A Quarterly Magazine from ABS

Spring 2010

Surveyor

ABS

Wind Energy Marches Out To Sea

In just ten years global use of wind power increased tenfold, from about 13 gigawatts of nameplate capacity in 1999 to nearly 160 GW at the start of 2010. Wind farms today contribute about 1.3 percent to global electricity demand, with 70 percent of that capacity found in five nations: the United States (33.2 GW), Germany (25 GW), China (22.5 GW), Spain (18.3 GW) and India (11.6 GW). Nearly all the world's wind energy – except for 2 GW – is generated onshore, but as coastal countries around the world look to increase their use of wind power, they talk with increasing enthusiasm of building wind farms offshore, where better winds promise higher-output power plants. The European Wind Energy Association (EWEA) is targeting 40 GW of offshore wind farming by 2020, while the US, in a vision articulated by the US Department of Energy in its report 20% Wind Power by 2030, is looking at the possibility of getting 54 GW from domestic offshore wind farms within two decades.

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COVERS:

The world of offshore energy turns on craftsmanship. Here, two workers bring a giant thruster housing towards completion in Thrustmaster of Texas' Houston plant. Dynamic positioning, offshore oil & gas and offshore wind power – and their areas of intersection – are the subject of this issue of Surveyor.

FEATURES:

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ABS Plaza
16855 Northchase Drive
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Tel: 1-281-877-5800
Fax: 1-281-877-5803
Email: abs-worldhq@eagle.org
Web: www.eagle.org

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Joe Evangelista, Editor
Susan Gonzalez, Assistant Editor
Christopher Reeves, Graphic Designer
Sherrie Anderson, Production Manager
Stewart Wade, Vice President

Mario R. Lugo,
Founder and
President,
TEI

Steps Towards the Subsea Dream

Step by step, innovation advances the dream of subsea processing.

In August last year, Brazilian national oil company Petrobras began working with FMC to enhance oil recovery from the Marlim field in the Campos Basin. Once regarded as the world's largest subsea oil and gas development, with 129 wells and eight floating production units, Marlim has been in operation for nearly 20 years, and today the aging reservoir's oil contains an increasing amount of water and sand, which strain and threaten the processing systems.

The solution announced involves a subsea separation, pumping and water reinjection system installed at a water depth of 2,950 feet (900 meters). The undersea machinery will receive the production stream and separate the sand, water, gas and heavy oil. The separated gas will be added to the oil stream to aid its lift to the floating processing unit, while the separated water will be pumped back into the reservoir to boost production. The first equipment is expected to be delivered in 2011, and when the system comes online may achieve two world firsts – first deepwater use of subsea separation in a mature field and first subsea separation of heavy oil and water – and put in place two big pieces of the decades-old dream of subsea processing.

Today, fixed or floating platforms support the processing systems that prepare offshore oil for transport to land. Typically, the well fluids are sent up to the platform where the sand is removed and cleaned for disposal, the water prepared for disposal or return to the reservoir, and the gas treated for export or return to the reservoir.

As the hydrocarbon reserve depletes, the well's natural pressure drops and subsea pumps are eventually needed to move the fluid along. At the same time, the output of a depleting reservoir can contain an increasing amount of water, sometimes up to 90 percent, making the processing facility work harder for diminishing benefit. Worse yet, since water is heavier than oil, the rising water content in the well stream increases the weight of the liquid column being lifted to the platform, causing a back-pressure on the reservoir that further slows the resource recovery rate. At a certain point, it becomes impractical to continue developing an aging reservoir.

Likewise, it can be impractical to even start development if the reservoir isn't big enough to justify the expense of its recovery. The costs and challenges of operating offshore are such that there are an increasing number of such 'stranded' energy reserves. As those costs and challenges increase, so does the incentive to put as much of the processing equipment as possible on the seabed. By eliminating the equipment and expenses of moving uncounted tons of water and sand up and down thousands of feet, subsea processing holds out the promise not only of rescuing stranded reserves and aging fields specifically, but also of bringing radical change to project economics generally.

"I believe that subsea processing will be done within the decade," says Mario R. Lugo, founder and President of Houston-based Trendsetter Engineering (TEI), an engineering consultancy in the energy industry. "At present, subsea systems tend to be very basic, bringing oil from the well, adjusting the choke, putting it on a system, comingling well streams and sending that back to the platform. The industry spent many, many years solving just the subsea trees, connections and controls. Just 15 years ago, comingling was a big step forward – we used to run a line from each well up to the platform," he says.

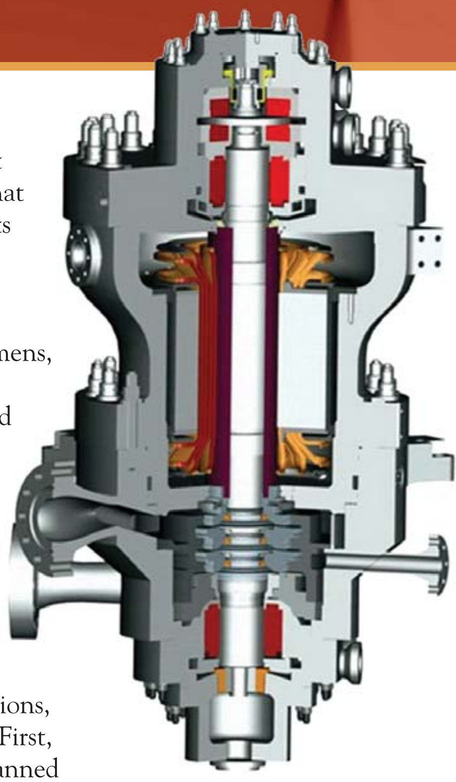
"That level of development work has to be done again, but for a completely new wave of equipment like pumps, separators and compressors. Just the sheer weight of the power cables needed in great water depths is a major challenge," he says. "There are many, many challenges to solve in subsea processing, but there are also many very smart people in this industry working on it to take us the next stage forward."

The great promise that has tantalized generations of subsea engineers is a future of offshore energy development without platforms, in which economical access to the deepest and furthest oil and gas reservoirs is achieved with near-perfect resource recovery. Some glamorous parts of that dream, like remote-control drilling complexes crawling along the seabed, seem right up there with cities in bubbles on the ocean floor, but others are taking significant steps towards reality.

A commercial subsea compressor, for example, may still be a ways off, but is a lot closer to reality than it used to be. For over a decade now, the Siemens Turbo Compressor – Electrical, Canned and Oil-free (STC-ECO) has been the company's platform for evolving the concept of subsea compression. A prototype, jointly developed by Siemens and Shell between 1999 and 2006, was tested for two years onshore with dirty process gases and such contaminants as sand and water. The work produced a canned, seal-less centrifugal compressor with integrated, variable-speed electrical motor drive, magnetic bearings and a solid rotor, in which no electrical part contacts process gas. Siemens reports that the ST-ECO reduces the 600 leak points of a typical compressor to 150, because it contains half the components and no gearbox. The next development stage, begun two years ago by Statoil and Siemens, has Statoil's K-Lab facility in Karsto, Norway testing the unit under simulated subsea process conditions.

Reaching the goal of subsea compression will take at least another decade, because "a revolution is needed in rotating equipment," said Gerrit Lenderink, head of new applications and systems strategy for rotating equipment at Siemens Oil & Gas Solutions, to an industry forum in Texas last year. First, manufacturers have to demonstrate a canned compressor can run for five years without maintenance – currently, reports Lenderink, a typical compressor has a mean time between failures of 1.5 years, 80 percent of the failures caused by liquid ingress – and then one must be installed and proven in the ocean environment.

Innovation sometimes springs from common corporate interests, but often needs the help of a technology incubator with the ability to organize joint projects, like the American Petroleum Institute in the US and the Industry Technology Facilitator (ITF) in the UK. Based in Aberdeen, Scotland, the ITF is owned by a coalition of 21 energy companies, and was established to seek out



STC-ECO compressor cutaway

Jeff Whipple,
Business Manager,
Subsea Systems,
INTECSEA

new technology solutions and innovative ideas and, by organizing joint-industry projects and field development efforts, help bring them from concept to implementable reality. Each year, ITF issues a short list of topics for technology development; the 2010 list calls for solutions to a range of challenges in subsea intervention, including subsea power, well diagnostics, artificial lift and high pressure/high temperature technologies. The organization reports that, since its founding in 1999, it has organized over 150 new technology projects with over £50 million in direct member funding.

One of those projects ITF is helping approach deployment is the subsea water injection treatment (SWIT) system developed by Well Processing A/S, a Stavanger, Norway-based subsea engineering company. Injecting seawater into a reservoir to maintain pressure and enhance oil recovery is a common offshore solution. While effective, it requires the raw seawater be treated before injection, to protect porosity and other aspects of the reservoir, which puts special equipment on the platform and a pumping and piping system to get it to the well. The SWIT changes that scenario by doing the filtering, treating and de-aerating on the sea floor at the injection wellhead. After six years of development, the unit is now in a full-scale, 18-month pilot test program, whose launch in December 2008 and sponsorship by four major oil companies was coordinated through the ITF.

"ITF coordinated the technology development through a structured procedure of investigating the needs for technology advancement amongst its members, soliciting technology ideas (e.g., SWIT) to meet the technology need, assistance with developing the idea into a proposal for JIP development, progression into a Joint Industry Project team amongst ITF's members and contractual and financial organization of the JIP," says David Pinchin, CTO of Well Processing. "Other than the straight cost issues of independent development, the SWIT JIP is proving to be a valuable tool in oil company verification, marketplace recognition and confidence in development of new technology."

Innovative solutions sometimes migrate offshore from other industries. The mechanical arms of remotely-operated vehicles, for example, can trace their origins to the robotic manipulators developed for hazardous materials work in the 1950s by Hughes Aircraft. The inertial reference positioning technologies recently applied to help keep dynamically-positioned vessels on station is a crossover from aerospace. Likewise a pipeline protection technology, proven in subsea applications in the North Sea and poised to enter the Gulf of Mexico, is an import from the processing industry.

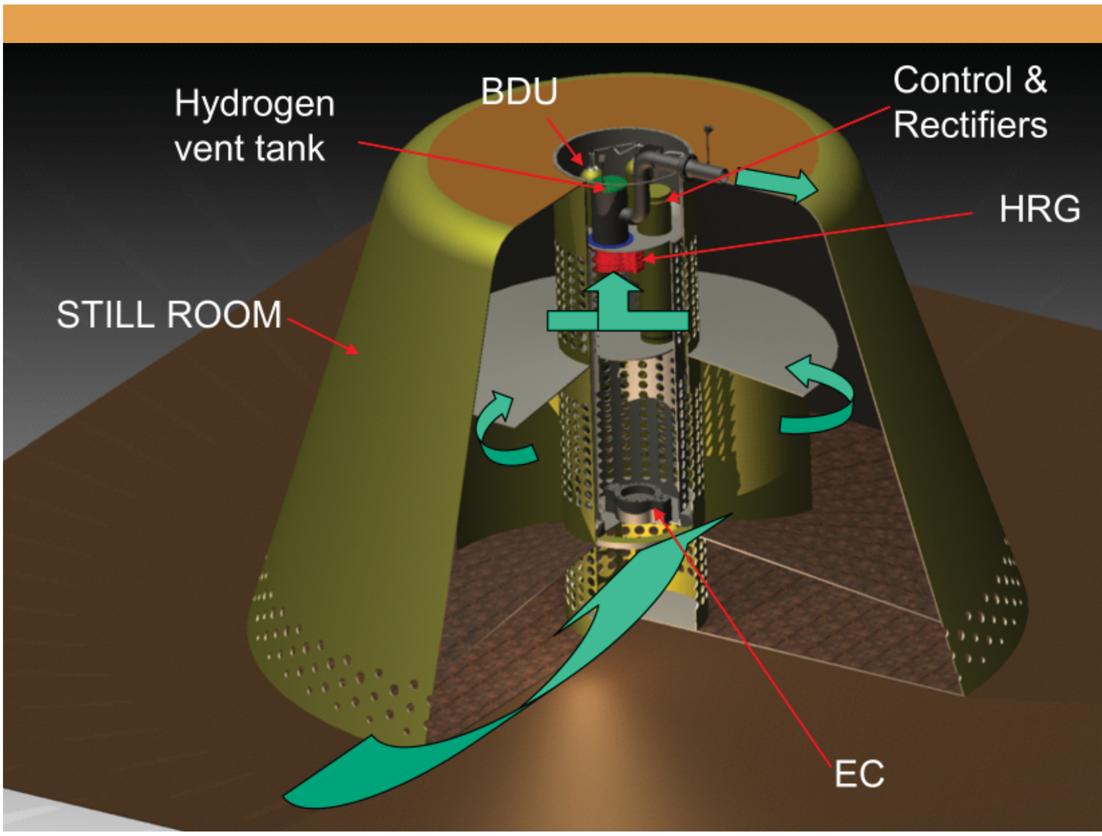
Most of the time, subsea systems – pipelines, manifolds, trees and so on – are designed to withstand the shut-in pressure of the well, which is higher than the normal flowline operating pressures. The High-Integrity Pressure (or Pipeline) Protection System (HIPPS) provides a pressure break between subsea systems rated to full shut-in pressure and a flowline and riser rated to a lower pressure. The HIPPS concept originated in the process refining industry several decades ago, as a means of preventing over-pressurization in the gas lines of chemical plants. In subsea applications where flow assurance supports the project, solutions incorporating HIPPS have safely allowed components to be made to lower pressure ratings, generating system-wide savings in materials and installation.

