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A Norwegian consortium, CETech, is considering the construction of special ships designed to haul compressed natural gas (CNG). Two types of vessel have been developed, including this dedicated hull, fitted with banks of horizontal cargo pipes. A second design is also able to load cargo oil as well. Further details appear in our Gas Carrier Update, which begins on page 32.

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Swinging back to Europe?

SURPRISING things are happening in the international shipbuilding industry, perhaps most extraordinary of all the reported ordering of low-speed diesel engines by a Korean shipbuilder at a Croatian engine works! True, the yard is a small newcomer (Dong Yang) but the contract is indicative of the bulging order books at leading Far East engine works (Hyundai, HSD, and STX, for example). Such contracts, in this case to the 3 Maj engine factory, will be manna from heaven for struggling European companies and could possibly indicate a mini new dawn for Europe's besieged industry, although we should also note that full order books in Japan, Korea, and China are, at the same time, causing shipbuilding contracts to be shifted to that other rising star on the Asian horizon, Vietnam.

Other hopeful signs for Europe also exist, such as investment by leading shipbuilders - Aker and Damen - in Romania, where the Korean major Daewoo is already entrenched at the Mangalia shipyard. Damen's Galatz yard has now taken delivery of complete ships from that country - the pioneering container ship *Geeststroom*, which has been specially engineered to load 45ft containers for charterer Geest Line; this ship is presented in the newly published RINA annual *Significant Ships of 2004*.

Recent news that could provide a most useful boost to Romania's new aspirations and its lower costs is the reported plan by leading German owner Hamburg-Süd to build a series of six post-Panamax 5500TEU container liners at Daewoo Mangalia. If that contract is concluded,

Typical of the quality tonnage being built today in European yards - and that might have been expected to be ordered in the Far East - is the P-Max tanker series for Stena. The design follows other innovative ships for this owner in having an extra wide beam, shallow draught, and twin screws and rudders.



it will add a completely new dimension to the country's industry. Reports indicate that the ships could be of advanced design - a further boost.

Leading Croatian shipyards, members of a significant marine industry in a country which has travelled through an extremely lean valley in recent years as a result of the most unfortunate civil wars, are currently enjoying a small mini-boom in export orders. Uljanik, at Pula, has taken a leading role - along with another European yard with great promise, Gdynia, in Poland - in the construction of ro-ro car/truck carriers. Indeed, the Pula order book includes 7100-unit ships for Leif Hoegh, which are believed to be the largest ever contracted.

Already, this yard has delivered eight smaller ro-ro ships of 4300-car capacity to the Italian operator, Grimaldi - the last, *Grande Anversa*, is reported to have been completed in only 32 weeks after the first block was placed on the berth. Three more are to follow this year.

Further south at Split, possibly the most interesting contract is that for a series of novel medium-range

tankers for the leading Swedish operator Stena. These 49,999dwt designs, known at the P-Max type (*The Naval Architect* October 2003, page 6), follow this owner's earlier V-Max (VLCC class) and C-Max small products/LPG tankers from Hyundai and Gdynia respectively.

They use the same philosophy of a wide (40m), shallow hull with two engine rooms, twin propellers and twin rudders for improved redundancy and safety; they will also have a higher speed than normal. The prototype is due for delivery this year. Brodosplit is additionally building other tankers, including Panamax designs, many of which will follow the current trend of being ice-classed (Det Norske Veritas 1A standard).

Even in mainstream Germany, prospects are looking up, with new orders at the two Aker Ostee yards for container tonnage, and the recent completion by Meyer Werft of *Eilbek*, the prototype ship of an interesting new class for Hansa Hamburg. Even small and recently financially troubled yards, such as Cassens, appear to be making a comeback with planned orders for small container ships. Meanwhile, Turkey, the country that straddles Europe and Asia, is working quietly away on an impressive order book for smaller commercial ships, especially product and chemical tankers.

Still to realise its full potential as an international player on the commercial scene is Russia, where a number of experienced shipyards are eagerly anticipating building various ships that will assist in opening up the country's extensive mineral reserve along the northern sea route, with its most difficult operating conditions. Various orders at both Admiralty Shipyards and Baltiysky Zavod have been mentioned for the 70,000dwt icebreaking Arctic tankers that were discussed in our September 2002 edition but at the time of writing, it is not known if these are confirmed.

What is certain is the construction of a large 18MW-power diesel-electric icebreaker, with one option, at Baltiysky Zavod, to support the growing number of oil tankers trading out of the Gulf of Finland with Russian oil exports, and a very special double-acting Arctic container ship under construction at Aker Finnyards for Russian operator Norilsk (*The Naval Architect* February 2005, page 48). At the same yard, an icebreaker/supply ship is also nearing completion in Helsinki for work in the Sakhalin oilfields. Inland yards such as Krasnoye Sormovo and Volgograd are already busy with a good load of river/sea ships but these are mainly for domestic operation or with the new republics to the south. All these are, however, almost certainly just the tip of a future iceberg that could perhaps see Russia emerge as a significant international builder, since yards there are also keen to build more for export.

It is too soon to confirm that all this most welcome European activity is a permanent feature or just a short-term windfall as a result of overflowing berths in the Far East, but it is heartening to hear from a leading engineering concern that it has not abandoned Europe for large LNG carriers and is much impressed by the achievements of IZAR, in Spain, on this front. Whether current and future contracts will be profitable is another worry, and what will be the effect of the huge recent rise in steel prices? The only sector where Europe definitely reigns supreme is in cruise liner construction, with confirmed leading players still being Fincantieri, Meyer, Atlantique, and Aker Finnyards. Notwithstanding, new orders in Europe at the present time are most welcome, wherever they might be. 

SAFEDOR: designing safer ships in Europe

A NEW initiative to raise the profile of safety in ship design has been launched with the arrival of SAFEDOR (Design, Operation, and Regulation for Safety) - another research project funded by the European Union. The 53 partners in this four-year work, which is being managed by the German classification society Germanischer Lloyd, will study ship design from a risk-based angle (not, of course, a new idea in the marine field), with safety levels considered as objectives of the design process from the outset, rather than being treated as a constraint - as is considered to be the case today when prescriptive rules are applied.

According to the organisers, the new approach should provide scope for novel and inventive design solutions and therefore should encourage innovation. The SAFEDOR project recognises that European players are strong in ship types where safety is a priority - ro-ro ferries, cruise liners, gas carriers, and container ships. It is hoped that not only will safety be improved but also European competitiveness.

Participating companies believe that the project is a positive response to many of the challenges currently confronting the maritime industry, such as high public expectation of safe ship performance, the need for innovative and more competitive designs, the increasing complexity of equipment, materials, and systems used on ships today, and the need to consider, at the design stage, a ship's full working life and any environmental impact of its scrapping.

It is hoped that 'a new philosophy of safety' will result. While SAFEDOR will build on existing methods of reliability theory and the established formal safety assessment approach (FSA), it will also develop a new regulatory framework to permit the approval of 'innovative ships that challenge today's rules'. Nine specimen designs will be used to demonstrate the project results.

Special studies will cover structural integrity and assessment of flooding, collision, grounding, also fire and explosion. In addition, consideration will be given to bridge management and operations, cargo securing, and lifesaving. SAFEDOR is claimed to be compatible with other current initiatives, including IMO's goal-based standards and the IACS common rules for tankers and bulk carriers. Leading European organisations taking part include Det Norske Veritas, the Danish Maritime Authority, Carnival (through member companies), IZAR, SAM Electronics, and Glasgow/Strathclyde Universities.

CHINA FACTORY FOR ROLLS-ROYCE - A new headquarters and factory for merchant ship equipment has been set up in Shanghai by Rolls-Royce; this is in addition to an existing factory in Korea. Although not everything that the group produces will be managed from China, the move is seen as a logical step in view of China's buoyant shipbuilding economy.

The headquarters office was set up in January this year, and the factory is expected to be fully operational by November. Its main products will be deck machinery, steering gears, and bow thrusters. Other countries, such as Croatia,



Seen here in February, arriving for final outfitting at the Royal Schelde yard, Vlissingen, in The Netherlands, is the new double-ended ferry *Dokter Wagemaker*. This vessel, ordered by TESO for its Texel-Den Helder service, was towed from the Damen yard at Galatz, Romania, where most of the building work was carried out. Although somewhat similar to two existing ships, she has extra vehicle space on two decks and is powered by a state-of-the-art diesel-electric plant with four thrusters (*The Naval Architect* September 2003, page 4). *Dokter Wagemaker* should enter service in June, when she will replace one of the existing ferries.

Poland, and Romania, are already being used to source low-cost equipment. Ship design will remain in Norway (at Ulsteinvik and Ålesund), where the group believes it is well worth paying extra for the considerable pool of first-rate experience there.

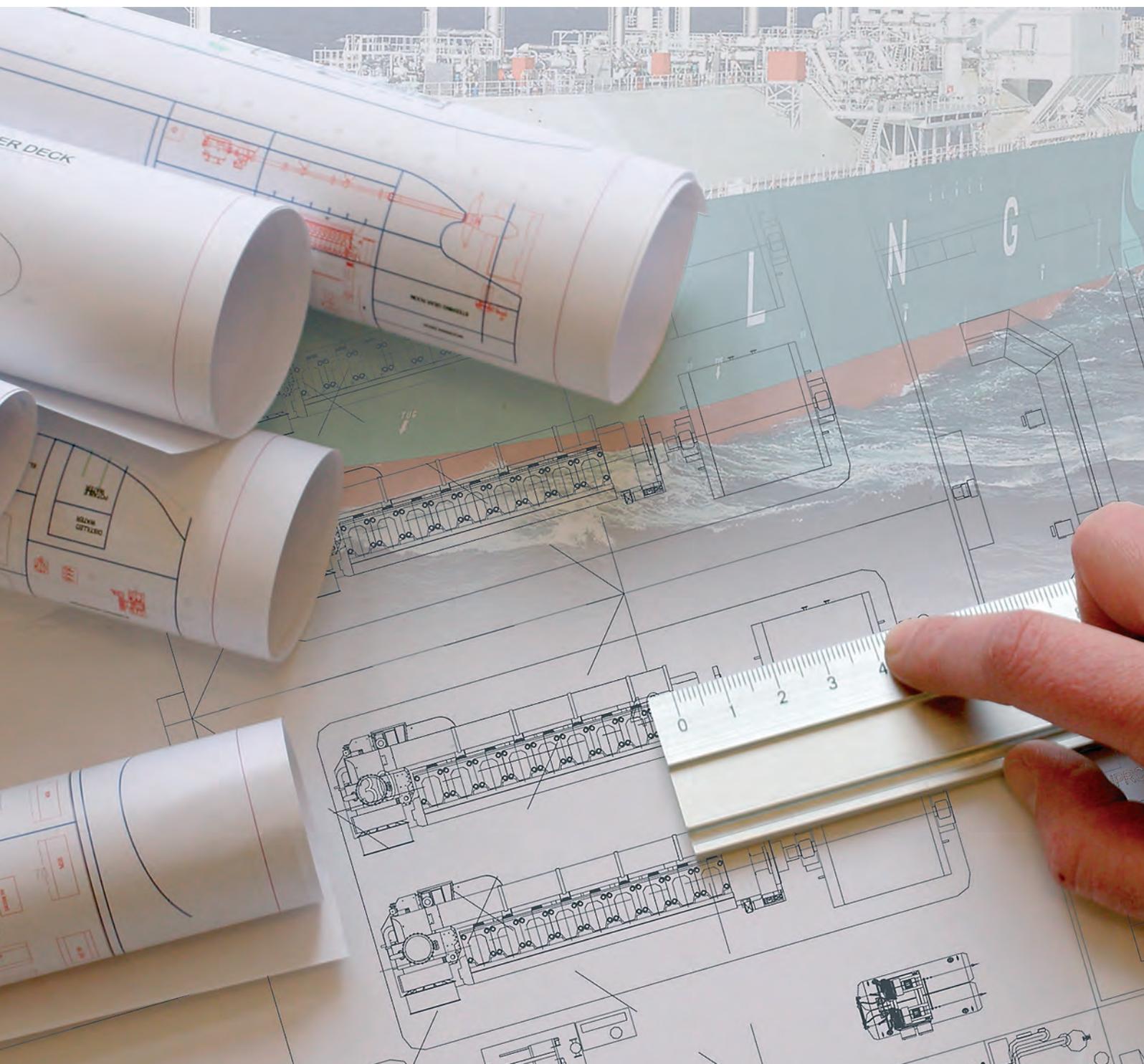
3rd ASRANET IN 2006 - The third international ASRANET colloquium will take place on July 10-12, 2006 in Glasgow, Scotland. The network brings together researchers and practitioners with interests in using structural reliability analysis (SRA) with advanced structural analysis (ASA). The need to draw these two disciplines together is seen as important for future safety management of a wide range of engineering structures. The organisers are inviting papers. Contact: Prof P K Das, Universities of Glasgow and Strathclyde. E-mail: p.k.das@na-me.ac.uk

THREE QUAYS ACQUIRED - The London consultancy Three Quays Marine Services, which once used to belong to P&O, has been purchased by the Oceanic Investment Corp, whose members already include along long-established naval architectural concern, Burness Corlett & Partners, and also Marine Safety Services. As a result of the acquisition, the group is being restructured,

and a new company, Burness Corlett-Three Quays has been formed to offer a full range of marine services. Offices will be in the Isle of Man and London.

Another new company, Maritime Sector Specialists, is formed from Maritime Corporate and Burness Corlett (Northern) to provide management consultancy, also financial, techno-economic studies, maritime transportation and concept/logistic design and planning for the shipping and port industries.

TONNAGE RISE FOR KR - The Korean Register of Shipping reports a significant increase in tonnage under its class. At the end of 2004, a total of 2078 ships of approximately 22.2 million gt were registered - an increase of approximately 2.4 million gt, or 11.8% over 2003. Growth is due both to ships transferring class and to new vessels. Since Korea is a leading builder of gas carriers, it is appropriate that the society has 18 LNG carriers on its register and expects to add more such ships during the next few years. More foreign owners, including some from Europe, are reported to be turning to Korean Register. The society's European committee, formed last year, will meet again in June in London. 



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Cost assessment in ship production

Estimating production costs are a fundamental part of ship design. The option for estimating production cost differs in the required information (input data); the less information is needed, the earlier a method can be employed in the design process. The more information is used, the finer differences between design alternatives can be analysed.

METHODS for estimating production cost are classified into two alternatives: top-down and bottom-up. The top-down method (macro, cost-down or historical, empirical, statistical and close-form equations) determines the production cost from global parameters such as hull weight, block coefficient, and ship length, as promoted by Schneekluth and Bertram (1998), and Carreyette (1977). The relations between cost and global parameters are found by evaluation of previous ships.

Thus, the top-down approach is only applicable if the new design is similar to these previous ships. Also, the cost estimation factors in the approach reflect past practice and experience. Despite their popularity and frequent references in literature, top-down approaches have serious disadvantages, which are often overlooked or concealed:

- the approach uses only global information and is thus incapable of reflecting local form changes or details of the design improving productability
- the approach is usually based on weight. Any change, which increases weight, will automatically increase the cost estimate, regardless of the real effect on cost. Extreme lightweight designs may drastically increase the number of required hours, while large frame spacing may increase weight, but decrease necessary man-hours. This is often not reflected in the formulae!
- the approach is based on historical data, ie, historical designs and historical production methods. In view of the sometimes revolutionary changes in production technology over the last decade, the data and formulae may sometimes be called 'prehistoric'. They do not reflect new approaches in structural design or production technology
- the approaches were probably based on inaccurate data even at the time they were derived. Traditionally, shipyards are poor

work process	man-hour/unit	units	man-hour	Euro/man-hours	Euro
Bending frames					
Bending plates (single curve)					
Bending plates (double curve)					
Manual welding					
Automatic welding					
TOTAL (labour)					
Material					
Frames					
Plates					
Welding material					
TOTAL (material)					
TOTAL (labour+material)					

Table 1. Bottom-up approach for estimating production cost.

sources of cost information. The data are frequently skewed, reflecting pressures of first-line managers and other factors

- the approach is not suitable for structure optimisation since there is no link between the cost and the design variables (scantlings).

The second alternative is the bottom-up (micro, cost-up or engineering analysis) approaches (direct rational assessment). These break down the project into elements of work and build up a cost estimate in a detailed engineering analysis. Southern (1980), Moe and Lund (1968), Winkle and Baird (1986), and Rigo (2001) developed simplified cost models based on direct calculation using quantities and unitary cost to assess the global production cost. Welding position, accessibility, and other aspects can be considered using additional corrections. Table 1 shows a simple example of a possible bottom-up calculation of labour cost and material cost for hull production.

For each work process, the number of necessary man-hours is computed by multiplying the average man-hours/unit with the number of units for this work process. Units for a work process could be, for example: 'number of frames and plates requiring bending' or 'metres of weld'. The total number of necessary man-hours is then the sum of all man-hours for the individual work processes. Man-hours are converted into cost by multiplication of the man-hours for each work process with the shipyard specific cost factor (monetary unit/man-hour) for this work process. The sum of all processes gives the total labour cost. Similarly, the material costs are estimated. The depth of differentiation of the individual work processes is chosen appropriately.

The bottom-up approach requires more effort and detailed information than the top-down approach, but unlike the top-down approach, the bottom-up approach also captures differences in design details and is thus suitable for scantling and shape optimisations. Changing the local hull geometry influences the number of frames which require bending, the effort in plate bending, and the degree of weld automation which depends on the curvature of the weld joints.

All these effects are reflected by an appropriate decomposition of the total work process into its

individual components. At present, this approach is not available in most shipyards, neither are historical databases from which it could be developed. It is then necessary to develop an appropriate approach, and collect the data required to use the approach. An advanced optimisation application in this field is the work of ANAST for ship structures using the LBR-5 system, Rigo (1992, 2001a,b, 2003a,b), Rigo and Fleury (2001), Karr *et al.* (2002). This is possibly the only such system that has been applied in shipyard work.

Advanced systems

PODAC cost model: US Navy approach

Deschamps and Trimble's (2004) recent discussion of 'Cost Estimating' disappoints, as it does not really provide an up-to-date survey and presents mainly top-down approaches. In their last section, Deschamps and Trimble refer to a series of systems (tools) used for navy ships: ASSET, ACEIT, UPA, PRICE, and finally the PODAC (Product-oriented Design and Construction) cost model. PODAC, Ennis *et al.* (1998), Keane and Fireman (1993), and Wade *et al.* (1997), is rather a sophisticated top-down approach. However, PODAC can be linked to other ship design tools with cost-estimating capabilities that operate at more detailed level analysis:

- parametric Flagship, a system developed under a Maritech ASE project, links various ship design and naval architecture analysis systems directly with the PODAC cost model
- Intergraph's multi-discipline GSCAD system was also linked with the PODAC cost model
- the US Navy's ASSET design tool was linked to the PODAC cost model.

Unfortunately, all these tools are oriented towards combatants and the real methodology and details are not published.

