A finished propeller in a manufacturer’s shop awaits transport to a shipyard, its flowing stripes and sweeping curves calling to mind the waves beneath which it will spend the rest of its working life. What appear to be swirls and ripples in the surface are merely the visual traces left by superfine finishing equipment – the eye perceives texture, but the hand feels only perfect smoothness.

Large modern marine propellers weigh up to 130 tons, yet are more carefully modeled, molded and finished than most cast sculptures. Machines grind and polish the flatter central areas of the blades, but it takes people to handle the harder curves and outer edges.

The course of every curve and the flow of every twist are precisely planned through computer-aided design and finalized using such analytical technologies as computational fluid dynamics, but the finished product can only come to be through a unique collaboration of machine accuracy and human artistry that takes place every day on the premises of the world’s leading propeller makers.
COVER:

It's all about teamwork. The superior efficiencies that distinguish high-quality marine propellers from second-tier look-alikes result not only from intelligent design work, but also from precision manufacturing and careful installation. Articles about improving fuel economy by retrofitting advanced propellers and using energy-saving devices begin on page 2 in this issue.

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High-efficiency propellers help owners reap better benefits from slow steaming.

Owners opting for slow steaming are discovering how one manufacturer’s advanced propellers and unique retrofit service help maximize the advantages of this survival strategy.

The idea of slowing a ship's speed to economize on fuel is nothing new, although it has been many years since the practice was as widely embraced across the maritime industry as it is today. The current drive for slow steaming began in earnest during 2009, in the wake of the global financial crisis, when the world’s ocean shippers lost an estimated $22 billion as international trade slowed, markets stagnated and a large number of new vessels, which had been ordered during the industrial boom of the previous five years, entered into service.

Among the sectors hit hardest by the downturn was container shipping, which saw a $12-billion reversal of fortune between 2010 and 2011 as $7 billion in profits turned into over $5 billion in losses. Although its collective bottom line has improved since then, economic pressure on the sector has not relaxed. In fact, despite scrapping, lay-up and delivery deferrals, the global container carrier fleet continues to expand annually. According to industry analyst Alphaliner, net fleet growth in 2013 was 5.7 percent and is projected to be 5.5 percent this year and 9.6 percent in 2015.

Slow steaming was initially adopted as a way of dealing with this excess tonnage while waiting for economic recovery. Rather than place ships in lay-up, many containership owners chose to lower voyage speeds fleetwide and insert the extra ships into the vessel 'string' in order to make up for the longer transit times. But the markets failed to rebound, fuel prices soared and new vessel deliveries continued while, at the same time, environmental legislation increased economic pressures on the industry. By 2012, with emissions restrictions under MARPOL Annex VI and efficiency-oriented
mandates like the Ship Energy Efficiency Management Plan (SEEMP) and Energy Efficiency Design Index (EEDI) entering into force, slow steaming began looking less like a stopgap measure and more like a long-term shift in operations philosophy.

Engine makers soon solved the technical problems related to slow steaming, particularly the deleterious effects on main engines of prolonged ‘de-rating’ – operating below design power levels, sometimes as low as 50 percent of maximum continuous rating (MCR) – that had sparked much initial resistance to the practice. Not long after, the overlap between fuel economy and environmental friendliness turned ‘efficient operations’ into a sales tool as well as a money-saver, and the industry declared its love of slow steaming.

Indeed, slow steaming is living up to its promise. The amount of power needed for a large ship to increase speed begins rising dramatically after about 14 knots, and beyond about 20 knots the ‘power curve’ describing that rise becomes so steep that even small decreases in speed yield high gains in fuel economy. For example, for a large containership of 8,000 teu, a speed drop from 24 to 21 knots can yield a power savings of around 33 percent; likewise, a typical VLCC that reduces speed from 15 to 13 knots can see daily fuel consumption drop from about 100 tons to about 66 tons. Taking this a step further, in 2012 Maersk reported that reducing speed from 24 to 18 knots boosted fuel economy of its ships by 60 percent.

Because the vessels are running at below design speeds, their efficiency improvement, though impressive, is not as high as could be. Now, owners taking a more permanent view of the practice are seeking supplementary technical solutions that can take the gains even further. Many are boosting fuel economy by changing propellers and, in particular, taking advantage of propulsion solutions provided by leading propeller maker Mecklenburger Metallguss GmbH (MMG). In 2012, MMG introduced a propeller replacement service called ‘propeller redesign’, in which a high-efficiency propeller is developed specifically for each vessel according to its operations profile and accurately installed in a proprietary retrofit process. MMG reports that, in combination with advanced rudders and energy-saving devices, its retrofit propellers have boosted fuel efficiency by as much as 10 percent.

MMG’s long history dates to the 1871 establishment of a machinery workshop and foundry in the picturesque town of Waren on Lake Müritz in eastern Germany. The workshop grew into the Waren Iron Works, which became a propeller-making cooperative in 1948 after nationalization under the German Democratic Republic. The company began its new life as MMG upon liberation from the Soviet Union in 1991, and spent seven years as part of the famed Bremer Vulkan shipyard group. Since 1999, MMG has been a property of DiHAG holdings, a group of ten German foundries, of which it is the only propeller maker and the only foundry for copper and its alloys.

Following a facilities expansion in 2001, MMG became, literally, the world’s biggest propeller maker. The company has the highest melt capacity in the business – 14,000 tonnes per year – and can produce the largest propellers, ranging up to 11.6 meters in diameter and a finished weight of 160 tons. In 2006, MMG produced the heaviest propeller ever made, a 9.6-meter diameter unit with a finished weight of 135 tonnes for the containership Emma Maersk.
methodology MMG jointly developed that extends conventional wake field calculation into a full-blown propulsion analysis.

Designers typically perform wake field calculations by simulating a steady water flow past a still propeller, simplifying the problem to where only normal levels of computing power are required to get a solution. In simulated propulsion, the propeller is turning in the wake field, which takes the exercise to a much more complex level because it calls for an ‘unsteady’, or time-dependent, calculation of many simultaneous events. In effect, the designer has to determine performance changes over time as the blade passes through the different water velocities present in the wake field. This requires not only a massive amount of computing power, but also a great effort from the designer in identifying and expressing these interactions mathematically.

“We have reached the point where we can make a propulsion test entirely on the computer, using CFD,” Greitsch says. “It is very challenging to do, because the interaction values are very sensitive. This approach requires quite a lot of preparation – but then, of course, you have the data in the computer and you can run as many tests as you need for different speeds and designs. To do the same with model tests you would have to build a new model each time you needed to change the design a little bit, each model taking several weeks to prepare. With the computer model, you can test many designs very easily. In fact, we have completed a few projects entirely on the computer, from concept to production without a model test. Of course, that requires some trust from the shipowner, but we have had clients who did trust us and enabled us to confirm this capability,” he adds.

A typical calculation considers the effects of the hullform – which is critical for initial design of the rudder and propeller – and then takes into account speed distribution, weather distribution, sea state and floating conditions. This requires having an idea of how long the ship will sail at which combinations of speed and draft – and, for long-distance voyages, developing an idea of the effects of trim on fuel consumption,” Greitsch explains. “At this point, you will have the full data set of what I would call the ship’s ‘propulsive profile’. Then, for your given input conditions, you consider statistical distributions of shaft speeds, power demand, vessel speeds, rudder angle and so on; from
there, you can make decisions regarding changes to propeller diameter or rudder that, for example, would improve the overall operating efficiency,” he says.

The need to have an operational profile as an input means that propeller redesign challenges the owner as well as the designer with a new way of thinking. This is so new, Greitsch says, that many owners are still adjusting to it, and coming to grips with having to make decisions today about the operational profile of a ship several years in the future. “Unfortunately many new projects are still very design point focused,” he notes, “which means, for example, that the effect of course-keeping rudder angles on the overall performance is not to be evaluated.”

‘Invisible Attributes’ Make all the Difference

“Propellers have evolved quite a lot in the years since I joined the company,” reflects Urban, who began his career as an engineer with MMG in 1980. “Back then, we talked about efficiencies of 52 percent, and today we are close to 70 percent. Today, thanks to finite-element calculations and CFD, we can identify where a propeller blade has its highest loading – which is not always in the middle – and, using that information, we can produce propellers that are both lighter and stronger than ever before,” he says. “These tools also allow us to precisely adjust design details like area ratio, and camber and pitch, which make all the difference when it comes to efficiency – and none of this is very visible to the naked eye. So, even though they look substantially the same, modern propellers are completely different from what they once were,” he says.

Among a propeller’s key ‘invisible attributes’ is load balance. Camber and pitch, the two main factors in sectional thrust (the thrust at any given point of the blade), need to be in good balance with each other and, as a system, to interact well with the ship's wake field.

“The more pitch means more thrust, but also more drag at a given blade section; the ideal balance between the camber of the profile and pitch – the angle of attack with the water – changes with each project. This is why we have no standard-design propellers,” Dr. Greitsch explains.

The key to it all, says Urban, is not merely having advanced design tools, but using them intelligently – and then manufacturing with a high-quality mindset.

“A 2-percent efficiency gain achieved by design can easily be wiped out by manufacturing tolerances that aren't high enough,” Urban says. “In order to ensure the finished product is correct, we often have to exceed the tolerances specified in the regulations. Because precision manufacturing is critical to every project, we spend quite a lot of time training and educating our workers, so they understand the importance of what they do,” he adds.