"Ultimately, the technology moves forward because it gives a savings somewhere," says Jeff Whipple, Business Manager, Subsea Systems for INTECSEA. "A vanguard of a few cutting-edge projects proves the technology, so to speak, and the rest of the industry follows its successful implementation. Consider the Gulf of Mexico: at one time, the shallow water was as unexplored and undeveloped as the deep waters are today. A vanguard of operators went out and developed it, doing it in such a way that others were able to follow. This is how the industry moves forward, and it is why one of the mandates in our business model is to be on the cutting edge of technology development, always pushing the envelope.

"During the 1970s, concepts of remote drilling units were being discussed and presented. In the 1980s, the concept was brought to life as part of a science fiction movie. What I find interesting today, after almost 30 years in the business, is that people are seriously putting forward designs for a remote drilling unit," says Whipple. "It's a long way off, but the mere fact that it's being seriously considered is a major milestone."

Innovation Snapshot:

Subsea Water Injection Treatment (SWIT)



Injecting seawater into an oil well is a recognized method of maintaining reservoir pressure to enhance production and increase hydrocarbon recovery. While a proven solution to production issues, it is also expensive: not just in the cost of the processing equipment itself, but also in the required flowlines running from platform to well and the precious topside well equipment slots it occupies, which operators would prefer using to generate saleable product.

In July 2009, the full-scale pilot of an alternative subsea solution – the Subsea Water Injection Treatment (SWIT) unit – was installed by Well Processing, a subsea engineering company based in Stavanger, Norway. The product of six years of development, SWIT takes in raw seawater and processes it for injection into wells, treating the water so as to prevent the reservoir pores from blocking or turning the reservoir sour.

A patented stillroom concept is the key element in the removal process. The removal process does not use any filters, which eliminates clog up, and there is no required maintenance for a continued operation of up to two years. The seawater is sterilized in a two-stage process: long exposure to electrically-generated hypochlorite is followed by exposure to electro-chemically generated hydroxyl radicals, which are produced through a patented technology. Hydroxyl radicals work instantly and are reported to be 2.5 times more bactericidal and fungicidal than chlorine. The sterilization process is designed for a minimum of two years' continuous operation without intervention.

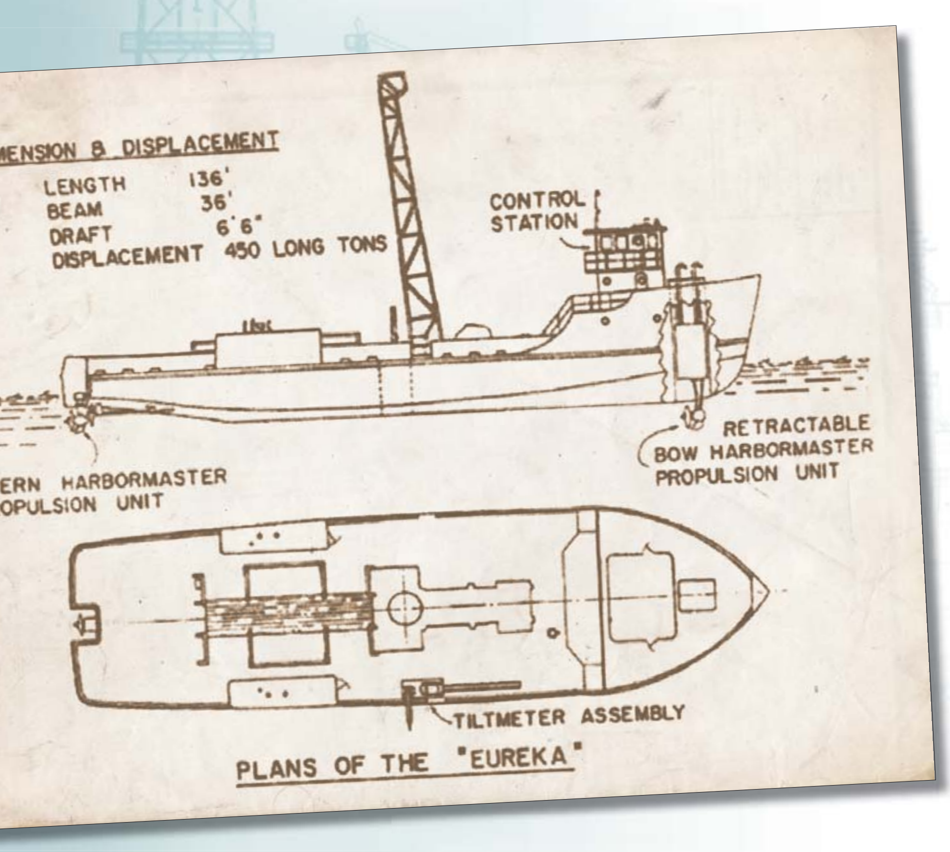
SWIT also provides periodic shock dosing with biocides, similar to conventional topside systems. The developers report that the system's superior sterilization reduces the biocide requirements such that dosing intervals may be extended significantly over topsides methods. The chemicals will need replenishing every two years, but are handled in sealed containers to prevent exposure to personnel.

The SWIT pilot, reflecting a design applicable to 7,500-15,000 barrels per day output, is installed in 60 m of water at a test facility on the Oslofjord in southeastern Norway. Test system includes the still room structure, electrochlorinator, hydroxyl radical generator, and control equipment. Proven equipment such as subsea trees and injection pumps are not included in the pilot. Tests include solids removal, water sterilization, system sterilization and remote monitoring and control.

Today, developers report the system returning excellent results, including an average removed particle size down to 8 microns and an extremely encouraging level of elimination of bacterial contamination in the seawater to be injected. As yet, there are no SWIT field installations, but the full scale pilot currently in operation is sponsored by four major oil companies, most certainly with a view to technology qualification and potential applications.

DP-50

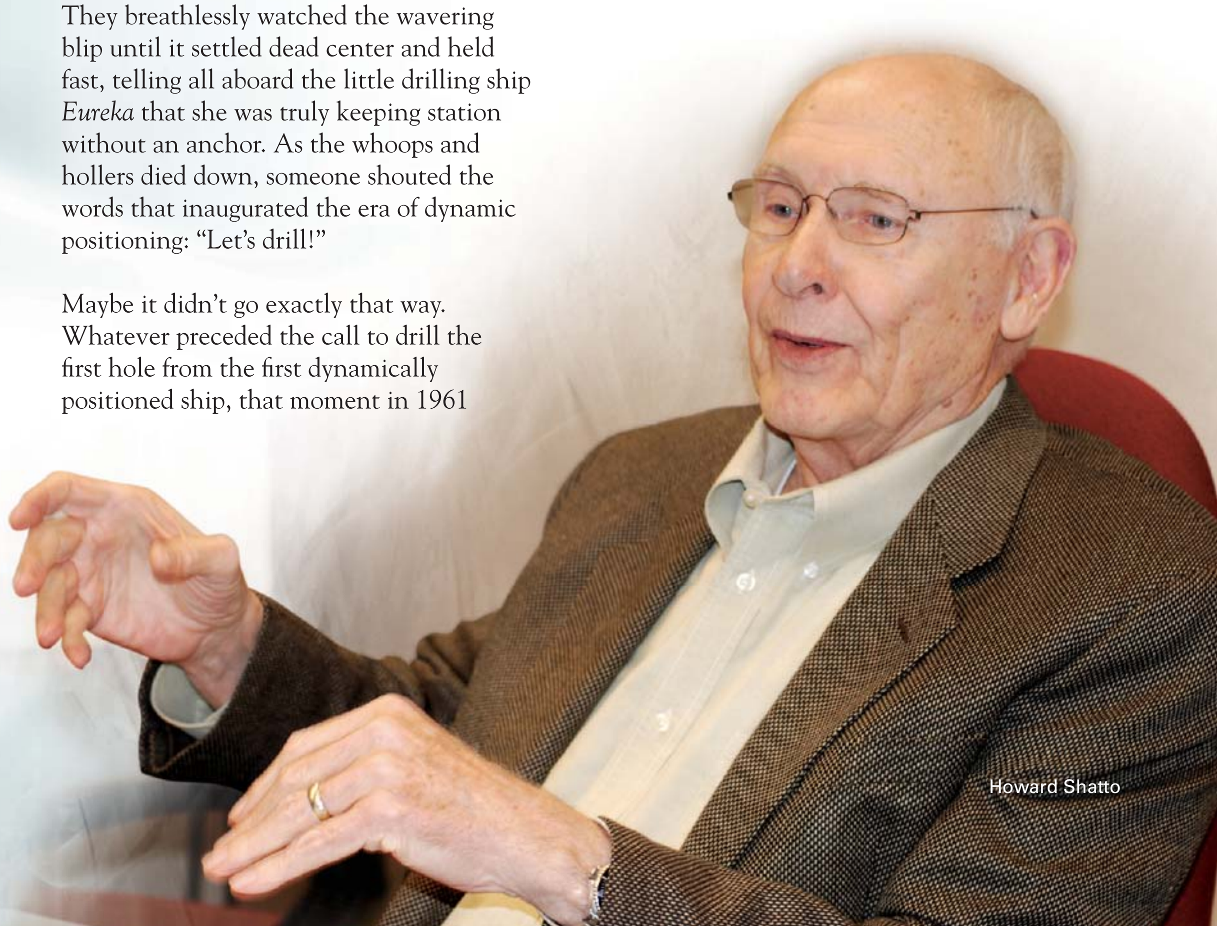
For nearly 50 years, dynamic positioning technology has been



The knobs were set, the switches thrown and all eyes fixed on the oscilloscope screen as a tiny blip darted into view. They breathlessly watched the wavering blip until it settled dead center and held fast, telling all aboard the little drilling ship *Eureka* that she was truly keeping station without an anchor. As the whoops and hollers died down, someone shouted the words that inaugurated the era of dynamic positioning: "Let's drill!"

Maybe it didn't go exactly that way. Whatever preceded the call to drill the first hole from the first dynamically positioned ship, that moment in 1961 did define a technology, affirm its application and set in motion an unending quest to better it. Installed on generations of drilling vessels, dynamic positioning (DP) systems have helped the energy industry extend its reach offshore for the better part of the past five decades. Today, an increasing number of deepwater developments depend on an expanding armada of *Eureka's* descendents.

Some family resemblance remains between that first DP ship and the latest, despite 50 years of evolution. Propulsion on *Eureka* was provided by single thrusters at the bow and stern that could swivel in any direction. Each thruster was controlled by its own throttle and set of momentary-contact pushbuttons, which would rotate the unit left or right. Meanwhile, the ship's position accuracy was indicated by a taut wire leading from a weight on the seabed to a tilt meter onboard. When the ship drifted off station the wire would lean away from perpendicular, its angle of deviation read by the tilt meter and displayed as an X-Y position on the oscilloscope. As initially conceived, the DP operator was supposed to watch the oscilloscope and manually control



Howard Shatto

in the vanguard of offshore energy progress.

EUREKA

the thrusters so as to hold the blip in the center of the screen and simultaneously hold the vessel to a fixed compass heading.

An hour of vain attempts to manually hold position and heading confirmed that the task was beyond normal human abilities. When the automatic electronic interface successfully took over, no doubt remained that dynamic positioning technology would only go forward as a cybernetic union of mechanical propulsion with an automatic electronic control. *Eureka* went on to a successful career in the Shell organization, drilling core samples for the oil major's offshore exploration program. Able to hold station in water depths of up to 4,000 ft (the length of the taut wire), the ship drilled four times as many core holes per month and in water ten times as deep as its moored rivals, despite teething problems that caused position losses about once a month.

