

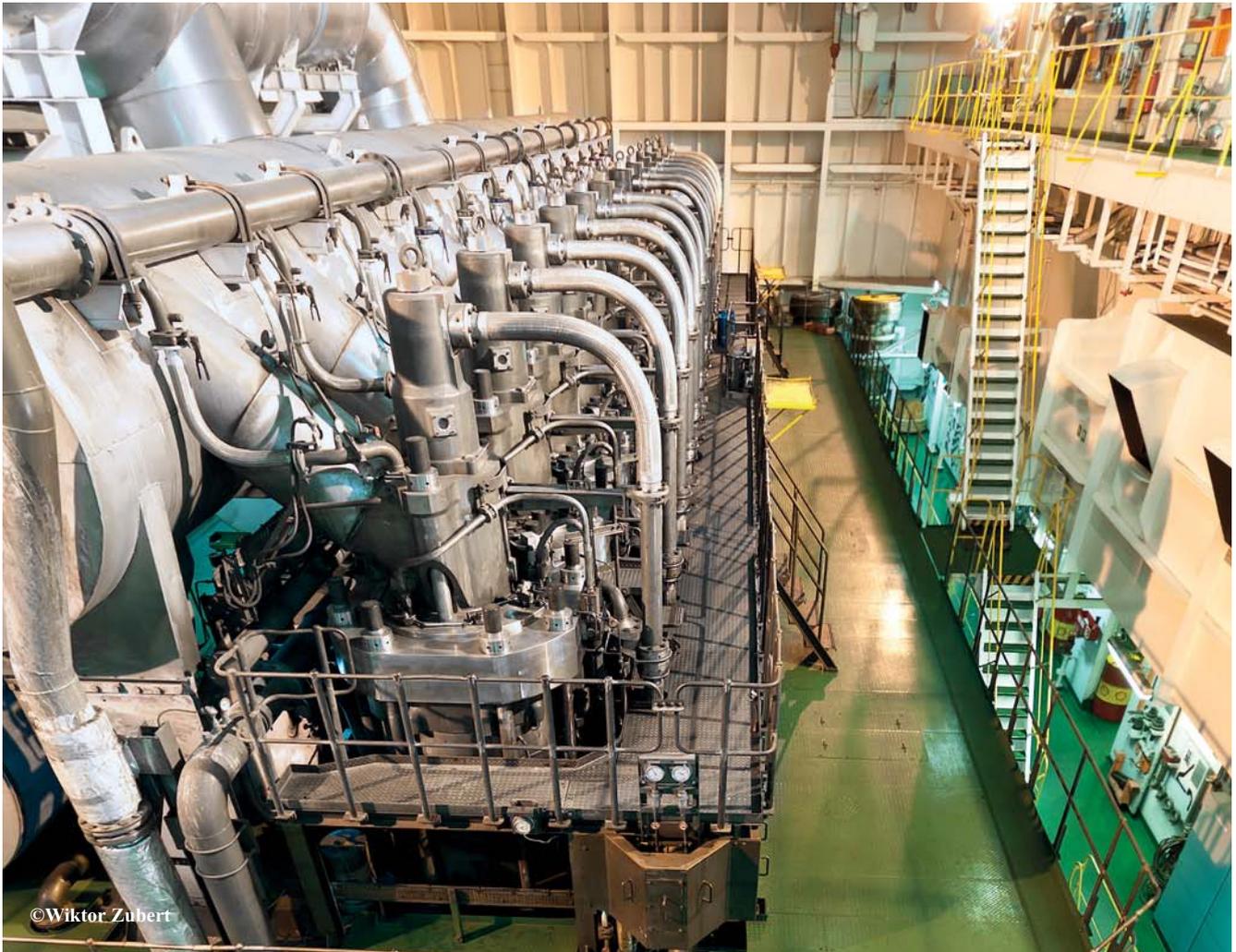
ECOSPEED®

SHIP HULL PERFORMANCE TECHNOLOGY

Magazine



Pioneering efficient exploitation of stranded gas reserves



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Ecospeed provides your vessel with long-term protection and dramatically improves the ship's performance.

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Ecospeed gives a very thorough and lasting defense against cavitation and corrosion damage for a ship hull's entire service life. The coating comes with a ten year guarantee. No repaint will be needed during future drydockings.