The Retrofit Challenge

The third part of the retrofit challenge involves installation – specifically, how to match the new propeller to the existing drive shaft.

A ship’s propeller must fit onto the tapered end of its drive shaft (called the shaft cone) with a high degree of contact. This means that, for newbuild vessels, the final boring of the propeller hub is usually performed in the shipyard, after the shaft is manufactured and before it is installed in the ship. Fit-up between the propeller and shaft is typically established through a repetitive operation reminiscent of the way a dentist uses blue contact paper to check the clearance of a tooth filling. The end of the shaft is painted blue and inserted into the propeller bore to indicate points of contact, after which the bore is hand-grounded to increase the contact area; this cycle of ‘blue-fit’ and grinding is repeated until the percentage of contact between the two parts, specified in the applicable classification Rules, is achieved.

A retrofit propeller does not have this opportunity, because the shaft is in the ship and isn’t coming out. Pulling the shaft is a lengthy, costly job and only done in extreme circumstances – of which propeller replacement is not one. For the owner, then, the decision to change propellers raises a logistical challenge.

“When we first developed the redesign concept we knew that, if we wanted to sell these high-efficiency propellers, we would need not only to design and manufacture a superior product, but also to offer a timely method for its installation,” recalls engineer Reinhard Kaps, Head of Quality at MMG. “The time allotted for the retrofit is very short, a few days at most; dry dock time is costly, the ship is off-hire and expenses mount from all sides. Because removing the shaft is not an option, we had to find a method whereby the propeller, when it arrives at the shipyard, fits the ship exactly.
To do so we had to be able to know the exact shape that the propeller must fit before it leaves our shop,” Kaps says.

After a year of research and development, MMG did devise an approach, based on advanced optical measurement technology that, for the first time, allows a manufacturer to produce an installation-ready retrofit propeller in the factory.

The first stage of this ‘digital fit-up’ is photogrammetry, in which numerous digital photographs record the position of a high number of reference marks that are placed on the surface of the existing shaft cone. These help define its geometry and enable the later adjustment of the propeller bore. Combining the data about the existing shaft cone and newly manufactured propeller bore, engineers then create a full digital fit-up model between the two parts that is accurate to 0.01 mm. Through this process, the new propeller can be adjusted in MMG’s workshop to fit exactly with the existing shaft.

MMG has other uses for optical measurements as well, applying it to the whole propeller and, especially, the shape of the blades. For retrofits, the technology is used to assess the performance of the ship’s original propeller and compare it against the replacement. For newbuildings, it is the basis for comparing the geometry of castings and finished propellers with their digital design models.

As for the economics of propeller exchange, Urban says the payback time is in the surprisingly short range of about six months.

The owner gets a head-start by selling the old propeller to MMG for materials, which accounts for about 45 percent of the cost because the old higher-speed propeller is generally heavier than the new one. The balance comes through fuel savings.

Thanks to the retrofit business, MMG is operating at full capacity this year, up from 75-percent utilization in 2013. With more customers lining up for retrofits and newbuilding orders beginning to rise, MMG expects to be working at 100-percent capacity for the next two years to come.

“We foresaw this market developing about four years ago, well before our competitors – and I’m happy to say our prediction was correct,” Urban says with satisfaction. “We were able to develop new ways to design and manufacture these highly efficient propellers and to come up with a completely unique way of changing them. Our installation service package makes the decision to change propellers much easier for the owner. It’s a completely new method that, as far as I know, is still unique to MMG.”

For Urban, one of the few positive side-effects to the shipping slump is that his customer base is not only better educated about what propellers can do for efficiency, but also is more willing to pay a premium for a superior product.

“She gives much more attention to the propeller today than in the past,” Urban says. “Seven years ago, I would always get arguments like: ‘Three percent more efficient? How can I even measure that?’ Today when you talk about getting a 2 percent efficiency improvement, they perk right up and say ‘oh, that’s a lot,’ and if you tell them you can achieve 3 percent, you really grab their attention,” he says. “Finally, they can feel between their fingers the difference that the right propeller can make.”

Half-bathed in blue light, a supervisor observes optical measurements being taken of a propeller, to compare the finished product against its computer-designed model. The markings are measurement points.
When a ship is in motion, the rotation of its propeller causes formation of a streaming vortex leading off the propeller hubcap, which produces a suction force that creates drag and reduces thrust. This hub vortex streams right into the rudder. Although it has been known for a long time that propeller and rudder can function together as a hydrodynamic team, the two components are, traditionally, designed at different times and produced separately by different manufacturers.

With the current industry interest in efficiency as a motivation, several manufacturer collaborations have arisen lately whereby shared design teams develop propulsion solutions in which propeller and rudder are designed and ‘tuned’ to each other so as to mutually enhance system-wide propulsive efficiency. One of these collaborations began last year, when propeller maker MMG and maneuvering specialists Van der Velden Marine Systems (VdV) started cooperating on an ‘energy-saving package’ that proposes just such a rudder-propeller combination. Their system is made of a high-efficiency, fixed-pitch propeller and an asymmetric-leading-edge rudder, and features a specially-designed hubcap positioned closely before a built-in bulb on the rudder. The cap smooths out the vortex and the bulb separates the flow, with the combined result of recovering lost energy and increasing propulsive thrust.

The MMG-VdV system is optimized for each vessel through flow simulations using CFD. Special statistical analysis tools and algorithms developed in cooperation with researchers at the Hamburg-Harburg University of Technology allow the partners to simulate such factors as vessel speed, floating condition and environmental inputs including wind and sea state.

According to MMG, the calculation results in system responses like rudder angles for seakeeping or situational power demand within the ship’s operational profile. After averaging, a clear comparison of different design options can be made based on the sum of losses and benefits in realistic operation scenarios. A further development of this technology produced simplified design tools that allow rapid analyses of multiple design variations. MMG says that, even if the project has a tight timeline, these tools “allow evaluation of a large number of design options without resorting to model tests, reducing the chances of missing the optimal option.”

The manufacturer reports that the system can offer a power savings of up to 4 percent for newbuild vessels and up to 8 percent as a retrofit, and notes that, because the flow simulations address a variety of operating conditions, the resulting system will perform with nearly constant efficiency across the vessel’s full operating range.

One proven way to enhance propulsive efficiency is by installing energy-saving devices before or after the propeller. Shown to the left, is MMG’s Energy-Saving Cap (ESCAP), which replaces the normal boss cap on the back of the propeller. The idea behind its particular body shape and fin orientation is to ‘smooth out’ the water that normally swirls off the boss cap, causing drag, and, thereby, to recover some propulsive energy that otherwise would be lost. This type device was first developed in Japan at the end of the 1980s, when it became known as a boss fin cap. Using computational fluid dynamics (seen in the modeling image), MMG engineers customize the concept to suit the characteristics of their propellers. The company reports that the ESCAP can contribute a power savings of up to 4 percent to a propulsion system, depending on vessel type and operational profile.
Refining the Ship’s ‘Wings’

With the drive for better fuel economy spurring an ongoing quest for better propulsive efficiencies, propeller and rudder makers are finding themselves enjoying a new level of prestige among shipowners and shipbuilders alike. Although a welcome change, it also brings some challenges. While advanced analytical and engineering technologies enable more sophisticated products to be developed, every new fractional percent of propulsive efficiency gain comes via an increasingly difficult balancing act between the complex collection of interacting factors that ultimately produce a ship’s thrust.

Despite outward appearances, the modern marine propeller is a close cousin of the airplane wing, and propeller designers, like their aeronautical counterparts, are very much concerned with lift.

Airplane wings have a curved topside and comparatively flatter bottom. When air strikes the wing at a proper angle of attack (or, angle of incidence relative to the flow), it will travel faster over the top than across the bottom, creating a lower air pressure above the wing than below it. This pressure difference creates a suction effect that draws the wing upwards, producing lift.

A cross-section through the blade of a ship’s propeller reveals the similarity: the surface of the blade facing the vessel (called the suction face) is curved, while the astern-facing surface (the pressure face) is comparatively flatter. This camber, like that of an airplane wing, creates a pressure difference in the water and an effect that, somewhat misleadingly, is also called lift. In the propeller’s case the ‘lifting’ force is horizontally oriented, becoming ‘thrust’ when it is transmitted to the ship via the tailshaft to cause motion.

Besides being cambered, the propeller blade is also twisted helically to achieve a certain angle of attack relative to the water, referred to as pitch; the angle of attack is partially responsible for creating the pressure difference that causes the lift effect.

Pitch is a value shared between propellers and screw fasteners (which is why both are called screws). As a theoretical expression, pitch describes how far the item should advance in one turn if screwed through a solid material – for example, a wood screw having a pitch of 2 mm would advance 2 mm through a board in one full turn. In practice, since a propeller moves through liquid, the relationship between travel and pitch is not so linear.

The resistance of a fluid to the surface of any propelling body, whether screw, paddle or oar, is not perfect, and there occurs between them a certain amount of yielding, or ‘slip’ – which leads to the column of rotating water produced by the propeller being called the slipstream. The concept of slip is widely used to generalize propeller characteristics, particularly the angle of attack between blade and water.

The effective angle of attack for a propeller blade derives from its rotational speed and the speed of the water relative to the blade. Represented geometrically, the inflow velocity of the water and the rotational velocity of
the blade form the hypotenuse and one leg of a right triangle; their relative orientation determines the blade’s angle of attack. Changes in either of these velocities will, therefore, change the angle of attack. As the vessel moves forward the blade moves with it, which increases the relative velocity of the water and, because of slip, changes the geometrical relationship between water and blade – the upshot is that, as vessel speed increases the angle of attack decreases. As a result, beyond a certain velocity every additional knot of speed comes at an increasingly higher power cost.