Smart product model (SPM), USA

The smart product model (SPM) of Proteus Engineering, Ross *et al.* (2001), Ross and Hazen (2002), and Ross (2004), is crafted in such a way that at all times during the design of a vessel it

Extracts from a paper by Volker Bertram, ENSIETA, Jean-Jacques Maisonneuve, SIREHNA, and Jean-David Caprace and Philippe Rigo, both of ANAST, University of Liège, which results from part of the work performed in sub-project II.1 of InterSHIP, a European R&D project funded under the European Commission's Sixth Framework Programme for Research & Technological Development. (Project No TIP3-CT-2004-506127).

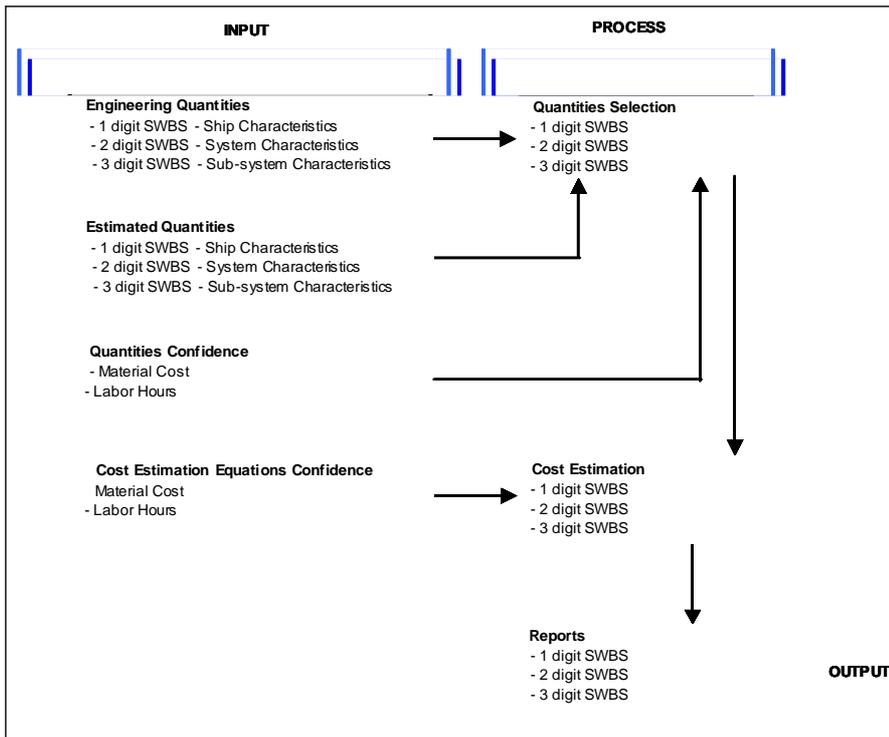


Fig 1. Cost estimating component flow chart, Ross (2004).

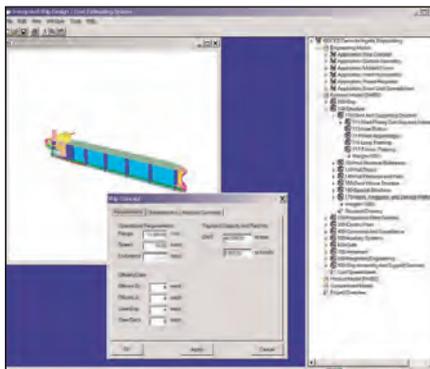


Fig 2. Example of a user interface, Ross and Hazen (2002).

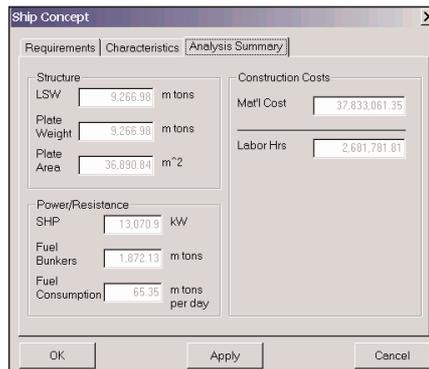


Fig 3. Analysis summary dialogue box, Ross and Hazen (2002).

will provide the best cost estimates for the available information. This system estimates ship production costs in a ship work-breakdown structure (SWBS) hierarchy for three independent levels of details (Fig.1):

- for concept design, the cost estimate will be based on whole-vessel technical and parametric relationships derived from approximately around 20 data items (eg, length, beam, displacement, installed power)

- for preliminary design, system information becomes available, and the cost estimate is based on approximately 125 data items
- for the contract design, the cost estimate is based on hundreds or even thousands of data items. As the design progresses, more and more of the technical and cost information migrates from statistical parameters to physics-based ones, and accuracy of the cost estimate improves.

The cost estimating software is divided into two linked elements, one focused on engineering and the other on cost. Each element has modules for specific operations. The cost element has the four modules:

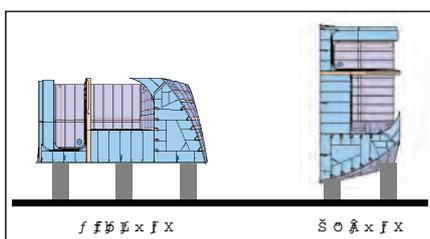


Fig 4. Application of bottom-up approach comparing shell-base production (left) and deck-base production approach (right); analysis gave 3% cost advantage for deck-base approach, Sasaki (2003).

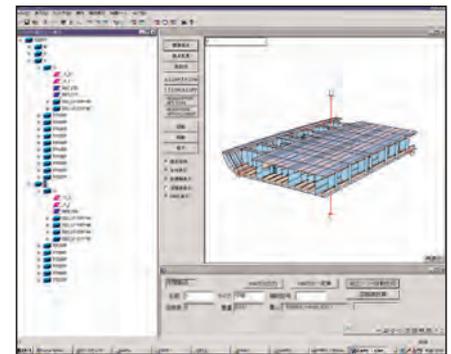


Fig 5. Computer-aided process planning system using expert knowledge, Sasaki (2003).

- parametric cost: cost is estimated for the design ship based on a proportionality with regard to the base ship
- assigned costs: assigned costs are directly entered into the module. These costs are based on data such as initial estimates from vendors and from purchase orders
- cost source selection: The user selects between the parametric and the assigned values
- cost reports: This module produces three reports: 1-digit, 2-digit, and 3-digit SWBS cost estimates, with overall confidence levels provided for each cost entry.

Fig 2 shows one version of the user interface to the SPM environment. In the upper left-hand corner is a cut-away view of the ship's structure. On the right side is a hierarchical breakdown of the engineering model, the ship work breakdown structure (SWBS), the product model, the compartment model, and the project overview. In the lower centre is a dialogue box for user input of a ship's requirements for operation, payload capacity, and number of officers and crew. Visible at the top of the dialogue box are tabs for two other dialogue boxes: characteristics and analysis summary.

The calculated cost estimate, estimated labour hours, and other estimates for structure and power/resistance are presented in an analysis summary dialogue box, Fig 3.

Mitsubishi CIM system, Japan

Mitsubishi Heavy Industries (MHI) has developed a CIM (computer-integrated manufacturing) system interfaced to its structural design CAD system, Sasaki *et al* (2001, 2002), Sasaki (2003). Production planning information, estimation functions, and levelling functions were added to a commercially available line simulation system. Application of the system to an actual vessel resulted in the reduction of the two~three week time period conventionally required for consideration to just one day.

The process planning system with 3-D visualisation function enables a designer to semi-automatically define the hull block assembly sequence and to calculate the evaluation value (cost, time, weight,...) for each process design candidate, Fig 4. The cost estimation function in the CAPP (computer-aided process planning) system of Mitsubishi multiplies weld length (for

each weld class) by a factor reflecting the work difficulty (eg, 1 for downward, 2 for upward, 1.5 for horizontal):

$$C_{\text{production}} = (W_{\text{conversion}} C_{\text{unitconst}})$$

$$W_{\text{conversion}} = W_{\text{real}} \times K$$

$C_{\text{production}}$ is the cost for production of one block

$W_{\text{conversion}}$ converted welding length (considering the different difficulty of welding depending on posture)

$C_{\text{unitconst}}$ the cost to weld 1m for each posture

W_{real} the actual welding length,

K a coefficient to express the difficulty of the welding work.

Fig 5 shows a basic operating screen of the process planning system. The left-hand side of the screen is a dialogue-type network editor for the intermediate product, and the right-hand side is a 3D representation of the intermediate product and its parts, showing shape and factory facility information. This allows study of the assembly procedure, while viewing the shape of the intermediate product. A knowledge-based system enables automatic definition of the assembly sequence based on production practices and an engineer's know-how.

Fig 6 shows how, first, the pre-assembly base plate of a hull block is selected, then an assembly tree of the block is defined automatically, using production rules accumulated in the knowledge base. This knowledge base stores knowledge specific to MHI with respect to assembly tree generation, and incorporates current practice obtained from the comments and observations of actual production engineers. Nevertheless, since it is difficult to obtain a practical assembly tree fully automatically for every kind of block, the system has been equipped with an assembly tree editor that helps a production engineer to modify it efficiently.

Simulation: cost assessment approach of the future?

Discrete event simulation develops rapidly, and pilot applications are also found in shipbuilding. Simulation can be used both for long-term and for short-term planning. Once workshops of a shipyard are modelled and interfaces to the CAD system established, specific applications for ship structures are

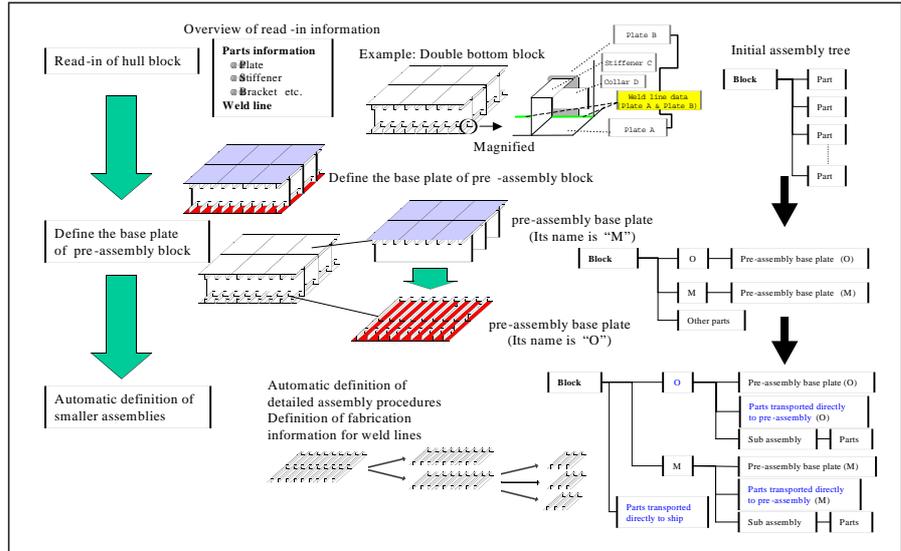
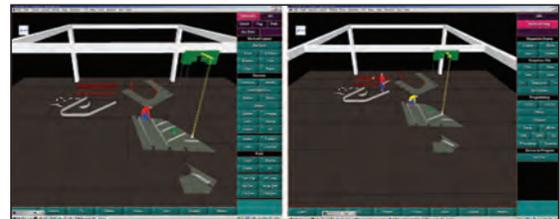


Fig 6. Flow assembly procedure definition function, Sasaki (2003).

Fig 8. An example of scenarios comparing one worker with two workers.



fast. These simulations serve to determine capacity utilisation and assembly times, also investigate 'what-if' scenarios, but could also be coupled to cost estimates for different build strategies.

Shin *et al* (2003) in Korea developed a virtual model of a shipyard-forming factory. The workshops (cutting, roll bending by 400tonne, 1500tonne, and 2200tonne machinery, also line heating), buffers, cranes and workers were modelled as 3D objects working together to fabricate the plate. The model thus allows a realistic simulation of the material flow and virtual reality visualisation.

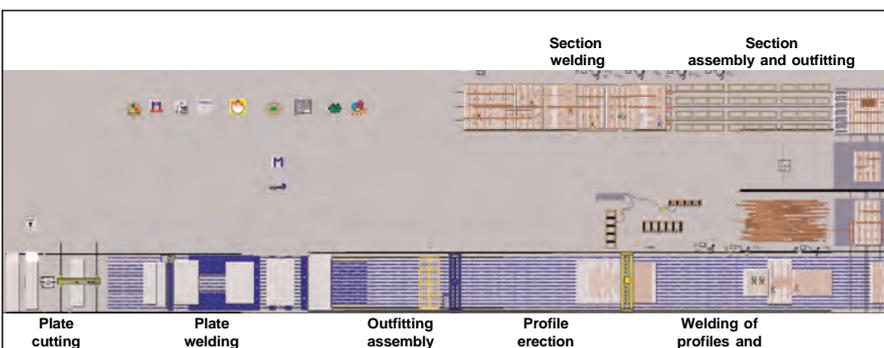
Steinhauer (2003) describes ship production simulation at Flensburger Schiffbau-Gesellschaft shipyard, Fig 7. The product data

contains all geometrical and methodical information about a ship while the simulation model includes all parameters describing the production facilities, resources, and processes. The simulation tool is not specific to any ship type and the same software is also used to model, for example, cargo flow in ro-ro ships already in the design stage. Recently, ANAST (University of Liege) started with the eM-Plant software also used by Flensburger to link production simulation and optimisation. It was found that the modelling is rather straight-forward, and practical simulations can be performed within a couple of months. Key issues are the data availability and data scatter.

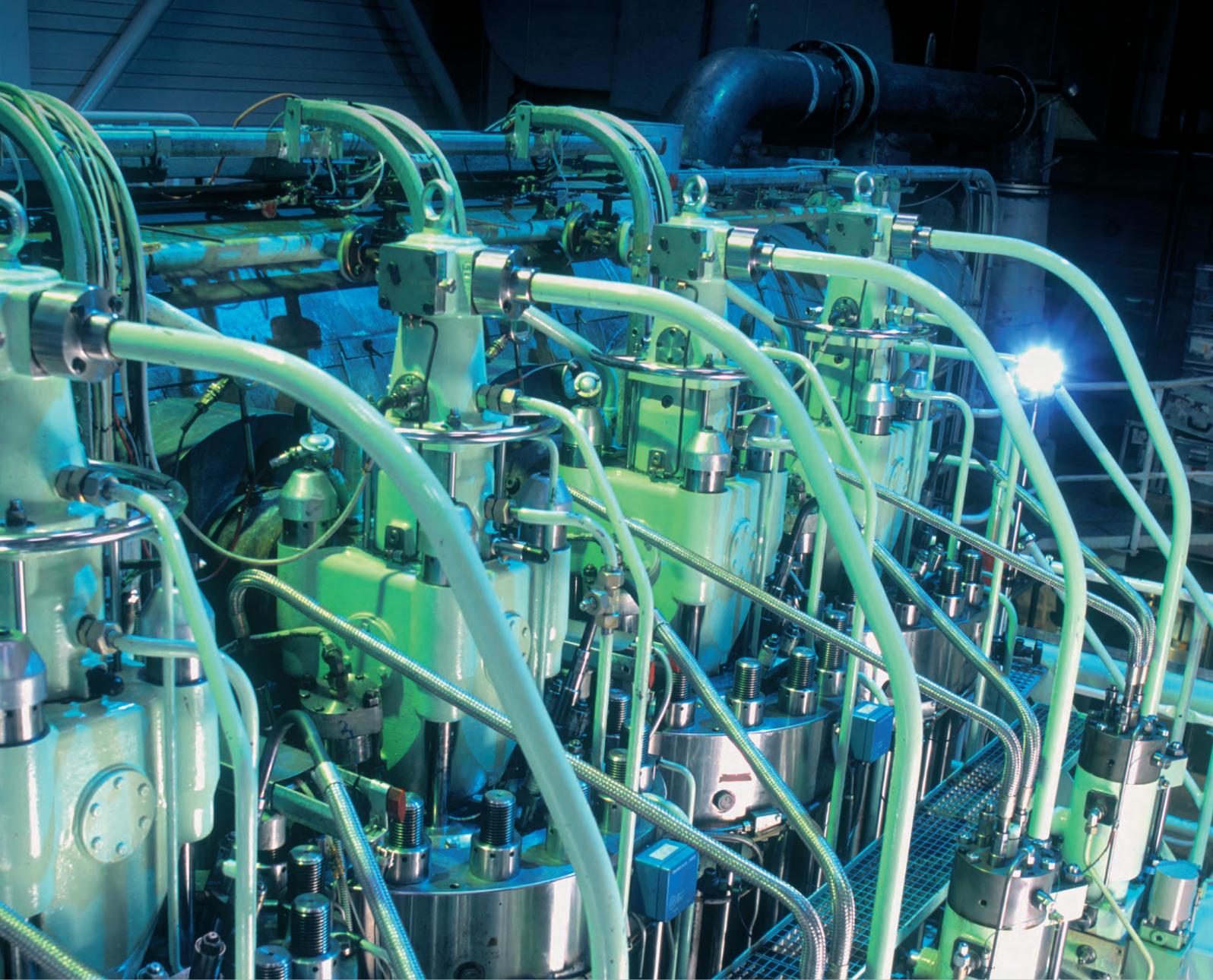
Sasaki (2003) also describes a virtual factory for production stage evaluation, employing some virtual-reality techniques and discrete event simulation. Basic motions of shipbuilding-related activities were converted and transferred into the database beforehand. Product and process data are then used for simulation. Fig 8 shows one example where a scenario with one worker is compared to a scenario with two workers.

The single worker performs everything from materials transport to tentatively fixing the positions, and welding. For two workers, Worker A transports material up to tentative fixing of the position, while Worker B does the final welding. The simulation gives the achievable speed-up for adding a worker and shows idle times and bottle-necks.

Fig 7. Simulation model of the pre-production from panel line to section welding at Flensburger Schiffbau-Gesellschaft.



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Diesel developments strengthen dominance

The Naval Architect's annual review of recent and current advances in the field of diesel and gas turbine technology begins with an overall examination of the diesel scene. Included in this feature for the first time is an overview of some possible new candidates for future tonnage: sails, nuclear fission, and fuel cells.

LOW-SPEED two-stroke engine dominance of mainstream cargo ship propulsion sectors (never seriously threatened by large-bore medium-speed designs) has been strengthened by the swift success of camshaftless variants with electronically-controlled fuel injection and exhaust valve timing. MAN B&W Diesel's ME types and Wärtsilä's Sulzer RT-flex versions of the respective MC and RTA models allow optimisation of these two most important parameters for adjusting an engine at all load conditions. Rising sales of ME and RT-flex engines across the bore spectrum for powering diverse tonnage - extending to large container liners and LNG carriers - suggest that electronic derivatives will displace camshaft-controlled models much sooner than originally anticipated.

Both designers promise unprecedented operational flexibility in terms of fuel economy and emissions optimisation, enhanced reliability, and lower lifetime running costs. Easier operation and trouble-shooting by crews are also facilitated, and control system software can be updated routinely throughout the life of a ship.