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Pioneering efficient exploitation of stranded gas reserves

EXMAR chooses Ecospeed to coat the hull of its first-of-a-kind floating LNG liquefaction, and storage unit, the Caribbean FLNG

In order to tap into Colombian stranded gas reserves, Pacific Rubiales Energy Corporation and EXMAR nv have partnered in a project to build and operate a floating LNG liquefaction, and storage unit, the Caribbean FLNG, which will be stationed at a jetty several kilometers off the Caribbean coast of Colombia for at least 15 years. In order to protect the hull of the Caribbean FLNG, keep it clean and facilitate class inspections over that time period without recourse to dry-dock and without causing harm to the local marine environment, EXMAR has applied an innovative glassflake, non-toxic, long-lasting hull coating system, Ecospeed, on the vessel's hull. EXMAR is a pioneer in offshore processing and storage solutions and this unit, the first of its kind ever to be built, presages a breakthrough in stranded gas monetization for the offshore oil and gas industry which promises to have worldwide application.

LNG and stranded gas

For economic and environmental reasons, global demand for natural gas as an alternative source of energy to traditional fossil fuels such as oil and coal has surged in recent years. Natural gas burns cleaner and therefore is responsible for reduced noxious emissions. If it can be produced and transported efficiently, it has the potential to be cheaper than

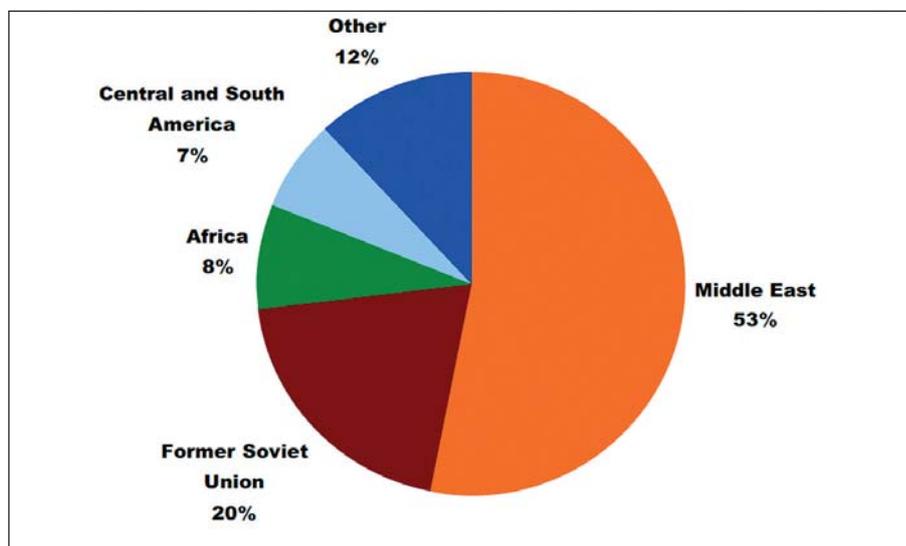


Chart showing global distribution of stranded gas reserves. (Source: IEA, 2005)

oil and coal.

However, vast natural gas supplies are often “stranded,” meaning that they are not or cannot be exploited for technical and logistical reasons. They are either too remote for economic transport or they are too hard to get at for economic production. Often this gas therefore remains unexploited and unutilized in its natural gas field, or is flared during oil production.