The link between airplane wing and propeller blade ends with the wake field, the area of water that flows off the ship’s stern into the propeller. The propeller designer faces a more complex analytical problem than the wing designer because the fluid (air) that passes over an airplane wing is of uniform velocity, but the water passing by a propeller blade is not. A ship’s wake field is, in fact, a collection of many small streams moving at different velocities, each of which is created by the part of the stern that it flows past. Thinking of the propeller as a clock face, the water speed it encounters at the 12:00 position is slowest, because the stern there is widest; likewise, water speed at the 6:00 position, where the stern is narrowest, is fastest.

One major challenge facing designers is that the propeller and the wake field form an interactive system, in which performance at each ‘hour’ position are different. For example, in moving from the 12:00 to the 6:00 position, the blade is, essentially, ‘cutting downwards’ into the water; as it returns to 12:00 it is cutting upwards. The changes in resistance, thrust and power consumption as the
blade cycles through these conditions present additional complications for the designer trying to tweak a propeller for efficiency gains.

Because of such variations in the wake field, a design change that creates a desirable performance difference at, say, the 1:00 position may create a negative effect at 9:00. As a result, the designer's job involves seeking balance among what is, effectively, a potentially infinite series of possible adjustments and consequences.

Just as the ship's wake field is the input to the propeller, so is the propeller's slipstream the input to the rudder. While the rudder does not have distinct suction and pressure faces like a propeller blade, it too acts like a wing; as it turns it creates pressure fields on either side of it, which also produce lift. Where the propeller's lift becomes thrust, the rudder's lift becomes steering force — the ship responds to pressure changes around the rudder by moving from the high-pressure side to the low-pressure side.

Recognizing this linkage between stern, propeller and rudder, many shipowners and shipyards are bringing the better propeller and rudder designers into the ship design process at very early stages, the idea being to mutually refine each of these elements so that they work as a system and, thereby, maximize the vessel's propulsive efficiency.

Efficiency is just one goal among many that the designer must strive to keep in balance. For a further glimpse into the complexities of the propulsion system designer's task, consider for a moment the challenge of vibration. Mitigating propeller vibration is important because it consumes energy, reducing overall propulsive efficiency, and is a contributor to total shipboard noise and vibration, a recognized health and comfort issue.

Propeller vibration is related to the velocity distribution in the wake field, which the designer analyzes mathematically as a series of harmonic velocities: a mean velocity, a once-per-revolution fluctuation, a twice-per-revolution fluctuation and so on. This analysis produces a so-called 'wake spectrum of harmonic velocity fluctuations' that contribute to overall propeller vibration and noise.

The propeller produces a fluctuating lift force in response to each harmonic, like the way an eardrum responds to sound. The responses that don't cancel out each other contribute to sectional thrust — the lifting force at any given point on the blade — and, ultimately, cause vibration at velocities that are multiples of the number of blades. If vibratory forces were the only consideration, then, more blades would make a better propeller. But it is not that simple.

Another contributor to noise and vibration is the pressure pulse that occurs when the blade passes into and out of the low-pressure (low velocity) parts of the wake field.

The main purpose behind the scimitar-like blades of high-skew propellers is to reduce this effect by having the tip 'cut through' the low-pressure area first, blazing, as it were, a smoother path for the body of the blade to follow. Using advanced analytical techniques like CFD, designers can 'tune' the skew to suit a given wake field — once they have committed to other design decisions like propeller diameter, blade shape and area ratio.

Yet another design complication due to the wake field is cavitation. Because water speed is slowest at the 12:00 position, the blade's angle of attack there is greatest. Since a larger
angle of attack produces lower pressures, the pressure at this point is the lowest in the blade’s entire cycle – so low, in fact, as to be below the pressure at which water becomes vapor. Quite literally, the water ‘boils’, forming vapor pockets that cling to the ends of the blade. As the blade turns, the pockets break into bubbles which, as they collapse and fly off, create tiny concentrations of intense pressure that impinge on the blade and, over time, can cause cavitation damage; the bubbles also contribute to the noise and vibration felt onboard. Further, because it has volume, the vapor pocket also effectively alters the blade profile, increasing drag and reducing thrust.

For these reasons and more, minimizing the size of the vapor pocket and reducing cavitation phenomena is a significant part of blade design. One way it is done is by controlling pressure distribution, among the most important characteristics of a propeller blade. Among the factors pressure distribution calculations take into account are blade shape and the inflow to the propeller. Inflow being a product of the ship’s stern form, and operational efficiency being so important today, propeller designers are now being consulted on wake field optimization and the interaction of stern and propeller at the earliest stages of ship design – a big change from the past, when they would often be told to fit a screw to an all but finished hullform.

Today’s heightened appreciation for the contributions that propeller designers can make is good preparation for dealing with one of the newest maritime industry regulations, the Code on Noise Levels on Board Ships (the Noise Code), which enters into force on 1 July 2014. An amendment to the Safety of Life at Sea Convention adopted by the International Maritime Organization’s (IMO’s) Marine Safety Committee, its stated purpose is “to provide standards on preventing noise levels hazardous to human health and reduce seafarers’ exposure to such noise levels.”

Environmentalists, armed with research indicating that noise from ships and other man-made sources is exerting harmful effects on sea life, particularly marine mammals that use echo-location and vocalizations, are voicing hopes that the Noise Code will be the thin end of the wedge bringing on regulations to specifically protect marine life from ship-generated noise.

Such hopes are not groundless. In 2008, the IMO established a high-priority work program for its Marine Environment Protection Committee to investigate “the incidental introduction of noise from commercial shipping operations into the marine environment, to reduce potential adverse impacts on marine life.” Among the investigative targets in the ongoing program are noise levels generated by machinery and propellers.
Innovative Asymmetry

Some energy-saving devices work so well because they look so strange.

A ship’s propulsion comes not only from the power of its main engine, but also from the flow of water through its propeller. In fact, some 20 percent of the power delivered to the propeller is lost in the slipstream, the cylindrical volume of water within which the propeller turns. This fact alone makes the stern region a potential goldmine for energy efficiency enhancement.

Energy losses at the stern have two principal causes: the ship’s wake field, the multiple speeds and directions with which water flows off the stern into the propeller; and the imperfect resistance of water to the propeller, which causes it to ‘slip’ rather than ‘grip’ in the water as it turns (leading to the term slipstream). The rotation of the propeller also creates vortexes behind it that exert a sucking effect against the direction of vessel motion, creating drag that reduces propulsive efficiency.

Industry interest in improving fuel economy over the past five years – which is higher than it has been during the previous three decades – has spurred a great amount of research and development into ways and means of making the back end of the propulsion system more energy-efficient.

As a result, a number of manufacturers have devoted significant time and resources to developing devices and technologies for improving performance of the stern, propeller and rudder, individually and in combination. Some, applying advanced analytical technologies like computational fluid dynamics (CFD) in this effort, have managed to develop products that deliver very impressive efficiency gains.

One such company is Hamburg, Germany-based Becker Marine Systems, which has brought several popular energy-saving devices (ESDs) to market in recent years. A leading manufacturer of rudders and maneuvering equipment, Becker units account for about 85 percent of the special-needs rudder market (and about 10 percent of standard rudders). Among its latest ESD products is the extremely popular Becker Mewis Duct®, which many users call the single most effective energy-saving add-on available.

Developed through a collaboration between inventor Friedrich Mewis (pronounced may-vis) and the Becker engineering team, the product was first installed in 2009 and, in many installations since then, has
demonstrated that it can reliably reclaim 4 to 8 percent of the propulsive energy lost in normal operations. Over the past five years, Becker has sold nearly 700 of the units, more than 300 of which are currently in service.

The Best of Two Worlds
Designed for wide-body vessels like tankers, bulkers and general cargo ships, the Becker Mewis Duct is attached to the stern directly in front of the propeller and works by attacking both main sources of energy loss, the wake field and the slipstream. It does this using a CFD-refined combination of two proven ESD concepts first brought to market during the 1980s, the wake-equalizing duct and the stator vane. The duct part of the unit handles the wake and the vanes take care of the slipstream.

The wake field has two distinct areas of differing water velocity, an upper half comprising a set of slow-moving streams that trail off the wide body of the vessel, and a set of faster-moving streams below it trailing off the narrower part of the ship closer to the keel. When the propeller crosses the boundary between these slow and fast areas, it experiences a kind of jerk and generates an energy-consuming pressure pulse. The duct part of the Mewis Duct improves the wake field by focusing the slower water streams and giving them additional forward thrust. By improving the water speed in the upper half of the wake field, the Mewis Duct reduces pressure pulses and enhances propeller efficiency.

In addition to channeling and accelerating the water flow, the duct acts as a frame for the stator vanes inside the unit. The vanes change the water's direction, causing it to swirl against the rotation of the propeller. Directing the water against the propeller increases its resistance to the blades, making the propeller ‘work harder'; this helps diminish the energy lost in the slipstream and, thereby, produce more thrust.

Improving propeller efficiency by creating this new flow pattern, called a counter-rotating pre-swirl, is an idea dating back more than a century. Various methods of applying the concept have been tried over the years, with limited success. It is only through CFD that Becker is able to identify the key points in the non-uniform wake field where fins and ducting have to be present, and then develop the shape and profile of the parts so that they actually do the intended job.