Decades of research since those days have elevated DP station-keeping to levels of precision once only imagined, by improving the accuracy of position and heading detection systems, the performance of control electronics and the capabilities of thruster propulsion. Many of the needed technologies advanced for their own reasons, but each added a step towards the main goal in DP development: better reliability for those who need it.

PURSUING RELIABILITY

"The two most important aspects of dynamic positioning are holding power and reliability," says consulting engineer Howard Shatto. Known as the father of dynamic positioning, Shatto developed *Eureka's* position control system and, ever since, has been a key figure in the evolution of the technology. "When we developed that first automatically-controlled DP system, there was no thought of reliability engineering as it is known today," he says. "We used what we considered the most reliable components, but there was no redundancy in any part of the system."

Rather than discuss reliability as such, Shatto prefers to talk of mean time between failures (MTBF). "Reliability, in the strict sense, is the probability that something with a given failure rate will not fail during some particular time period. Mean Time Between Failures – the reciprocal of the failure rate – is more straightforward, especially if given in months or years," he explains. "Our downtime with *Eureka* averaged about 20 percent per month," he recalls. "Fortunately, our consequences of failure were small – some bent drillpipe and the occasional loss of a coring assembly."

The consequences of failure were huge, well-recognized and addressed in the design stage on the next major application of DP: the development in 1970 of *Sedco 445*, the world's first dynamically positioned oil well drillship. Built by Sedco under contract

SEDCO 445

DISCOVERER SEVEN SEAS

Steven M. Jones, Executive Director, IDPOA

to Shell, the vessel was fully equipped with blowout preventers and risers for mud circulation. With the potential cost of damage or downtime reckoned in the millions of dollars, Howard Shatto and his team developed a propulsion system built around mechanical redundancy: eleven thrusters, two main screws, seven engine/generators and duplicate control computers, gyrocompasses, wind sensors, acoustic processors and a taut-wire position system. Six years later, for the drillship *Discoverer Seven Seas*, Shatto was able to include such reliability advances as power management systems and acoustic position sensing. By this time, the MTBF of DP systems had crept upwards to about six months (based on failures significant enough to cause an emergency riser disconnect). By supporting technology advances with such analytical techniques as Failure Mode Effects and Criticality Analysis (FMECA), MTBF was increased to about two years and, with later improvements, particularly the use of satellite positioning, moved up to around five years.

DP technology rapidly took hold in the early 1990s, migrating from drillships and semisubmersibles to diving support vessels and general-purpose workboats, heavy lift vessels and even small support craft. Small-vessel frugalities caused many in that first wave of new DP installations to be non-redundant or 'single-thread' systems (where a single component failure can cause loss of position). As the concentration of vessels in a given work area increased, so did the risk cost of failure, resulting in a constant push to upgrade redundancy and reliability of all DP systems.

Today DP is applied on everything from small tourist boats and large cruise ships to huge semisubmersibles, and the marketplace presents a variety of redundancy options. The technology has greatly expanded its presence in offshore energy projects, where permanently moored deepwater production units often make use of a DP support fleet. In fact, virtually all deepwater exploration and development projects now depend on DP drilling rigs, DP supply boats and DP construction, pipelaying, cable laying, well maintenance, diving and subsea support vessels. Elsewhere, DP systems are increasingly found in the world fleet of tugs, firefighting and salvage vessels.

The result of all this advancement is that there is no authoritative number for the size of the world DP fleet. With many offshore support vessel designs marketed as 'DP-compliant', the availability of retrofit and portable DP systems and the adoption of the technology by new vessel types, not even the sector's trade associations have been able to track its rapidly spreading use. Best estimates indicate there are between 2,100 and 2,500 DP vessels afloat now,

with about 400 newbuilds expected to enter service during the next two years.

The imprecision in fleet count troubles the advocates at the recently-formed International Dynamic Positioning Operators Association (IDPOA). “DP usage is growing wildly,” says Steven M. Jones, IDPOA Executive Director. “The Nautical Institute knows how many DP Operator Certificates it has issued and how many logbooks are in the system; the International Marine Contractors Association knows how many of its logbooks are out there; and the individual companies know how many DP vessels they have. While each entity knows its own piece of the puzzle, the complete picture is obscured.

From a human element perspective, this is very challenging – if we don’t know how many DP systems are out there, we can’t know with certainty whether there is a sufficient, competent workforce to man them,” Jones says, noting that the IDPOA has begun a series of initiatives to boost development and quality of DP operators. “The DP sector can be a real shining light for shipping, with a fantastic record of safety and efficiency, but only if we ensure a competent labor supply as we move forward,” he adds.

Another characteristic of the growing DP fleet is its wide reliability range, which has evolved for good reason, says Shatto. “The reliability needed depends upon the job to be done,” he says. “If the consequence of DP failure in your operation is very great, you need to know exactly where in that range of reliability you are.”

In offshore energy, where loss of position can cause millions of dollars in damage, developers with DP-centric projects are requiring ever more reliability from their support vessels. As risk profiles rise for big-ticket projects, some players are agitating for greater equipment specificity from DP vessel classing conventions.

The base document describing DP equipment classes is Circular 645 from the Marine Safety Committee of the International Maritime Organization (*Guidelines for vessels with dynamic positioning systems*). The document characterizes Class 1, Class 2 or Class 3 equipment according to worst-case failure

Doug Phillips, Controls Consultant, DP

modes. Classification societies base their DP notations on this nomenclature, with some also recognizing a DP-0 rating (a subset of DP-1 used by the Norwegian Maritime Directorate).

For a Class 1 equipment rating, a DP vessel does not need any redundancy, meaning loss of position may occur after a single fault. Class 2 vessels have redundancy such that no single failure of an active component or system (generators, thrusters, switchboards etc.) will cause loss of position. Failure on Class 2 vessels may occur after failure of a static component, such as cables or pipes. Class 3 vessels have redundancy and must also withstand fire or flood in any one compartment without loss of position.

"The current system of classing DP equipment has a kind of machinery mentality to it – it tells you that all the pieces of a DP system are in place, but not whether the vessel can do the job you are hiring it to do," says DP Controls Consultant Doug Phillips. A 35-year industry veteran and Marine Director at Shell, Phillips says reliability would be better served by equipment grades that help charterers perform an activity-specific assessment of a DP vessel before hire.

"Say you hire a vessel with a Class 2 DP system. You know it has three gyrocompasses, three position reference systems and thrusters; what you don't know is whether that ship has the right position reference system for your job, or whether it has the thrust power and control for heavy lift or putting in a riser," he explains. "In my own experience I've had cases where a DP-2 ship is hired and only when it gets out in the field do we find the water's too deep for its acoustic positioning system; where the vessel comes alongside a TLP only to find the platform is moving so much its laser positioning system won't work; or where the vessel finds that its GPS signal gets lost because there's too much structure overhead."

CONSTANT IMPROVEMENT

Dynamic positioning brings together many technology streams, progress in any of which brings DP further along the road to better reliability. Until about twenty years ago, thruster speed control was typically done with variable-voltage DC drives, which are expensive and troublesome. An alternative was to use induction motors run at full speed driving variable pitch propellers, but even in light weather at near-zero pitch this took 20 percent of full power and required extra engines just to sustain the starting surge. The latest systems use variable-frequency AC drives with variable-speed induction motors and fixed-pitch propellers – highly reliable and highly efficient at light loads.

Thruster technology took a big step forward with the commercialization of the 8-degree tilt. Years ago, it was discovered that the wake from a normal, right-angle thruster tends to 'stick' to a vessel's hull, causing friction that subtracts from the thrust force. When the wake crosses the hull, it not only sticks to it but also follows the turn of the keel, where it creates a suction that reduces thrust force even further. Semisubmersibles

have an added problem, in that their thrusters can line up such that the wake from one severely retards the thrust of the other. During development of *Sedco 445*, Shatto found that pointing the thruster downwards by 7 or 8 degrees can improve overall thrust by 20 percent or more. "To not use a tilted thrust is simply wasteful; it should be a rule requirement," he says.

One of the latest advances in position control combines traditional acoustic sensing with inertial referencing, an aerospace technology. Acoustic sensing, which uses sound waves reflected off the sea floor to determine position, is by nature subject to a time lag between readings and signal anomalies caused by the marine environment. Inertial referencing determines position by processing accelerometer readings through calculus computations – integrating acceleration gives velocity, integrating velocity gives position. It is accurate only for short periods, as miniscule errors in sensor readings become magnified over time through the repeated calculations and eventually cause the system to lose its place. Together, the two systems provide a highly accurate, constant eye on vessel location.

Still, if equipment evolution teaches anything, it is that nothing is idiot-proof. As with any industrial technology, the most powerful reliability variable in dynamic positioning is found on the human side of the equation, in the training, experience, aptitude and attitude of the operator.

"The most important factor in successful DP operation is having well-trained, educated and motivated DP operators working within a sound system of procedures and under good supervision," Shatto says. "Some investigators estimate that about half of all DP system failures are caused by the operator. Others say that operators often prevent system failures through quick and appropriate action. My own view is that the majority of failures attributed to operators really trace back to system design issues. Great progress has been made in design over the past 30 years, but still too little effort is devoted to the man/machine interface," he explains. "If designers were held accountable in some way for the consequences of DP failures, I'm sure they would come up with even better systems. For example, much could be done within the normal capacity of modern computers to help operators make correct decisions. Even your word processing program asks if you really want to delete a file."

Meanwhile, the basic goal in DP development remains much as when Shatto developed the technology a half-century ago. "DP is still done with three controllers, one for lateral response, one for longitudinal and one for yaw or heading control. Reliability depends on redundancy and how well your system components are designed and maintained. So, we're always trying to get more holding capability, always trying to make the systems more reliable, always trying to make the operators better – that's what it's all about," he says. "I would like to see DP become more reliable than anchor systems."

DP Developed to Make a Hole in the Ocean

CUSS-1

The offshore energy world is no stranger to the productive power of crazy ideas. It should come as no surprise, then, that dynamic positioning technology, so critical to offshore energy development today, originated in the technical solution to one very peculiar proposal: Project Mohole, an attempt to drill the deepest hole ever, through the earth's crust into its boundary with the mantle, to explore the area known as the Mohorevicic Discontinuity (Moho).

Though theories abound, it isn't known exactly what lies beneath the crust; the Moho is known only through changes in the behavior of seismic waves. So in the late 1950s, Walter Munk, a scientist at the US National Science Foundation (NSF), proposed drilling into the Moho to have a look. The NSF accepted the challenge, referring to Project Mohole as the geological version of space exploration, and handed its management to the American Miscellaneous Society (AMSOC).

Possibly the oddest government think-tank in US history, AMSOC was created in 1952 by the Geophysics branch of the Office of Naval Research to examine proposals that couldn't be categorized. It soon developed a reputation as a board of eccentric academics with a taste for absurdity and amusement. The purpose of one of its earliest committees, for example, was to inform animals of their proper taxonomic classification; another's was to establish groups around the world for the proper greeting of visitors from space. AMSOC also established a not-exactly-annual award for the under-appreciated field of oceanography: a stuffed adult male albatross that had been swiped from a storeroom in the Scripps Institute. Although the group officially dissolved in 1968, the bird is still occasionally flipped to a deserving oceanographer.

AMSOC's Moho committee was most likely its most serious endeavor. The Mohole team, led by scientist Willard Bascom, thought the best way in would be to drill through the seabed where the crust is thinnest (about 7 km in some spots, as opposed to 30 to 50 km beneath land). That meant drilling in water depths of some 11,000 feet, which they thought would be possible if a drilling ship could be made to hold position using thrusters alone. AMSOC called in a drilling consultant, W.F. Bates, who was then Manager of Shell's Marine Division. Struck by the industrial potential in this concept called dynamic positioning, Bates returned home convinced that Shell should build such a vessel as a core drilling ship – the perfect complement to the company's research efforts for its growing offshore oil exploration program.

Soon, dynamic positioning technology was being developed on two different drillships at the same time. In one project, AMSOC persuaded NSF to rent *CUSS-1*, a Navy surplus barge that had been converted into an anchored drilling rig for the purpose of

Shell developed dynamic positioning and remotely-operated vehicle (ROV) technology together. Shown here, an ROV from leading DP manufacturer Kongsberg.

developing floating vessel drilling. Named for its backing consortium of Continental, Union, Superior and Shell oil companies, the *CUSS-1* was outfitted with four steerable engine-driven thrusters to test this idea of holding still enough to drill. Despite the difficulties of manual control, their tests in 1961 were successful enough to keep the vessel within a 180-meter radius and take cores in water depths to 11,000 ft.

Project Mohole team aboard the CUSS-1 off Guadalupe Island in 1961.