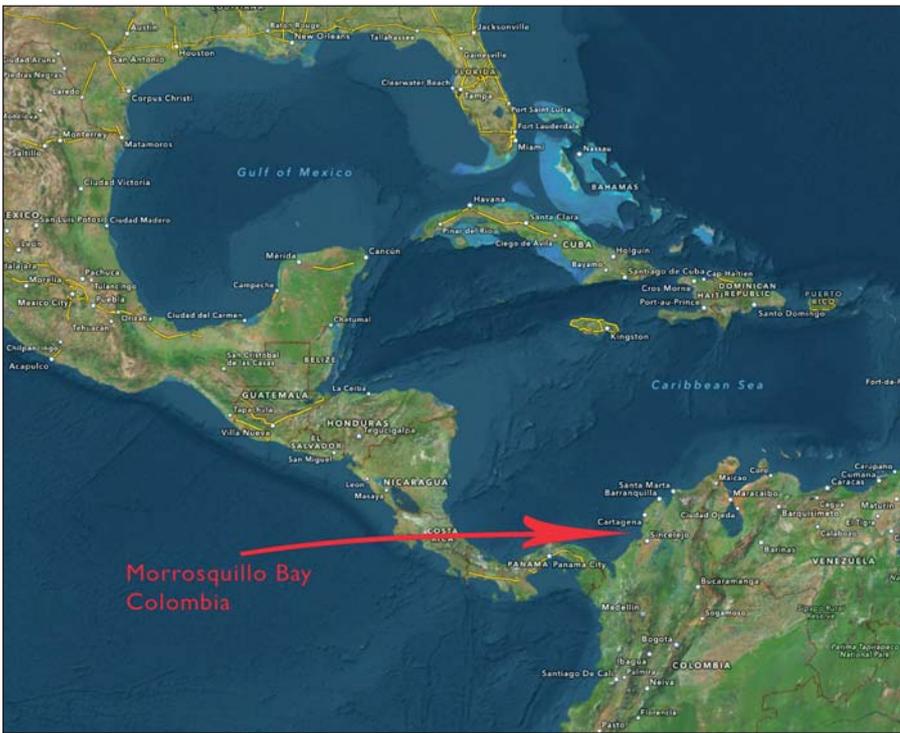
The total amount of stranded gas reserves worldwide is 6000 EJ (exajoules, unit of energy – 1 EJ = 10^{18} joules), or 140,000 megatons (Million Tonnes of Oil Equivalent). This stranded gas constitutes about half the global gas reserves, equal to sixty years of current gas usage. The geographical distribution of these reserves is shown in the graph on this page.

These huge quantities of stranded gas represent enormous potential revenues for their owners. However, monetization and profit depend entirely on efficient recovery and transport of the stranded gas reserves.

Northern Colombia gas exploitation project

La Creciente is a field in northern Colombia, owned and operated by Pacific Stratus Energy Colombia (PSE), a wholly-owned subsidiary of Pacific Rubiales Energy Corporation (PRE).

Pacific Rubiales Energy Corp. is a Canadian-based producer of natural gas and heavy crude oil. In addition to other Colombian interests, PRE, through PSE, has 100% working interest in the La Creciente natural gas field in the Sucre Department in northern Colombia. The Company is



Morrosquillo Bay, Colombia.

focused on identifying opportunities primarily within the eastern Llanos Basin of Colombia as well as in other areas in Colombia and northern Peru.

PRE has taken the initiative of exploiting the stranded gas reserves at the La Creciente field by partnering with Antwerp-based EXMAR nv, in a pioneering project – the first of its kind. EXMAR has agreed to build, own, operate and maintain a floating LNG production unit to be located in Morrosquillo Bay on the Colombian Caribbean coast which is to be made available exclusively to PRE for 15 years.

Natural gas will be supplied to the Caribbean FLNG from PSE’s La Creciente field to the Caribbean Coast near Tolú via an 88 km, 18” diameter pipeline which PSE is building as part of the project, with an initial design transportation capacity of 100 MMscf/d (million standard cubic feet per day). The La Creciente field has 6 tcf (trillion cubic feet) or 170 bcm (billion cubic meters) of gas reserves, and ongoing studies estimate a potential of 30-43 tcf (850 bcm- 1.2 tcm). The Caribbean FLNG will be moored in Morrosquillo Bay, about 4 km offshore at Tolú.



Rendering of the Caribbean FLNG at its jetty.