Each hullform has its own wake field and each propeller its own slipstream characteristics; CFD analysis of these results in the Becker Mewis Duct being such a strange-looking instrument. For example, sometimes the duct ring is egg-shaped, sometimes it is peanut-looking, and very rarely is it perfectly round. Likewise, such advanced analysis is why the fins are positioned asymmetrically within the duct and why each fin has a different thickness, length and profile. Because the wake field and propeller field are different for each ship, every vessel needs its own unique Becker Mewis Duct.

“Every Becker Mewis Duct is individually designed for its specific ship, and subject to about four weeks of very comprehensive CFD analysis and verified through model tests,” says Dirk Lehmann, Managing Director of Becker Marine Systems. “At this moment, we are the best single customer of all the world’s model test facilities. This year we will do 75 model tests; last year we did 66 and the year before we did 60. Today we use the services of 14 institutes all over the world, from the United States to Japan,” he says.
“That said, hydrodynamics alone are not enough, because you also need to engineer the structures,” he adds. “When we developed the Becker Mewis Duct, there were many choices of how to do it. Above all, what we wanted was to create a new component that would last for the lifetime of the vessel, without any special maintenance and without any moving parts. It took three years of development, but we did it.”

Unique Product, Unique Guarantee
In these days of tight margins and nail-biting cost-consciousness, clients often need a little more than the promise of successful prior results to invest in vessel modifications. To help sell the Becker Mewis Duct, Becker came up with a risk-mitigating offer that’s as innovative as the device itself: a ‘fuel savings guarantee’ that promises to refund the client’s investment if model tests of the device Becker designs do not support the company’s predicted efficiency boost.

“As an example, say a medium-range tanker owner wants to convert five ships to Becker Mewis Duct use, and that each unit will cost €150,000,” Lehmann says. “At the start of the project, the owner will pay us €135,000 for the design of those systems – that’s a design fee needed to create his unique Becker Mewis Duct, because it is not an off-the-shelf product,” he explains. “With this fee, we develop our design and perform our model tests. Before the CFD starts, we give the owner an estimation of how much fuel savings we expect. If, say, that estimation is 5 percent, and if the model test cannot show a 5 percent savings, then the whole order is cancelled, the owner gets his fee back – in other words, no cure, no pay.”

The guarantee, which can be exercised by either Becker or the client, serves as much to protect the reputation of the product as to keep customers satisfied. Some vessels are not ideal candidates for a Becker Mewis Duct – for example, those having a V-shaped aft and low-load propeller – and, says Lehmann, the company doesn’t want units out there giving only miniscule results. A side benefit of the experience, he adds, is that the model test results serve the vessel throughout its life because they testify to its energy efficiency.

“When you install a Becker Mewis Duct you get the model test data that guarantees your fuel efficiency gain of, say, 5 percent. That can make the vessel more competitive when it is up for charter or is in a pool,” he says, pointing out that the model test results are documented results that fully conform to the standards of the International Towing Tank Conference (ITTC), which makes them valid for evaluation under the Energy Efficiency Design Index (EEDI) for new vessels and for the Energy Efficiency Operating Index (EEOI) for existing ships.

With such encouragement, Becker has attracted a long list of clients for Becker Mewis Duct retrofits. Because fuel can represent up to 85 percent of voyage costs for a VLCC, interest has been high particularly among tanker owners. Last year, for example, Maersk Tankers made the Becker Mewis Duct part of a systemic efficiency improvement scheme under
the ECO-Retrofit effort initiated by Maersk Maritime Technology. In May 2014, the company installed nine different fuel-saving technologies as part of a pilot program aboard its ABS-classed VLCC Maersk Ingrid, which the company’s sustainability report refers to as its 2013 flagship project for environmental efficiency.

Maersk recently reported that the Ingrid’s ESD installation alone – a Becker Mewis Duct in combination with a propeller boss fin cap – is expected to provide a 6.6-percent reduction in fuel consumption. At the time Maersk stated that, at current fuel prices, such an efficiency gain represents a cost savings to VLCCs of close to $800,000 per year per vessel.

**Need Breeds Innovation**

Due to changes in water flow, the Becker Mewis Duct becomes less effective after about 18 knots of speed, and is also not efficient with fine-formed vessels like fast containerships. Knowing this, shortly after its introduction the company began working on adapting the idea to these other ship types.

In early 2013 the company unveiled the Becker Twisted Fin® (BTF), its evolution of the Becker Mewis Duct concept for higher-speeds and finer vessels. The BTF looks like a miniature version of the Becker Mewis Duct, but – reminiscent of stator vanes from the old days – has the fins extending beyond the duct ring. Like its predecessor, it is another odd-looking instrument, with the fins asymmetrically positioned and of varying length, width and profile. The BTF is the product of three years of development, including, says Lehmann, “very comprehensive resonance and fatigue analyses as well as analysis by CFD. Many first-generation vane installations broke apart in service, and we wanted to be certain ours wouldn’t fall off!”

The secret to its success, he says, is that the drag created by the fins is counteracted by the thrust created through the duct. The first order for the BTF was received shortly after its release, when leading containership operator Hamburg Süd installed the unit on a series of ten containerships coming into ABS class.

Another peculiar-looking ESD from Becker is the twisted rudder, the unique profile of which is designed to deal with the rotational water flow off the propeller and the varying water speeds in the vessel’s wake. The lower profile of the rudder is very slender, to make best use of the high water speeds in that region of the wake, while the profile of the upper part is thicker. Like the Becker Mewis Duct and the BTF, the Twisted Rudder is a custom design, created as a match for the propeller with which it must work.

“Every segment of the Twisted Rudder is designed to provide the same lift ratio,”
Besides propulsion assists and propeller change-outs, other technologies are assisting the drive towards slow steaming, particularly as regards the challenges that the practice presents to the ship’s main engine.

One internal challenge is a phenomenon called ‘cold corrosion.’ Responding to escalating fuel costs and increasingly stringent environmental regulations, many shipowners are turning to new-generation main engines that offer improved fuel consumption through longer piston strokes.

Engine maker MAN Diesel & Turbo recently noted that an emerging issue with these new engines is that, in super-long-stroke operation, the cylinder walls cool down more than older engine designs. This extra cooling time allows water to condense on the surface of the cylinder liners, where it reacts with sulfur dioxide in the combustion gases to form sulfuric acid and, ultimately, cause corrosion. After this, iron compounds formed during this process are then flushed into the cylinder oil, leading to excessive wear of the cylinder liner. MAN says average replacement costs for a liner today range up to $150,000.

As this issue went to press, leading lubricants maker Castrol was preparing for the worldwide release of a next-generation cylinder oil named Cyltech CL 100 ACC (for advanced corrosion control). Castrol says the oil is its “considered technical response to the corrosion issues that can arise in modern two stroke marine engines, especially when ships are slow steaming.”

A newly-formulated lubricant for the latest generation of main engines, its development drew on several years of evidence that the company has gathered indicating corrosion issues arise from fuel sulfur content when engines are run at part-load.

On announcing the impending product release in December 2013, a Castrol spokesman pointed out that the new oil addresses technical challenges to modern super-long-stroke engines, which “operate at higher pressures, causing higher dew points and increased sulfuric acid formation, which in turn can result in severe corrosive wear, particularly where higher-sulfur fuels are used and the engine is operated at lower loads.”

Meanwhile, an external solution for ships equipped with multiple MHI turbochargers, developed fairly recently by MHI’s Marine Machinery & Engine division (MHI-MME), reportedly allows operators to squeeze some extra mileage out of slow-steaming without slowing even further.

Ships normally employ turbocharger cut-out during slow-steaming, meaning that, for an
Becker Marine is an internationally renowned manufacturer, but one without a plant; it builds its equipment at many sites, controlling production and quality through extensive site supervision teams. Research, development and design, however, are performed entirely at home.

“For us, it’s important to be a technology leader in our areas of activity,” Lehmann says. “We don’t need our own factory because we work with fabricators all over the world. Our strength is to have not only the know-how in-house, but also, and more importantly, what I call the ‘know-why’ – understanding. To me, the term know-how relates to production; anyone can acquire it. The unique thing that we are building is know-why.”

In the know-why spirit, Lehmann envisions a not-too-distant future when the industry welcomes a revolution in one of the most ancient pieces of ship’s equipment, the rudder.

“I see completely new rudder designs coming in the future,” he predicts. “In ten years, rudders will look nothing like they do today. Changes will come in the form of new materials, new shapes, new structures and new profiles. The internal structure of rudders today is very old-fashioned: it is rectangular, and there is no need for that – water flow is not rectangular, so why should we have a rectangular structure to respond to it?” he asks. “Rudders of the future will have completely new internal structures; they will be lighter and stronger and yet more durable than ever before.”

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“Engine equipped with several turbochargers, one of them is stopped at slow engine speeds and the exhaust gas distributed to the remaining three, which increases the scavenging air pressure and improves fuel efficiency. As a hardware-based alternative to that procedure, MHI-MME developed the Variable Turbine Inlet system (VTI).

