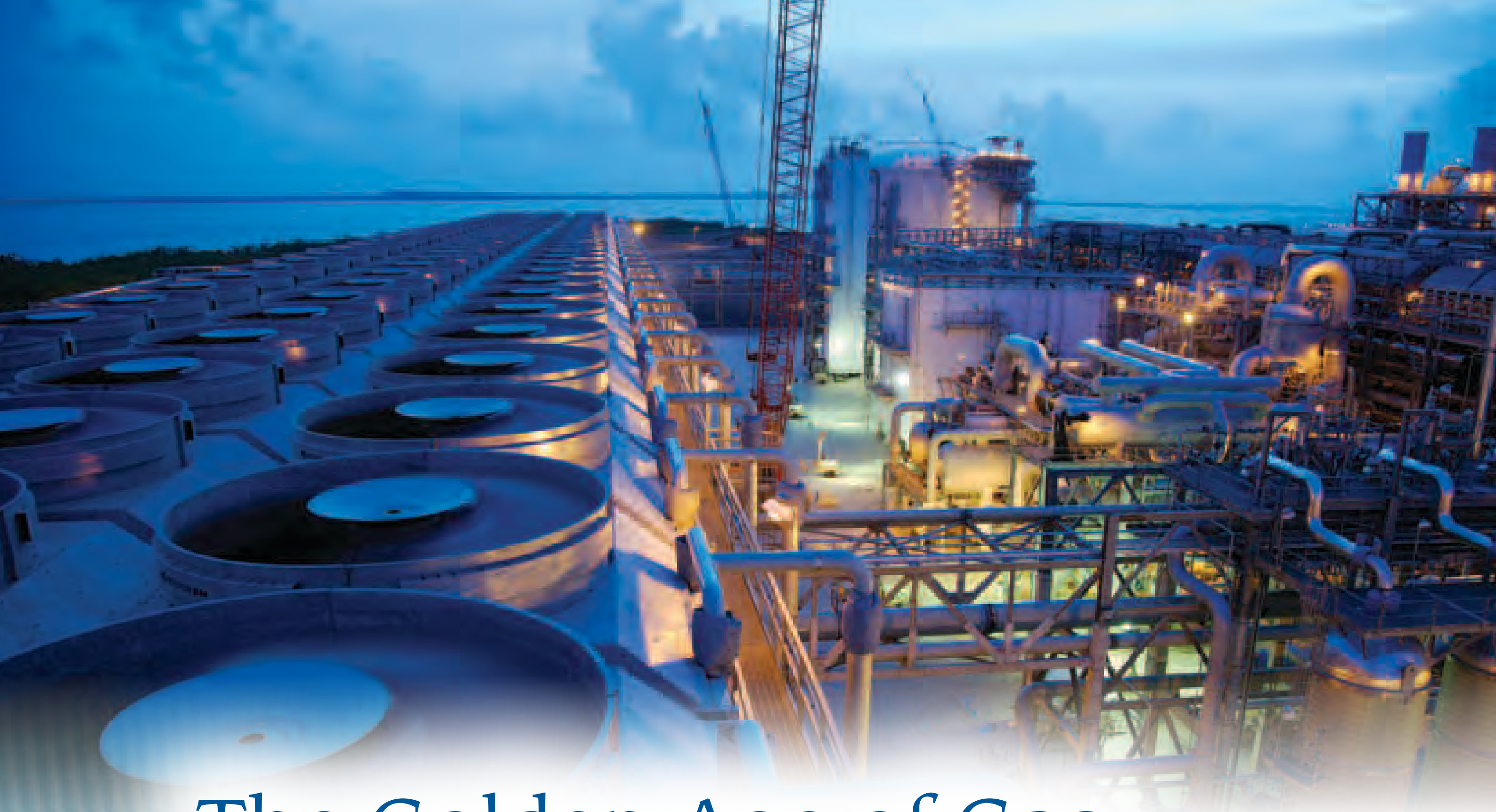
As a concept, MODUs have been around almost as long as ABS has been in existence.

In 1869, an inventor from Brooklyn, New York, named Thomas F. Rowland patented a design for a tender-assisted drilling platform, similar in principal to the Kerr-McGee unit that inaugurated the offshore drilling industry in 1947. Rowland's design called for hydraulically activated telescoping legs that extended to the seabed and could be adjusted to account for the unevenness of the subsea terrain while elevating a drilling platform above the water.

The tender, described in the patent as "a boat, float or scow," contained a steam engine power supply to raise and lower the legs and rotate the drilling table. The steam pump and boiler would be connected to the platform by two lengths of flexible tubing, one leading to the hydraulic drilling motor and the other to the leg elevating manifold. According to the patent, this was to "facilitate drilling while the floating pump is free to rise and fall with the undulation on the surface of the water."