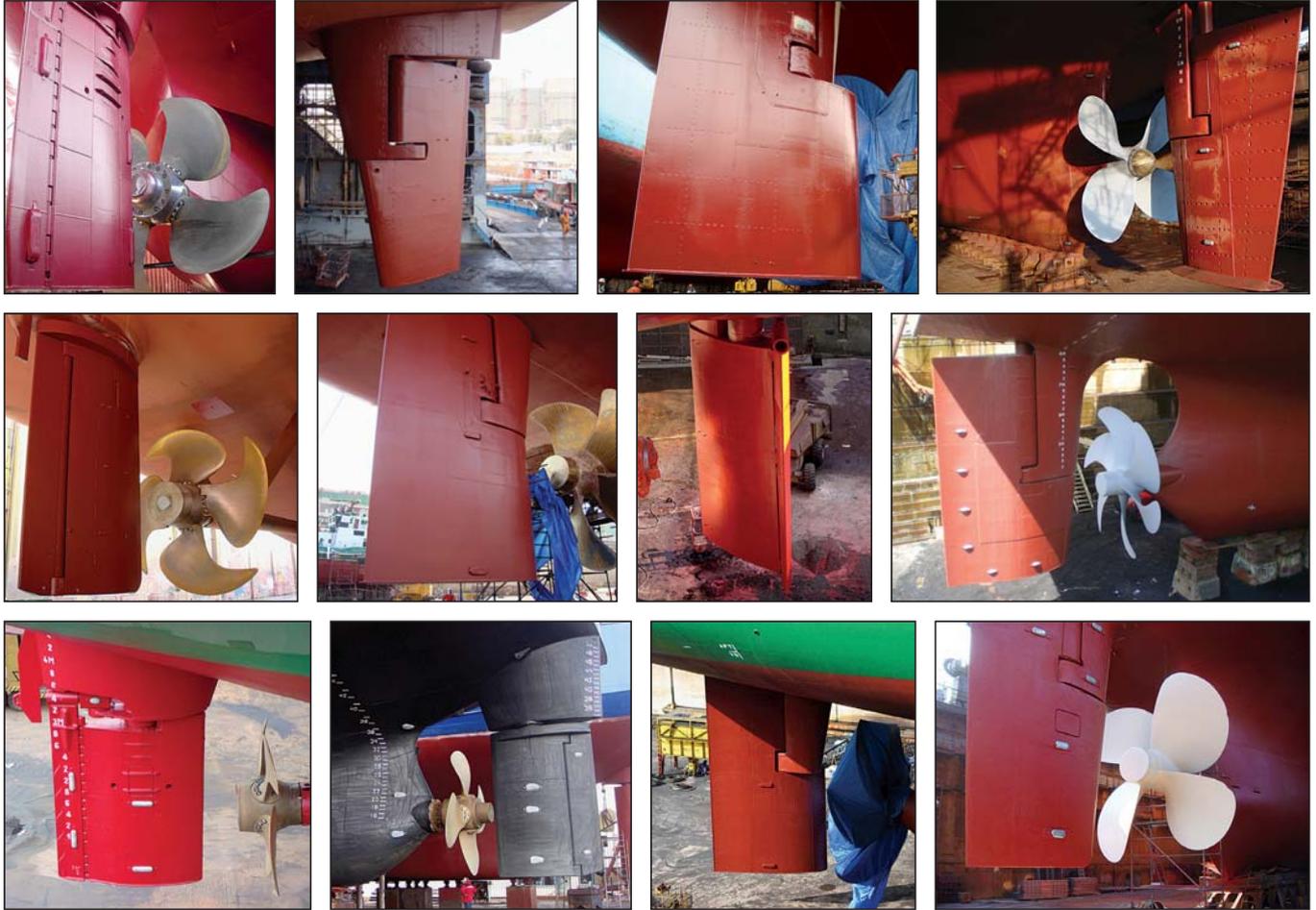
Frederik Van Nuffel, EXMAR Project Manager in charge of the design, engineering and construction of the unit explains: “On 5th November, Pacific Rubiales Energy Corp. and Gazprom Marketing & Trade Limited announced the execution of a Heads of Agreement with respect to a five year Sale and Purchase Agreement covering approximately 0.5 million tons per year of liquefied natural gas commencing commercial operations in the second quarter of 2015. This LNG cargo will be produced in, and loaded from, EXMAR’s Caribbean FLNG barge.” The FLNG will stay permanently on site for at least 15 years without drydocking.

The cooperation between PRE/PSE and EXMAR will result in a potential export of 0.5 million tons of LNG per annum from Northern Colombia.

With this project, PRE will initially be targeting markets of Central America and the Caribbean, aiming to replace fuel oil and diesel currently used for power generation. The project will also open potential industrial and residential market opportunities for natural gas in the area, while putting in place new incentives to explore and develop the large undiscovered natural gas resources in Colombia. Ronald Pantin, Chief Executive Officer of PRE commented: “We are very excited with this agreement as it opens new markets and fast-tracks monetization of PRE’s extensive natural gas reserves. This leverages PRE’s strategy to explore and develop its large gas resources in northern Colombia, and also reinforces our view that Colombia has enough gas resources to become a reliable LNG supplier for the region.”