Developed for the company’s MET turbocharger series, the VTI features a gas inlet passage equipped with an on-off valve. This valve changes the turbine’s capacity in two stages by admitting exhaust gas into two separate concentric segments of the nozzle ring. When a ship operates in slow-steaming mode, the scavenging air pressure of the main engine is increased by closing the on-off valve, thereby decreasing the fuel consumption rate. The manufacturer says that tests show a fuel consumption reduction of between 1.6 and 3.2 percent in a load range of 10 to 50 percent MCR.”
Launched 170 years ago, the SS Great Britain was an innovation showcase that introduced a number of operational and technical innovations that became building blocks of the modern maritime world.

Brainchild of one of the 19th century’s greatest engineers, Isambard Kingdom Brunel, the Great Britain was a ship unlike any other. The first large ship with an all-iron hull, it introduced the world to such futuristic design elements as: a flat double-bottom without a standard center keel and built of cellular construction; five watertight bulkheads; a balanced rudder; a clipper bow; a hydrodynamically designed hullform; and, as its principal form of power, a large, six-bladed propeller. In 1845, Great Britain became the first ship to cross an ocean driven by propeller.

A sail-assisted steamship, the vessel was also a pioneer in the use of wire rope rigging, and the first vessel ever built with six masts (although one was removed early on). Nautical terminology having no established nomenclature for them, the masts were named for the days of the week. With an overall length of 322 feet and a breadth of 51 feet, Great Britain was the largest ship in the world and part of a radical new vision for international commerce: an intermodal transportation network.

In 1835, Brunel proposed to the UK’s Great Western Railway Company (for which he was a consulting engineer) the novel idea that the railroad line could be ‘extended’ across the Atlantic by means of a regularly scheduled steamship service. Passengers could buy a ticket at London’s Paddington Station (also a Brunel design) straight through to New York City. He insisted the ship for this service be large, putting forth the then-controversial concept of economies of scale; that a large steamship could carry its own fuel and still haul a sufficient amount of cargo and passengers to operate economically.

He supported his case by drawing on an even more controversial technology, the barely accepted science of hydrodynamics. “The resistance of vessels on the water does not increase in direct proportion to the tonnage,” Brunel argued. “The tonnage increases with the cubes of their dimensions while the resistance increases at about their squares, so that a vessel of double the tonnage of another capable of containing an engine of twice the power does not really meet with twice the resistance. Speed, therefore, would be greater with the larger vessel, or the proportion of power in the engine and the consumption of fuel may be reduced.”

He eventually made his case and built the paddlewheeler Great Western, an oak-hulled vessel strengthened by iron bands. Operated by the Great Western Steamship Company, the ship was 236 feet long – the biggest of the day – and its eight years of successful sailing made it the conceptual cornerstone
of all oceangoing steamship service that followed. The vessel proved so profitable that the company's board quickly authorized construction of a second ship for the service. Advancing the same concerns, Brunel succeeded in building Great Britain, which at 2,936 gross tons was more than twice the capacity of its companion. Breaking completely with tradition, the ship abandoned wood and paddlewheel for the two hotly debated new technologies of iron hull plate and screw propulsion.

Although iron had been used to some extent in small vessel construction for about 20 years, its use for the entire hull was considered faddish and dangerous – in fact, it would be almost another three decades before iron achieved worldwide acceptance. Meanwhile, common wisdom about propellers was reflected in the pages of Scientific American, the first issue of which coincided with the Great Britain's maiden voyage to New York:

“The steamship Great Britain, the mammoth of the ocean, which has recently arrived from Liverpool, has created much excitement here as well as in Europe; being in fact the greatest maritime curiosity ever seen in our harbor,” the magazine's editors wrote. “If there is anything objectionable in the construction or machinery of this noble ship, it is the mode of propelling her by the screw propeller; and we should not be surprised if it should be, ere long, superseded by paddle wheels at the sides.”

The ship's power plant was also unusual: an inverted V4-cylinder steam engine with a chain-driven propeller shaft and pistons that were 88 inches in diameter, among the largest ever put to sea. At 18 rpm it produced 1,870 horsepower and could drive the vessel reliably at 14 knots, although average cruising speed was more like 10 knots. In 1984, this amazing engine was honored as an international historic engineering landmark by the American Society of Mechanical Engineers.

Unfortunately, after a spectacular start the Great Britain was beset by problems, including an incompetent captain who grounded the vessel. Although the incident proved the wisdom of its double bottom, the vessel was underinsured and ultimately led to the company selling its two ships. Under new owners, the vessel spent 19 years carrying passengers and freight from England to Australia and was arguably the world's fastest and most profitable long-haul carrier.

The beginning of the end came when new owners pulled the engines, covered the hull in pitch pine and removed the passenger cabins, using it as the kind of vessel it had been built to obviate. Finally, losing most of its masts to an 1886 hurricane, Great Britain was abandoned in the Falkland Islands, where for more than 50 years it served as a floating warehouse in Stanley Harbor. When that job ended, the former ship of the future was beached ostensibly forever, the residents being too fond of the old vessel to scrap it.

Generous ship aficionados brought Great Britain home to Bristol in 1970 and, with some heavyweight patronage, began a long restoration campaign. The ship now rests in its original graving dock, which has been modified with an innovative moisture-controlling glass enclosure that protects the ship's lower hull from further corrosion – the hull is still all-original, and in a fairly delicate condition.

Great Britain gave the world a window into the future of commercial shipping by proving the superiority of steam over sail, screw over paddlewheel and metal construction over wood, and by demonstrating the power of economies of scale. Its dramatic and successful break with the slow, evolutionary pace of maritime design provided an archetype in form and spirit for the generations of new and better ships that followed. Today again beautiful, restored as far as possible to its original specifications, the proud old ship welcomes about 150,000 visitors each year, providing a monument both to the triumphs of the past and to the possibilities of the future.

ENGINES & DRIVE
The GREAT BRITAIN's unique inverted-V main engine had four cylinders working in pairs and inclined inwards and upwards at an angle of 60 degrees. The pistons were 88 inches in diameter and worked with a 72-inch stroke to drive an overhead crankshaft. On this crankshaft was a wheel 18 ft in diameter and 38 inches wide which, by a system of endless chains toothed on their inner side, turned a smaller six ft wheel on the propeller shaft below.
As the focal point of massive new offshore energy projects, the fuel for a new generation of clean-burning oceangoing ships, a driver of change in the petrochemicals sector and an increasingly important source of electric power generation in many nations, natural gas is bringing positive change to industrial activity all over the world.

The biggest boost for the global gas revolution comes from the United States, where shale gas now accounts for nearly half of all natural gas production. Gas extracted from shale is so plentiful and available at such low prices that it has made the US the world’s Number One gas producer, has brought about a growing export activity in liquefied natural gas (LNG), and is now fueling an industrial renaissance in the country, most notably in the $770-billion chemicals sector.

Not too long ago, the US was one of the most expensive places on earth to manufacture chemicals and, accordingly, plants and factories were closing and manufacturers planning new facilities in the Middle East and elsewhere. Now it is among the cheapest. Over the past four years shuttered facilities have been reawakened and investment in the US chemicals sector has skyrocketed.

The American Chemistry Council (ACC), a trade association, reported in February 2014 that a total of 148 new chemicals sector projects have been announced to date, with an aggregate investment of $100.2 billion – all stemming from the long-term availability of inexpensive US gas. According to the ACC, petrochemicals account for 55 percent of that spending, plastics for 22 percent and fertilizers for 14 percent, with chief beneficiaries of the investment being the US Gulf Coast (78 percent), the Ohio Valley (13 percent) and the Midwest (8 percent). These projects, about half of which are funded by international interests, range from new plant construction...
to facilities modifications and processing upgrades, and are predicted to add 637,000 permanent jobs and boost overall US chemical industry output by some $81 billion annually. At the core of this renaissance is ethane, a hydrocarbon belonging to the group of natural gas liquids (NGLs), which also include propane, butane and natural gasoline.

**The Other Gas Revolution**

Often, discussions about the shale gas revolution are actually talking about methane, the main component of natural gas and the one used for power generation (and shipped in the form of LNG). There’s good reason for that, since cheap US methane is making LNG an economically viable fuel for oceangoing ships, widening its use for power generation and forcing changes in international gas markets and world geopolitics. These effects are long-term – according to industry analysts, the US has not only more than 100 years’ worth of natural gas reserves, but also, within that, a 30-year supply (some 900 trillion ft³) that can profitably be produced at $4 per million btu or less. In addition, because shale gas typically has a high NGL content (making it ‘wet’ gas as opposed to ‘dry’ gas, which is virtually all methane) and, because ethane is the largest component of the NGL stream, the US gas revolution has also been an ethane revolution.

Ethane’s primary use is in the petrochemical sector, where it is broken down in large processing systems called ‘crackers’ to make ethylene, a basic component in the manufacture of many chemicals and plastics. Ethylene is so important that it accounts for about 40 percent of the world’s chemicals trade by volume.

Reflecting the potential in this new market, as of January of this year, there were projects in place for ten new ethane crackers in the US, most with start-up expected by 2017, plus expansions of ten existing facilities. Industry analysts now say that the cumulative effect of all 20 projects going as expected could be a 52-percent boost in US ethylene output to 41 million tons per year and that, by 2021, some 75 percent of it will be derived from ethane.