Ship manoeuvrability is also enhanced by the ability of these engines to run stably at very low speeds: the first 12-cylinder Sulzer RT-flex96C engine, tested last summer at Diesel United in Japan, operated smoothly down to 7rev/min, and *The Naval Architect* has witnessed a MAN B&W 7S50ME-C engine running at 12rev/min at the Frederikshavn, Denmark, factory of the Alpha division.

Extension to ME programme

An extension to the ME programme introduced last year by MAN B&W particularly targets the propulsion requirements of Capesize bulk carriers. The new 650mm-bore long-stroke S65ME-C design is also appropriate for Suezmax tanker applications, the seven-cylinder model delivering 17,990kW at 92rev/min. Twin seven-cylinder engine plants are considered ideal for propelling large LNG carriers (twin versions of the S70ME-C model have been chosen for some contracts, as explained in a separate article in this feature).

Bulker debut for new Sulzer model

Wärtsilä's new Sulzer RT-flex50 engine will debut in a series of 53,800dwt Handymax bulk carriers due for handover in 2006/2007, the 6-cylinder models yielding 9720kW at 124rev/min. The 500mm-bore design was developed in conjunction with Japanese licensee Mitsubishi, with the programme's



Electronically controlled low-speed engines, such as this Wärtsilä Sulzer 8RT-flex96C model seen on its official test last April at the HSD Engine Co in Korea, are becoming increasingly popular - even faster than originally anticipated.



Wärtsilä's new 46F engine (the 'F' stands for 'future') uses the same dimensions as the 46 type but has an increased rating of 1250kW/cylinder at 600rev/min and employs some interesting new technology.

power band - from 5650kW to 12,960kW - addressing new generations of Handymax and Panamax bulkers, large product tankers, feeder container ships and medium-sized reefer vessels.

Camshafts deleted by Mitsubishi

Mitsubishi has followed Wärtsilä and MAN B&W in dispensing with the camshaft, now offering Eco versions of its UEC low-speed

engines with electronic control of fuel injection and exhaust valve actuation. Interestingly, unlike Wärtsilä for its Sulzer RT-flex engines, Mitsubishi (a long-time Sulzer licensee) did not adopt a common-rail fuel system but instead a hydraulic power configuration similar to that of MAN B&W on the ME engines. The fuel injection pump and exhaust-valve driving gear of the Eco-engine are actuated by hydraulic oil at a pressure of 320bar, with control by an on-

off type solenoid valve unit. Fuel injection and exhaust valve opening/closing are controlled electronically to secure the optimum solution for any operating mode and to match changing conditions.

Development of 330mm, 500mm and 600mm-bore Eco-variants of the established UEC-LSII models is complete, the concept now being extended to the larger bore designs. The first production engine, an eight-cylinder UEC60LSII-Eco model rated at 15,540kW, is destined for service in mid-2005 powering a 6400-unit car/truck carrier ordered by NYK.

Wärtsilä's new 46F model

Turning to four-stroke engine developments: since its introduction in 1988 the Wärtsilä 46 medium-speed design has earned popularity in diverse cargo and passenger ship propulsion sectors, including ro-ro freight and ro-pax ferries. More than 1000 engines have been produced for marine and land installations. An output of 905kW/cylinder at both 500rev/min and 514rev/min was offered by the original 460mm-bore/580mm-stroke design, whose development potential allowed subsequent upratings to 975kW/cylinder (1992 B-version) and 1050kW (1995 C-version).

Market drivers, among them environmental regulations, dictated not just an upgrade but the development of a new design based on the original cylinder dimensions and exploiting novel solutions for key components and systems. The resulting 46F engine, launched last year (*The Naval Architect* November 2004, page 38) is described as more powerful without compromising reliability, offering attractive power-to-weight and space ratios, 'best in class' fuel and lube oil consumptions, and very low emissions regardless of fuel quality.

A power band from 7500kW to 11,250kW at 600rev/min is initially covered by in-line six-to-nine-cylinder models, although V-cylinder versions are planned for introduction later (the original Wärtsilä 46 engine continues to be offered alongside the new F-series.)

The higher output (1250kW/cylinder) was achieved by raising engine speed instead of mean effective pressure and applying the latest turbocharging technology to make wider use of the Miller valve timing concept. Common-rail or conventional fuel injection systems are available - though the former is standard - both exploiting high injection pressures for low smoke emission.

Installation, operational and maintenance benefits flow from the increased specific rating since an engine with fewer cylinders (say, seven instead of nine) can be specified to deliver the same power. More compact machinery spaces and easier installation procedures are further fostered by built-on support system modules.

Reportedly the first engine on the market with continuous big-end bearing temperature monitoring as standard - using Kongsberg Maritime's Sentry wireless system - the 46F is also offered with condition-based maintenance support from Wärtsilä. The main bearing temperatures (as with the 46 engine) are also monitored.

Higher outputs from MaK

Germany's Caterpillar Motoren strengthened the competitiveness of its popular MaK M43 engine last year by raising the output of the 430mm-bore/610mm-stroke design from 900kW to 1000kW/cylinder at 500/514rev/min. Uprating to the new C-status initially benefited the in-line cylinder (six, seven, eight and nine) models but will be applied also to the V12- and

V16-cylinder models, taking the upper limit of the M43C programme to 16,000kW. M43 engines with the original rating remain available. Apart from seeking a higher power output, the M43C engine designers sought increased reliability, simplified maintenance, reduced noise levels, and lower emissions.

The M43C, like its predecessor, can benefit from Caterpillar's ACERT technology, which is particularly valuable for emission-sensitive applications such as ferries. NOx emissions can reportedly be reduced to 8g/kWh and below down to 25% engine load (30% less than the current emission standard); and smoke remains below the visibility of 0.5 over the entire operating range (optionally, smoke can be reduced to less than 0.3 for engines meeting IMO NOx standards only).

The V12-cylinder M43 model made its debut in ferry propulsion early last year with a 43,200kW four-engine/twin-screw installation giving Brittany Ferries' 41,700gt ro-pax vessel *Pont-Aven* from Meyer Werft (*Significant Ships of 2004*) a service speed of 27knots-plus. Each developing 10,800kW at 500rev/min, the flexibly-mounted engines are arranged in pairs to drive 5.2m-diameter Wärtsilä CP propellers via Flender reduction gearsets designed to transmit 21,600kW apiece.

Gas-powered advances for ferries

An anticipated Norwegian and overseas market for gas-powered ferries - recently signalled by orders for five such vessels of similar design but in two different lengths - from Aker Brattvaag (with hulls from Aker Tulcea in Romania) for Norwegian coastal operator Fjord 1 - stimulated Bergen's development of suitable lean-burn Otto-cycle marine engines based on its successful experience with land-based installations, as discussed in *The Naval Architect* June 2004, pages 3 and 9. The resulting new 250mm-bore spark-ignited K-G4 and 350mm-bore B35:40V gas engines from the Rolls-Royce group company cover power demands up to 8500kW.

At the time of writing, a contract for the Fjord 1 ferry engines had not been placed, but the K-G4 model must be a prime candidate. The ship designs (from LMG Marin) were presented in our January 2005 edition, page 18.

20-cylinder Ruston RK280 offers promise

Large fast ferries typically impose extended daily running hours on their propulsion systems at close to maximum ratings, with perhaps frequent stops and starts, and limited time for maintenance outside peak seasons. Comparatively few medium-speed enginebuilders have appropriate designs for higher-powered monohull and multi-hull installations.

Among the contenders is the new Ruston RK280 engine, today part of the MAN B&W Diesel portfolio, launched as the world's most powerful 1000rev/min design. The 280mm-bore engine in V20-cylinder form has classification society type approval for a continuous rating of 9000kW, equivalent to 450kW/cylinder. An output of 500kW/cylinder is envisaged later, however, equating to a rating of 10MW from the 20RK280 model, which will

A Rolls-Royce Bergen K-G4 spark-ignited gas engine on test. Although much experience has been accumulated on land-based plant, no engines of this type have yet gone to sea. This however may change very soon, as a decision is awaited on machinery choice for the gas-fuelled engines specified for five new Norwegian coastal ferries.



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be complemented by V12 and V16 variants. A competitive specific fuel consumption of under 190g/kWh, NOx emission levels of less than 10g/kWh from primary reduction measures alone, and reduced particulates emissions throughout the load range are claimed.

Compactness and lightness are reflected in a dry weight of 46tonnes and a power density of 5.1kg/kW for the V20-cylinder model, which measures 7.33m long x 2.1m wide x 3.18m high. Ease of installation is fostered by an engine-mounted lube oil cooler, filters and thermostatic valve, and simple cooling water interfaces.

A recent order called for four 20RK280 engines to power a 122m-long monohull ferry ordered by Swedish operator Rederi AB Gotland from Fincantieri. A maximum speed of around 40knots and a service speed of 36knots at 85% MCR are anticipated for the 800-passenger/160-car capacity vessel in Baltic deployment. Each engine will drive a Rolls-Royce Kamewa S140 II waterjet via a ZF 6000 NRH gearbox.

Strengthening fast-ferry status for MTU

Strengthening its status in the fast ferry market, MTU Friedrichshafen introduced its most powerful-ever design, the 265mm-bore Series 8000. Outputs up to 9000kW were initially sanctioned for the V20-cylinder model in naval and megayacht installations, with a rating of 8200kW at 1150rev/min for high-speed commercial vessel propulsion.



Typical quadruple-20V 8000 engine packages for fast ferries can thus deliver 32,800kW, a forthcoming example being the 126m-long trimaran *Benchijigua Express*, ordered by Fred Olsen from Austal Ships for Canary Islands service and due for imminent delivery. A speed in excess of 40knots is anticipated. Each engine will be rated at the standard 8200kW output but an agreement to increase this to 9100kW during first-quarter 2006 indicates the power reserve in the design. Such a rating will also be available for subsequent 20V 8000 engine deliveries.

A common-rail fuel system allows all injection parameters affecting combustion to be independently controlled, including such variables as timing, period, and pattern of injection as well as the pressure. Fuel economy and emissions performance can thus be optimised throughout the load range. Sequential turbocharging, applied by MTU to its engines for many years, is adopted to

secure a large performance map width. Excellent acceleration, lower fuel economy, and lower smoke emission levels are fostered.

A modular cylinder unit-based design helps to ease maintenance and minimise life-cycle costs, while a V48-degree configuration creates a narrow engine (1.9m wide) for catamaran and monohull ferries in which machinery space is at a premium. The specific power output related to volume and weight is reflected respectively in figures of 200kW/m³ and around 5kg/kW, depending on the application.

MTU's popular 165mm-bore Series 4000 high-speed engine has benefited from a recent power uprating, some V12 and V16-cylinder models now being offered with 6%-10% higher outputs than before. Two newly added V16 models, the M61R and M61, address commercial vessels with ratings respectively raised to between 1520kW and 2000kW. Ⓢ

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Gas turbines sharpen their competitive edge

KEY certifications and US naval orders in the past year should strengthen Rolls-Royce bids for gas turbine propulsion business in commercial shipping, particularly for LNG carrier and cruise ship projects - and an anticipated invitation to tender for a project (*The Naval Architect* January 2005, page 23) is expected soon, probably during this year. ABS certification was gained after successful endurance test running of the British group's new simple-cycle MT30 gas turbine, which has a thermal efficiency exceeding 40%. The completion of 1500 hours' operation at 100°F proved the ability of the 36,000kW unit to maintain power at high ambient temperatures - a US Navy requirement.

Design approval from DNV had been earned earlier in 2004 for the Trent 800 aero-engine-based turbine, certifying it at 36,000kW under the Norwegian class society's rules for high-speed, light craft and naval surface vessels.

Rolls-Royce has already been boosted by an order for a twin-MT30 propulsion plant to power the Littoral Combat Ship (LCS) designed by Lockheed Martin for evaluation by the US Navy for a possible 57-vessel programme. These gas turbines will be incorporated in a CODAG configuration with V16-cylinder Fairbanks Morse-built Pielstick PA6B STC diesel engines, arranged to drive four Rolls-Royce Kamewa waterjets via Maag gearing.

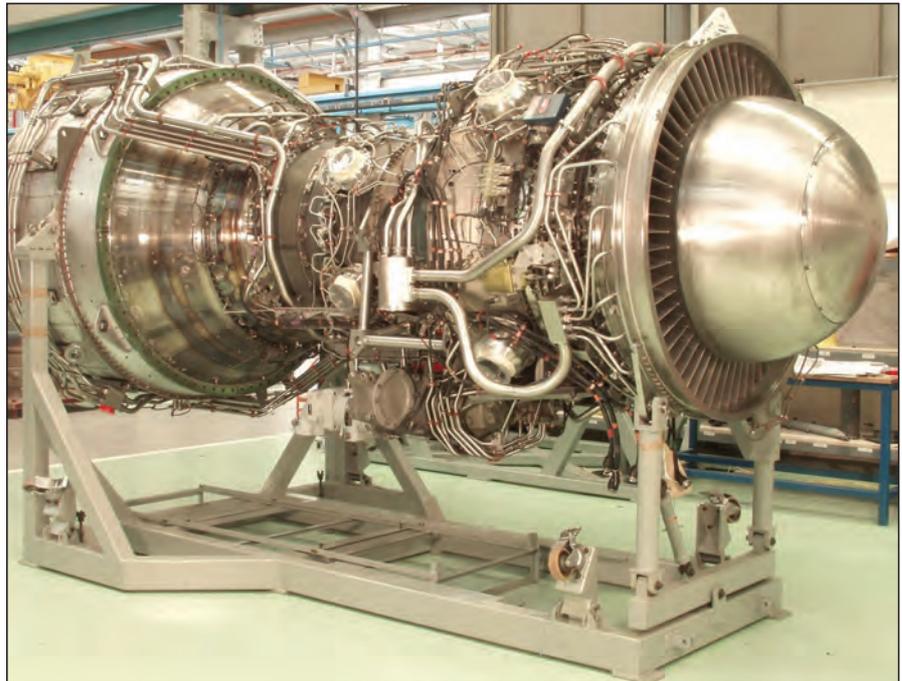
An earlier breakthrough in the naval sector saw the MT30 selected for the engineering development model of the US Navy's DD(X) future surface combatant's integrated power system. The unit is also in the baseline specification for the Royal Navy's two large aircraft carrier projects and under consideration for the Franco-Italian FREMM frigate programme.

Targeting the LNG sector

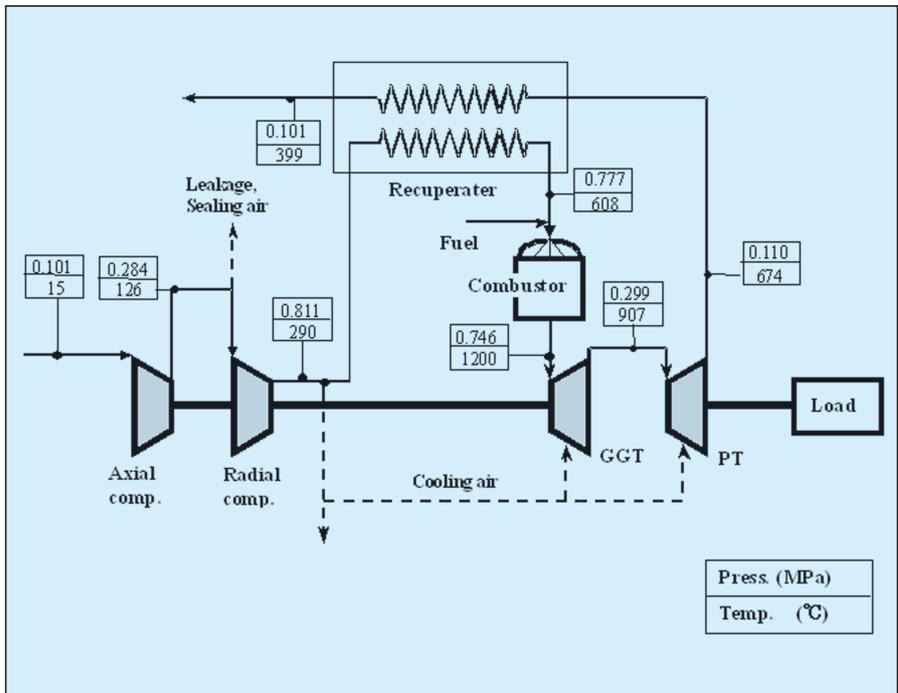
As reported in our January article, a range of compact dual-fuel MT30-based propulsion systems for LNG carriers between 145,000m³ and 250,000m³ capacity is offered by Rolls-Royce, with or without a waste heat recovery steam turbine to boost overall thermal efficiency to more than 50%. Cargo boil-off gas would be supplied to the turbine at a pressure of around 40bar.

Among the economic merits cited are increased cargo capacity released by machinery space savings over steam and diesel installations, and reduced through-life costs. Electric propulsion configurations enable cargo area and machinery layouts to be further optimised: for example, the very lightweight gas turbine-generator plant could be moved from inside the hull and located aft on the quarter deck behind the superstructure.

High reliability and durability, with undemanding plant supervision, are promised since the MT30 - which shares 80% commonality with the very successful Trent 800 engine - would operate at a power significantly less than the aero rating. Little difference in aggregate maintenance costs



The heart of Rolls-Royce's assault on the merchant ship sector - and particularly LNG carriers - is the MT30 gas turbine.



A cross-section through Japan's new small Super Marine gas turbine, which is currently undergoing endurance testing. A 2500kW turbo-electric plant using this machine is planned to power the Super Eco-Ship, which is envisaged to revolutionise coastal shipping in that country.

between diesel and gas turbine systems is anticipated by Rolls-Royce, which offers to take the risk through tailored support packages, in exchange for the operator paying an annual fee and a 'fired-hour' charge.

Aero-derived gas turbines inherently yield far lower emissions than low-speed diesel engines

running on heavy oil, asserts Rolls-Royce. Also, since the LNG industry is based on transporting gas for the eco-friendly generation of electrical power ashore, it would seem a paradox if this clean fuel were shipped in carriers burning heavy fuel. Operators should also appreciate that more environmentally-

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friendly tonnage would be welcomed by communities around LNG import and export terminals.

Extending the options at GE

Similar arguments can be advanced by GE Transportation, whose LNG carrier propulsion proposals feature its LM2500+ gas turbine in electric and mechanical drive arrangements. COGES plant can also be supplied, the US group's references including large cruise ships with combined gas and steam turbine-electric machinery for higher efficiency.

Outputs up to 30,000kW are offered by the LM2500+ turbine but GE's options will be extended after gaining ABS certification for the most powerful member of its aero-derived programme - the LM6000 series - at a rating greater than 36,000kW based on US Navy standard day conditions (100°F). In service in

numerous industrial and offshore power generation installations, the engine is already certified for commercial use by DNV.

GE expects to complete the relevant testing programme and secure ABS certification during 2005. The company also intends to invest in developing the LM6000 'well beyond its current rating without increasing the engine's shipboard size and weight footprint'.

Small gas turbine progress in Japan

At the other end of the power spectrum, a new generation of small gas turbines dedicated to marine applications has progressed to endurance testing in Japan. This Super Marine Gas Turbine (SMGT) results from a joint venture embracing Kawasaki, IHI, Daihatsu, Niigata, and Yanmar.