In the other effort, Shell's purpose-built drillship *Eureka* was also intended to have manually-operated thrusters, but the fully automatic Dynamic Positioning control was conceived and built just in time to be installed as she prepared to leave the shipyard. *Eureka* held position automatically within a few feet of its set point.

While *CUSS-1* was a public project, *Eureka* was part of a top-secret R&D effort in which Shell developed dynamic positioning, remotely-operated vehicles (ROV) and subsea wellhead technologies. Their offices were placed in the basement of Shell's Los Angeles offices, unlisted in any telephone directory and never discussed in an unsecure location. Before going home each day, the researchers would place their work in shopping carts, wheel them into a big vault and lock it up for the night.

Though very successful, there was one drawback to the secrecy, says Howard Shatto, the engineer who developed the automatically controlled dynamic positioning technology. "When we tried to get leases in deepwater offshore, the California State Land Office told us that, because there was no company that can bid against us, we would have to share the technology," Shatto says.

"So, we put a three week school together in 1963 and invited the industry, at a tuition fee of $100,000 per company, each of which could have five students in attendance. We got about a hundred students, including some freebees for licensees," he recalls. "When it was over, the head guy from Humble Oil (now Exxon), who had come along because he authorized the expense, stood up and told us that he had come with misgivings but that this was the best money Humble ever spent – 'pure gold', he said. And it was."

From the Front Lines:

At Thrustmaster, a Relentless Pursuit of Reliability

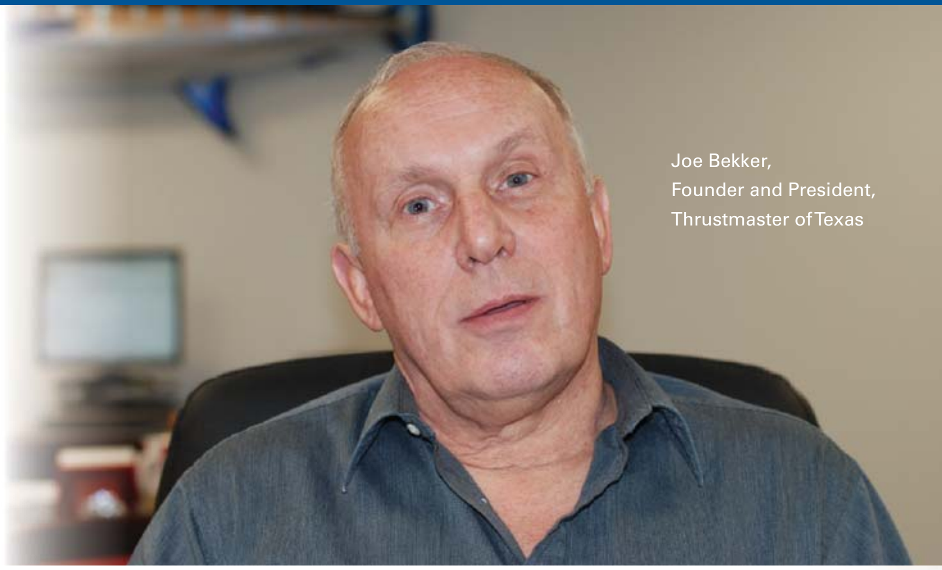
"Reliability is even more important for thrusters than for the DP control system," says Joe Bekker, founder and President of Thrustmaster of Texas. "I say that because thrusters are mechanical systems, mounted under a drillship where they cannot be accessed for maintenance or inspection, but where they operate 24 hours a day, 365 days a year, and are expected to do so for at least five years before they get inspected. Therefore, the thruster manufacturer must always be working to make his systems more reliable."

Established in 1984, Thrustmaster designs and builds tunnel thrusters, azimuthing thrusters and retractable thrusters ranging in power from 35 hp (26 kW) to 10,750 hp (8.0 MW). Among the world's leading thruster manufacturers, the company has its headquarters in Houston, Texas and its dedicated service centers in Singapore, Dubai, Rotterdam, Rio and China. Last year Thrustmaster celebrated its 25th anniversary by opening a new head office and a 200,000 ft² manufacturing facility, the largest thruster shop in the world under one roof.

The company manufactures its own components, hydraulic systems, lubrication systems and control panels, building almost everything in Houston. In support of its manufacturing, research and development efforts, the new facility incorporates an internal school, classrooms and a laboratory. "We train the people we hire to be proficient at the specialist welding, machining and electrical skills required to make our thrusters," says Bekker.

About 70 percent of Thrustmaster's annual $100 million in sales is exported outside North America. While its thrusters are installed on everything from cruise ships to tugboats, the company has seen much of its business in recent years come from the booming world of dynamically positioned (DP) vessels.

"DP has always been an area we have concentrated on," says Bekker. "As the offshore industry moves into deeper waters and mooring systems become uneconomical, they turn more and more to dynamic positioning for drilling equipment and support vessels. At the same time, the fields in shallow waters are getting so congested that anchors can cause problems with undersea infrastructure. We therefore see a continually expanding worldwide thruster market for the next ten years or so."



Joe Bekker,
Founder and President,
Thrustmaster of Texas

Reliability improvements to support that expanding market take on forms great and small. One large-scale example is Thrustmaster's thruster housing, which is produced as one big, integrated steel weldment. "Other thruster manufacturers make their housing of separate cast iron sections and a nozzle that are all bolted together – a perfectly serviceable solution if you can ensure the tightness of the bolts," says Bekker. "Thrusters are subject to a lot of vibration and the bolts of a bolted housing can sometimes loosen. There have been a number of documented cases where the whole nozzle has come loose and damaged the propeller. Welding eliminates that possibility."

On a smaller scale, internal reliability is bettered through better seal design. "Historically, seals have always been a bit of a weak point on thrusters," he says. "These large thrusters are filled with high-grade gear oil, which no one wants leaking into the sea. Conversely, neither does anyone want seawater leaking into the gearing. So, for our propeller shafts we use two seals – an inner mechanical seal that makes sure the gear oil stays inside the thruster, and an outer mechanical seal that makes sure seawater doesn't enter."

Between the two seals is a cavity that is used to monitor the seals. Any leakage from either seal enters this cavity and is drained to a tank for safe disposal. The mechanical seals are good for the life of the thruster, which is typically 25 to 30 years. In another internal reliability improvement, Thrustmaster recently began a condition monitoring program, in which instrumentation inside the thrusters allows the operator to monitor the condition of the bearings and gears.

Behind its new manufacturing facility, Thrustmaster owns 19 acres of land where it is installing the future. Presently under construction is a test pond measuring about 450 ft long x 200 ft wide x 30 ft deep, where it will perform full-scale testing of large thrusters. "We'll be studying the bearing load variations and strain of load bearing components of our thrusters in transient conditions with the thruster in the water under full power. There's very little literature about this," says Bekker. "It is research we feel we must do to make our thrusters totally reliable."

"We're not just following what the other thruster manufacturers around the world are doing," he adds. "We are developing a better product."

New Jacking Criteria for a New Era

Arturo Revenga,
Assistant Chief Engineer,
ABS

The jacking systems on modern self-elevating, mobile offshore drilling units (MODUs) are the product of a half-century of incremental evolution based on operational experience and, as such, are proven, robust designs. Classification Rules for jacking systems were introduced by ABS in 1968 as part of the industry's first set of MODU Rules and, like the rigs themselves, developed incrementally as experience grew. The newly-revised ABS jacking criteria reflect not only this evolution of equipment and experience, but also some of the forces shaping it.

New applications receiving attention include Arctic drilling and wind farm installation, while special sections focus on such design considerations as low-temperature materials and fatigue. The Rules also reflect industry concerns that grew out of the jackup building boom. The rapidly expansion of the jackup market attracted a number of newcomers to the business – from rig owners and designers to manufacturers – who had no previous direct experience with the technology, and who began making design decisions that troubled industry veterans.

"Traditional jackup owners and designers are very knowledgeable, with many years of experience," says Arturo Revenga, ABS Assistant Chief Engineer, Offshore. "We all began to be concerned about the actions of some new players who, for example, may think that any gear manufacturer can make a jackup jacking system and do not recognize the unique nature of this equipment. The industry wanted to do all it could so that safe structures would continue to be built, and so it brought together its knowledge and operational experience so that the jackup safety principles that have been applied so successfully, and for so long, are clearly preserved in the Rules in a way that anyone can follow," he says.

Traditional rig designs incorporate very high safety factors, which, he says, reflect first-hand understanding of rig survivability in severe storm conditions. Lacking this experiential prudence, newcomers may be tempted to economize in their designs by using lower safety factors and Rule minimums. This "can lead to a situation where a design meets the basic requirements in theory, but in fact may end up with safety concerns because of unknown factors arising, for example, during welding, grinding or other manufacturing processes," Revenga explains.

Three main areas in the new criteria that were developed with industry assistance concern materials, mainly for low-temperature environments; strength analysis, mainly as regards fatigue; and the holding capacity of the brakes.

"The jacking system serves a unique function: it is both a critical mechanical and structural system," says Gamaralalage

"Karu" Karunaratne, Senior Engineer with ABS' Offshore Engineering Department. "The entire platform hangs on the legs via the jacking system – if the jacking system fails you may have a total collapse. This is the risk that is involved when you have manufacturers that are not familiar with the uniqueness of jacking systems," he explains.

"If you design and manufacture a jacking gear thinking it is just another gear, then the industry will start to have problems," adds Revenga. "Yes, it's a gear, but it is critical, and the loads are so large, that it must be treated as a unique gear. That's one of the reasons why, in the proposal for the Rule changes, we said that that we are treating the jacking system not just as a mechanical system, but also as a structural system. While jacking, it is a machinery item; however, when the unit is elevated, the holding mechanism acts as a structural element, transmitting the loads from the hull to the legs."

The two main jacking systems in the market today are rack-and-pinion and yoke-and-pin, although the latter has not been installed on a newbuild drilling rig for some time. Lately, alternative designs and the occasional strange concept have begun appearing, prompting ABS to write a section into the Rules specifying that novel designs not covered under rack-and-pinion or yoke-and-pin technologies must be considered using special analytical means. Other design elements reflected in the new requirements include toughness criteria for materials in low-temperature applications, buckling and fatigue criteria, mechanical components or alarms, controls and monitoring systems.

The new criteria for jacking systems were developed with the strong participation of an ad-hoc industry group, formed from members of the ABS MODU Special Committee and some invited major manufacturers, which worked with Revenga, Karu and other ABS personnel between August and October last year. "The people on the ad-hoc group worked very hard and were very helpful to us, sharing their information and understanding and bringing the operational experience needed to make Rules that are valid and reflect real current practices," says Karu. "We had designers, manufacturers, operators – a very extensive range of people, all of whom brought different points of view and gave us good insight into where we had to take the Rules and how to get there."

"For example, we included the requirement of submitting a Failure Modes and Effects Analysis (FMEA). Although the Rules always included basic objectives – the basic objective for a jacking system is that, after a single failure, the unit is not going to have an uncontrolled descent – they did not always indicate how it can be proven that the basic objective is met," he says. "Through an FMEA, it will be possible to demonstrate and document that a single failure will not cause an uncontrolled descent of the unit."

One objective in the Rule development effort was to formalize the collective knowledge ABS accumulated and applied over the past decades of jackup evolution. "The basic idea was to put all our knowledge into words, in a formal, more user-friendly manner," says Revenga. "We also added new requirements to reflect technologies and methods that have come into use in the energy industry and are being, or will be, applied to jackups."

"Being the leader in offshore classification gives us the responsibility to reflect the state of the art," he adds. "That is why we are pushing our Rules forward all the time – to remain in touch with the evolution of the industry – and that's what we did here. The idea is to think of the future, of how the industry is evolving and of how the Rules must evolve with it. In the end, the new requirements for jacking systems are nothing more than the normal evolution of the ABS Rules, so that they reflect the state of the art at the time they are written," Revenga explains. "For me, that is what most important: that the Rules we create today are going to be useful into the future."

Gamaralalage "Karu" Karunaratne, Senior Engineer, ABS

A Flag State's Approach

By Robin Phillips, Deputy Director, Bahamas Maritime Authority

It often appears that flag States are inflexible and show a lack of appreciation for the offshore industry, in their earnest pursuit of applying regulations to the letter. It is a relatively simple matter for the BMA to apply international codes and conventions to mainstream shipping; but offshore ships are individual specialised vessels, whose mode of operation is often outside that envisaged when safety, security and environmental regulations are developed and applied through IMO. Occasionally, guidelines are issued by IMO in order to apply the regulations which appear to fit this sector best.