Inexpensive US ethane is also having an impact in the petrochemical industries of Europe, Japan and China, where most of the ethylene crackers don’t use ethane as the feedstock, but instead burn naphtha (a generic term for liquid hydrocarbon mixtures). Because naphtha is an oil product, its price is tied to the oil market and today it is much more expensive than ethane – so much more expensive that many facilities are considering improving their profit margins by converting to ethane use and importing the feedstock from the US.
The first major international commitment to US ethane came from Swiss-based chemicals giant INEOS, which last year completed a set of long-term contracts surrounding the import of ethane from a Sunoco Logistics processing terminal at Marcus Hook, Pennsylvania to the company’s cracking plant in Rafnes, Norway. For a hint of the level of industrial activity stirred up by shale gas, consider that this commitment not only calls for building and hiring two ships dedicated to ethane transport and construction of a new storage facility at Rafnes, but also that it is an anchor for Sunoco’s Mariner East pipeline project. Mariner East, meanwhile, involves construction of a 50-mile link from a shale gas field to an existing pipeline network and refurbishment of a link from that network to the Marcus Hook terminal (itself an abandoned refinery that Sunoco repurposed).

Then, consider that Mariner East is just one of several new pipeline projects spurred by growing international interest in importing shale gas products.

A third leg to the US gas revolution, following the changes wrought by its superabundance of methane and ethane, is the accompanying increase in production of liquefied petroleum gases (LPG). LPG is a broad designation that includes a variety of gases derived in refineries from NGLs and crude oil, but most often refers to propane and butane.

In 2012, the US became, for the first time, a net exporter of LPG. In its recent Annual Energy Outlook, the US Energy Information Agency projects that the US will remain a net LPG exporter through 2040. Such projections have spurred an ordering boom in LPG carriers, particularly in the very large gas carrier (VLGC) segment, which had 56 ships on order as of February 2014.

Evolving World Calls for Inventive Engineering

An important role in the global gas revolution belongs to the designers and engineers of the cargo handling and storage systems that enable transporters and offshore energy developers to make natural gas and its products easily available around the world.

One such company is Bonn, Germany-based TGE Marine Gas Engineering, an engineering contractor with more than 30 years’ experience in designing cargo handling and storage systems for cryogenic gases (principal LNG, LPG and ethane/ethylene). The top designer of ethylene carriers, whose work accounts for 54 percent of the world’s fleet, and a leader in the small LPG carrier segment, TGE Marine provides a turnkey service involving system design and engineering, procurement, construction supervision and seeing each vessel through the completion of gas trials.

Over the years, TGE Marine has provided cargo systems for more than 160 liquid gas carriers of all types – including the world’s first LNG/ethylene combination carrier – and delivered novel gas plant solutions for floating liquefaction systems and one of the largest LPG floating storage and offloading units in service. Today, four of the company’s current projects touch some of the salient aspects of the gas revolution: building the world’s largest ethane/ethylene carriers; building the largest Type C LNG carriers (using the IMO Type C pressure vessel type containment system); developing the fuel gas system for the first conversion of a two-stroke diesel main engine to dual-fuel gas/oil operation; and providing various technologies for a supply network that will distribute LNG as fuel for island power plants in the Caribbean.

In January of this year, TGE Marine won a contract from UK-based shipowner Navigator Gas to provide the cargo handling systems, high-pressure fuel gas system and tankage for the first of a possible four 35,000-m³ ethane/ethylene carriers. The vessel, designed anticipating long-term, large-scale ethane exports from US shale gas producers, is currently building to ABS class at China’s Jiangnan Shipyard. When delivered in 2016, it will be the largest of its kind afloat – but, possibly, not for long. The designer is already working with Jiangnan, Navigator and other clients to develop an 80,000-m³ ethane carrier.
Key to realizing this project was TGE’s development of a new bi-lobe cargo tank design to maximize use of the ship’s available hull space. The design allowed TGE to create a three-tank vessel with individual cargo tank volumes of more than 12,000 m³. Previously, the largest ethylene carriers were 22,000-m³ vessels with maximum tank sizes of approximately 6,000 m³.

The new ships feature two 1,000-m³ multifunctional deck tanks to contain the ship’s LNG fuel reserve. The size was chosen to allow the ship to make two transatlantic trips on gas fuel alone, allowing it to always fuel-up on lower-cost American LNG.

LNG is the focus of another project that TGE announced at the start of 2014: an agreement with MAN Diesel & Turbo to design and supply an LNG fuel gas package for the world’s first conversion of a slow-speed, two-stroke diesel to dual-fuel gas/heavy fuel oil (HFO) operation. The vessel in question, ABS-classed Rasheeda, is a 266,000-m³ Q-Max LNG carrier; its MAN series ME-GI electronic main engine is to be converted at the Nakilat-Keppel Offshore & Marine Shipyard in Qatar. The conversion is expected to take MAN engineers 40 days to complete, but, owing to the equipment development timeline, the work is slated to be carried out in the spring of 2015.

With a growing number of new vessel projects specifying dual-fuel engines, plus increasing interest in LNG as a full-time fuel for electric power stations, the long-anticipated market for ‘small-scale’ LNG – bunker services for vessels and local delivery in small-capacity vessels – is beginning to develop. In one of the first shipbuilding projects anticipating this emerging market, TGE Marine is supplying the cargo handling and containment system for a 30,000-m³ LNG carrier, design which it developed in conjunction with the Shanghai Ship Design & Research Institute (SDARI) and the vessel owner, the China National Offshore Oil Company (CNOOC). Currently building under the watchful eyes of ABS and the Chinese Classification Society (CCS) at Jiangnan Shipyard, the vessel will feature the largest Type C LNG cargo tank yet built.

The technology for the tank is a direct outgrowth of TGE Marine’s expertise in ethylene carriers. The new ships represent a step up in sophistication, but the technical challenge has been manageable. For example, cargo tanks for liquid ethylene, which must be kept below -104°C, are made of 5-percent nickel steel; for LNG, which is transported at -160°C, and the material is 9-percent nickel steel. Various upgrades of the handling system were also required, such as moving from flange-type to welded valves, developing a new gas compressor suited to LNG, and engineering a special cradle for the containment system that could accommodate tank shrinkage due to the low temperature of the cargo, which depending on tank diameter, can be as much as 40 mm.

**Vision for the Future**

According to Dr. Manfred Küver, Managing Director of TGE Marine Gas Engineering, the company has been preparing for the gas revolution for the past eight years. What sparked its vision of a gas-fueled future was not early experimentation with dual-fuel prime movers by engine makers, he says, but subtle changes of thinking in the power generation sector.

“We were inspired by the awareness that small power plants were becoming interested in substituting LNG for HFO, the prices of which had begun to climb, and we had the thought that a milk-run service to these plants from the larger terminals would be needed,” says Dr. Küver. “We saw that small terminals would one day be built and

Rendering of a shipboard gas handling system designed by TGE Marine, with a view into the under-deck equipment and the cargo tanks below.
Group (one of its shareholders), TGE Marine has completed conceptual design and the front-end engineering design (FEED) package to support a planned switch from HFO to LNG fuel for small power plants on the islands of Martinique and Guadeloupe. The idea is to have a 20,000-m³ shuttle vessel circulating between the gas supplier in Trinidad and the two islands, where floating regasification units (also designed by TGE Marine) will be permanently moored. From there the gas will be piped to the onshore facilities, whose existing MAN diesels will be refurbished to have gas capability.

“This island power generation scenario is a very interesting potential market – there are so many islands in the world whose power plants are burning expensive, dirty fuels like HFO and coal,” says Küver.

Between floating gas systems, small-scale LNG distribution and expansion and replacement of the global gas carrier fleet, the future holds great promise for his company, he adds.

“For the future, I see small-scale LNG distribution growing, along with the development of LNG bunkering,” says Küver. “Shell is looking for an LNG bunker vessel; GDF-Suez is working on one with NYK; Exmar is looking into the technology; and we have Norwegian clients interested as well. There is no doubt, the era of LNG bunker vessels will come,” he says.

“For a long time, everyone was keen on LNG as ship’s fuel, but the shipowners were stopped by the question of where to get the gas,” he continues. “Now, however, due to the price of fuel oil and ecological demands, more merchant vessels, passenger ships, container carriers, ferries and ro/ross are looking at gas for fuel. They will all need to bunker, and the logical solution is to have small vessels bring the LNG from central storage facilities, in the same way that oil is brought to ships via bunker barges,” he adds. “The gas revolution is happening now, and is here to stay.”

that a distribution chain for small volume shipments would be set up. That was the first trigger element. There were also some small ships that had entered that kind of service during the 1990s, most notably in a dedicated run between Indonesian LNG terminals and Japanese power plants. Therefore, we saw a need for ships of about 10,000-m³ to perhaps 35,000-m³ capacities, which would bring LNG from large terminals to smaller facilities and then re-export it to smaller, isolated centers, either for power plants or industrial consumers; and that all of this would come about because LNG was a little bit cheaper than HFO, has a higher heating value and is much cleaner energy,” he explains. “That is why we thought this day would come.”

TGE Marine has a hand in another dimension to the global gas revolution also occurring in the Americas: a proposed small-scale LNG distribution network for island power plants in the Caribbean. Working with the Gasfin
TGE Marine: A Gas Engineer’s History at-a-glance

TGE Marine Gas Engineering was founded in 1980 in Bonn as Liquid Gas International (LGI), which began as a designer of gas handling systems for small gas carriers building primarily in the shipyards of northern Germany and Holland, but soon expanded its scope of work to include designing onshore cryogenic terminals. In 1989, LGI won a contract to supply the gas handling system for the first-ever gas carrier to be built in Mainland China, beginning a relationship with the Jiangnan Shipyard group that continues to this day.