Construction of the special floating

Supreme Rudder Protection



Ecoshield gives a very thorough and lasting defense against cavitation and corrosion damage for a ship hull's entire service life.

The coating equally provides the rudder with an impenetrable protective layer while its flexibility enables absorption of the forces that are produced by cavitation. This prevents the damage normally caused

by this phenomenon.

Without proper protection against cavitation and the resulting erosion and corrosion damage, the financial consequences can be severe.

By removing the existing paint layers and applying Ecoshield on the rudder we can break the never ending cycle of painting, suffering damage, having

to perform extensive repairs in drydock followed by a full repainting, again and again.

With an Ecoshield application no full repaint will be needed during drydocking. Ecoshield is guaranteed for ten years. At the most, minor touch-ups will be required.

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Rendering of the Caribbean FLNG at its jetty.

LNG production unit which will liquify, regasify and store the natural gas supplied by the La Creciente field is well under way.

EXMAR innovation and the Caribbean FLNG

EXMAR NV, headquartered in Antwerp, is a diversified and independent shipping group serving the international gas and oil industry. Apart from providing the ships for the transportation of these products, it also performs studies and undertakes the management of commercial, technical and administrative activities for the oil and gas industry. EXMAR has successfully pioneered innovative floating liquefaction and regasification solutions to help bring LNG to the marketplace in the fast-track, cost-effective, flexible and reliable manner needed for success in this market. The company introduced LNG Regasification Vessels (LNGRVs) in 2005 and the Ship-to-Ship transfer technology in 2006. So it is not surprising that EXMAR is now involved in developing yet another first: the world's first floating LNG liquefaction unit.

EXMAR CEO Nicolas Saverys explains, "We are proud to assist PRE in reducing the carbon footprint of Central America and the Caribbean. This will be the world's

first operational floating LNG production unit. We were the first to do re-gasification onboard a ship and the first to do ship-to-ship liquid transfer. Now we will be the first to do floating liquefaction of natural gas. The unique technology on board the unit is the result of EXMAR's innovative leadership in the LNG industry during the past years. The energy markets are short of gas supplies and EXMAR's floating LNG unit approach offers the opportunity to add stranded gas to these markets, and correct the current imbalance in trade in terms of both price and supply."

Building the Caribbean FLNG

EXMAR is investing \$300 million on this first-ever floating LNG production unit which is seen as the beginning of a longer term initiative to develop stranded gas worldwide. The unit will consist of a non-propelled barge equipped to convert natural gas into LNG, and to store for offloading to a permanently moored storage unit or to shuttle tankers.

The Caribbean FLNG will have a storage capacity of 16,100 m³ of LNG and will be able to accommodate alongside an LNG Floating Storage Unit (FSU). The floating

plant will process 69.5 MMcf/d of natural gas, and produce about 500,000 metric tons of LNG per annum.

The FLNG barge is 144 m (472 ft) long, 32 m (105 ft) wide, 20 m (66 ft) deep, and has a normal draft of 5.4 m (18 ft).

In June of last year, Shanghai-based Wison Offshore & Marine Ltd. signed an engineering, procurement, construction, installation, and commissioning contract (EPCIC) to design and build the flat-bottom barge for the project. The barge is being built at Wison's new, wholly-owned fabrication facility in Nantong, China, with further support supplied from the company's subsidiary in Houston, Texas, USA. Dwayne Breaux, executive vice president of Wison, commented, "The contract is first of its kind in the industry, and has put the new yard in a great burgeoning market."

Black & Veatch was contracted to execute the engineering and procurement of the topside liquefaction equipment and packages using its patented PRICO LNG technology which employs a single-mixed refrigerant system to accomplish the gas liquefaction with a refrigerant that is a mixture of nitrogen and hydrocarbons ranging from methane to isopentane. By using a single-mixed refrigerant process with one refrigeration loop startup, Black & Veatch aims to achieve high reliability and availability. Black & Veatch is providing the detailed design of the topside LNG production facilities to Wison. Through a global design team led from its Beijing office, Black & Veatch will also supply all LNG process equipment and provide installation and start-up oversight services to Wison.