Initiated in 1997, the project aims to develop a 2500kW propulsion system burning marine diesel oil and achieving a 30% lower fuel consumption than existing industrial gas

turbines of equivalent output. Environmental goals include a reduction in NOx emissions to below 1g/kWh (one-tenth that of marine diesel engines and one-third that of industrial gas turbines). Unlike most marine gas turbines in service, the SMGT is not derived from an aero engine and exploits a regenerative cycle with a recuperator in the exhaust duct to achieve a higher thermal efficiency (at least 38% is targeted).

Extensive testing carried out since 2001 on an experimental unit demonstrated that the development goals could be met, and trials of a second unit (SMGT2) assessed reliability through full load running and start/stop cyclic tests. An SMGT-electric propulsion plant is planned for installation in the first Super Eco-Ship, an innovative coastal vessel project initiated in 2001 by the National Maritime Research Institute of Japan (*The Naval Architect* October 2003, page 40). 

Complying with new exhaust-gas emission levels

SMOKE and gas emissions from marine diesel engines are becoming an increasing technical issue, especially for vessels operating in sensitive areas such as Alaska, the Baltic Sea, and in many harbours. May 19 this year marks the compliance date (first scheduled docking after that date) for owners to meet the provisions of MARPOL Annex VI and the NOx Technical Code. These apply to ships above 400gt and fitted with marine engines with outputs greater than 130kW (ie, covering auxiliary engines as well as propulsion units), installed on ships built after January 1 2000 and to all engines that undergo a major conversion after January 1 2000.

Unfortunately, many engines which have their performance trimmed to minimise NOx can end up burning more fuel - up to 4%; however, by installing an onboard NOx monitor, a UK company, Martek Marine, claims that it is possible to optimise engine performance to deliver major fuel savings. Three alternative methods are open to owners to comply with the new legislation: apart from a direct monitoring method, as proposed by Martek Marine, there is the parameter check method, and the simplified parameter check.

The direct monitoring technique would appear to be the most practical, since the parameter check method requires a physical inspection, which means a strip-down of certain engine components, and a record book inspection, plus verification of engine-adjustable features. It seems that to use this technique will involve an owner's commitment to use only engine manufacturers' critical components (IMO stamped) at a possible price premium. It also appears that the new breed of electronically controlled engines such as the MAN B&W ME type and the Wärtsilä Sulzer RT-flex series will not be able to use this technique when optimised for greater fuel efficiency.

The simplified check method involves both a direct measurement of emissions, to the same accuracy as that on an engine test bed, as well as the measurement of recording of a list of parameters.



The Martek Marine MNX GA15 sample probe, which is inserted in an engine's exhaust line to record NOx emission levels. Data is analysed in a data-secure floor-standing cabinet, and details appear on an integral touch-screen.

Given the apparent complexity of both these techniques, it is perhaps not surprising that companies such as Martek Marine are promoting the third option - direct NOx measurement only, which needs to be carried out monthly in a secure format and which should cause minimal disruption. This method is also claimed to be the one favoured by major classification societies.

Readings have to be taken at two engine load points, and owners can source equipment from wherever they prefer. The arrangement allows engines to be adjusted to meet any NOx level, such as might result from further proposed European Union and US lower limits, as well as to meet the SOx emission control areas (North Sea and Baltic Sea) which will come into force next year.

The Martek Marine Marinox MNX GA15 special-purpose heated sample probe collects the gases in an exhaust duct and transfers them to an

analyser along a heated line. An optional model (Marinox +) will also monitor SOx, O₂, CO₂, CO, HC, and dust particles. Data is transferred to a floor-standing cabinet (1600mm high, 600mm wide, and 600mm deep) which is fitted with a touch-screen display, automatic calibration prior to each test cycle, and secure data storage facility. Type approval is anticipated early this year.

If required, the results can be used to optimise NOx levels - Martek Marine claims that on a large two-stroke engine, significant reductions in special fuel consumption can be achieved, equivalent to 4% annual fuel savings. A Marinox system has already been operating successfully on a VLCC, where it has achieved figures of between 13.90g/kWh and 14.00g/kWh - which is well below the 17.00g/kWh specified in the legislation for two-stroke engines running at speeds of below 130rev/min. 

Diesels drive a wedge into LNG carrier propulsion

YEARS of marketing the merits of diesel engines for LNG carrier propulsion have paid off during recent months for MAN B&W Diesel and the Wärtsilä Corporation, respectively logging orders for low-speed and medium-speed machinery solutions in a sector hitherto dominated by steam turbine plant. Wärtsilä has staked a strong claim for dual-fuel (DF) medium-speed diesel-electric propulsion, following a debut in the European market, with a breakthrough in the high-volume Korean newbuilding arena.

A pioneering installation was logged with the recent completion of the 75,000m³ *Gaz de France Energy* by Chantiers de l'Atlantique (featured in the newly published *Significant Ships of 2004*). Four 5700kW six-cylinder Wärtsilä L50DF-driven main gensets supply electrical power to a pair of 9550kW Alstom synchronous propulsion motors arranged to drive a single FP propeller via Renk gearing.

Scheduled for handover by end-2005 to *Gaz de France* from the same French yard is the 153,500m³ *Provalys*, specified with a scaled-up electric propulsion plant based on one six-cylinder and three V12-cylinder 50DF engines with a combined rating of 39,900kW. Another Wärtsilä DF-electric LNG carrier of similar capacity, *Gazelys*, is also in the Chantiers de l'Atlantique backlog for delivery at end-2006 to a *Gaz de France/NYK Line* partnership.

Further penetration of the rapidly expanding LNG market came last year with orders from Hyundai Heavy Industries to supply four packages of 50DF engines for a series of 155,000m³ LNG carriers commissioned by BP Shipping. Four ships (with four options) were booked with diesel-electric plants for delivery from mid-2007 from the Korean group's Ulsan and Samho yards. Each shipset comprises two V12-cylinder and two 9-cylinder 50DF engines with a combined output of 39,900kW, the deliveries to be made by Wärtsilä's Trieste factory in Italy from early 2006.

The propulsion requirements of larger LNG carriers can be met by more powerful combinations of 50DF engines: four V12 and one or two six-cylinder models for a 200,000m³ carrier, for example. Configurations incorporating V16-cylinder models can also be specified for higher capacity tonnage and ships with higher service speeds.

Significant benefits are cited by Wärtsilä for its DF diesel engine technology in LNG carrier propulsion. Maximum use can be made of the cargo boil-off gas, while the high efficiency of the engines yields a much lower overall fuel consumption than with a comparable steam turbine plant. Much reduced exhaust emissions are also claimed, with NO_x levels reportedly one-tenth those of equivalent 'pure' diesel engines; furthermore, the high fuel economy and use of natural gas foster low CO₂ emissions.

Low-speed breakthrough for MAN B&W

Similar economic, environmental and technical advantages over steam propulsion in LNG carrier propulsion have long been argued by MAN B&W Diesel for low-speed diesel engines.



Although not for installation in an LNG carrier, this MAN B&W 6S70ME-C electronically controlled low-speed engine (seen here on official test in a Korean engine works) is similar to those specified for the first-ever large LNG carriers to be powered by diesel machinery solely burning heavy fuel oil. The ships will be built by Hyundai, Daewoo, and Samsung.

Now, demand for larger ships with higher operational flexibility and efficiency for more varied contractual speed and deployment profiles (including spot market opportunities) recently opened the door to the Copenhagen-based designer.

Debut contracts call for twin-screw packages to serve four 210,000m³ ships booked at Daewoo, each shipset comprising two 6-cylinder S70ME-C electronically-controlled engines. Similar installations are required for four 216,000m³ newbuilding projects for the US-based Overseas Shipholding Group, split between the Hyundai and Samsung yards. All the tonnage is intended for Qatar-UK deployment.

The engines, each rated to deliver 18,660kW at 91rev/min, will be arranged solely to burn heavy fuel oil - the first time ever for large LNG ships, with all cargo boil-off gas returned to the containment tanks via an onboard reliquefaction system supplied by UK-based specialist Hamworthy.

Twin low-speed engines arranged to drive FP propellers via clutches avoid concerns over plant reliability, says MAN B&W, although 75% of the ship's design speed can still be secured with one engine out of action, the working engine having to accept a higher torque. With the electronically-controlled ME engine concept, this 'single engine running mode' is simply effected by push-button; the facility is pre-programmed into the software in the same way as the 'economy' and 'low NO_x' modes.

Propulsive power availability is assured, and maintenance can be carried out in port on one engine or shaftline. Arranging the engines and their support systems in completely independent machinery rooms further enhances redundancy.

Securing single-shaft redundancy

Propulsion redundancy with a single low-speed engine installation - if that is preferred over twin screws - can be secured with a shaft-mounted electric motor and clutch arrangement. In the event of main engine breakdown or shutdown for repair, electrical power is supplied by the ship's gensets to the motor to provide get-home or harbour manoeuvring propulsion.

Support for direct-drive low-speed diesel engine proposals for 200,000m³-plus carriers has been expressed by classification society ABS, which suggests that such machinery, coupled with onboard reliquefaction, appears to offer 'the greatest operational efficiencies'. It is more economical to use bunker fuel to power a ship and to reliquefy the cargo boil-off, claims ABS.

Gas-burning alternatives

For those still wishing to burn boil-off, high-pressure gas injection (GI) versions of its ME engine are also offered by MAN B&W Diesel. The dual-fuel ME-GI engine is designed to burn any ratio of oil and gas desired, depending on the amount of natural or forced boil-off gas available. No experience can yet be reported with GI engines at sea, although successful long-term feedback is claimed from land-based installations.

Specifying a GI engine avoids the need for a shipboard reliquefaction plant (with its potentially high electrical requirements for compressor power) but installing both elements allows the operator to exploit fluctuating LNG/fuel oil price differences over the extensive lifetime of an LNG carrier. Ⓜ

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Brighter horizon for sails and fuel cells

SUSTAINED periods of high bunker prices invariably give a boost to wind power proponents, whose marketing efforts should also be stimulated by tightening emission controls and possibly diminishing fossil fuel reserves. Concepts range from a full-blown return to sailing ships - albeit with computer-controlled rigs - to auxiliary sails of varying sophistication. Already in Japanese service is a small windmill-powered genset mounted on the upper deck.

Pushing hard for business is Hamburg-based SkySails, whose towing kite-sail system promises to reduce fuel costs by up to 50% or increase ship speed by up to 10%. The system is reportedly valid for all types of deepsea tonnage at the newbuilding stage or by retrofit.

Featuring a large aerodynamically-optimised aerofoil profile comparable with the wing of an aeroplane, the towing kite is made from a robust, weatherproof textile for compact onboard stowage when not deployed.

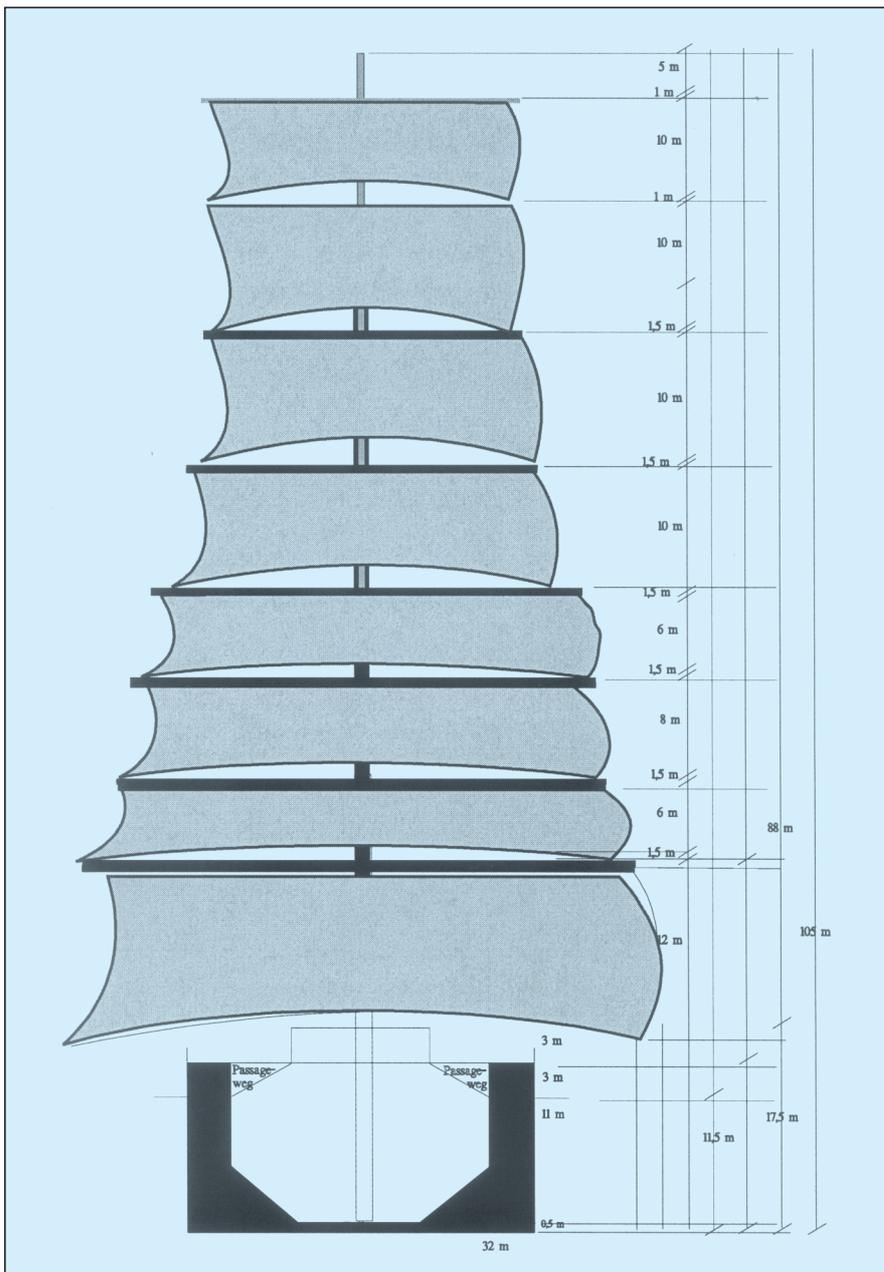
Depending on a ship's propulsive power, the sail areas can total up to 5000m². Easy launching and recovery from the ship's bow is claimed.

A central tractive cable and patented mounting system transfer power from the kite to the ship, with control cables arranged for steering and trimming the aerofoil. The kite is operated and kept in shape by chords of light synthetic fibre ensuring high resilience and negligible extension under heavy load, the designers explain.

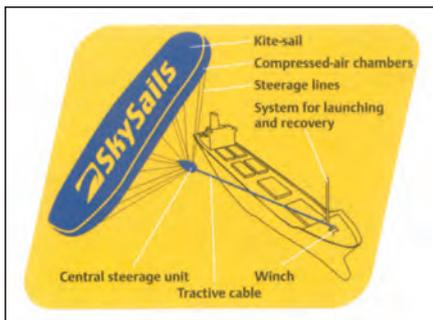
A variable tractive point secures optimum positioning of the kite regardless of ship's course or wind direction (courses up to 50deg to the wind can be achieved). Positioning is according to the direction and strength of the wind as well as ship's course and speed, with control of the towing kite fully automatic and similar to a plane's autopilot.

Route management based on accurate weather forecasting services would be tapped to avoid hazards and ensure the security of the system, the data from forecasts enabling a performance analysis to be made with a prediction of the power contribution expected from the system.

Another German organisation keen to promote sail technology is Sail Log, part of Schwab-Orga GmbH, whose technology was briefly discussed in *The Naval Architect's* November 2004 Editorial Comment. This company has designed a 70,000tonne displacement, 50,000dwt bulk carrier, with dimensions of 200m length, 32m breadth, and



Cross-section of a proposed 50,000dwt square-rigged bulk carrier from the German company Sail Log (Schwab-Orga), which could offer attractive benefits on long-haul bulk routes.



11m draught, which would be capable of navigating through the Panama Canal. The hull would have enough tankage for 40,000tonnes of ballast and a square-rigged sail area of 20,000m².

Captain Schwab, who heads this organisation, believes that even larger ships are possible,

Components of the proposed SkySail kite concept, which it is claimed, can increase ship speed by up to 10%.

although the comments of Andrew Spyrou in his January Letter to the Editor about the limited volume of wind available should perhaps be borne in mind. The 50,000dwt bulker is anticipated to have a service speed of around 13knots to 14knots, although Captain Schwab believes that in some conditions up to 20knots - achieved by earlier square-riggers - could be possible.

Bulk cargoes, which do not normally require a liner-type service, are considerable the prime target sector. Long-haul routes, eg, South

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An MTU HotModule fuel cell in operation at IZAR's Cartagena yard.

Fuel-cell progress

Substantial investment in fuel-cell technology for automotive and naval sectors will almost certainly eventually benefit commercial shipping (as Mr Andrew Spyrou also believes, in his January Letter to the Editor). In the long term, fuel cells could challenge virtually all contemporary sources of shipboard power, ranging from individual reserve power batteries to main and auxiliary power generating plant.

Small passenger and cargo vessels operating in environment-sensitive coastal regions, cruise ships, and LNG carriers promise eventual applications. LNG carriers are particularly favourable candidates for marine fuel cell generators and could exploit some of the first multi-MW high-temperature type plant in shipping

Diverse types of fuel cell are under development, each offering specific advantages for different applications. Of the five basic types, the high-temperature molten-carbonate (MCFC) and solid-oxide (SOFC) fuel cells are perhaps most suited to the existing marine operating environment.

High efficiency, cost-competitive solid-oxide cells operating in the 650°C-800°C range are under development by Wärtsilä in co-operation with Danish specialist Haldor Topsoe. MTU is also active in high-temperature fuel cell development, its HotModule being well established in a number of land-based plants, including one in partnership with IZAR at its Cartagena yard.

MTU's low-temperature CoolCell, operating at around 65°C, is installed in a German yacht and arranged to drive a propeller motor and supply onboard electrical power. U212-class submarines from HDW feature a 240kW proton-exchange membrane-type fuel cell developed by the German shipbuilder with Siemens for air-independent propulsion. A submerged endurance up to five times longer than existing U-209-class boats is reported. Orders have been received from the German, Greek, Italian and South Korean navies. Ⓢ

America to Europe and return, or South America across the Pacific Ocean to eastern Asia could be most attractive. Ships conceived by Sail Log are estimated to need their diesel engines for approximately one-third of a typical journey length.

Propulsion and weather-routing system in Japan

Japanese developers have long pursued and applied advances in commercial sail technology - including various commercial ships in the early 1980s which were fitted with sail assistance. Now, the country's National Maritime Research Institute (NMRI) is maintaining that tradition by unveiling a new propulsion and weather routing system.

In recent tests based on route calculations for a bulk carrier equipped with the sail system, carbon dioxide emission reductions of up to 17.4% were reported compared with a conventional bulker. Wind tunnel tests demonstrated that the maximum lift coefficient reached 2.15, considerably exceeding the value of 1.8 attained in previous projects of this type.