Not long after Rowland's patent was issued, another Brooklyn visionary named Samuel Lewis proposed yet another type of offshore drilling apparatus that might be called the world's first drillship, or at least the first lift boat. Appearing on the cover of the 19 June 1869 edition of *Scientific American*, his patented Submarine Drilling Machine was a steamboat with a gang of drills mounted amidships. The steam-powered drills extended through an opening in the hull and were stabilized by a template on the seafloor. As with many modern MODUs, the hull was raised out of the water through a rack-and-pinion jacking system. The unit was conceived as an intelligent way to chop up the rocky seabed for removal during construction of New York City's Hell Gate Railway Bridge.

Proof that either Rowland's or Lewis' designs were built has not yet emerged, although the article on the latter does mention a syndicate forming to construct the unit. For now, the honor of oldest known jackup unit built must go not to a drilling unit but to a work platform, erected in 1882 by Scots engineer William Arrol to support construction of the second Tay Rail Bridge in Scotland. ◆



The Golden Age of Gas

Abundance, affordability and environmental appeal have moved natural gas from the periphery into the spotlight.

Liquefied natural gas (LNG) is arguably the hottest topic in energy and shipping markets at present. Its potential as one of the 'fuels of the future' is a subject in the news almost daily. Perhaps because of this volume of coverage, it sometimes can be difficult to get a clear picture about the number of ships on order or the size of the market at any one time.

What can be said for certain is that the LNG market is growing fast and changing quickly and that its development is being shaped by multiple factors. ABS' role is to monitor market developments to gain an understanding of how they affect ABS clients – whether in terms of broad trends, technology changes or regulatory demands – and to develop appropriate Rules and guidance in response.

There are several major demand drivers:

- Huge potential demand growth in China
- The trend away from nuclear power globally
- A push to replace other fossil fuels
- Increased use of gas as a transportation fuel

Global LNG demand increased about 15 percent in 2011, and by 2035, its use is projected to rise by 50 percent to account for 25 percent of the world's energy supply. For the shipping sector, increased demand from Asia is the key driver, as the region may consume two-thirds of global LNG supply by 2015. In response, Australian LNG production could increase threefold by around 2020 to supply key customers in China, India and Japan.

The natural gas resource base is vast and widely dispersed geographically. Australia is assuming a leadership role in LNG supply, but North America is on the way to becoming self-sufficient and a potential exporter.

Over the last decade, the United States has gone from being short on gas and needing to import LNG to a potential bonanza in domestic shale gas production. Having completed the process of getting import terminals built, the entire topography of the market has changed and is now leaning toward the US becoming a major exporting country.

Fleet and Market

In terms of ship supply, 2012 will be a year of few deliveries because limited orders were placed in 2009. This is in part due to the high number of orders – some 52 ships – delivered in 2008, which added to a temporary oversupply effect. By 2010 owners began placing orders again, which means a higher delivery profile in 2013 as well as in subsequent years.

In the medium term, ship demand growth is projected to increase from less than 2 percent in 2011 to 7 to 8 percent per annum for the next few years. Some 140 newbuilding orders will be fulfilled over the next four to five years, and the expectation is for the total LNG carrier fleet to continue to expand to 2020.

Lower newbuilding prices in recent years have prompted a number of owners to order LNG carriers, some of them for the first time. Looking both at the price of gas and the demand for LNG carriers, as well as the returns on LNG shipping compared to tankers and dry bulk, it certainly makes sense to see new entrants coming into the market.

Short-period and spot trades have become more common. In fact, spot rates have more than doubled since the end of 2010. Spot market earnings for vessels have hit $145,000 per day and have been as high as $165,000; they could go as high as $200,000 this year. This is explained when one considers that there have been on average 340 LNG cargoes a month shared among 370 vessels, compared to 280 cargoes a month being chased by a fleet of 600 very large crude carriers.

This is another significant change from the traditional LNG market model, in which a producer would build a liquefaction plant and sell all its gas under a 20-year contract with ships built against that contract for dedicated service.

Today the supply of gas on the market is increasing, and this has opened the door to spot trading and arbitrage opportunities, especially given the relative prices of gas in the US against Europe or Asia.