Protecting the hull for 15 Years – ECOSPEED

A key requirement for the Caribbean FLNG is that it be able to stay moored at the jetty in Morrosquillo Bay for at least 15 years without the need to drydock. At the same time, the unit is being built and will be maintained in strict accordance with all the regulations of a major internationally recognized classification society. These regulations include 5-year class inspections.

The biggest barrier to this kind of extended drydocking interval is the protection of the hull which includes the prevention of corrosion and the ability to effectively deal with bio-fouling. Whether or not the vessel goes to drydock, periodic inspections by the classification society are required, in this case every five years.

EXMAR is trying various approaches to hull protection and maintenance, including traditional biocidal anti-fouling, foul-release coatings and cathodic protection on bare steel. As Frederik Van Nuffel explains, “With underwater coatings you don’t really see the benefits until after five or six years. The first year everything is good but it’s only after a few years that you start to feel the difference between a good coating and a bad coating.”

Based on prior experience and new research, EXMAR chose Ecospeed as the coating for the new Caribbean FLNG. Ecospeed is a hard, non-toxic, long-lasting glassflake reinforced coating ideally suited to this kind of application where long-term protection, the capability of being cleaned *in situ* underwater without any damage to the coating, and the fact of being environmentally benign with no emission of heavy

metals or toxic substances during normal use or during cleaning are all of the greatest importance.

The main reason for choosing Ecospeed, the Project Manager explained was, “We wanted to select a coating which can ensure that the underwater hull will not corrode for at least 15 years.”

As long as it is standardly applied and correctly maintained, Ecospeed can be guaranteed for 15 years in this type of application. This puts it in a league of its own. There is no question about the glassflake coating’s ability to protect the hull for 15 years and much longer.

But another key factor in choosing the hull coating system was the fact that a standard class inspection needs to be carried out every five years and for this the hull must be sufficiently free of fouling for the class inspector to do his job. A weld seam that is coated with inches of macrofouling cannot be properly inspected.

Operating in tropical waters means that the rate of fouling growth is likely to be very high. Although fuel efficiency is obviously not a factor since the barge will not be going anywhere, the use of soft coatings such as biocidal antifouling or foul release paints would not be able to withstand the onslaught of barnacles and coral and other fouling organisms without penetration right through to the steel. This type of coating could not be cleaned in the water without severe damage to the coating. And these types of coating are toxic and emit heavy metals and/or other toxic substances which would not be tolerable in the sensitive Caribbean waters where the FLNG will be stationed.

Ecospeed on the other hand has been proven to be impenetrable by marine organisms. It can be cleaned as often as needed by divers using rotating brushes and other tools and so brought back to its original pristine condition. The cleaning process does not produce any pollution or contamination. Nor does it damage the coating.

It remains to EXMAR and Hydrex to work out the optimum cleaning regimen for the ship. Probably one full cleaning per year will suffice. While it would be possible to clean the hull only once every five years prior to class inspection, the level of growth after that period of time will be very considerable and the time and cost required for cleaning would be significantly more than if the hull were cleaned annually and the fouling thus kept to a lower level of growth.

Application

The barge was built in blocks and these blocks were coated individually before assembly, leaving only the weld seams and the areas inaccessible due to the support blocks to be painted after the barge was assembled.

Application of Ecospeed can be done at newbuild or, to replace another coating, in drydock after the vessel has been in service. The new-build option is ideal. In either case the surface preparation requires a profile of at least 75µm and white or near-white steel (SA 2.5 or better). Once the preparation has been carried out and inspected, Ecospeed can be applied rather rapidly. No primer or other type of coating is required. Just two or more coats of Ecospeed each of 500µm with an overcoat time of about three hours minimum and no maximum.



Application of the second coat of Ecospeed. Two colors are used for ease of spotting any flaws in application.



A fully coated block leaves the fabrication hall ready for assembly.

As with all Ecospeed applications, a trained and qualified paint inspector was on site supervising the entire preparation and application to ensure adherence to the manufacturers specifications at each step of the process, to help with training applicators where they have not previously applied Ecospeed as in this case, and to assist with any problems that may arise. This is essential for a coating that is intended to last the life of the ship and which will carry a 10- or 15-year warranty. In this case, the inspector was Raul Yu who has supervised many successful Ecospeed applications in China.