Supporting the sail system, an advanced weather routing program developed by the institute will determine the shortest and most energy-efficient voyage based on the anticipated wind and sea conditions. A novel feature of the technology allows the sail booms to double as cranes for cargo handling - as in earlier centuries.

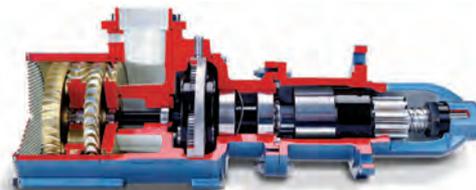
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Success for home-grown Hyundai engines

A NEW contract to export one of its own-design diesel engines further reflects the success of efforts by the engine division of Hyundai Heavy Industries to penetrate the marine market with home-grown products rather than the more traditional licence-built machinery. As this journal reported in September 2004, this HiMSEN range consists of two established models, H21/32 and H25/33 - the latter jointly developed with Rolls-Royce Bergen, of Norway.

At the end of 2004, around 550 engines in total (both models) had already been sold - including three 21/32 auxiliary models (3 x 780kW) driving alternators on the new BP tanker *British Liberty*, built by Hyundai Mipo Dockyard (*Significant Ships of 2004*). This year, a further smaller model, H17/28, is due to be launched.

Although the prime target market for the range is auxiliary machinery for alternator drive, one of the most recent contracts is to supply a 9H25/33P engine (the P notation signifying a propulsion model) for the Turkish Sener group, to provide propulsion power on a new 5850dwt chemical

tanker. This contract follows a similar one last April, placed by Sener Petrol; that engine was shipped to Turkey in December.

The latest engine, scheduled for May completion, is destined for the Yildirim Shipyard, where Sener's newest tanker is being built. It is particularly interesting to note that Hyundai will actually supply a complete propulsion package; the 2610kW engine, running at 900rev/min, will drive a ZF (France) CP propeller through a ZF (Italy) reduction gear. Hyundai will also supply the propeller shaft.

Official shop tests for the new H17/28 engine were completed last December in the presence of six classification society surveyors, including one from ABS. This type has a power range from 575kW to 920kW (900rev/min or 1000rev/min) and although the smallest of the three HiMSEN series, it is claimed to be amongst the most powerful for its size, as well as complying with new emission rules.

The two larger HiMSEN engines (H21/32 and H25/33) come in six-, seven-, eight- and nine-

cylinder versions, covering a power band between 960kW to 2700kW; in addition, the H21/32 comes in a five-cylinder version (800kW) but only at speeds of 720rev/min and 750rev/min. The new H17/28 model comes with five, six, seven, and eight cylinders only. All engines can burn heavy fuel up to 700cSt, offer smokeless operation at low load, and are designed for easy maintenance. 

Permanent power monitoring

A NEW system for permanently monitoring engine power has been developed by the German company Lehmann & Michels. Its Lemag Shaftpower concept puts emphasis on low cost allied to long-term accuracy and easy installation. A Shaftpower unit will display effective power (kW), a propeller curve comparison, and an overload alarm. Optional extras include recording of specific fuel consumption and thrust, also a black-box unit for recording of running time outside the propeller curve, and an additional bridge display.

A Shaftpower package is claimed to enable an operator to reduce fuel consumption by optimising cruising speed and trim. In addition, protection is provided against unwanted operation outside the propeller curve, which can considerably increase machinery safety and reliability.

The company decided against using adhesive strain gauges for measurement, since it claims to be 'highly sceptical' of their long-term stability - the slightest changes could significantly falsify results, the company says. Instead, a contact-free measurement of shaft twist using two fixed points was chosen. These two points lie 500mm apart to amplify signals, which in turn increases accuracy of the measurement. The transfer of power and signal is contact-free and the alarm output is potential-free. Standard systems are suitable for propeller shaft diameters of up to 1100mm, but larger models are available on request. 

A Hyundai HiMSEN 9H25/35P propulsion engine on the test bed at Ulsan. Two 2610kW engines of this type have been ordered by the Turkish Sener group to power two 5850dwt chemical tankers building at the Yildirim Shipyard. The second engine will be supplied as a package, complete with gearbox, shafting, and CP propeller.



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NEREUS: small-scale nuclear power for commercial shipping

Despite perceived hazards, inherently safe nuclear propulsion plants can, claim two Dutch engineers, be designed for next-generation merchant ships, employing the newest technology in association with gas turbo-alternators.

COMBINING an existing and well-proven gas turbine plus heat exchangers with inherently safe nuclear technology for small-scale energy conversion promises a viable alternative propulsion solution for various tonnage types, suggest the Dutch proponents of the Naturally safe, Efficient, Reactor, Easy to operate, Ultimately simple and Small (NEREUS) concept. This interesting but probably controversial concept was first reported in *The Naval Architect's* November 2004 Editorial Comment, page 3, when this journal discussed the outlook for future fuels, and was subsequently reported in the Letter to the Editor by Andrew Spyrou (January 2005, page 37).

Among the key reasons cited by Gulian Crommelin, a retired Captain (Engineering) of the Royal Netherlands Navy, and Ir Walter F Crommelin, for advancing NEREUS development are the increasing demand for fossil fuels and consequent higher CO₂ pollution, which will lead to greater operating costs and/or penalties in the future.

An earlier study featured a closed-cycle helium gas turbine as the energy conversion unit but that concept was found to be too complex and expensive. In the current high-temperature reactor with gas turbine (HTR-GT) proposal, the non-nuclear element comprises a standard open-cycle gas turbine arranged to drive a generator or propeller via a gearbox, a recuperator, an intermediate heat exchanger, and a mass flow power control system. A 'cool' gas turbine is specified, the low inlet temperature (around 800°C) allowing the blades to be uncooled and requiring no expensive coatings.

Uranium, packed in a special way - a pebble-bed - is used as the fuel. The nuclear heat source is cooled by a helium flow, driven by a helium blower, to an intermediate heat exchanger which heats compressed air from the compressor. This heated air drives the turbine.

After an operational period of three years, approximately 7m³ of fuel elements would be removed from the core, this nuclear waste being transportable in shielded containers. After some 10 years, the radioactivity and heat production would have decayed to such an extent that this waste can be classified as 'middle radio-active solid nuclear waste'. After around 10-50 years of interim storage, the waste can be sent to final storage in relatively simple 0.4m³ drums. This is mainly possible thanks to the high mechanical integrity and chemical stability of the fuel elements, which simplifies their final isolation from the biosphere.

Safety of the gas turbine

Safety of the non-nuclear element of the concept is claimed to be higher than that of existing fossil



A home-made model by Gulian Crommelin showing the position of a NEREUS plant (reactor/gas turbine/electric propulsion motor) in a typical merchant ship. The motor is shown in green, and the reactor (red) at the first tweendeck. The gas turbo-generator is positioned on the second tweendeck, with the intermediate heat exchanger on the third tweendeck. The decay heat removal route is along the main deck to the top of the funnel.

fuel-fired energy conversion units, since there is no fuel treatment plant, fuel transport system, or high-pressure fuel piping requiring regular servicing.

In the nuclear element, safety is secured by the inherent character of the pebble-bed reactor based on:

- three coatings for the fuel pellets, called Tristructural Isotropic (TRISO) - the first barrier
- spherical fuel elements containing the pellets (second barrier)
- criticality control by burnable poisons: a chain of fission reactions has to be maintained in the reactor core during its fuel cycle. Because of the fissions, the amount of fuel, as well as the reactivity, decreases after time.

In an HTR system, no excess reactivity is expected - a major plus factor, which should

prevent catastrophic accidents ('Burnable neutron poisons' are materials with such a high neutron absorbing property that when placed in the reactor core, their concentration diminishes because of transmutation as a function of time. They facilitate higher fuel concentration in the core and consequently a reduced pace in the decrease of reactivity. At present, a three-year refuelling period is foreseen).

The combination of fuel enrichment and burnable poison will be designed to produce 20,000kW energy in the reactor, resulting in around 8000kWe at the generator, over a period of three years.

the HTR fuel's negative temperature coefficient implies that when the temperature of the reactor temporarily decreases to some extent, its reactivity increases, its power generation increases and

continued

The Royal Institution of Naval Architects

Recycling of Ships and other Marine Structures



4-5 May 2005, London

Second Notice

The disposal of ships and other marine structures raises a wide variety of issues. Recent high-profile cases in the developed world such as the US Navy's so-called "Ghost Ships" and the Brent Spar oil platform have highlighted some potential issues associated with disposal, mostly identified by persons or organisations raising environmental concerns.

However, at present, the vast majority of ships are broken up on beaches in Asia where concerns have been raised either with regard to the lack of environmental or safety legislation or the degree with which it is enforced by the recycling states. As a result of this, the activity, in the way it is carried out by some recycling facilities in those countries, is now regarded by the International Labour Organisation (ILO) as one of the most dangerous in the world. There are calls to ensure that more facilities become capable of breaking up and recycling ships both cleanly and safely, in both Europe and Asia. The need for yards of this type in Asia exists as the vast majority of the scrap steel extracted from ships finds a ready market in the construction industry and the various components of the ships (auxiliary engines, batteries, hydrocarbons, brass fittings, copper, household fittings such as wash basins, taps, toilets and showers etc) are re-sold for further use.

There is a requirement for all single hulled oil tankers to be replaced by 2010. This is expected to lead to a massive increase in the number of ships requiring disposal, magnifying the problems faced today. There are also approximately 200 decommissioned ships, the so-called "Ghost Ships", owned by the US government awaiting disposal in James River, Virginia.

The 1972 London Convention and the OSPAR Convention of 1998 have effectively ruled out the disposal respectively of ships and oil and gas platforms by dumping at sea. This means that methods must be found to dismantle them safely and cleanly on shore.

CONTENTS:

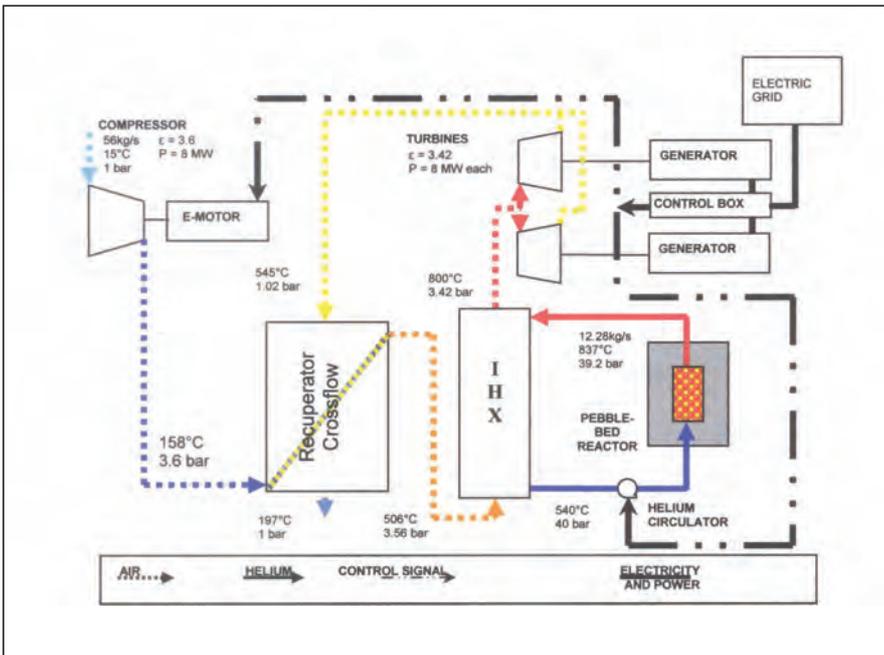
Papers were invited on the following topics:

- Assessments of the future demand for recycling
- The economic and environmental case for recycling. Can the developed world compete?
- Design for recycling: Use of easily recyclable materials, creating and keeping an inventory of potentially hazardous materials and taking measures to facilitate the removal and disposal of these materials.
- Regulatory matters: International and National regulations and their enforcement, industry guidelines and voluntary codes of practice.
- Controlling the environmental impact of recycling.
- Working conditions in recycling facilities
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A schematic diagram of a proposed inherently safe NEREUS plant with electrically coupled compressor and expanders.

Hitherto, the control of an energy conversion unit has been effected manually or by an automatic control system relying on sensors; in the HTR system, however, the energy output is controlled by the laws of physics. Features are:

- passive removal of the decay heat by natural draught
- low power density (3000kW/m³)
- fuel integrity maintained under all conditions, including depressurisation and loss of cooling, so that no 'safety procedures' and no 'defence in depth design' are necessary.

Fission products under all circumstances remain in the double containment of the TRISO, and the 60mm balls are not damaged by high temperatures.

Flooding safety

The reactor can be designed in such a way that in the event of flooding of the core, the nuclear chain reaction will stop inherently (as a consequence of the physical properties of the process) and immediately. Present ship propulsion reactors do not comply with this requirement and must be stopped by active means ('reactor scram' by insertion of control rods) in the case of problems at sea.

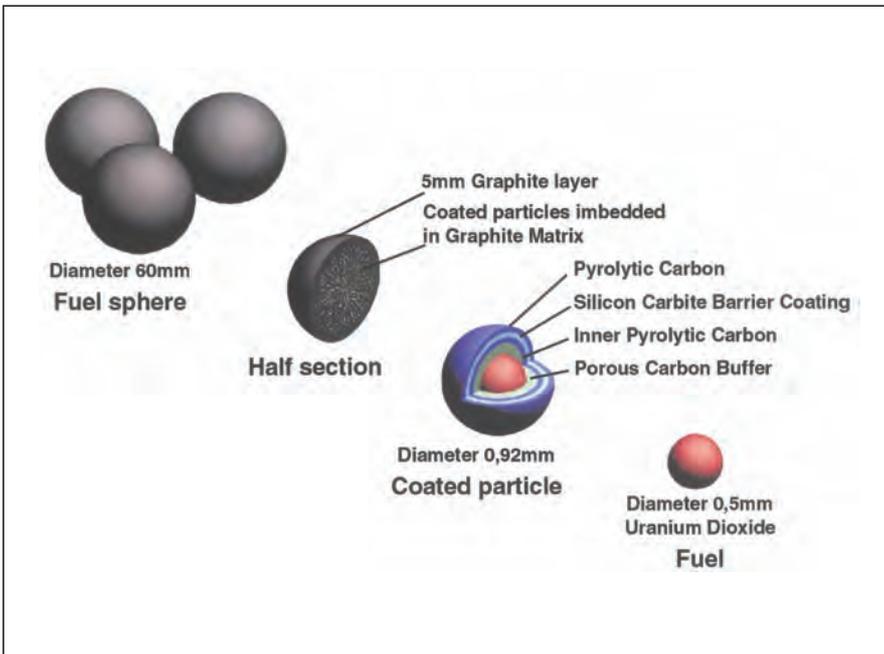
The likelihood of an implosion of the reactor, should the complete energy production installation sink to great depths, does not exist due to the fact that the fuel is ball shaped and neatly packed in the fuel chamber.

A number of solutions are available to protect a whole 10m x 10m x 10m NEREUS installation, including the possibility of locating it in a structure that is practically unsinkable. Bulkhead constructions have been designed in The Netherlands to withstand heavy collisions and explosions, and Kevlar armour, as applied in the latest US aircraft carriers, could be used for protecting the most important compartments.

Space requirements are reportedly similar to that of an equivalent diesel propulsion plant but with a reduced requirement for ancillary equipment. Hull construction dictates extra attention, however, due to the greater weight of the installation and to prevent the loss of a reactor. The ballasting system also calls for consideration because the effect of the normal bunker fuel load is eliminated.

Logistic support for the installation - including logistic management, nuclear fuel replacement, nuclear fuel treatment, nuclear waste management and repair and maintenance - would be handled by a pool-management system and based on through-life costing.

Summarising, NEREUS proponents assert that the well-proven, helium-cooled pebble-bed reactor is suitable as an inherently safe heat source indirectly coupled to a recuperative gas turbine for unmanned engine rooms.



Diagrams showing the construction of the pebble-bed pellets for a NEREUS plant.

the original temperature level is restored. The reactor thus functions like a thermostatic device (reactivity is strongly

dependent on fuel temperature). This feature is used to control the required output with start-stop rods; no control rods are required.

Gensets get the packaged treatment

AS reported in *The Naval Architect* November 2004, at least two leading engine builders are today offering factory-commissioned generator sets. The reasoning behind this interesting new move by both Wärtsilä and Caterpillar MaK is based on avoidance of potential problems - which can sometimes be costly - when third-party 'packagers' are involved.

Under a brand named Auxpac, Wärtsilä's new standard genset packages offer ratings from 60kWe to 2850kWe and for either 50Hz or 60Hz operation. The sets are based not only on Wärtsilä medium-speed designs but also those with Volvo Penta high-speed prime movers. Competitive prices, ease of installation and operation, and low operating costs are additional benefits claimed to result from modularisation and a high specification.

High-speed gensets driven by marine gas oil-burning Volvo Penta engines cover a power band up to 1630kWe, while Wärtsilä 20- and 26-powered sets burning the same heavy fuel as the main engine offer outputs from 520kWe to 2850kWe. Auxpac gensets are supplied complete and ready for installation - and self-



Caterpillar MaK is one of at least two major diesel engine builders now offering factory-commissioned generator packages. Seen here is a radiator-cooled Caterpillar 3406C DI-TA engine with an alternator developing 300kVA at 50Hz. It is classification society-approved.

supporting in terms of ancillaries - after factory-acceptance testing, which includes full parallel running when multiple sets are involved. Type approval by the major classification societies allows delivery with full certification.

A recent decision by Caterpillar Marine Power Systems to also build, package, test and type-approve all its marine gensets in-house means that all sets - with either Cat or MaK engines - will be supplied fully warranted from the factory. Caterpillar's genset range,

embracing Cat and MaK high- and medium-speed diesel drives, covers output demands from 11kWe to 15,750kWe.

Meanwhile, excellent service experience with its innovative and successful L16/24 genset engine last year encouraged MAN B&W Diesel to introduce a 10% uprated version delivering 110kW/cylinder. The programme now offers engine outputs up to 990kW at 1000/1200rev/min for 50/60Hz applications from 5-to-9-cylinder models. 

BOOK REVIEW

Introduction to Naval Architecture (Fourth Edition)

By Eric Tupper. Published by Elsevier, Butterworth-Heinemann, Linacre House, Jordan Hill, Oxford OX2 8DP, UK. 446 pages. Softback. ISBN: 0 7506 6554 8. Price: £34.99.

This fourth edition of an *Introduction to Naval Architecture* by E C Tupper follows on from the previous well-established edition of a text book of naval architecture that many find an invaluable reference in either studying or practising many aspects of marine technology, whether as naval architects, marine engineers, or as sea-going ship engineers and commanders. From the original *Muckle's Naval Architecture for Marine Engineers* to the current edition shows a progression in the books' content that reflects both a broader readership and the requirement for an understanding in an ever-increasing range of subjects as both part of ship design and operation today.

This latest edition of the publication reflects this by addressing some of these continuing advances. At the same time, it builds on the strengths of the previous edition as a very valuable introduction to naval architecture that is clearly written and with well-presented figures.