There is a range of tools available when it comes to the regulation of ships. In addition to the mainstream Conventions and Codes, such as SOLAS, MARPOL, Load Lines and STCW, there are also supplementary Codes such as the Code of Safety for Special Purpose Ships, MODU Code, Code of Safety for Diving Systems and importantly (from a manning perspective) IMO Assembly Resolution A.891(21). In addition to those above, there are a number of smaller codes, guidelines and circulars which may be implemented or referred to, such as the OSV Code and Guidelines for the Training and Experience of Key DP personnel. The Special Purpose Ships Code (2008), while benign in its intention, has caused some Administrations, Bahamas included, to query the intended application of specific requirements. It is expected that these matters will be resolved shortly.

As an example of the "grey areas" associated with offshore vessels, a Bahamas Recognized Organization notified the BMA that the diving system on board one of their Bahamian ships was not surveyed under class rules and was not in fact subject to inspection or survey under any statutory regime. A Bahamas Information Bulletin on this matter was quickly issued for future guidance. This required in essence, that all diving systems should be subject to inspection and survey under either a classification society or a statutory regime. The statutory regime that we chose to give effect to by issuing the bulletin is of course the Code of Safety for Diving Systems. However, like the SPS Code it is not a mandatory Code unless the Administration makes it so.

As an example of the influence that The Bahamas can exert, a major charterer noted that particular development, and immediately required that the Code of Safety for Diving Systems be applied for all its chartered ships, based on the Bahamas Bulletin.

Sometimes, due to the type of ship or operation that it is involved, the MODU Code might be more suitable to be applied than straight SOLAS. If the vessel is not a drill ship, only the relevant aspects of the MODU Code are surveyed against, resulting in a "modified MODU" or "MOU" certificate being issued. Due to the poor fit of some offshore vessels to the regulations, the BMA have produced a matrix with cross reference of ship type, ship shape, semisubmersible, drilling, non-drilling, etc. against the various available Codes and conventions. This enables a broad overview of applicable regulations to certain types of vessel, although there are no hard and fast rules regarding application of this matrix.

In order to clarify interpretations and implementation of Resolution A.891(21) for manning requirements, the BMA has introduced an information bulletin on this and also modified the vessel safe manning document to more accurately reflect the actual

to Offshore Regulation

Robin Phillips, Deputy Director, BMA

qualifications and experience of people in the industry.

Flag States are aware of the risk based safety culture in the offshore industry. This appears to work well, judging from the industry's safety record. It is recognized that there is a future for risk assessment within the statutory regime. Risk assessments are carried out in relation to the rule-making process at IMO. Risk assessment in rule-making is already being explored by classification societies. Risk assessment is already accepted by BMA as justification or mitigating factor in applications for equivalence to some regulatory requirements.

Many offshore ships appear to have difficulty complying with the prescriptive requirements of SOLAS Chapter III or MODU Code Chapter 10 on lifesaving appliances (LSA) due to additional demands made of them in operation. Occasionally a charter may require 20 extra persons on board, and the ship might need an exemption for having inadequate lifeboat capacity. It is likely that an exemption will be issued, provided that temporary "equivalent arrangements" are in place. However, for future contracts we would expect that the LSA be upgraded, as a second request for temporary exemption or equivalent arrangement indicates that this is an ongoing or regular situation.

There are no second class citizens at sea, regardless of rank, race, creed or color. Everybody is entitled to exactly the same chances of survival in any abandon ship scenario. It has long been recognized that the lifeboat is the seafarers' primary means of escape. However, there are various permutations of life raft and lifeboat capacity allowed under SOLAS, MODU and the SPS Code. What is important is that a shipowner has a single regulatory regime applied to his vessel and does not selectively determine which element of the various Codes and Conventions are deemed to be applicable to his unit. The BMA has also had to consider applications for exemption from LSA capacity, based upon the additional presence of a stand by vessel. There are obvious merits in considering that scenario on a contract basis, but it is clear that full compliance is preferable, as the BMA will often have no control over what LSA is carried on board the standby vessel.

When Bahamas Recognized Organizations apply for exemptions or equivalent arrangements on behalf of a ship manager, supporting technical information will accompany the application, so that it may be properly considered. This is usually received by email. However clarifications by telephone and/or meetings are often the best way to ensure that the situation is fully understood by all concerned.

The BMA's strategy for offshore regulation is constantly developing but can only maintain the pace of development with input from industry. To this end we are in almost constant dialogue with shipowners and Classification Societies on the many offshore projects. We also work closely with the International Maritime Contractors Association and its members, in the course of our daily work, at IMO and at the IMCA annual seminar. The annual seminar in particular has proven to be both an excellent opportunity for networking and an educational experience for the BMA.

Offshore Wind
Picks Up Speed

Invigorated by a national focus on renewable energy supplies, the US wind power sector prepares to take its technology offshore.

"We are establishing a program to authorize – for the very first time – the leasing of federal waters for projects to generate electricity from wind as well as from ocean currents and other renewable sources. This will open the door to major investments in offshore clean energy."

■ *US President Barack Obama, April 2009*

By end 2009, over 60 governments around the globe had policies in place supporting programs to pull an increasing proportion of their power portfolios from "renewable" resources – energy reserves replenished by nature, such as sunlight, water and the wind. After more than a decade of effort, many of them had product as well as policy. Incubated in the warm embrace of financial incentives, subsidies, feed-in tariffs and mandates, the renewables sector blossomed as global use of renewable energy increased more than tenfold in ten years. A bright spot in that flowering came in 2007, when, for the first time, renewable energy sources (other than conventional hydroelectric) accounted for the largest portion of power capacity addition in the US. In 2008, renewables accounted for more than half the total added power capacity in both the US and Europe.

The wind power sector, which presently contributes about 1.3 percent to global electricity demand, has been particularly energized during all this activity. Over the past five years, worldwide installed wind generation capacity has more than doubled, from 59 GW in 2005 to 160 GW at the start of 2010. Today, five countries boast over 10 GW installed wind power: the United States (33.2 GW), Germany (25 GW), China (22.5 GW), Spain (18.3 GW) and India (11.6 GW).

The US became the leader in installed wind power in 2008, when national investment in new energy capacity hit $24 billion. The US American Recovery and Reinvestment Act of 2009 continued the renewables momentum, specifying more than $70 billion in direct spending and tax credits for clean energy and associated transportation programs. As 2010 began, the United States had 23 wind farms in place, 57 more under construction and, more significantly, an articulated vision of where wind energy could be taken.

That vision was expressed in *20% Wind Energy by 2030*, a report published in July 2008 by the US Department of Energy. Known as the 20 by 30 Report, it analyzes

the promises and challenges of realizing an energy scenario in which wind generation provides 20 percent of US electricity by 2030. Its '20 percent wind scenario' calls for the installation of over 300 GW wind energy capacity in 20 years, more than twice the current world total. Of that, the report envisions 54 GW coming from offshore wind farms.

Offshore Challenge

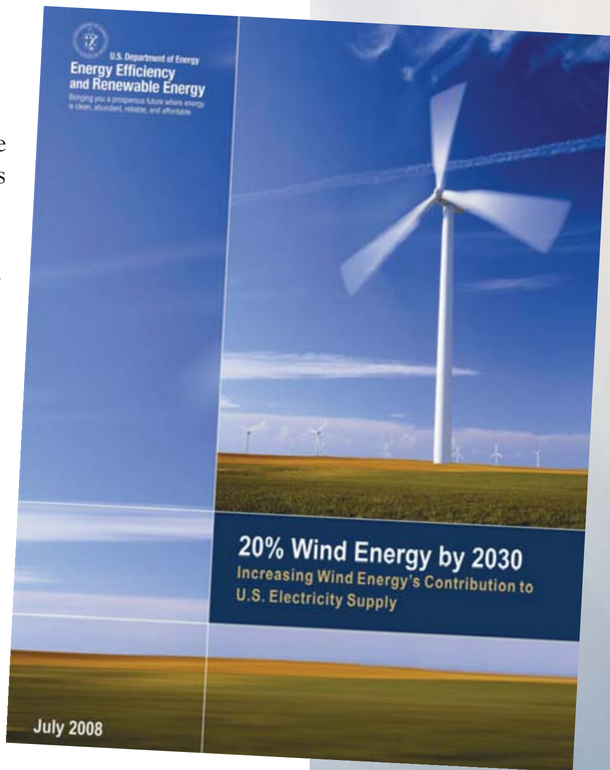
There are currently no offshore wind farms in US waters, which makes the 20 percent wind scenario seem quite the ambitious goal. The report's authors acknowledge as much, but conclude that the Scenario could be feasible if its technical challenges can be overcome. The Department of Energy (DoE) has undertaken that technological development through its Wind and Hydropower Technologies Program, which works with industry partners to increase the performance and reliability of large wind technologies while lowering the cost of wind energy. The Department reports that, between 1998 and 2007, its research efforts helped increase average turbine capacity factor (a measure of productivity) from 28 to 35 percent of nameplate output. In addition, the wind program has helped develop improved turbine components, improved blade materials and even some commercially successful turbine units, including a 1.5-MW design for GE Wind Energy and a 2.5-MW design for Clipper Windpower.

Last year saw some important legislative hurdles cleared that brought offshore wind farms a few serious steps closer towards reality. In early 2009, the US Minerals Management Service (MMS), which governs development of resources in Federal waters, achieved a memorandum of understanding with the Federal Energy Regulatory Commission (FERC, the other US energy project siting authority). Under the agreement, MMS became the lead agency for offshore wind projects and FERC the lead agency for offshore hydrokinetics. In April the MMS released its Final Rule for permitting offshore wind projects and in June issued leases for data collection at five proposed wind farm sites offshore New Jersey and Delaware. The meteorological testing towers for these new sites are scheduled to go up this year. MMS then began moving towards issuing Requests for Interest in offshore wind projects from other states, the first of which are expected to go out to East Coast states during 2010. For the sector's trade association, the American Wind Energy Association (AWEA), these achievements are true milestone moments.

"It was absolutely huge to have the MMS rule come out; we waited years for it," says Jennifer Banks, AWEA's Offshore Wind and Siting Specialist. "We're in a really good place now, because we have a lot of support from the Administration, particularly from President Obama and Secretary Salazar (Department of Interior). There are still things that need to be addressed in order to realize the full potential of offshore wind, but with the rules now in place the outlook is very promising. There is still a lot more to do, but we are very excited at how far we've come."

Jennifer Banks, Offshore Wind and Siting Specialist, AWEA

Founded in 1974 during the country's first Energy's Crisis, AWEA has been patiently waging its campaign of awareness, advocacy and assistance to the US wind sector for 35 years. The perseverance is now paying off, as the association's membership, which ranges broadly from parts manufacturers to service providers, has hit an all-time high of 2,500. AWEA provides a sort of consultancy to its members through outreach programs that extend from legislative guidance to R&D support. Recently approved by the American National Standards Institute (ANSI) to develop US wind power standards, AWEA has also begun an evolution from trade association to standards authority, much like the American Petroleum Institute did during the 1970s.



"Members come to us with issues they are facing – for example, in the permitting realm – and ask us for guidance," says Banks. "For offshore wind in particular, we do a lot of work on the legislative front. We also interact with the Department of Energy as far

In 2008, the US became the leader in installed wind power. However, there are currently no offshore wind farms in US waters.

as supporting research and development," she adds. "Our R&D Committee provides input when DoE creates its budgets, in terms of what the association sees as the most important R&D drivers for the industry onshore and offshore."

Broad Support

From the AWEA point of view, topping the to-do list for realizing the dream of offshore wind farms is establishment of a national Renewable Energy Standard (RES), a government mandate used around the world, and in a number of US States, specifying that power providers purchase a percentage of their electricity from renewable sources.

"We think the RES will drive both the onshore and offshore wind industries," says Banks. "If you have an RES on the East Coast, for example, a lot of those states would have a hard time meeting their RES requirements without offshore wind, as most don't have enough land area for alternative energy. Another thing the RES would do for industry, on and offshore, is send a clear message that the US is dedicated to the renewable energy sector," she adds. "That would allow us to build up our supply chain and encourage turbine manufacturers build facilities here."

Another item high on AWEA's list is the establishment of a domestic wind power supply chain – a national effort with a broad range of goals, from developing a new workforce of engineers and wind power support personnel to building the manufacturing facilities that will produce new onshore and offshore turbines. A study by Texas Tech University's Wind Energy Institute estimates that reaching 20 percent wind energy by 2030 could create upwards of 180,000 US jobs in a variety of sectors. Before such promise can come to pass, however, advanced turbines have to be production-ready, which makes R&D the ignition key for the 20 percent scenario.