Raul Yu provides some insight into the application, none of which is a surprise for a shipyard's and applicator's first experience with Ecospeed. As usual with anything new, there was some initial reluctance to change from the traditional coating systems which the yard and applicators were familiar with.

Two applicators have carried out the blasting and spraying of the Caribbean FLNG: the application to the blocks in the painting workshop was done by Nantong Hengrong Marine Engineering Co. Ltd. and the subsequent finishing job at the dry-

dock is being done by COSCO (Nantong) Clavon Engineering Co. Ltd. This was a first time application of Ecospeed for both companies and for the Wison yard.

“The applicators had not worked with Ecospeed before,” explains Raul Yu. “I gave them the necessary instructions and had them apply Ecospeed on a small test patch. This gives them a practical feeling of an Ecospeed application. During the spraying of the first block, they found that Ecospeed application is actually quite easy. They realized that if the Ecospeed specifications are followed by the coating subcontractor, the application goes very well and smoothly. Compared to traditional coating systems with multi-layers, Ecospeed coating saves them much time as after surface preparation only two similar Ecospeed coats each of 500µm DFT need to be applied. Because of the short interval required between coats (three hours at 20° Celsius), a block can be fully coated with two coats in the same day. The senior coating sprayer who has more than 12 years spraying experiences in different shipyards both in China and Japan was amazed at such a high application rate.”

Raul adds that, “while we are strict on the pot life and the thorough cleaning of spray equipment, in general Ecospeed application is like that of any other coating system.” The preparation also has to be done to exact specifications.

The uncoated areas where the supports for the blocks prevented preparation and coating in the paint shop were subsequently prepped and painted in drydock so that the entire hull is full coated.

Application of Ecospeed to the



The Caribbean FLNG being assembled at the Wison shipyard.



Close-up of erection joints before prepping and coating with two coats of Ecospeed.



The uncoated areas left by the support blocks in the paint shop were prepped and coated in drydock after assembly.



Care has been taken to ensure that the entire hull is fully coated with Ecospeed so that the Caribbean FLNG can stay on station for at least 15 years without any corrosion problems.

Caribbean FLNG was a first for the Wison shipyard. According to Raul Yu, “Wison are very satisfied with Ecospeed due to the ease and speed of application as well as the quality of the coating. They told me that had the hull been coated with a traditional coating system it would have taken at least seven days from surface preparation to the final coat, but Ecospeed has changed this completely. Two coats in a single day minimized the risk associated with multi-layer applications, saved time, labor costs, operation costs and other related expense.

“Also there is almost no chemical smell during the spraying, in comparison with other paints. This makes the application environment comfortable for the sprayer. They now understand why Ecospeed is so named: Eco for Economical and non-toxic environmentally, and Speed for the fast application and short overcoat interval. They said that Ecospeed is worthy of the name, a really high quality coating system.” (Note that this is before the ship even left the yard. The Economic, Ecologic and Speed factors are even more noticeable when the ship is operating.)

All that was left to finish at time of writing as far as the Ecospeed coating was concerned was the completion of the erection joints and burn patches.

Because the Ecospeed system consists of a single, homogenous covering of the steel, painting over weld seams after the blocks have been assembled is very easy and leaves a smooth finished surface, the erection joint paint blending in perfectly with the coating of the rest of the hull.

The construction of the hull of the Caribbean FLNG has largely been

completed and work on the topside is progressing.

The future

At the project launch event in June 2013, EXMAR CEO Nicolas Saverys stated, “This contract represents the start of a new era for EXMAR. The Caribbean FLNG project highlights the business potential and investment in Colombia. Colombia has the fastest growing economy in South America, and one of the fastest in the world.” Colombia is ramping up oil production to 1 MMb/d (million barrels per day) this year. The country's current gas production is estimated at 1 bcf/d (28 MMcm/d) of gas.

The future appears to be bright for FLNG projects well beyond Colombia, but EXMAR is taking one project at a time. As for the company's future, Saverys said: "There are places where gas production is just impossible. Indeed I can share with you that my ambition is to produce gas from those areas in the next decade. I would like to see that we are the first ones doing more complicated projects by going into harsher environments and handling gas which comes with a sludge,



The assembled hull of the Caribbean FLNG at the Wison yard. The weld seams and some repair where hot work has been done need to be coated as the final step of completing the hull coating.

which will need to be cleaned and purified. We will have a real cracking system out there.”