The comprehensive revisions to this new edition are most apparent in the inclusion of an additional five chapters. This results in a very different and beneficial structure to the book. The order in which topics are introduced is improved, with an emphasis on providing a treatment of the fundamentals of our profession plus an overall appreciation of the ship design process, before considering more complex creation and operational issues.

From the extended and excellent introduction, there are additional chapters that result from both separating out the contents of chapters from the previous edition to provide a more complete treatment of these subject areas and as a result of additional material in these topics. As a consequence, there are new chapters as a result of: flotation and initial stability being separated from stability at large angles; strength being considered in terms of main hull strength and structural elements in two separate chapters; launching, docking, and grounding together in a single chapter; and noise, vibration and shock being considered in new chapters on ship dynamics and the internal environment. These revisions also result in the book having a clearer structure that, in conjunction with the enhanced contents page, makes it a still more useful ready source of reference.

In those chapters dealing with the relatively complex topics of manoeuvring, directional stability, and vibration, emphasis has changed from not just providing an introduction to the mathematical treatment of these topics but to also providing a more descriptive approach, to allow an appreciation of the physics underlying these phenomena. This helps to provide a general understanding of these topics that is desirable before attempting application of the mathematical principles and assumptions used to model them. This will be particularly useful to new students of these subjects who might otherwise find such topics daunting without such an introduction.

The vessel types considered have been extended to discuss a broader range and contemporary designs, reflecting the ever-increasing diversity and variation of merchant vessels, high-speed craft, and warships. There is useful discussion of

the key design requirements, features, and the outline arrangement of such vessels. There is greater emphasis on the national and international regulatory organisations, and their influence on design, such as the requirement for double-hulled tankers, and the need for a designer to be aware of such regulatory influences.

A comprehensive list of further sources of reference for each chapter is given in a section towards the end of the book, to allow the reader to identify other useful publications if they require a more in-depth treatment. Additionally, web references are given in some instances as an acknowledgement of the additional valuable resource they provide.

A further welcome addition is the inclusion of a number of exercises and worked examples to allow practice of calculations. These are presented next to the relevant section in the accompanying chapter and are highlighted to allow them to be readily identified in the text.

Solutions are presented clearly in a manner that would allow for them to be practically implemented using computer-based techniques, such as within a spreadsheet or other programming tools. There are additional questions in the appendices that also provide valuable practice and an opportunity for the reader to consolidate material covered in the book.

In summary, this fourth edition builds on the strengths of the previous edition, with significant beneficial revisions to provide an excellent and comprehensive text on naval architecture that will be an invaluable source of reference for all students and practising professionals in marine technology.

Dr Peter N H Wright
University of Newcastle

The Royal Institution of Naval Architects

WARSHIP 2005 NAVAL SUBMARINES 8

22 - 23 June 2005

Second Notice



The changing face of naval warfare means that the role of the submarine has altered in recent years. Their use is increasingly moving away from the open ocean into shallower waters and the littoral.

Most navies are currently facing a reduction in resources, which will also affect the design of future submarines and size of complement. Lower complements are becoming more attractive with advances such as total integration of combat systems, machinery controls and data presentation. However, lower complements mean improved support infrastructures are required. Much can be done in making the submarine more 'support friendly' with more efficient supply chains both in production and for support.



The issue of safety aboard submarines is becoming increasingly important. Effective evacuation and fire fighting are complicated by the enclosed atmosphere and deep operation. A further issue is the resolution of minor incidents, such as onboard fires, while still retaining covert operations.

This will be the twenty-fifth in the Institution's successful WARSHIP symposia. The symposium will cover developments since 'Naval Submarines 7' in 2002. The Institution invites papers on the following subjects:

- **Propulsion:** nuclear power, air independent propulsion (AIP), hotel & combat system energy requirements, fuel processing, hull resistance, propulsors.
- **Design & Construction:** developments in design and analysis methods, advanced materials, more efficient structural configurations, ease of construction, inspection techniques, quality assurance.
- **Combat Systems:** sensor and data integration and presentation, non penetrating masts and periscopes; command, control and communication systems, weapon stowage and launch solutions, shore bombardment weapons.
- **Signature control:** passive & active anti-ASW.
- **Life Support:** atmosphere control and monitoring, acceptable concentrations of contaminants, food, water, accommodation standards.
- **Upkeep & Support:** equipment re-supply, refit support, maintenance, through life support, access to the submarine, disposal.
- **Emergency Situations:** escape & rescue, fire fighting, policy, equipment, life support.
- **Submersibles:** ROVs & AUVs in ASW and other roles.



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New welding control panel system

Orbimatic GmbH, manufacturer of high quality automatic welding equipment, has enhanced its range with the introduction of PSS (Pro Service System) to its ORBIMAT 165C Basic unit. PSS is a system which is said to make on-site operator maintenance a reality. It employs a special indication panel which is housed on the rear side of the power supply.

This control panel is equipped with four rows of LEDs which indicate the state of the



The new Pro Service System control panel from Orbimatic.

individual internal supplies, fuses, and components in the power supply. By simply looking at the control board, an operator can establish whether all fuses are intact and that all supply voltages are correct.

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The ORBIMAT 165C Basic has a ultra-modern design, with a carefully developed housing which makes it a simple operation to access any component in the power supply should parts need to be replaced in the future.

Contact: Orbimatic GmbH, PO Box 416, Peterborough PE7 3FT, UK. Tel: +44 1733 244063. Fax: + 44 1733 244463. E-mail: info@orbimatic.co.uk http://www.orbimatic.co.uk

Oily-water separator meets new regulations

Since 1995, Promac has been producing bilgewater separation systems based on ceramic membrane techniques. The Aquacleaner produces a clear and clean effluent fully compliant to IMO as laid down in the MEPC 107(49), which came into force at the beginning of January this year, and the unit is certified by Lloyd's Register to MED B standard, as well as being type-approved by IMO.

The innovative combination of gravitation and cross-flow filtration with special ceramic membranes ensures that any mixture of light or heavy oil, emulsion or dispersion, can be safely separated, in an overboard discharge far below the 15ppm limit (normally between



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Contact: Promac BV, Van Voordenpark 14, Zaltbommel, The Netherlands. Tel: +31 418 683333. Fax: +31 418 683 355. www.promac.nl

Lifts for new ferry

A contract to supply lifts for Tallink's new cruise-ferry, which is building at Aker Finnyards (Rauma site), has been won by MacGregor's passenger ship division. This 48,300gt vessel - the third new ship for this owner - is set for delivery in spring 2006, where it will operate on the Baltic Sea between Tallinn and Helsinki.

The 2800-passenger ship will have nine lifts. Five passenger models make between five and seven stops, and can carry 16 people, or a load of 1200kg. One service lift has been designed for the same load and makes nine stops; a further two have capacities for 1500kg or 20 people and make between two and seven stops. All units use MiniSpace technology and have a service speed of 1.0m/sec.

Contact: MacGregor (FIN) Oy, Passenger Ship Division, Hallimestarinkatu 6, FIN-20780 Kaarina, Finland. Tel: +358 2 412 11. Fax: +358 2 412 1267. E-mail: bjorn.stenwall@macgregor-group.com

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Korea Gas

Developing CNG transport technology - the CETech concept

Two new ship types to haul compressed natural gas are being proposed by CETech, a consortium of three industry leaders. One offers the attractions of additionally being able to load oil in a standard tanker hull below. Richard White reports.

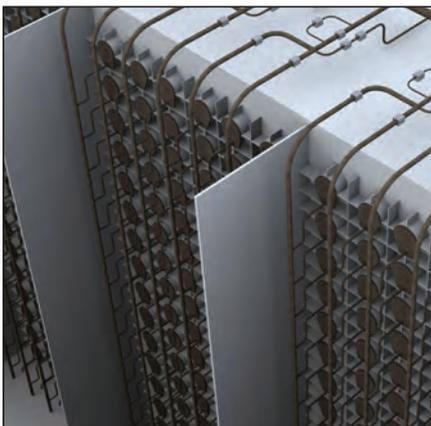
TRANSPORTING natural gas by ship under high pressure and at ambient temperature (compressed natural gas - CNG, or pressurised natural gas - or the alternative PNG, as Knutsen OAS calls it) can be a valid alternative to liquefying it, in certain circumstances, as reported on several occasions in *The Naval Architect*, including in our *Design and Operation of Gas Carriers* supplement, September 2004, page 39. Last year, a company named Compressed Energy Technology AS (CETech) was set up by three well-known organisations, Statoil, Teekay Shipping, and Leif Höegh & Co. A joint industry project to develop and qualify CNG technology has been pursued since April 2002 in cooperation with DNV Research.

Studies have shown that CNG ships can complement LNG carriers and pipelines in a range of defined conditions. Generally, these are over moderate route lengths between 300nm and 2000nm and where the amount of gas to be transported annually is fairly small - 500 standard m³ to 3000 million standard m³ annually.

CNG carriers can also open up possibilities for exploiting limited gas supplies that would be uneconomic to transport by other methods. Examples are associated gas, stranded gas in remote areas, or gas that might otherwise be flared. Such ships can play a part where there is no existing LNG or pipeline infrastructure. Large investments in onshore infrastructure are not required at the loading end of the route, and requirements at the receiving terminal are simpler. Compressing natural gas rather than liquefying it is also claimed to reduce the energy loss.

Two ship concepts using horizontal pipes

CETech has been developing two types of CNG carrier: the CNG Shuttle that transports only gas, and the Shuttle Producer concept. In the latter, a



A computer-generated image of the CNG Shuttle, which is purely designed for hauling CNG. With the bridge and accommodation at the forward end of the hull, the long 1219mm-diameter cargo pipes can be jacked in from the aft end.

CNG storage unit is installed on what is basically a shuttle tanker, so that the vessel can transport both oil and gas at the same time.

In the CETech CNG carrier concept, the gas storage system is separate from the ship itself. The company evaluated many possible storage configurations before settling on a horizontal pipe system. Gas is loaded at a pressure of 250bar into banks of long horizontal pipes (as opposed to the vertical concept planned by the EnerSea consortium). Each pipe is 1219mm diameter, made of X-80 steel with a wall thickness of approximately 36mm. A vessel to transport 100,000m³ of gas would have a total of 510 pipes each around 200m long.

The attraction of treating the gas storage and the ship itself as two separate systems is that the vessel's steel structure closely resembles a VLCC hull, and the owner therefore has a wide choice of shipyards capable of supplying the hull. The CNG system is mounted later, somewhat similar to the techniques employed in fitting topsides equipment to FPSOs. To support the pipes, a series of eight bulkheads are provided, spaced along the cargo area. The accommodation and bridge are at the bow, so that the pipes can be jacked through holes in the bulkheads from aft when the ship itself is completed.

Cargo pipes would be free to expand longitudinally, being fixed at the forward end only and restrained against vertical and sideways movement.

Each pipe is fixed only at its forward end, and all the other bulkheads are designed so that they restrain the pipes vertically and against side forces while allowing them to expand and contract freely longitudinally. Small-diameter pipes and manifolds connect the storage pipes in groups, the connections and associated valves (on deck level) being housed in an enclosure.

Similar principles are used in the Shuttle Producer, but here the hull is configured as a conventional tanker, with the CNG storage system above the oil tanks and a separation unit is installed on board. The concept is aimed at fields that may be marginal to exploit with traditional technology, and which require simultaneous production and off-take of oil and associated gas.

Two sizes of vessel have been designed. The smaller unit, based on an Aframax design, would be able to carry 60,000m³-70,000m³ of oil and 8000m³ of gas. The larger Suezmax vessel would transport 120,000m³ of oil and would have a 30,000m³ CNG plant. One attraction of the Shuttle Producer is that it can operate as a conventional oil tanker if not required for simultaneous oil and gas transport.

According to Alf-Petter Olsen, general manager of CETech, the CNG shuttle concept has been approved in principle by Det Norske Veritas, and patents are pending on the CNG Shuttle and Shuttle Producer. 'We are now engaged in optimising the designs, and are moving into the commercialisation phase and discussions with potential operators.'

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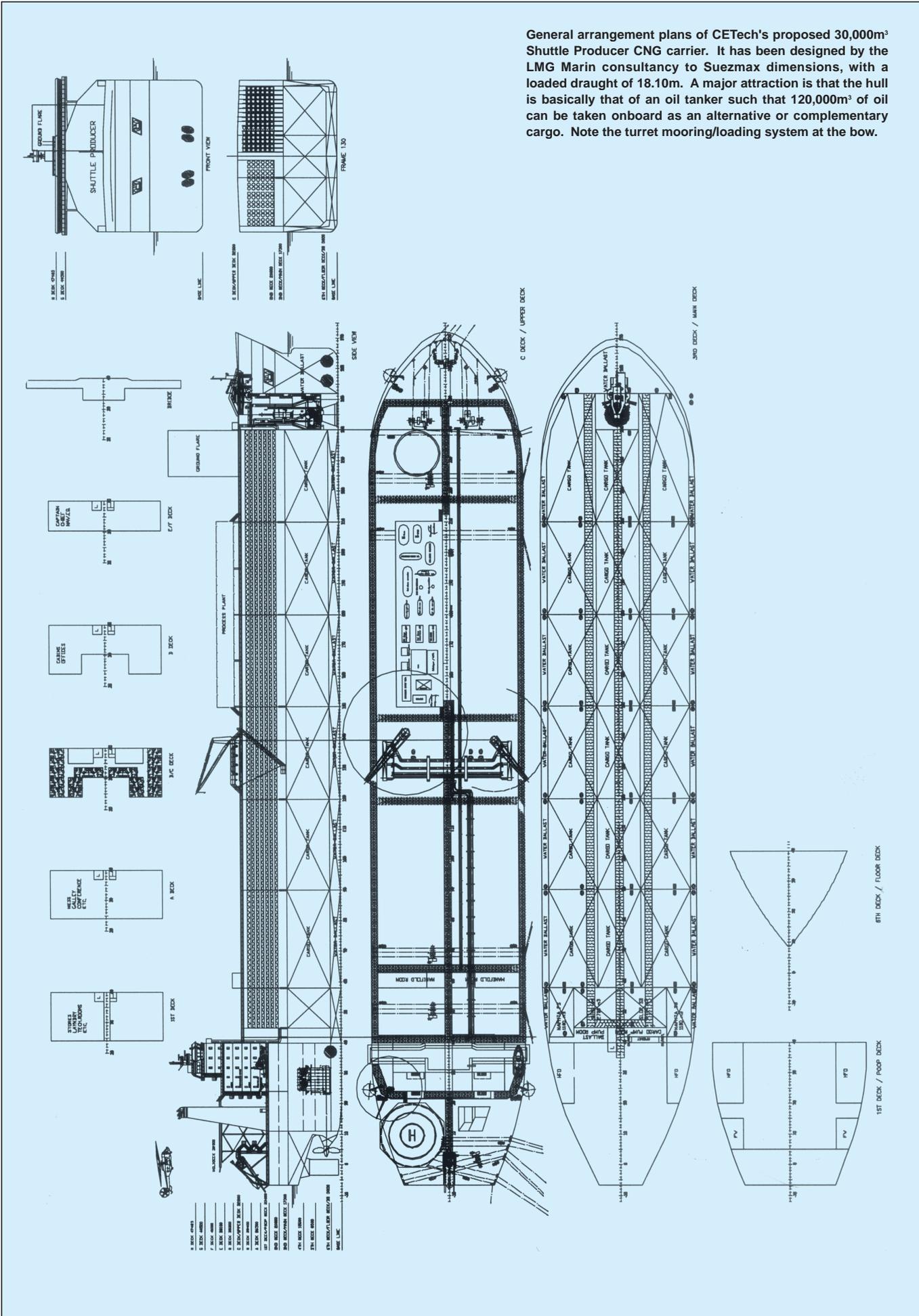
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General arrangement plans of CETech's proposed 30,000m³ Shuttle Producer CNG carrier. It has been designed by the LMG Marin consultancy to Suezmax dimensions, with a loaded draught of 18.10m. A major attraction is that the hull is basically that of an oil tanker such that 120,000m³ of oil can be taken onboard as an alternative or complementary cargo. Note the turret mooring/loading system at the bow.



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Hyundai: maintaining a lead in LNG carrier design and construction

SINCE the early days of modern Korean shipbuilding in the mid-1970s, Hyundai Heavy Industries, as a member of that elite band of Korean shipyards that now occupies a premier world position in the LNG sector, has dedicated substantial time and effort into refining all the complex aspects on LNG carrier design and construction. Until very recently, this yard concentrated on Moss spherical-tank ships but last year the Ulsan giant completed its first ship with GTT Mk III membrane containment technology; this was *Golar Viking*, which is presented in *Significant Ships of 2004*. Hyundai is believed to be the only Korean yard to hold licences for both spherical tank and membrane ships.

Studies have also commenced into the new GTT membrane concept, the CS1 (this is currently employed for the first time on three ships at the Atlantique yard in France; reports indicate that there are some adhesion problems in glued components on the prototype system on *Gaz de France Energy*). It is hoped to build a mock-up CS1 tank soon.

Today, as a result of new orders, two construction docks at Ulsan are dedicated to membrane-type ships and one to spherical tanks, which should mean that either five Moss-type carriers or eight GTT ships can be completed annually, irrespective of size. In future, these figures will be enhanced following a decision to additionally build LNG carriers at the group's Samho yard at Mokpo (the former Halla 'greenfield' yard on the west coast of the country), where an additional three ships could be completed annually.

As at other Korean gas-tanker yards, Hyundai has developed its own automatic welding machine for joining the complex Mk III corrugated cargo-tank sections; this machine has been approved by GTT, also by classification societies Det Norske Veritas and Bureau Veritas. Computers and sensors are used to monitor both the flat and corrugated components, while the plasma welding process is said to reduce defects significantly as well as increasing productivity - in contrast to current TIG methods.

Welding speed is said to be faster than TIG techniques, and the machines can handle all



Although Hyundai Heavy Industries has held a GTT membrane licence for many years, the 140,207m³ *Golar Viking*, delivered at the end of 2004, was actually the first LNG carrier from this yard to feature a membrane containment system (GTT Mk III type). Until then, this Korean yard had been concentrating on Moss spherical-tank types and has to date delivered 13 such ships, with three more on order.

angles, with adjustment to conditions being made automatically according to torch location. Arc length can also be controlled, both easily and automatically. Much of the work for these machines was carried out at the Hyundai Industrial Research Institute inside the Ulsan yard.

For the future, Hyundai has, in recent years, been studying anticipated very large LNG tanker designs - up to 250,000m³, and particularly two key issues - cargo sloshing and vibration, as well as the much-heralded alternative propulsion systems, as discussed in last September in *The Naval Architect's* supplement *Design and Operation of Gas Carriers*. At the end of 2004, all this work was rewarded by two significant contracts: for two 216,000m³ membrane-type ships for the Overseas Shipholding Group, to be powered by the pioneering specification of twin slow-speed diesel engines plus full cargo reliquefaction (a further two ships will be built by Samsung), also four 155,000m³ carriers, also membrane types, for BP Shipping. These latter vessels will feature diesel-electric propulsion, and some of them will be built at the Samho yard.