Developing large turbines is an important part of making offshore wind farms a reality, because a higher output per tower improves farm economics and makes it easier to offset the high cost of installation at sea. The 20 percent scenario implies a massive construction effort rivaling the road-building projects of the Great Depression. Consider the best available wind turbine 'capacity factor' (the percentage of nameplate output the turbine actually delivers) is about one-third. In order to get 54 GW deliverable offshore wind power using 5-MW turbines, you would need to install about 32,000 wind towers. With 10-MW units, the number would be cut to 16,000. Because higher outputs go a long way towards relieving some of the construction and economic strains in the 20 by 30 report timeline, developers are looking to improve everything from the generators to the blade materials in the search to add every fraction of a megawatt possible atop the tower.

On all fronts, promising new equipment and technology are being developed, for the most part encouraged by a variety of special DoE programs. Some 5-MW marine turbines are reportedly nearing production in the US. At least one 10-MW design is expected to be available by 2011; composites companies across the country are developing stronger, lighter blades; and power system manufacturers are coming up with new generator and power electronics designs. The change is happening and the hope is tangible, says Banks, but the sector is still in a nascent stage needing government nutrition.

"Financial incentives are still very important for the offshore wind sector," she says. "Right now, we have production tax credits in place until 2012; those incentives need to be in line with the time frames for which offshore projects can be constructed. We need to move forward as quickly as we can, to get projects in the water to get the benefits of offshore wind."

The Way Forward

Another subject absorbing AWEA's attention is power transmission. For both onshore and offshore projects, questions about how power lines are planned, paid for and permitted raise some highly contentious issues on local, regional and national levels. Working these out is an important part of clearing the road forward. "Integrating a large amount

of offshore wind will require a large, new transmission infrastructure; our position is, the more of an integrated electrical grid we can have, the better," Banks says.

Meanwhile, the wind sector is waiting for an offshore wind proposal to undergo the new Federal permitting process. AWEA expects that, while some uncertainty remains about how well the process will work, any aspects needing improvement will be sorted out as the first project goes though. "We are working to ensure a streamlined permitting process, to help projects get into place as soon as possible," says Banks.

How soon is 'soon' in the world of offshore wind? As this issue went to press, there were two proposals with a power purchase agreement (PPA) in place – the Bluewater project offshore Delaware (PPA with Delmarva) and the Deepwater project off Rhode Island (PPA with National Grid) – but neither had started the permitting process. Meanwhile, the Cape Wind project offshore Massachusetts, which has been held up for a variety of reasons for nine years, had not firmed up a PPA and was nearing the end of a public comment period. Even if it is some years before a US offshore wind farm project really gets going, says Banks, AWEA believes public support for wind energy will not wane.

"Public support – and support from all stakeholders – is vital to getting renewable energy projects off the ground; one reason why offshore wind energy has so much public support is that there is more understanding of energy problems and climate change today than in the past," Banks says. "Wind power is a clean energy source that produces no greenhouse gas emissions. It has an economic advantage in that you can lock in the cost of wind energy for 20 years and, with most of the US population living on the coast, it provides an energy resource very near the populations that will use it. So, even if offshore wind projects don't go forward quickly, I believe the public will still see the need for them. In fact, the more time passes, the more the need for wind energy in general will be underscored," she says.

"Offshore wind is a significant segment of the wind industry and AWEA is dedicated to ensuring that it has a solid foundation and bright future in the United States," says Denise Bode, AWEA's CEO. "It is my hope that offshore wind will soon become a reality in the US and follow the amazing success of the onshore wind industry."

Denise Bode,
CEO,
AWEA

Feed-In Tariffs:
Instrument for Incubation

By 2009, according to Paris-based international renewables advocates REN21, 64 countries had some type of policy in place promoting renewable power generation among which 45 national and 18 local governments had feed-in tariffs among their strategies.

REN21 Renewable Energy Policy Network for the 21st Century

Feed-in tariffs are government policies designed to encourage the adoption of renewable energy sources by paying the electricity producer for the power generated. In this use, 'tariff' means the rate paid per kilowatt-hour for electricity and 'feed-in tariff' is that rate paid per kWh for power 'fed into' or sold to the grid. They generally rest upon three key features: guaranteed grid access; long-term contracts for the electricity produced; and a purchase price schedule based on the cost of renewable energy generation. They are typically accompanied by an obligation imposed on electric utilities to buy power from renewable sources.

The concept got rolling in 1984 when the California Public Utility Commission released Standard Offer Contract No. 4, created under the Public Utility Regulatory Policy Act (PURPA). Part of the 1978 National Energy Act, PURPA let renewable generators be connected to the grid and specified that such producers be paid for the value of the oil- and coal-fired generation they avoided. Basing that compensation on estimated long-term avoided costs, Standard Contract 4 is regarded as the push that brought 1,200 MW of new wind generation to California by the late 1980s.

Springing off this model, Germany developed its 1990 Law on Feeding Electricity into the Grid (StrEg), which required that utilities purchase power from renewable sources at rates based on retail electricity costs. The move is credited with bringing 4,400 MW of wind capacity online between 1991 and 1999. StrEg was revised as the Renewable Energy Sources Act of 2000 (the Erneuerbare Energien Gesetz or EEG), which granted renewables priority access to the grid and set forth in law that the tariffs, to be guaranteed for 20 years, would be based on the cost of generation from each technology plus a 'reasonable profit'. This meant different feed-in tariffs would apply to different technologies, and also within those technologies based on considerations like project size and application. According to the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), the EEG helped renewable energy usage jump from about 6 to 15 percent of national power demand between 2000 and 2009.

Normally, when a utility seeks to recover its costs for a new power plant, regulators analyze the project after completion and award tariffs based on their findings. The German practice determines cost reasonableness in advance of construction, adding in considerations of the money needed to reach public policy goals for renewable energy development. A number of countries now use such 'Advanced Feed-in Tariffs,' which follow the German model and collectively are credited with sparking the renewable energy boom. Such programs are credited with bringing large percentages of wind power into the national grids in Germany (7 percent), Ireland (9 percent), Spain (11 percent) and Denmark (20 percent).

One criticism of feed-in tariffs is that they unfairly cause consumer electricity prices to rise. While supporters acknowledged a price rise, they generally say the green premium is not unbearable. A 2008 European Commission analysis concluded that "well-adapted feed-in tariff regimes are generally the most efficient and effective support schemes for promoting renewable electricity," and a 2009 report by the BMU said the green energy premium for the average German household was between €2 to 6 ($3 to 9) a month.

Department of Energy Aids Wind R&D

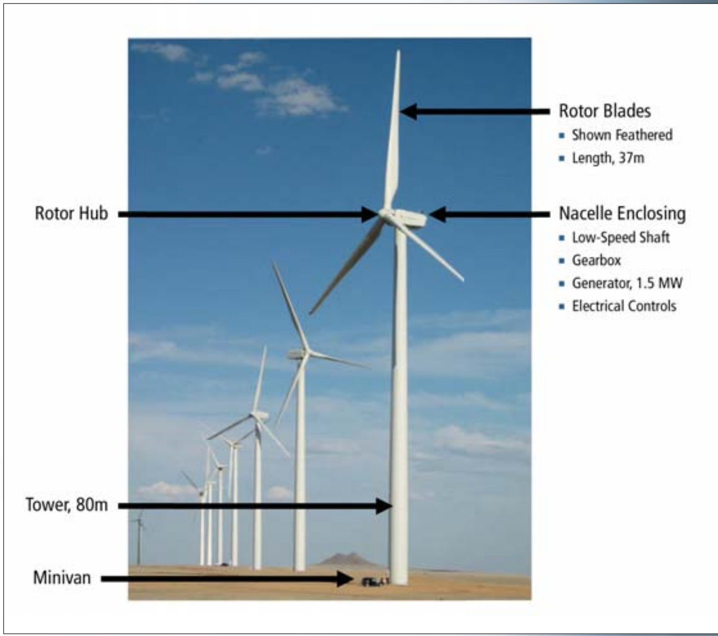
The US Department of Energy (DoE) has developed several lines of activity dedicated to expanding wind power's contribution to US national electricity consumption. Some of these activities include: prototype and component development; working to integrate wind energy into the national grid; technology development through wind generator modeling studies and wind farm performance monitoring; and planning new generators and transmission lines.

A large part of these efforts is focused on addressing the technical challenges identified in the *20% Wind Energy by 2030* report that the DoE issued in 2008. While stressing that the 300 GW of online wind power (including 54 GW from offshore wind farms) is technically feasible, the report highlights a number of R&D issues that first need resolution, particularly those related to increasing wind energy system reliability and operability; addressing transmission and grid integration issues; improving manufacturing processes; and mitigating siting and environmental issues.

Through its Wind and Hydropower Technology Program, DoE focuses on increasing the technical viability of wind systems and building up the use of wind power in the marketplace. One of its stated goals, for example, is to "reduce the cost of electricity produced by large land-based wind systems in Class 4 winds (15.7-16.8 miles per hour) to 3.6 cents/kWh by 2012, from a baseline of 5-8 cents/kWh."

The Wind Technology Program is also focusing on one of the best-known problems with intermittent renewable power sources like solar and wind energy: how to store electricity so that it can be delivered to customers when the air is still and the sun has set. As the Department works with the wind power sector to increase turbine reliability, its Wind Systems Integration Program is working with the electric power industry on ways to integrate wind power into US electricity supply while maintaining stability and reliability of the grid.

The DoE's Wind Energy Technologies Program also funds research and development projects at the National Wind Technology Center (NWTC) of the National Renewable Energy Laboratory (NREL), efforts which have led to the development of commercially successful wind turbines for GE Wind (a 1.5-MW unit) and Clipper Windpower (a 2.5-MW unit). New projects are focusing on increasing national wind capacity and developing wind technologies that will operate cost-effectively at lower wind speeds.



A modern 1.5 MW wind turbine installed in a wind power plant

DoE's Component Development Program has also had some notable highlights, including development of new gearboxes and permanent-magnet generators. In one project, DoE scientists from Sandia National Laboratories worked with California-based wind blade manufacturers Knight & Carver to develop an innovative turbine blade – the Sweep Twist Adaptive Rotor – that reportedly increases energy capture by 5 to 10 percent with no decrease in fatigue life.

Last year the Department gave its support to the National Wind Energy Center, a cooperative effort in technology incubation that will be run out of the University of Houston under Drs. Su Su Wang and Raymond Flumerfelt. Its primary goal, to develop a sound engineering basis for offshore wind energy, will proceed along two parallel lines: one to develop existing wind power technology for offshore application and the other to develop the wind turbines of the future.

Outside the country, DoE is a member of the Wind Energy Executive Committee of the International Energy Agency, supporting 10 areas of international R&D. In January 2010 the Department announced new projects under the Low-Carbon Communities of the Americas (LCCA) program to "assist countries in Latin America with sustainable energy market transformation initiatives," including an energy efficiency center in Costa Rica and a project to study and install small wind turbines on the Caribbean island of Dominica.

Bringing Offshore Wind Online

The US wind power sector takes on the technical challenges of plugging into the potential of offshore wind energy.

These days, it seems that everywhere there's a good breeze there's an energy authority running after it, hoping to turn it into electricity. Over the past decade, global use of wind power increased tenfold, from about 13 gigawatts of nameplate capacity in 1999 to nearly 160 GW at the start of 2010. In 2008 alone (the last year for which statistics are available), over 27 GW of wind power capacity was installed worldwide, in the form of some 19,000 units worth nearly $52 billion. Wind generation currently delivers a bit more than 1 percent of global electricity supply, but the world's renewable energy advocates are optimistic it will grow to provide a much bigger piece of the planet's power puzzle during the next two decades.

Many countries have high hopes for making dramatic changes in their energy portfolios that, cumulatively, will bring several hundred thousand megawatts of new energy online in just twenty years. Advocates in Germany, India and Spain, for example, hope that 30 percent or more of their national energy needs can be drawn from the wind by 2030, while in the United States the hope is for 20 percent by that year. This international push to mine the wind for power is bringing great attention and rapid growth to the offshore wind energy sector. Offshore, space is wide open and unobstructed, winds are generally stronger, the resource is closer to the user and the population impact is minimal. Winds blow so much better offshore than onshore that, say scientists, wind farms at sea can produce electricity about 50 percent of the time or better, significantly superior to their onshore counterparts.

The variable nature of the wind means wind turbines generate different amounts of energy at different times relative to their nameplate capacity. This deviation from full power production is expressed as the unit's 'capacity factor,' the percentage of the rated output that you can expect to get. Research in the US and abroad has improved capacity factors to better than 30 percent for newest land-based turbines. As a practical matter, then, a 5-megawatt wind turbine might average about 1.5 MW to the grid onshore but, with a switch of location, might be able to generate 2.5 MW offshore. With a 60 percent power boost to gain, it's no wonder the leading users of wind power are scrutinizing their offshore areas for suitable sites.