LGI was acquired by the Belgian Tractebel Group in 1993, renamed Tractebel Gas Engineering (TGE) and, by the end of the decade, was handling all of Tractebel Group’s gas engineering activities, including design of LNG terminals, storage and logistics systems. In 2003, Tractebel was acquired by France’s Suez Group, which merged it with another property, the Société Générale De Belgique, to become Suez-Tractebel; this made TGE the gas engineering arm of one of the world’s largest industrial services organizations. Three years later, Suez decided to divest its contracting activities as non-core interests, and TGE returned to independence through a management buy-out (MBO) aided by a new partner, UK-based Caledonia Investment plc.

Although successful, the MBO left TGE with a dilemma. The company possessed two business lines, one in gas handling and storage systems for marine and offshore applications, and the other as an engineering, procurement and construction (EPC) contractor for onshore cryogenic terminals. While Caledonia is big, with a balance sheet of £1.5 billion (approximately $2.5 billion), it isn’t big enough to support all its own interests and still provide the kind of financial guarantees required by today’s large-scale terminal engineering projects.

“The contracting side of the onshore terminal business was too big for just a financial investor,” recalls Dr. Manfred Küver, Managing Director of TGE Marine Gas Engineering and CEO of TGE AG. “We had built three LNG terminals at that time, with contract values between €250 and €350 million (about $340 to $480 million). With the balance sheet of Suez-Tractebel, it was no problem to secure those contracts. But Caledonia, while willing to give us a certain amount of backing, could not be expected to provide its whole balance sheet to back these large contracts. So, we de-merged after the MBO and made a separate entity, which was then sold.”

The de-merged company, TGE Gas Engineering, was acquired by the Chinese CIMC Group. Today, the TGE name is seen attached to three entities on the door of the company headquarters in Bonn: TGE Marine AG, the holding company for TGE Marine Gas Engineering, which is owned 67 percent by Caledonia; the balance is held by the Gasfin Group, which is owned by Vladimir Puklavec, one of the original founders of LGI. CIMC owns 60 percent of TGE Gas Engineering, with the balance held by Gasfin.
A SHIPYARD OVERHAULS ITSELF

A famed ship repairer grasps a new destiny via the offshore energy sector.

Responding to changes in the global shipping industry and offshore energy markets, a shipyard known for decades as a ship repair specialist has spent the past six years converting itself into a regional hub for a wide range of marine and offshore services. While a significant transformation in the eyes of its traditional client base, the change is more like an extension of a relationship with the energy sector that began nearly 40 years ago.

Arab Shipbuilding & Repair Yard (ASRY) opened for business in 1977 as the first ship repair facility in the Arabian Gulf region dedicated to supertankers. Its 500,000-dwt graving dock, measuring 375 by 75 meters, was the largest available in the long stretch between Europe and Japan, and the yard accordingly serviced many great vessels of the supertanker era that brought Middle East oil around the world. As its reputation grew among the world's energy transporters, ASRY augmented its facilities with two notable upgrades: the 1992 construction of two floating docks, with respective maximum capacities of 120,000 dwt and 80,000 dwt; and the 2008 addition of twin slipways, each with a dry berth length of 255 meters and maximum capacity of 5,000 dwt.

During the end-phase of the 2004-2008 shipbuilding boom, ASRY’s management foresaw the coming retraction in the worldwide ship repair business and began contemplating what actions must be taken to keep the company competitive. For, although ASRY is government-owned, with shares held by seven member States in the Organization of Arab Petroleum Exporting Countries (Bahrain, Saudi Arabia, the United Arab Emirates, Kuwait, Qatar, Iraq and Libya),
business is not guaranteed. It is a for-profit corporation that must compete for survival like any other. Convinced that ship repair would soon be insufficient as a sole source of income, and aware that two new shipyards would be raised in the region, in 2007 ASRY’s shareholders brought His Excellency Sheikh Daij bin Salman bin Daij Al-Khalifa onboard as the new Chairman, and charged him with steering the yard towards a new future.

Realizing that ASRY needed to render itself ship-shape inside and out before it could effectively seek a new destiny, Sheikh Daij set the company on course towards a complete overhaul and conversion, with extensive modifications ranging from corporate restructuring to the installation of new facilities.

“ASRY carried out some exceptional work over the years, and it is a credit to my predecessors and previous management that we have won so many repeat customers, internationally and within the Arab market. That said, by the time I arrived, the yard had serious issues and was in need of restructuring,” Sheikh Daij recalls. “We systematically updated policies and procedures, especially those related to tendering, to procurement, to warehousing and to financial concerns. We overhauled every aspect of the company, starting at the top, with my office – I practice what I preach, so that positive change filters through all levels of the company,” he explains.

**Change Starts at the Top**

“I believe that, before any plan or any strategy can be put in place, especially when a company has new management coming in, the first order of business is, putting it lightly, to get the house in order,” Sheikh Daij says. “Only when that is done can you execute your plans and strategies. If the house is not in order when you start planning, you will neither get the best plans nor the best execution,” he notes.

The first phase of ASRY’s restructuring involved restructuring management, tightening procedural controls, strengthening internal auditing practices, and revising and redeveloping management policies.

“One of the major changes we introduced was a formal corporate governance policy, which the company never had before,” Sheikh Daij says. “Not being a publicly traded corporation, the law does not require it, so one was never developed. While that approach worked in the past, the expectation in today’s business climate is that reputable companies operate with formal policies and procedures.”

Once those changes were initiated, the board turned attention to the factory floor and sought new leadership by promoting from within. The new Chief Executive was a 20-year veteran of the company, and proved invaluable in assessing the yard’s technical capabilities and finding ways to cut costs without compromising the quality service on which it had built its reputation.

As ASRY streamlined operations and brought its new slipways into service, its new management team began seeking directions of diversification. Identifying the offshore energy sector as the richest area of opportunity, the yard took its first steps towards the future with a 2008 strategic initiative in the rig repair market through the formation of ASRY Offshore Services (AOS). Exceeding all hopes, within three years the new division was able to account for 40 percent of the yard’s overall sales. Soon, AOS evolved from being a successful business line into a spearhead of transformation, leading the yard to broaden its horizons and work towards becoming a multi-sector complex of maritime and energy services.

Part of that transformation involves a drive to diversify income through joint ventures and various alliances with service providers. Already, a number of companies have begun setting up shop on the yard’s premises and, hand-in-hand with ASRY’s substantial workshop complex, are creating a kind of shopping mall for marine and offshore technologies.

One of the first steps in this transformation through alliance came in 2011, when AOS began a joint venture with Bahrain’s Gulf Agency Company, a diverse organization providing a wide range of vessel services that includes ship agency, freight forwarding, vessel lay-up and logistics support for maritime and energy-related operations. Most recently, at the start of 2014 ASRY announced an agreement with Dubai-based SOLAS Marine Services Group, under which SOLAS will increase its activity by building a 2,000-m² service center on the yard’s premises for, among other things, lifeboats, life rafts, firefighting equipment and lifesaving appliances. SOLAS is one of more than 20 specialist contractors currently onsite. They will be joined by other companies – such as Wilhelmsen and Seven Seas – which...
have confirmed that they will increase their presence in ASRY and will be launching workshops throughout 2014. The most recent addition to this impressive list is ABB, which opened a workshop in April 2014.

“Seven years ago we had one division – ship repair – and now we have four. These diverse income streams have led to steadily increasing revenues for us over the past four years,” Sheikh Daij says. “In 2013, in fact, we hit $207 million in sales, one of the best years in the yard’s history in terms of revenue.”

AOS has been a critical factor in this performance. In its first full year of operation, AOS generated $10 million in sales, which jumped to $30 million the next year and $62 million the year after. In 2013, its fourth year in business, AOS contributed just shy of $90 million to the company’s coffers, and now represents 43 percent of ASRY’s total revenue.

NEW FACILITIES FOR FUTURE GROWTH
ASRY unveiled the biggest symbol of its transformation while celebrating its 35th anniversary in 2012: a new quay wall measuring 1,380 meters long.

The upgrade also included construction of a 180-meter berth for smaller vessels up to 40,000-dwt and the construction of four azimuth stern drive tugs for the shipyard’s own use. Featuring a 45-ton bollard pull, the 24-meter tugs were built by ASRY to ABS class on land and launched using its new slipways.

“When we decided to build the quay wall, we proceeded under the theory that, because the market was heading downwards – this was in the 2009 timeframe – we were at a good moment to make investments,” Sheikh Daij says. “We were debt-free and, with our very good reputation as a ship repair yard, the banks were eager to loan us money. At the same time, construction costs had dropped because that market too was suffering. We also figured that, by the time the quay wall was ready, the market would rebound – even with the two new shipyards in Qatar and Oman coming up. As it happened, the market did not rebound exactly as we had hoped and everyone felt the pinch,” he says.

“Today, competition is fierce and margins are low all around – I would say they are razor-thin, actually – and profits are, consequently, lower than we had expected. It is not a bleak picture, though,” he adds positively. “Our revenues are increasing, and we expect to continue moving forward.”

That forward movement depends in part on innovation, as exemplified by a daring step made in 2011, when the yard formed a joint venture with UK-based packaged power specialists Centrex Ltd. to develop a series of barge-mounted portable power plants. Now being built to ABS class by ASRY’s Energy
Division (AED), the plants can deliver 125 MW of electrical power to any place near a sheltered marine location. ASRY sees great potential in applications ranging from aiding the industrialization of isolated locations to providing rapid-response power solutions in emergency situations.