Hyundai continues to maintain an interest in alternative transportation techniques, especially the EnerSea VOTRANS concept for hauling compressed natural gas (CNG) from small and remote fields, where a full production system is not justified. The shipyard is part of a consortium (with EnerSea, K Line, and the class society ABS) developing this technology (discussed in *The Naval Architect* June 2003, page 12) and has secured class in-principle approval from ABS for a suitable CNG carrier design. In addition, the yard is still keeping an eye on other possibilities, such as pressurised natural gas (PNG), pressurised LNG, and FPSOs for processing LNG.

Since the delivery in 1994 of Hyundai's first LNG carrier, the 127,000m³ *Hyundai Utopia* (*Significant Ships of 1994*) to Hyundai Merchant Marine, a further 12 ships have been completed, while the order book stands at 15 vessels (12 of them membrane types). This backlog will keep the two yards busy until January 2008; however, given the buoyant state of the LNG market, further orders seem very likely. 

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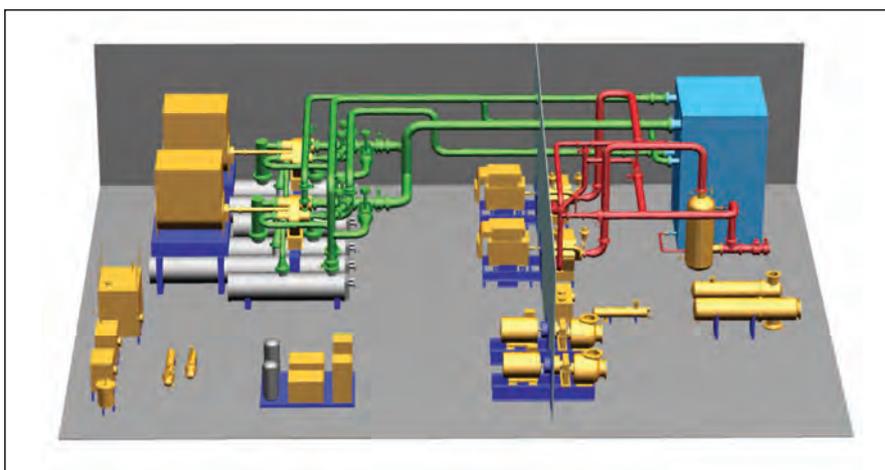
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Huge reliquefaction-plant contract for Hamworthy

As noted in our January issue, pages 3 and 4, the UK gas-handling specialist Hamworthy Plc has been awarded a contract to supply £48 million worth of reliquefaction equipment for installation on the four pioneering 216,000m³ membrane-type LNG carriers ordered at Hyundai Heavy Industries and Samsung by Overseas Shipholding Group (OSG). These twin-screw ships will be the first ever to feature heavy-fuel-burning diesel engines, with all cargo boil-off reliquefied. Hamworthy also has letters of intent to supply similar packages to four slightly smaller ships contracted by Pronav at Daewoo. Both series of ships have been ordered as part of joint ventures with QatarGas Transport Co. The contracts include engineering the systems, delivery of all equipment, installation supervision, and commissioning. Options are also in place for a further 11 sets of equipment.

Hamworthy's technology is based on that used in the onshore LNG liquefaction plant delivered in 2003 to Gasnor in Norway; it includes designs from Moss Maritime, for which Hamworthy has an exclusive licence. The principal attraction of a diesel engine plant with separated reliquefaction and not burning cargo boil-off is the high thermal efficiency of the engines - up to 50%, which is



A computer-generated image of a typical Hamworthy LNG reliquefaction plant, such as might be installed on the new ships to be built in Korea for OSG and Pronav.

much greater than the 30% quoted for steam turbines. To be offset against this, however, is the need for a large generating plant to drive the

reliquefaction compressors. This can range up to 4MW, claims the leading Japanese builder of LNG carriers, Mitsubishi. 

New LNG carrier contract for IZAR

After some months of negotiation, the troubled Spanish shipbuilding group IZAR has succeeded in winning a most useful order for a further LNG carrier, from the Norwegian owner Knutsen OAS. The 138,000m³ vessel will be almost totally similar to the five ships already built by the group for three owners and three charterers, the lead one of which was

Inigo Tapias, presented in *Significant Ships of 2003*. Construction work has started already, and delivery should be in three years time, when the ship will enter a charter with Repsol YPF and Gas Natural SDG.

At the present time, it is not clear which yard will assemble the new vessel - *Inigo Tapias* was built at the Sestao yard in Bilbao, but some

were constructed in the south of the country at Puerto Real. They were ground-breaking - and successful - contracts for the Spanish builder, since no major LNG carriers had been built in the country for 30 years. The project - aimed at increasing Spain's consumption of natural gas by 50% - was discussed in our March 2002 Editorial Comment. 

Safety and logistical planning for new LNG terminals

At a recent presentation from BMT Energy, Stephen Rowe, managing director, BMT Fluid Mechanics, and Tom Johnson, president, BMT Scientific Marine Services, illustrated the work that has been carried out on designing new terminals and into studies to increase LNG transportation reliability and safety. Issues covered include feasibility and concept evaluation, terminal design and layout, vessel manoeuvring and mooring, and transportation issues.

As readers will be aware, global increases in energy demand mean that current oil and petroleum gas supplies are probably insufficient, and natural gas is an alternative. There are also large proven gas reserves in discoveries that remain undeveloped because the transportation cost is at present uneconomic. Consequently, there has been considerable interest in and development of new ship and reception technology, both for the more common LNG and for the

alternative compressed natural gas (CNG), as *The Naval Architect's* special supplement last September, *Design and Operation of Gas Carriers*, illustrated.

Feasibility and concept evaluation

During feasibility and concept evaluation, it is necessary to demonstrate the future economic performance of a planned development to investors and stakeholders. Typically, this requires modelling or simulation of all the processes from field to market. Simulations extend over the anticipated field life so that significant inter-relationships can be identified and appropriate trade-off judgments made. Overall performance of the main components in the production, process, transport, and market-delivery phases is optimised by this approach. Such aspects as exports, downtime, ship sizes, and storage capacities are investigated.

BMT's SLOOP simulation programme, which for the past 10 years has been used in the oil industry, has been employed for several operators and it has played a significant part in assuring future economic operation by confirming or modifying parameters such as LNG plant size, storage capacity, number and size of LNG carriers, predicting the impact of equipment reliability on overall performance and the effect of ocean weather on LNG delivery schedules. A recent simulation, on a 25-year field-life study, had 100 components.

Terminal design and layout

At the present time, approximately 70 new LNG export/receiving terminals are planned worldwide. Terminals come in many shapes and sizes and may be in ports, inland, or - most interestingly - offshore; a single development project may involve several types, including perhaps an offshore loading

unit and an inland delivery point, or any variation thereof. Issues to be considered include environmental constraints applicable to bringing the LNG carriers alongside, how they are to be moored, and under what environmental conditions they must stand off.

All of these impact upon operating economics. The location of a terminal in relation to variables such as natural geography - sheltered bay or fully exposed location - will determine the need for factors such as special handling, also approach and environmental monitors. Safety and environmental issues must be considered during the design process, and BMT provides its clients with environmental impact assessments, gas dispersion, ventilation, and explosion consequence studies in support of the design, also guidance on issues which impact on day-to-day operating conditions.

In addition, BMT can give advice on insurance. LNG shipping, to date, has had an excellent safety record, and this is due to designs that include good mooring and cargo systems, ventilation, and studies into the consequences of gas releases, fires, or explosions, for example.

Manoeuvring and mooring

Assessments and studies can also be made into the manoeuvring and mooring performance of LNG carriers in the approach to and within a terminal area. These are used in support of both ship and terminal/port design. Familiarisation for vessel masters and their shore-based counterparts can also be supplied, regarding the behaviour of specific vessels in both normal and abnormal conditions. This enables both normal and emergency procedures to be developed.

Sloshing concerns

Although LNG has been transported for more than 40 years, safely and without incident, the significant growth in this trade, the increase in vessel size, and increases in the amount of vessel traffic generally mean that safety issues must be addressed with ever greater rigour if this good record is to be maintained. One such concern is that of cargo sloshing either in transit or at a terminal (although the sea-going aspects have been extensively analysed by class societies such as ABS).

BMT has researched the means by which a sloshing advisory system can be developed and installed on board LNG carriers in order to provide the master with information about the likely onset and severity of any sloshing. This system will offer options such as a change of heading or speed in order to minimise sloshing and the risk of potential damage to the tanks or vessel. Ⓢ

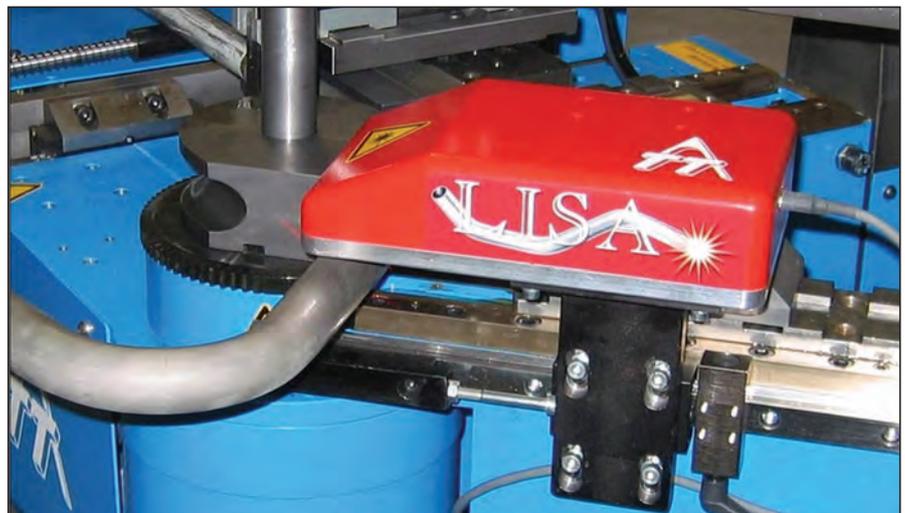
New optical measurement system wins award

AS part of Euroblech 2004, the 18th international sheetmetal-working technology exhibition (held in Hanover, Germany, in October last year), Tracto-Technik GmbH won the MM-Award, which is presented for innovative achievements in the field of forming technology, with its new optical bending-angle measuring system LISA (Laser In-Situ Angular-Measurement). This optical measuring system, which has been developed in cooperation with the Fraunhofer Institute for Factory Operation and Automation (IFF), Magdeburg, Germany, works according to the light-section technique, which is based on the triangulation principle - a popular technique which has proved its precision in many applications.

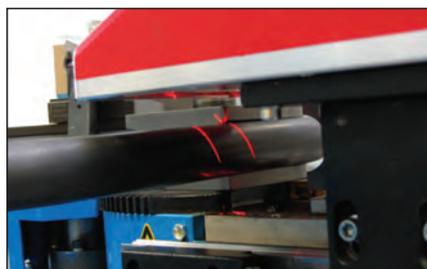
A fan-shaped laser beam is projected onto the test object, creating a sharp light-dark line on the surface; the course of this line is recorded by a camera and evaluated automatically by means of special algorithms. Equipping a pipe-bending machine with the LISA measuring system enables determination and documentation of the effective bending angle within the bending machine after the bent workpiece is sprung back.

The operator can now either measure each single pipe bend or carry out random tests with each part to check the bending angles. Due to the integrated quality assurance, it is no longer necessary, says Tracto-Technik, to check bending angles after finishing a workpiece, eg, by means of an articulated measuring arm. LISA is a very small unit, and the actual measuring/evaluating operation only takes a fraction of a second, thus the bending space is largely maintained and the increase of cycle times is limited to a minimum. Moreover, the system is claimed to be almost maintenance-free.

Beside the module for determining the bending angle, the measuring and evaluation software is also equipped with a calibration function and several diagnostic and service features. All modules are executed as Windows applications. A menu-supported user guide leads



The new bending angle measuring system LISA fixed to a pipe bender.



Laser measurement for precise determination of a bending angle.

the operator through the individual steps of the process. Via remote data connection, the results of the diagnosis and service functions can be evaluated directly by a Tracto-Technik employee, if required.

Results can be saved in an ASCII data format, enabling conversion (eg, into Excel) without any problems. Storage of the graphic metafiles is also optional. As the software for bending

angle determination is installed directly in the control computer of the bending machine, costs for additional hardware are omitted. The machine control processes the measuring results at once, so that it is possible to react immediately to tolerance variations (caused, for example, by a batch change of the raw material), by automatically adjusting the desired bending angle. Ⓢ

LNG transport - risk assessment and operational analysis

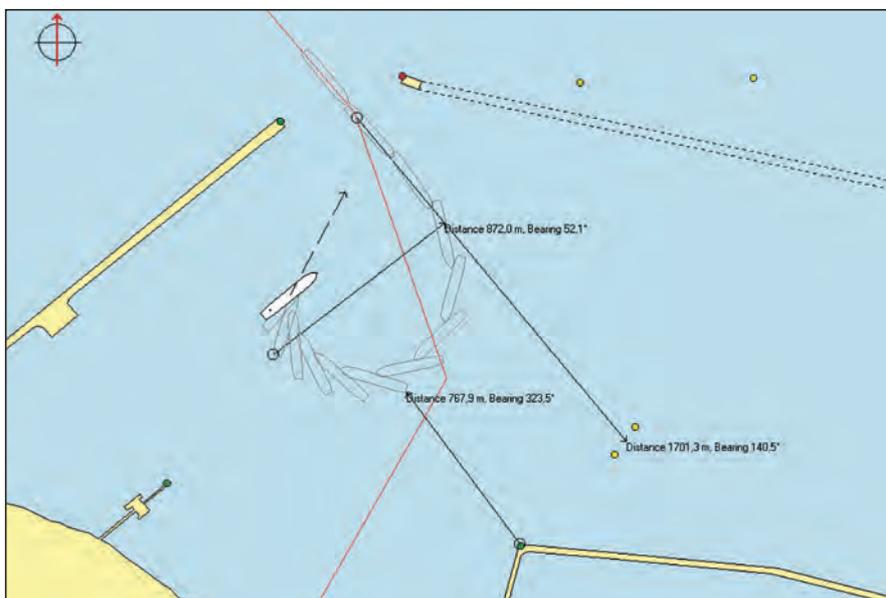
For many years, SSPA, in Sweden, has developed and model-tested a large percentage of the LNG carriers being built around the world. The test tank there has been committed to carrying out hull form optimisation by parametric database and/or CFD, model testing - resistance, propulsion, wake survey, cavitation, manoeuvring, and seakeeping tests, as well as manoeuvring and seakeeping simulations (separately or combined), and other studies, such as operational analysis, routing, risk and safety assessment. Erland Wilske and Peter Trägårdh, project managers at SSPA, discuss the safety issues surrounding LNG carriers*.

THE consequences of an accident or collision that results in fire with a large LNG tanker, particularly if it occurs in a port adjacent to densely populated areas, can be potentially devastating. Therefore, efforts concerning risk reduction should primarily be devoted to preventive measures. Both technical and hydro-mechanical aspects as well as other features, also equipment enhancing the operation of the ship and minimising the risk of human error, should be considered.

Twin-screw ships are generally favoured for larger designs (as witnessed by the new 210,000m³/216,000m³ ships recently ordered in Korea), since manoeuvrability is generally better for a twin-screw ship than for a single-screw one. Two independently controllable propellers improve turning capacity at low speeds in ports. This reduces risk of accidents during manoeuvres in ports and other confined areas. Manoeuvrability is enhanced by using CP propellers, since the engines are generally kept running during manoeuvres, thereby a quicker response can be obtained when changing propulsion force or direction. Manoeuvrability, particularly at low speed, can be improved by using high-lift or oversized rudders with angles greater than the standard 35deg.

Importance of redundancy

Redundancy is a key factor in minimising risks. It means back-up capacity in case of failure or loss of control of propulsion or manoeuvring functions, as well as other vital equipment for operating the ship. The twin-screw concept with its two propellers and two rudders is favourable also in this aspect. Model tests and simulation studies for several twin-screw ships have shown that, with a combined engine/rudder failure on one side, a ship can, in most cases, comply with the IMO manoeuvring standards and be able to



Evolution of manoeuvring performance of a large LNG carrier with conventional flap rudder in Bilbao harbour, using PORTSIM software.



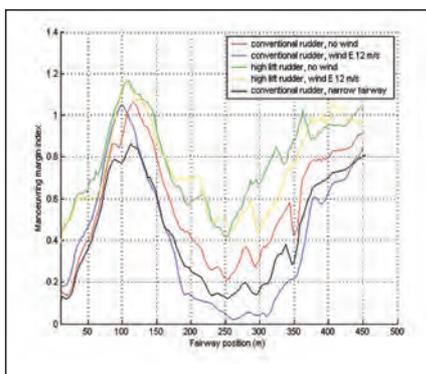
Example of track envelope from several simulations of port arrivals and departures with a large LNG carrier.

continue operations more or less as is normal for a single-screw ship. In case of failure of both rudders, twin-screw ships will still have a considerable manoeuvring ability.

Operational analysis

Operational analysis is a method of assessing the availability and performance of a ship in

its environment from a statistical point of view. Examples of input are seakeeping analysis, calculation of contribution of resistance due to wind and waves, manoeuvring simulations with given terminal design and facilities, and statistics of winds and waves for the intended routes. Especially in LNG carrier projects, where the investment costs are tremendous, outputs of an operational analysis are important figures in a cost/benefit analysis for optimal decision of hull design, power generation, and manoeuvring devices. SSPA has also seen an increasing interest from owners in using the results of an operational analysis as benchmark indicators for fleets in service.



SSPA's manoeuvring index illustrates the influence of changes in rudder efficiency, wind impact, and fairway width for a ship proceeding through an S-shaped channel. If the index reaches zero, the ship will exceed the fairway limitation no matter what measures are taken. The index is suitable for defining acceptance criteria. If, for example, an index above 0.4 is accepted, the result in the figure then shows that the alternative is to equip the ship with a high-lift flap rudder. The index also shows that the wind impact in the tested wind direction can be up to 12 m/sec.

*This article is based on one first published in the 3/2004 issue of SSPA Highlights.

As an example of an operational analysis carried out for LNG carriers, results are shown (Table 1) of estimated average annual speed at constant power. A number of routes have been analysed based on results from model tests (resistance and propulsion, seakeeping, and wind tunnel) and statistics for wind and waves.

Tools for simulation studies

For the assessment of a ship in a specific harbour or at a terminal, SSPA has developed a software package that covers different development stages, ranging from early concept evaluation to operational studies and crew training. The simulation tools cover

speed-power and manoeuvring prediction, seakeeping simulation, and manoeuvring simulation in harbour and fairway, including tug handling and confined-water effects.

The quality of a harbour and fairway assessment is highly dependent of the accuracy in the mathematical model of the ship. These tools are a condensation of decades of experience of model testing, full-scale trials, and simulation modelling.