The European Union presently has all the world's offshore wind power – about 2 GW installed in over 30 projects – and is looking to greatly expand this capacity. The European Wind Energy Association (EWEA) is targeting 40 GW of offshore wind farming by 2020. At last year's European Offshore Wind Conference, EWEA unveiled a development plan for EU offshore wind power that describes creating a transnational offshore power grid and proposes building eight new offshore grids by 2020 and a further six by 2030.

The 20-Percent Solution

In the US, a period of uninterrupted federal support for wind power that began in 2006 has spurred several years of record growth in the sector. A 2008 report by the Department of Energy (DoE), entitled *20% Wind by 2030* (often called the 'the 20 by 30 Report'), articulates a scenario in which, within 20 years, more than 300 GW of domestic electricity comes from wind power, including 54 GW from offshore wind farms. The US currently has no offshore wind farms, but the report's authors conclude such a scenario is feasible if certain technical challenges are overcome. Some of those challenges stem from issues of permission, like establishing national certification, inspection and safety regimes. Others stem from issues of design, like handling the high wind speeds and unique environmental realities of North America. Still others involve general technology development, such as improving turbine blade, rotor and power conversion technologies.

Walt Musial,
Principal Engineer for
Ocean Renewable Energy,
NREL

While some of the know-how needed to make that happen can be imported from Europe, critical differences in extreme wind speed and the offshore environment mean the US wind sector has to develop its own solution to the problem of bringing wind farms into US waters where they can then operate safely and reliably over the long term. The American Wind Energy Association (AWEA) is leading an effort to develop standards and practices and technical criteria, while the DoE is running a technology research and development effort. While the DoE has not yet completely defined its new role in offshore wind power, its activities are presently understood to include technology development, resource assessment, support for the permitting process and research into the uncertainties of surrounding turbines in the marine environment.

One organization aiding AWEA in standards development is the Boulder, Colorado-based National Renewable Energy Laboratories (NREL), the main institution in the US for incubating wind energy technology. Founded

in 1977 as the Solar Energy Research Institute, NREL was renamed and designated a DoE national laboratory in 1991.

"NREL's mission is to develop technology and help shepherd it to the commercial sector and bring it into the mix of US energy supply, as well as to nurture the industry to where it can export the same product – that's where we and DoE have a similar mission," says Walt Musial, NREL's Principal Engineer for Ocean Renewable Energy. "Thus, NREL's role in offshore wind is the same as for all the other renewables it has helped develop: we try to find a way to ensure these projects are successful; to anticipate technology challenges the industry will face, not just on the first few projects but also on the ones that follow; and to anticipate how offshore wind can contribute to the big picture for energy security, economic development and energy supply," he says.

The first generation of US offshore wind farms will most likely be installed in shallow water (less than 30 m deep), using structures proven in service around the world – a tapered, tubular monopile tower fixed to the seabed via a driven pile or concrete caisson, with the turbine mounted around 80 meters high. In photographs they look modest in size, but in reality are immense structures requiring transport, assembly and installation by specialist vessels.

For an idea of how big they are, take as an example the 2-MW turbines installed in the Horns Rev field offshore Denmark. According to their manufacturer, Vestas, the foundation is a steel pile, four meters in diameter, driven about 23 meters into the seabed. The 150-tonne tubular steel tower, which reaches about 70 meters above the water's surface, is connected to the foundation by a 'transition piece', a large steel sleeve that allows the installer to correct the angle of the tower so that it stands perpendicular to the seabed. Atop the tower is a 2-MW Vestas model V-80 turbine. The turbine body, or nacelle, measures about 5 m high and 10 m long and weighs 69 tonnes. Attached to it is an 18-tonne hub that holds three blades. Each blade, handmade from fiberglass materials, is 40 meters long and weighs 6,500 kg (about 14,000 lbs). Altogether, the assembly at the top of the tower weighs over 100 tonnes – and that's among the smallest units being installed offshore.

Because higher outputs mean more productivity and a better return on investment, the push is not just to get wind turbines offshore, but also to make them as large as possible. Power ratings of offshore turbines today range from 2.0 to 5 MW, and units of 7.5 and 10 MW are under development by several manufacturers. Balancing these massive weights atop their towers raises site-specific challenges that need addressing in order to improve their long-term reliability. Considering the expense and complexity of installing such structures offshore in the numbers needed – farms of 80 to 100 units are common – it is no wonder US researchers are obsessing over wind farm survivability

against such environmental stressors as tropical storms on the East Coast, ice floes on the Great Lakes and hurricanes in the Gulf of Mexico.

Floating Solutions

While first-generation offshore wind farms are expected to be installed in shallow depths, some next-generation farms are already being planned for deeper waters. With fixed towers considered impractical for depths beyond 60 m, one major area of study at NREL is the challenge of setting these immense structures on floating bases. Projects in Europe and the US are tackling the issue with prototype floating installations, two of which have been installed offshore Italy and Norway. Others are planned for offshore Portugal and Maine in the US.

One focus of NREL research is related to the motions of floating platforms, from the pitch and yaw of catenary moored structures to the more planar motion of tension-leg systems. "With floating systems you have a moving base, and today's turbines are not designed to carry those extra dynamic loads and motions. Such turbines don't exist yet, but they will," says Musial. "These motions have to be accounted for in the design of new systems. The prototype installations will prove the concept works, but will need to be followed by a lot of testing and production development," he adds.

While advances in turbine technology will be critical to the effectiveness of floating wind farms, the real groundbreaking will occur in the development of the systems themselves, says Jason Jonkman, the NREL scientist who has dedicated the last several years of research to analyzing floating platform concepts for wind turbines. These concepts include tension-leg platform (TLP), spar, semisubmersible and barge-like bases. So far, NREL has built computer models for a barge, a spar and a TLP concept, running them through a series of design load cases to identify the fatigue loads and ultimate extreme loads.

"Our job at NREL is to be the objective, third-party assessor of different concepts," says Jonkman. "For floating bases we've built a multi-physics model to look at aerodynamics, structural dynamics, hydrodynamics and control systems. We ran them through thousands of simulations to identify how much the choice of platform affects the turbine design. We have also supplied these tools to the industry, so they can use them in their own design work."

Although it is too early for research to identify an optimal floating base concept, he says, the barge appears least desirable, being so susceptible to wave-induced motion that safe operation would require unfeasibly heavy system components. The choice between spar and TLP is not so clear. Their loads imposed on the rotor are close, but the spar would likely need a stronger tower to counteract the bending moment generated by the turbine assembly when the platform pitches. While that information doesn't resolve the question, he says, it will contribute to what will ultimately be a project-specific decision.

In the meantime, there are still plenty of issues to resolve that are shared by fixed and floating systems alike. One is structural fatigue. "Fatigue of the structural components is a very important design factor in a wind turbine," says Jonkman. "Wind flows are not nice and uniform; there's turbulence, for example, which produces continuous oscillation and vibration of the components, and shear. Their effects

Jason Jonkman, Scientist, NREL

are what will really wear the systems down over time." It isn't just wind magnitude and direction changes, he explains, but the whole stochastic (varying with space and time) environment in which the turbine operates that makes fatigue the prime consideration in structural design of a turbine system.

The other big component in the fatigue problem is the load imposed on the blades by their own weight. When a blade stands vertically, gravity imposes an axial compression; when horizontal, the load becomes a bending moment. As it turns around the hub, the blade undergoes a continuous cycling between tension and compression, which is transmitted through the components and into the tower. Researchers thus remain focused on reducing blade weight, searching for a solution that would lower the cyclic forces on the tower and also cut the payload that a floating structure would have to support. Work at NREL on blade technology has demonstrated substantial reductions in blade weight through the use of carbon fiber materials.

Long To-Do List

In moving their technology offshore, turbine designers are considering some concepts that have largely been phased out of the onshore sector. Two that Jonkman thinks could resurface offshore are twin-blade propellers and downwind rotors. Onshore, three-blade units evolved as the industry standard because they spin less noisily and, with a uniform balance, have proven the longer-lived configuration.

"The two-blade machine experiences a periodic inertial effect that the three-blade doesn't," Jonkman explains. "Because designers in the past didn't have the analysis tools to handle these complex dynamics, many more two-blade units failed. With today's improved modeling software, and because noise is less of an issue at sea, it's worth taking another look at two-blade systems for offshore use."

Today's standard onshore turbine has the rotor 'upwind', meaning wind strikes the blades before the tower. In the downwind configuration wind hits the tower first, creating a wake (velocity deficit and turbulence) behind the tower through which the blades must slice as they rotate, generating more noise and vibration. A drawback to the upwind type is that, because fiberglass blades bend, it needs blades of greater stiffness (and weight) to prevent the tips from bending so far as to strike the tower. Downwind designs allow use of larger, lighter, more flexible blades, which, because power output increases with rotor diameter, can increase productivity.

Battery technology also needs improvement to bring offshore wind power to the US – not to store produced electricity, but to keep the towers standing. Nacelles have roughly the dimensions of a two-storey row house, and

as designed today are sleek and aerodynamic when aligned with the wind. As the wind comes around to broadside, however, they take on forces so great that the tower can be threatened. To protect against such misalignment, most wind turbines use active (electrically powered) onboard systems called yaw controls that detect wind direction and automatically rotate the nacelle so that it points properly. These systems draw power from the grid, but when that connection is lost (say, in a storm) they draw from backup batteries.

The matter is addressed in the International Electrotechnical Commission (IEC) Code document 61400-3 (Design Requirements for Offshore Wind Turbines), the fundamental standards document for the global wind power industry. The Code requires tower design to withstand nacelle misalignments. Design Load Case 6.1, for example, says: "a yaw error of up to ±15 degrees using the steady extreme wind model or ±8 degrees using the turbulent model shall be assumed, provided that no slippage in the yaw system can be assured. If not, a yaw error of up to ±180 degrees shall be assumed." In the absence of battery power, then, the nacelle must be considered as taking a broadside hit, with the consequence that, under certain conditions, the structure's design survivability rating falls to a one-year return period event (about equivalent to a severe thunderstorm). As the batteries used in wind turbines typically hold about six hours' charge, wind structures would be endangered in a high-duration revolving tropical storm like Hurricane Ike, which continuously changed direction in some spots for 18 hours.

Another point raised in the 20 by 30 report is that failure analysis from systems in service will be a critical key to unlocking the full potential of US offshore wind energy. As existing onshore and offshore wind farms experience problems, they may expose issues that need consideration if the reliability required for lengthy unattended operation offshore is to be attained.

Onshore, for example, towers have bent and collapsed in storms; foundations have failed; nacelles have burst into flames; and blades have shattered, throwing pieces hundred of yards. As the technology moves outward, offshore installations have experienced teething issues as well. One farm was delayed from starting construction because all its pilings had to be rejected for substandard fabrication; another had to switch out all its gearboxes within three years of installation; a few others shut down due to electrical connection failures; and others have shut down due to failure of their subsea cables. Each incident, though painful for its stakeholders, may hold valuable lessons for improving reliability.

The wind energy challenge extends beyond technology development, to the creation of a new, skilled labor force. According to a study by the Texas Wind Energy Institute of Texas Tech University, the 20 percent wind scenario will need a workforce totaling some 180,000 trained professionals in wind energy engineering, manufacturing, construction and operations. The workforce need is underscored in the 20 by 30 report as well, which notes that, while the number of wind technology-related educational programs is growing, US universities still only graduate about 500 power engineers annually, a figure that must rise as wind power advances.

Clearly, then, for offshore wind to come to the US as a reliable power source, government and industry must jointly chip away at the mountain, developing standards, technologies, capabilities and human capital. It's a big mountain, but NREL's Musial is optimistic that its challenges can be overcome.

"All along the East Coast, governors of coastal States are supporting wind power, looking at using indigenous resources to take control over their situation and to be less dependent on others for their energy supply," says Musial. "People are starting to realize that they have resources in their own back yards and that it's not going to harm their economy or their environment to go get them."

Wind Power Plugs into the Oil Patch

Hard-won know-how about drawing energy from under the sea is being used to help those who would draw energy from above it.

The first pages of a new chapter in US energy history are now being written, as the Department of Energy (DoE), the Minerals Management Service (MMS) and an increasing number of renewable energy players turn to the offshore oil and gas industry for help in getting wind technology into US waters.