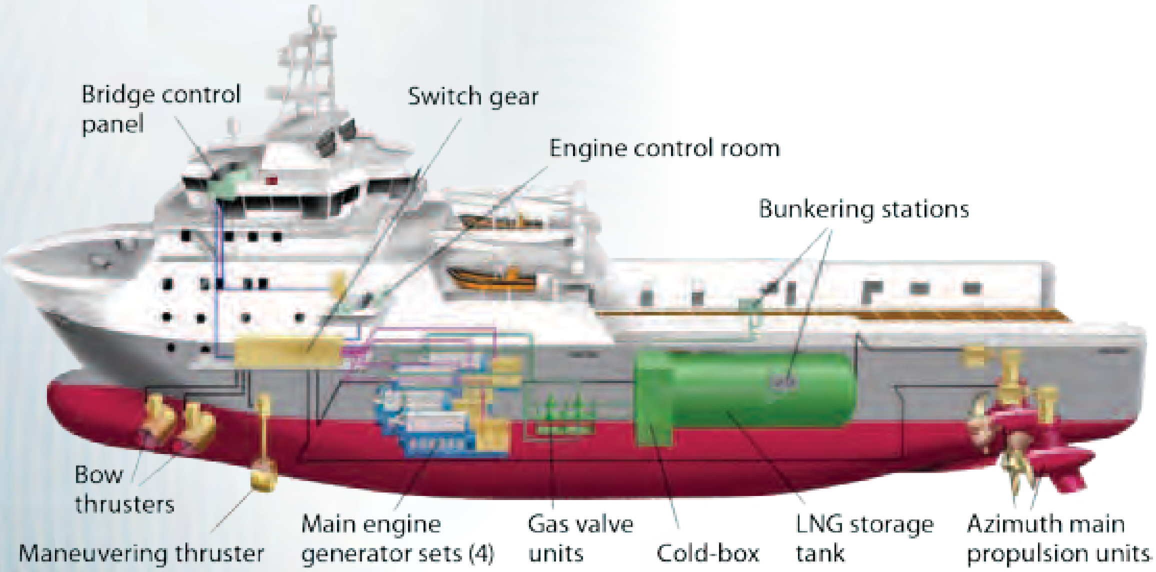
Technology Advances

Recent technology advances have expanded the size of liquefaction and transportation projects, with much larger LNG carriers, floating LNG terminals and compressed natural gas transport options becoming readily available.

The mid-2000s saw a rapid growth in ship size to the Q-Flex and Q-Max vessels built for Qatar Gas of 210,000 m^3 and 260,000 m^3. Today designs of 160,000 to 170,000 m^3 are considered optimal in terms of flexibility at ports and terminals.

Regulations also can affect how technology is deployed. As noted, the US likely will become an LNG-exporting country in the not-too-distant future. ABS is exploring what this reversal in cargo flow will mean and how future regulation might affect the design of ships for operations in the US.

Another area of activity for ABS is the projects in the Barents Sea off northern Russia. For these projects, ABS is developing Rules for LNG operations in harsh environments, working with shipyards on harsh weather designs and tackling the issues that have to be overcome for reliable operations in these testing environments.



Fuel Demands

A significant part of future demand for LNG will come from gas-fueled propulsion for transportation, particularly for ships. LNG carriers already use boil-off gas from the cargo as propulsion fuel, but in the near future there is every likelihood that the industry will see conventional bulk carriers, tankers and containerships powered by LNG as well.

Over and above the environmental benefits of lowering CO_2 and other emissions, studies in the US suggest that by changing from marine diesel to LNG, an owner potentially could achieve significant savings per gallon of fuel used, which given the volatility of the bunker fuel price, is a huge incentive.

Small gas-fueled ships have been in operation in Norway and the Baltic region for some years. Now, interest is growing in the US and other parts of the world in determining how LNG as fuel can be applied more widely.

ABS already has completed joint development projects with South Korean shipyards on large vessel designs and worked with owners including A.P. Moller-Maersk on the practical implications of LNG as a fuel on the current and next generation of large containerships. In addition, Harvey Gulf International Marine has selected ABS as the class society for its four new dual-fueled LNG-powered offshore supply vessels constructed at Trinity Offshore LLC for operation in the Gulf of Mexico.

An important stage in the move toward greater use of LNG will be the completion of the International Code of Safety for Gas Fueled Ships, which will provide a roadmap of what Administrations and regulators will require in terms of infrastructure and operations for bunkering with LNG. In response to the industry's need for technical guidance for new construction and existing vessel conversion to LNG as fuel, ABS released in 2011 the *Guide for Propulsion and Auxiliary Systems for Gas Fueled Ships*.

ABS is also working with engine-makers on technology issues around gas propulsion such as backup requirements and how to achieve optimum efficiency in dual-fuel diesel engines. Work also will be needed to better understand how LNG as a fuel affects a ship's rating in regard to the IMO's Energy Efficiency Design Index, which will be in force in the next few years.

The other major issue that must be tackled when considering LNG as fuel is the need for a broad program of education and training. A completely new section of personnel, including supply boat crews, surveyors and bunker operators, not to mention the ship's officers and crew, will have to be trained to deal safely with cryogenic fuel.

With many more gas-powered vessels in operation, the level of risk is potentially increased, so these risks have to be addressed and mitigated. ABS is developing and will be providing training for its own staff and for industry partners. This will make up a considerable part of the organization's commitment to the new LNG landscape as the world moves forward into a gas-fueled future. ❖

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