Frederik Van Nuffel stated, “It is EXMAR's intention to build more FLNGs. In each case the coating will be carefully selected in view of the environment in which the FLNG will be placed.” And the company's experience with the various coating types will grow with time making the selection process easier.

Ecospeed is a strong contender for being the best choice of protection of offshore vessels and structures that need to be kept on site in production for extended periods of time (15, 20, 25 or even 40 years) without drydocking. The 15-year guarantee and the environmental safety of the coating make it even more attractive. ■

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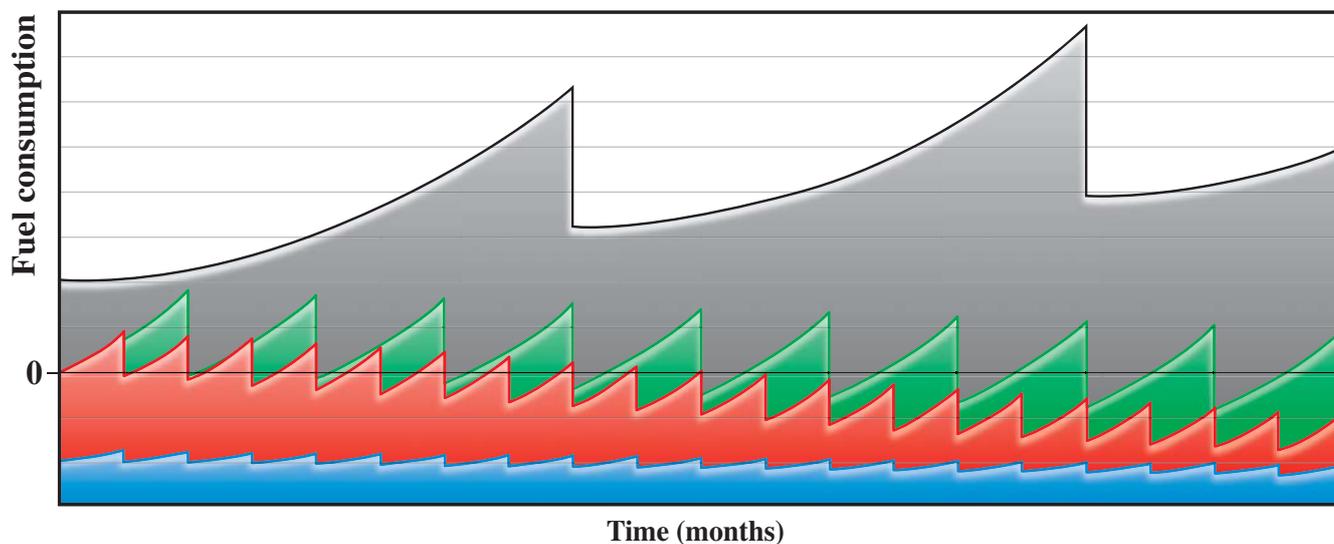


With the hull construction completed, topside construction continues as the complex systems required for the LNG production are assembled.



Optimization of ship performance

Development of additional fuel consumption over time



-  Ecospeed with 2 cleanings per year
-  Ecospeed with 4 cleanings per year
-  Ecospeed with optimum cleaning intervals
-  Active antifouling paints

The expected development of added fuel consumption over time for a biocidal antifouling is compared with three treatment scenarios for Ecospeed for one particular trading area.

In the green scenario, Ecospeed includes an underwater treatment every 6 months. In the red scenario, the treatment interval is halved to three months; fouling will not occur as extensively and the associated added fuel consumption is limited. Both scenarios show that

with each treatment, effective cleaning restores the added fuel consumption to the zero reference observed at sea trials. The unique conditioning aspect that is carried out simultaneously with each cleaning optimizes the surface gradually over time, producing fuel savings with each treatment. In a third scenario, extensive best possible conditioning is carried out immediately after curing. As a result the fuel consumption observed at the sea trials will be lower and better protection pre-

vents that fouling will occur as rapidly. The total savings in fuel consumption over the life-time of a vessel is directly proportional to the area between the antifouling plot and the different Ecospeed scenarios.

Adjusting the frequency of underwater treatments allows an optimization of the vessel's service speed and minimization of its fuel consumption.

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