The technological cross-pollination began about three years ago, when MMS commissioned a study comparing the standards and practices for US offshore oil and gas facilities, issued by the American Petroleum Institute (API), with the recommendations for offshore wind facilities from the International Electrotechnical Commission (IEC). In a series of subsequent studies and joint projects with industry, the regulator has been steadily drawing offshore oil and gas experience into its efforts to develop a system of submissions and checks to use in safety assessments of offshore wind farms, which will provide a comprehensive safety regime without onerously burdening the developing industrial sector.

Ultimately, MMS instructed that offshore wind farms planned for the US Outer Continental Shelf (OCS) will be required to follow guidelines in API Recommended Practices document RP-2A (*Planning, Designing, and Constructing Fixed Offshore Platforms*) and further, will be expected to have in place a demonstrable Safety Management System (SMS). In early 2010 MMS published a template designed to guide the content and subject matter for such an SMS, the first product from a set of projects geared towards developing standards of structural safety, reliability and survivability of offshore wind farms on the OCS.

One particular aspect of the SMS template indicates the extent of common ground stretching between the seemingly distant worlds of the wind power operator and the offshore contractor. "The document was developed using the format, several ideas and even some of the wording from the *Health, Safety and Environment Case Guideline for Drilling Contractors* issued by the International Association of Drilling

Contractors (IADC)," says its author, offshore technology consultant Dr. Malcolm Sharples. "The installation and servicing of offshore wind farms may be guided by the practices of contractors and subcontractors from the oil and gas industry. Incorporating the IADC guideline into the SMS template makes it readily familiar to oil and gas contractors, and easily adapted by experienced organizations," he explains. "The wind business has its unique characteristics, but there are many areas where oil industry know-how can cross over to wind power."

One of those areas is standards development. For some time now, US offshore experts have been working with the National Renewable Energy Laboratory (NREL) in Colorado, the leading Department of Energy laboratory for wind research. "We've engaged consultants from the oil and gas sector to help us in some of our studies like, for example, structural reliability; I don't see that cooperation ending," says Walt Musial, Principal Engineer for Ocean Renewable Energy at NREL. "When we get to inspection, certification, design and construction, there is tremendous input to get from the oil and gas side. If we were to try developing all that we need from scratch, it would take at least another 20 years to get a wind farm offshore. An offshore wind sector can't exist without help from the oil and gas sector's engineering and marine practices."

The standards road-mapping workshop, convened by the American Wind Energy Association (AWEA) and accredited by the American National Standards Institute (ANSI), provides an example of such cooperation. As an example, Musial points to the work NREL is doing with ABS and other industry members in developing technical guidance for the permitting process to which offshore wind farms will be subject.

"ABS is engaged in the work we're doing on road-mapping industry standards," says Musial. "There are standards developed by the oil and gas industry or the maritime industry that are going to be directly applied to wind turbines," he explains. A broad, collaborative effort that began last year, the workshop has engaged a number of oil and gas experts to working alongside NREL and MMS in developing US wind power standards.

"The idea behind the road-mapping project is to develop standards and practices for onshore and offshore wind farms, being sure to address their unique structural and electrical issues," says Ken Richardson, Vice President of Energy Development at ABS. Through Richardson, ABS serves as secretary to the offshore wind power group of the road-mapping workshop. "When finished with the road-mapping, we should have a set of Rules for offshore wind farms that will supplement the IEC Standard with specific requirements for North America," he says.

"Installing shallow-water wind farms basically involves putting fixed structures in the ocean, which the oil and gas industry has been doing for over 60 years," Richardson adds. "All that experience from all those years of working offshore is codified in the API documents, which is why MMS has said that offshore wind power installations must take account of API RP2A provisions in the design basis document."

The link between offshore oil and gas and offshore wind energy reach beyond the practicalities of construction at sea, extending into technology innovation, advanced computer modeling and validation, structural integrity, quality assurance, life cycle performance and condition monitoring, safety and health and transportation, says Dr. Rolando Vega, Engineer for Renewable Energy Services with ABS Consulting, an affiliate of ABS.

"NREL has an incredible legacy in wind turbine technology innovation, analysis and testing, while ABS has its own long history in offshore energy," says Vega, who heads the road-mapping workshop's onshore structures group. "Working for utilities, insurance and re-insurance companies, government, process, oil and gas, nuclear and renewable industries, our group has built an integrated analytical expertise that includes risk, safety and integrity management. It is a natural fit to combine this expertise with that of NREL to help get wind farms offshore."

"As time goes on, we see an increasing number of wind power projects asking oil and gas consultants for help in understanding the risks of offshore operations," says Richardson. "In particular, they are looking to understand the scheduling and budget

Dr. Malcolm Sharples

Ken Richardson,
Vice President of Energy Development,
ABS

Dr. Rolando Vega,
Engineer,
Renewable Energy
Services,
ABS Consulting

Ken Arnold,
Energy Consultant

risks to working offshore in an environment they're not familiar with."

One area where oil patch smarts can make a critical crossover to the wind world is project engineering and execution, says energy consultant Ken Arnold. "To make an offshore project work, you need a very good understanding of the construction equipment and the environment," he says. A former Shell executive and co-founder of Paragon Engineering Services (now AMEC Paragon), Arnold has been solving offshore engineering problems for over 45 years. "So, there is a real need to apply offshore oil and gas knowledge to offshore wind farms, particularly what we know about construction, foundations, soil mechanics, wave loads and wind loads on structures."

Still, there are differences between offshore oil and gas platforms and offshore wind structures that make the wind farm challenge unique, he says.

"When we design offshore platforms we have to remain constantly aware that the ocean environment is full of worse surprises than you ever expected; that's why we use high safety factors," says Arnold. "With offshore wind structures you can't use the same safety factors – they add cost to the structure. Wind turbines develop so much less energy per pound of structure than offshore oil and gas platforms, that they just cannot afford such margins. The economics of wind farms are very tight. This means designers are challenged to define their load cases much more closely and be much more specific in understanding their design solutions," a challenge that, he says, is deepened by the severe dynamic effects and force interactions to which wind turbine structures are subject.

If the wind sector picks up any wisdom from the oil patch, it should be that industry's healthy respect for the ocean environment, he adds. "As an industry, we've been engineering platforms in the Gulf of Mexico since the 1950s – we know what works offshore and what doesn't," says Arnold. "Despite this, after Hurricanes Katrina, Rita and Ike we still had to go out and change some of our design criteria. So, even with all our experience, we learn new things."

There is one wind power developer familiar with both worlds: Herman Schellstede, who, after four decades of designing offshore platforms for oil and gas, has a wind farm proposal for offshore Galveston, Texas. "The offshore oil and gas industry has a tremendous wealth of know-how about installing equipment in the water," he says. "In ports all along the Gulf Coast, you have fabricators, craftsmen, electricians, welders, painters and

other professionals making up an infrastructure you don't see anywhere else in the world. Placing equipment, driving piling, running cable – all of these are everyday services in the offshore oil and gas business. When it comes to working offshore, we can teach the wind power folks a lot," he says.

Nature, meanwhile, can teach anyone. About three years ago, Schellstede picked up a used tripod jacket for his meteorological test tower, refurbished it to API specifications and installed it in 58 ft of water offshore Galveston. Hurricane Ike passed right over it. "We watched the wind speed readings jump from 20 mph to 110, drop to zero as the eye passed over, shoot back up to 140 and return to normal as the storm moved ashore," he says. "The big surprise was that a wave had deposited a load of very big logs in the tower steps – 35 ft above the waterline."

Some lessons are subtler. "We have five sites in Texas, and we've found that the winds off Corpus Christi and Brownsville are even stronger than those off Galveston," Schellstede says. "We kind of knew that already from our oil and gas experiences; we always got blown out of the Gulf whenever we tried to work down there," he recalls. "The wind was our enemy in those days, but now it's our friend."

A Short To-Do List for Offshore Wind Farming

"Studies of existing standards for wind power systems show that no currently available documents can be directly applied to the US Outer Continental Shelf (OCS) as a complete set of offshore wind standards," notes offshore technology consultant Dr. Malcolm Sharples. "Several sources of guidance information will need to be used in design, construction, installation, operations and demolition of offshore wind farms on the OCS. In the field, control monitoring and condition monitoring have become reliable methods of maintaining structural safety," he adds, "and inspection programs may need to vary from the annual and periodic inspections now applied to oil and gas structures. Software and power backup will likely be required to maintain structural integrity in tropical revolving storms."

Drawing on years of oil patch know-how, Sharples has compiled a short heads-up list for offshore wind farm design:

- Corrosion and salt effects from the marine atmosphere must be considered for all components, including gearboxes and ventilation systems in the nacelle;
- Metocean considerations for extreme storms should draw from offshore oil and gas industry experience;
- As towers in any given wind farm are likely to be built the same, an event threatening one will threaten all in a particular field. Thus, new load case combinations are needed, particularly for hurricane-prone areas;
- Site-specific considerations must be emphasized in design, particularly regarding soil parameters and collision risk particularly as it relates to the subsea cables where there have been some expensive lessons in Europe;
- Limited access for maintenance, repair and rescue makes design reliability a critical factor offshore. High reliability must be considered in the design phase;
- Lightning and fire protection should be considered mandatory, offshore at least;
- Offshore farms operate unattended for long periods, so the importance of Quality control in manufacturing and condition monitoring in service cannot be over-emphasized;
- Because of the remoteness of the wind farms and the consequences of failures, meticulous attention to the safety management system is mandatory.

Gulf Coast Know-how Can Help Wind Power Projects

Herman J. Schellstede,
Herman J. Schellstede & Associates,
Wind Energy Systems Technology

The US oil and gas industry has a tremendous wealth of information that wind power folks can use to get their wind farms offshore – and we old boys from the Gulf Coast can teach them a lot about putting structures in the water.

Take offshore mooring, an area in which I have a lot of experience after 40 years of doing offshore oil and gas projects. I hear a lot of talk about floating platforms for wind farms, but I don't think the wind industry has any idea of the true cost of building spars and semis and doing operations in deep water. They need to get this kind of knowledge from the people who have been there before them.

In shallow water, when you're setting the structure on the bottom, it's a manageable job, but in deep water it's a different deal. Believe me, it's expensive to get these things in the moored position. And the more your operation costs, the more you'll have to get for your electricity.

The bottom line is, when we do oil and gas projects we have some room regarding the cost of working offshore – the structure, the pipeline, whatever it might be – because the rewards are so great. But it's a different game when you're looking at the economics of wind farms. With wind, we've learned we have to watch every penny. Every pound of steel we put into the towers, how we bury our cables, how we do installation and maintenance, everything is important because we're only going to get a certain amount of money for our electricity. So you must be very careful not to over-design your structures or end up with something that is complicated to install offshore.

In our oil and gas work we've done a lot of float-over projects, where you build the structure onshore and just float it out to install offshore, and we're using that same technique for the Galveston Wind Farm. In Europe they're doing a lot of the work offshore, but that's too expensive to do here. Our design calls for the tower, nacelle, generator and blades to be connected at the shore line. Then we make one lift offshore – we've designed a special marine fleet to do it – and it's ready to operate.

One thing our wind people don't need to do is call Europe every time they need advice. Those projects were government-subsidized; we don't have that luxury in the US. They should be calling down to the Gulf Coast. If they want to know how to get something offshore at the right cost, there's 60 years of expertise down here ready to show them how.

There is a lot of know-how to pass along, but I would say the most important thing wind people can learn from oil and gas is the mentality of cost control. It can cost several hundred thousand dollars a day to rent some of the special equipment for offshore construction. If you add up your daily costs and figure them in seconds, you will always be thinking about how long it takes to do things – the mind naturally starts to work that way. You have to have that kind of discipline once you leave the shoreline, to be sure you have no interference offshore. Poor logistics can give you a runaway budget, and if you have a runaway situation offshore you can easily double your expenses, even if all your onshore costs are lined up.

Working offshore is not a lackadaisical operation. Your mentality has to be: watch the money every second. If we can instill that in the wind energy people, we will have helped them greatly.

Of all the forces of nature, I should think the wind contains the largest amount of motive power – that is, power to move things. Take any given space of the earth's surface; and all the power exerted by all the men, and beasts, and running-water, and steam, over and upon it, shall not equal the one hundredth part of what is exerted by the blowing of the wind over and upon the same space. And yet it has not, so far in the world's history, become proportionably valuable as a motive power. It is applied extensively, and advantageously, to sail-vessels in navigation. Add to this a few windmills, and pumps, and you have about all. ... As yet, the wind is an untamed, and unharnessed force; and quite possibly one of the greatest discoveries hereafter to be made, will be the taming, and harnessing of it.

– *Abraham Lincoln*
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