In order to support its vision for a power barge business, ASRY needed to develop and organize a comprehensive set of technical skills. Doing this led to the formation in 2013 of another new division, ASRY Consultancy Services (ACS), which was founded to provide independent engineering and design services for projects in the marine and oil and gas sectors.

Although a new business, it has a long service legacy with roots in ASRY’s less formal role in the Arabian Gulf community as a respected giver of technical advice – a role that, for example, led to its involvement in the development of plans for a competing shipyard facility at Duqm, Oman.

“The Omani authorities sought our assistance when they wished to start a shipyard,” Sheikh Daij recalls, “and we offered brotherly advice. Why not? We have the reputation, we provide good work and we are known internationally. We should be willing to assist others, even competitors. The way I see it, if we are afraid of competition, we should just shut down the business.”

A BUSINESS BUILT FOR PEOPLE

Although a commercial entity, ASRY also has an important social motivation behind its existence. One of the reasons behind the company’s creation nearly 40 years ago was to provide much-needed job opportunities for Bahraini citizens. Of the 5,000-plus people typically at work in the shipyard on any given day, approximately 2,000 are direct ASRY employees, about half of which are Bahraini. As the company grows and evolves in pursuit of new opportunities, it continues seeking both traditional and novel ways to fulfill its social responsibilities.

The yard invests substantially in its workforce, and over the past several years has won a number of awards for worker safety and Corporate Social Responsibility. One particularly attention-getting effort of recent years was the yard’s announcement that it would construct an $8.6-million reverse-osmosis desalination plant, which is now under development. Designed to cover all of ASRY’s sweet-water needs, ranging from the industrial water requirements of its repair business to the potable water needs of its labor camps, the plant is also expected to become an
important source of sweet water for the local consumer market.

ASRY is also emerging as a regional leader in employee care. The yard recently opened a state-of-the-art onsite medical facility that operates around the clock, staffed by several permanent doctors and a team of nurses and equipped with an ambulance and the latest technology to deal with everything from emergency cases to common ailments. Meanwhile, the yard remains proud of the dozens of medical social events it offers workers each year, and of the training initiatives that total more than $7 million annually and have brought vocational education and career advancement to the local labor force.

“We focus intently on training and invest heavily in it,” Sheikh Daij says. “A business has to invest in people. This business, any business, only succeeds because of the quality, the skills and the hard work of its people. Therefore, we have to help them develop skills and give them the opportunity to excel and to succeed in life – to help those who wish it to move up the ladder and advance in their profession.”

BRANCHING OUT, LOOKING FORWARD
ASRY anticipates that, as it moves forward, its new endeavors will provide much employment opportunity for the local community. A portion of that opportunity is likely to come from a strategic initiative designed to build on its long-running business activities in Saudi Arabia. The initiative began in 2013 with the opening of an ASRY branch office in Saudi Arabia’s Eastern Province. The office is seen as a base for developing ongoing shipyard businesses and to build on AOS’ growing portfolio of offshore energy work in Saudi waters.

“The Saudi market is significant for us in terms of the repair of commercial and military ships, as well as of offshore platforms,” Sheikh Daij says. “There is great potential in the strong relationships that already exist between Saudi Arabia and Bahrain in all fields, but it is especially true in terms of economic co-operation. Saudi is considered the major economic partner of Bahrain, in addition to being a shareholder in ASRY.”
In December 2013, when ASRY’s board approved its latest package of corporate initiatives – including enhancements to its restructuring plan and installation of a new Chief Executive, Nils Kristian Berge – it also provided more details of its planned expansion into Saudi Arabia. The company reported that it had begun researching the markets for lift-boat size rigs and land rigs, commenting that the small to medium-sized rig segment “has enough potential for it to definitely be on our near-future radar.”

Still, whether all this means that ASRY has offshore construction in its future remains to be seen.

“Our offshore business is still in its infancy stage, in a sense,” Sheikh Daij says. “We have done very well and we should continue to build on our successes, but with care. The areas we have entered during the past seven years are vast compared to what we did before,” he points out. “We have the slipways; we have the quay wall; we’re in the offshore sector; we’re entering the power generation business; and we’ve opened an office in Saudi Arabia and are expanding our oil and gas activities there – and that’s in addition to the internal changes that have taken place. We have come a long way, but our progress has not come easy; it has taken a tremendous amount of time and effort,” he says.

“We can say proudly that ASRY is in much better shape than it was in 2007, but we cannot forget that development is a continuous process,” he concludes. “We will take the company forward and plan future expansions, but all at the right time. In the end, success or failure depends on how well you can combine productivity, efficiency, service delivery and cost management, but is also very much about timing – that’s the story in a nutshell.”

Over the past five years, ASRY has diversified greatly, adding to its ship repair record by building a business in the offshore energy sector. In 2011, the yard introduced an innovative approach to the energy business in its joint venture company with UK power generation specialists Centrax. Named ASRY-Centrax Ltd., the new company has created a unique offering for the developing world: floating high-capacity electrical generation plants, or ‘power barges’.

The barges are being constructed by ASRY’s Energy Division (AED). While AED’s flagship product is the power barge, it can also handle other newbuild projects such as offshore vessels and workboats – in fact, AED built ASRY’s new set of four tugboats.

The first power barge design developed under the new venture, designated the Turbine Power Barge (TPB) 125, is based around a matched pair of Rolls-Royce Trent 60 gas turbine gensets that together produce a total of 125 MW. The idea behind the vessel is that a self-contained, portable power plant can deliver electricity to any place near a port, a river or any sheltered marine location, thus aiding industrialization in areas far from any power grid and, because it can easily be towed, providing quick response to power outages or other emergency situations.

The hulls for two barges have been completed on speculation to ABS class at ASRY. The business got off to a slow start, the company reports, due to the newness of the offering, the need to develop local regulatory frameworks and infrastructure regarding operation of such barges, and the complicated, cooperative nature of their commissioning, packaging and installation. However, ASRY is a patient pioneer and recognizes that forging new ground requires time and patience, and reports that negotiations regarding their deployment are making progress.
Is the Captain Still the Captain?

Richard Du Moulin, President of Intrepid Shipping, Chairman of the Seamen’s Church Institute, and board member of Tidewater, Inc. and Teekay Tankers

There is one critical question all ship owning companies and ship management organizations must ask themselves as they develop and evolve the management systems and philosophies for their ships: Is the captain still the captain?

Technology advances in our industry have been truly phenomenal, but have not changed the fundamentals of safe operation at sea, nor the basic truth that safety at sea rests on having a well-trained captain and quality crew on board, supported by qualified and competent staff on shore.

Think of the 1912 Titanic disaster, the 1978 Amoco Cadiz and 1989 Exxon Valdez oil spills, and the 2012 Costa Concordia incident: all occurred during periods of great advances in technology, and all resulted from fundamental failures in leadership, navigation and seamanship. Together they teach a lesson that technology amounts to nothing if the fundamentals of good seamanship are not onboard. These are leadership, common sense and situational awareness – knowing what’s happening around you, anticipating what will happen and what needs to be done.

Consider the stories of two sailing ships named Bounty. Captain Bligh of the original Bounty may have been a hard leader, but he was also a magnificent seaman who in 1789 brought loyal crew members to safety in a longboat across 3,600 miles of open ocean. In 2012, a modern replica of the Bounty left a safe port and tried to sail behind Hurricane Sandy and went down with loss of life. People survived the former event guided only by a compass and great seamanship; people and a ship were lost in the latter because of bad decisions that ignored the guidance of the best weather forecasting technology available.

Technology has greatly advanced ship safety, but also greatly changed the flow of information following an incident. When the Titanic went down, no one ashore knew who had lived or died until the Carpathia arrived in New York with the survivors. When the Exxon Valdez ran aground, the port of Valdez was alive with reporters and responders and still much disinformation reached the public. But as the Costa Concordia incident played out, information flowed freely from passengers with cell phones. It is now clear that acting a press conference and waving around your ISM documents after an incident doesn’t cut it anymore. Today, between mobile phones, email and online services, statements can be verified almost instantly, and woe to any company or executive falsely claiming to have a working safety management system. No longer can management just talk the talk; it must also walk the walk.

This raises an important lesson about empowerment from the Amoco Cadiz. She was lost and oil spilled because the captain was not allowed to make a basic decision: he had to get permission from ‘superiors’ in Chicago before accepting a towline from a salvage tug.

In all the companies with which I have been involved, we always told our captains to communicate with us onshore, to request support if needed, but to never forget that they are in command and we fully support their decisions. We wanted to be sure they could fulfill the role of captain by fully applying their seamanship and situational awareness towards looking out for the welfare of the ship and the crew.

The importance of management properly supporting and training its mariners cannot be overstated. In this, technology is a great help – in particular, bridge simulator training, like at the Seamen’s Church training facilities in Paducah, Kentucky and Houston for river and intercoastal operators and lightering companies.

That said, the people onshore and aboard need to remember that they must command technology, not be commanded by it; use all available technology onboard, but don’t abdicate responsibility to it.

And so the question remains for each operator to answer: is the captain still the captain; does he use his good training, seamanship and leadership for the benefit of vessel and crew, or has he abdicated responsibility to technology – or had it taken away by the company, whether intentionally or accidentally?
“W
e shall not cease from exploration;
and the end of all our exploring will
be to arrive where we started and to know
the place for the first time.”

– T.S. Eliot
(1888-1965)