Manoeuvring margin index

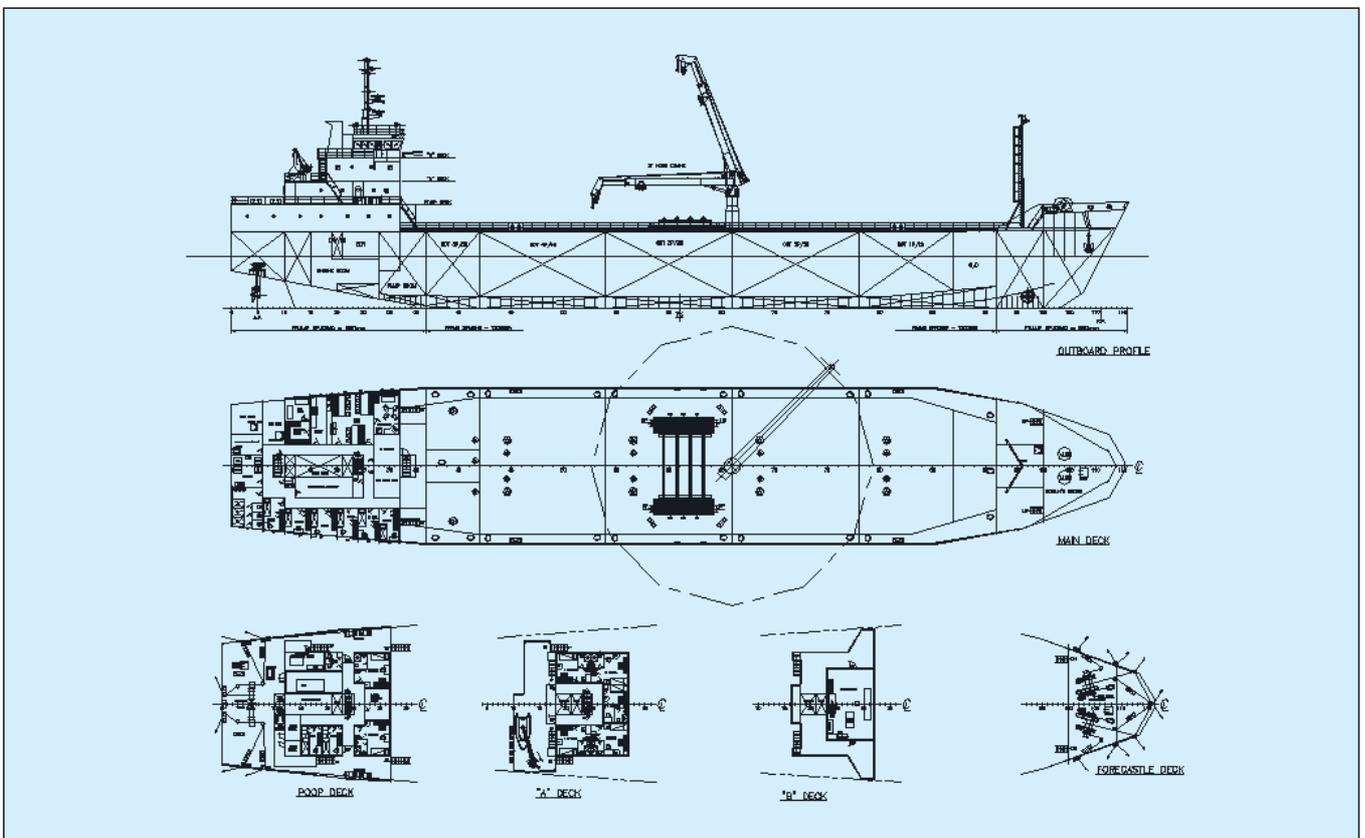
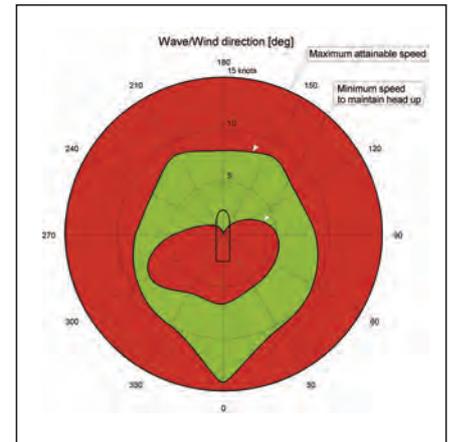
In order to improve the procedure of assessing the results from manoeuvring simulations, SSPA has developed a method of calculating a manoeuvring margin index. The method is

based on systematic simulations, which are analysed in order to assess a ship's possibility to succeed along the intended route. The algorithm assumes that difficulties in handling the ship follow a Gaussian distribution both with respect to proximity to fairway limitations and utilisation of manoeuvring forces. This index is very useful for assessing influence of changes in fairway design and/or ship design.

Table 1. Example of an operational analysis, showing estimated average annual speed at constant power.

Route	Average annual speed [knots]
Algeria to Boston	19.4
Trinidad to Bilbao	19.6
Australia to Barcelona via South Africa	19.8
Australia to Japan	19.9
Norway to Boston	19.2

Polar diagram showing the maximum attainable speed and minimum speed to maintain heading in seastate 6 for a twin-screw ship with one-side engine and rudder failure.



General arrangement plans of a series of four coastal bunkering tankers under construction at Dubai Drydocks for Emirates National Oil. This shipyard is more well-known as a leading player in the international shiprepair and conversion market but in recent months has made a decision to take a more active role in new vessels. Currently, a total of 14 projects are under way.

The 6200dwt tankers, which have been designed by the yard's own naval architects, will have a length overall of 102.70m, a breadth of 18.00m, and a summer draught of 5.95m. They will be powered by twin azimuthing thrusters, which should give a service speed of 8.00knots at 80% MCR engine output. The first tanker should be delivered in the first quarter of 2006, with the remaining three following at two-monthly intervals.

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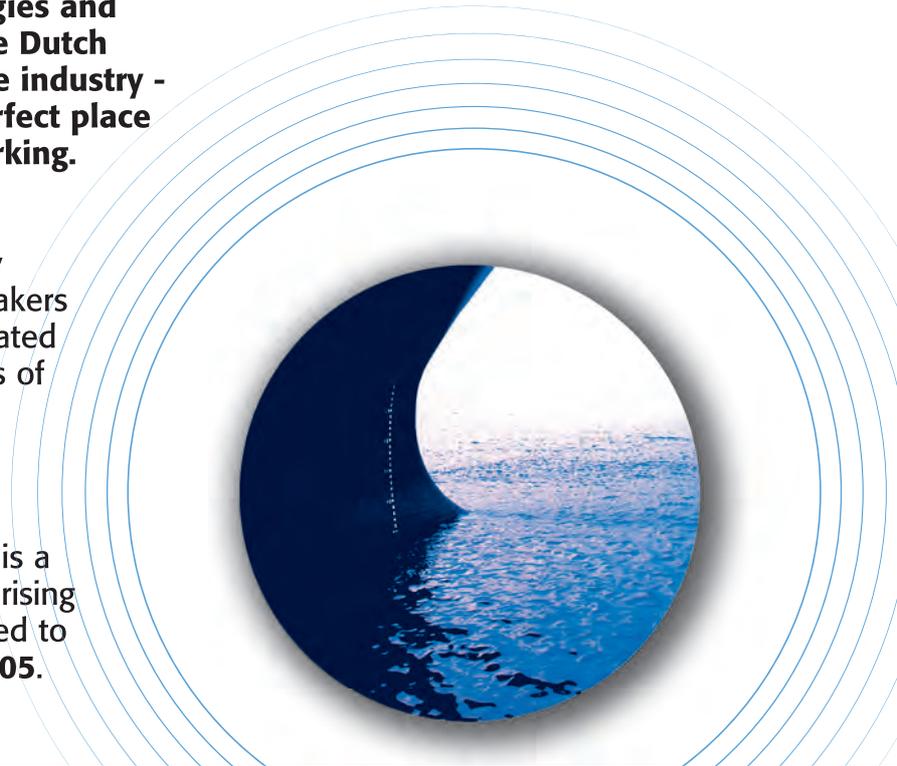
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10 years with Comfort Class

Einar Brubakk considers the achievements of Det Norske Veritas in controlling noise onboard cruise vessels through use of the Comfort Class notation.

PREVENTION and control of onboard vibration and noise have, over the years, received increasing attention in connection with ship design and construction. This has partly been due to required low vibration levels for delicate instruments and machinery but above all because both crew and passengers require a more comfortable environment.

Traditionally, comfort has been regarded as an important property and quality of a design but the definition and criteria have been dealt with in a rather random way. Many owners, yards, and designers have experienced difficulties in communicating comfort levels due to lack of acceptance standards and inadequate knowledge in this field. Therefore, in the early 1990s, a DNV project was started to evaluate and establish criteria for the various influencing factors.

Investigations into the relative importance of environmental factors among seafarers have proved that noise and vibration are of the most significant parameters. Although the reference investigations dealt with seamen onboard large merchant ships, it was assumed that the same situation roughly applied to passengers onboard. Besides, it was further important that the crew was allowed sufficient peace and quiet for rest.

From a safety point of view, all persons on board should be able to comprehend messages and alarm signals. On cruise liners, vibration and noise ought to be as low as technically possible. Passengers onboard such vessels expect a high degree of comfort and may be unfamiliar with ships. Further, they are spending too short time onboard to become acclimatised to the environment. High vibration levels may also cause damage to structure and machinery in addition to being uncomfortable, and should be avoided on all types of vessels.

Comfort Class: the beginnings

Based on the above project, the DNV Comfort Class was issued in 1995 - DNV is believed to have been the first classification society to issue comfort standards on noise and vibration. The voluntary notation gives standards to noise and vibration as well as onboard climate. A comfort rating from 1 to 3, which reflects 'high' to 'acceptable' comfort standard, is included. During the early years, interest was low and the class text was used as reference for specifications only. However, after a few years the market realised the benefit of following-up procedures from the class rules, and today more than 100 ships have the Comfort Class notation.

During those early days, interest was mainly from the cruise industry - passenger vessels have always been particularly noise-sensitive. When the cruise industry developed during the 1960s and 1970s, relatively small and low-powered vessels were used, but increased ship size and

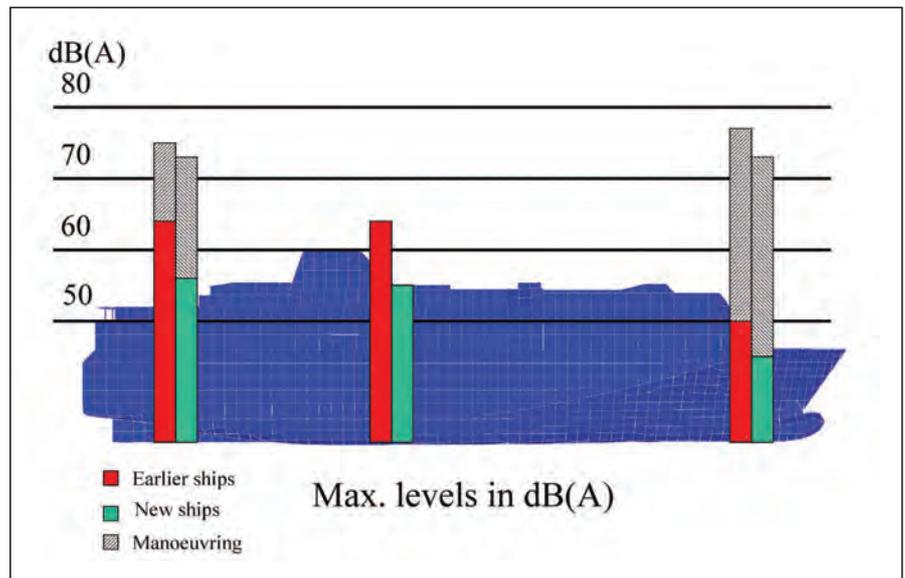


Fig 1. Noise distribution on a typical cruise liner, analysed by DNV and showing the propellers to be a major source of excitation.

correspondingly higher machinery powers caused propeller noise to become a significantly more important issue.

As shown in Fig 1, the propeller is the major excitation source for noise and vibration onboard modern cruise and passenger vessels. Besides, it is attractive to use the aft part of the hull for public areas such as restaurants and top-grade passenger suites. The other main excitation source, diesel engines, may effectively be controlled by resilient mounting systems (vibration isolators).

Controlling cruise-liner propeller noise

To obtain the highest grade of comfort, such as DNV Comfort Class rating 1, in the aft part of cruise vessels, prudent propeller design has to be applied. This applies for conventional shaft arrangement as well as for pods, provided that the design parameters and detailed design are properly evaluated and carried out. Industry knowledge of propeller excitation caused by transient cavitation on the blades has increased during recent years.

The magnitude of the blade-pass frequency components of hull pressures are now small compared with what they were some years ago. The introduction of podded propellers has also improved the situation. However, 'broad-band' pressure generated by propellers still causes problems, both with respect to vibration and noise.

An example of measured pressure field generated by the propeller is shown in Fig 2. At the propeller plane, the pressure field consists mainly of harmonics of the blade passing frequencies generated by transient cavitation on the blades. This type of pressure field is normally the most important excitation source for low-frequency ship vibration. The other type is the pressure field generated by cavitating tip

vortices, which contains a continuous pressure spectrum. This 'broad-band' tip vortex cavitation is responsible for the audible inboard noise from propellers.

Fig 2 shows the measured A-weighted levels which correspond to the human reaction to noise. It is seen that the most low-frequency contribution is suppressed and response to the inboard noise completely dominated by the more high-frequency, 'broad-band' contribution from the tip vortices.

In connection with FP propellers as well as CP types at the design pitch, the vortices increase gradually with propeller revolutions. However, for CP models, vortices from the pressure side of the blades are generated at reduced pitch. Hence, the noise and vibration in the aft parts of hulls may be more severe at reduced ship speed than at full speed if CP propellers are used.

It should be possible to avoid such tip-vortex cavitation problems by applying the novel knowledge on 'broad-band' pressure fields generated by propellers in the design of both ships and propellers.

DNV has developed a method to predict the 'broad-band' pressure field generated by cavitating tip vortices, the so-called tip-vortex index method (TVI method). This technique was published in 1996 (*The Naval Architect* July/August 1996 issue, page 11) as the first method ever to predict particularly low-frequency noise from a propellers. It still seems to be the most reliable method commercially available.

Modern medium-speed diesel engines will normally require CP propellers since they have very little flexibility in speed variation. Specification of shaft-driven alternators also requires fixed engine speed. Therefore, the propellers will operate at low pitch for reduced ship speeds. Modern propellers with skewed

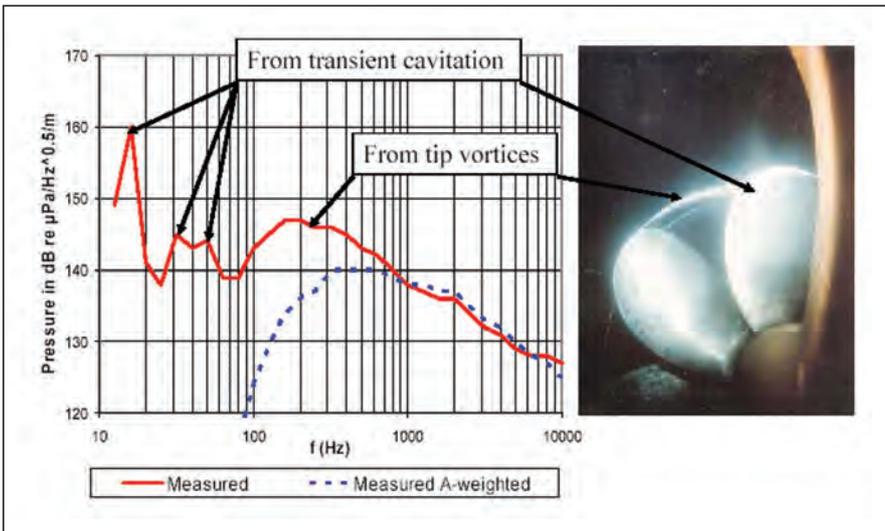


Fig 2. Measured propeller-noise source strength by DNV. The dotted line shows A-weighted levels which correspond most to human reaction to noise.

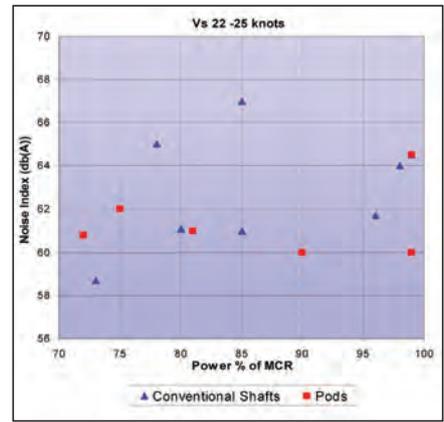


Fig 3. Noise index measurements from cruise liners fitted with open propeller shafts and those fitted with the newer technology of azimuthing propulsion pods. As can be seen, the levels do not vary greatly. CP propellers in the off-design condition were not included in this DNV study.

blades generate 'broad-band' noise and vibration in 'off-design' conditions. Multiple-step gearing (usually two steps), can, however, be utilised to obtain smooth operation over a broad ship speed range.

Experience with podded propulsors

The benefit of podded propulsion is that flow into the propellers can be smoother than for conventional open shafts with brackets. However, DNV experience indicates that this advantage has

not always been fully achieved with low noise and vibration in ship aft ends. With reference to the society's full-scale measurements so far, the results do not show any significant difference between conventional propellers and podded propellers, from a noise point of view. This is shown on Fig 3.

In this plot, noise measurements are shown at the aft end of cruise liners with both conventional shafts and those fitted with pods. To be able to make a direct comparison, DNV has estimated the noise index from the measured noise levels. The

results are plotted as a function of loading relative to the maximum continuous power rating (MCR) in Fig 3.

Noise levels from the propellers are expected to increase around 4dB(A) in the considered power range from 70% to 100% MCR. As shown in the figure, the results do not reveal any significant difference between conventional propellers and podded propellers from a noise point of view (CP propellers in off-design condition are not included in this study). Ⓡ

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Geislinger couplings for new Algerian ferries

THE new pair of passenger/vehicle ferries for the Algerian operator ENTMV (Enterprise Nationale de Transports Maritimes de Voyageurs) are both fitted with Geislinger couplings in their propulsion lines to smooth noise and vibrations. These ships were ordered from IZAR's Sevilla yard, and the first, *Tassili II*, was delivered in October last year. She is presented in the newly published RINA annual *Significant Ships of 2004*. Her sister, named *El Djazair*, was completed at the beginning of 2005.

The propulsion plant for this pair, which are planned to operate between Algiers, Alicante, and Marseilles, comprises two medium-speed Wärtsilä 12V46 diesel engines, each developing 12,600kW at 500rev/min.

Through the two shaftlines, Wärtsilä SH115 reduction gears and Geislinger couplings, these engines drive two CP Wärtsilä CPS 115 propellers. This plant enables each ferry to reach a 22-knot service speed. The Geislinger couplings (BC 110/25/106N/2/R + GFL S90T6A) are combinations of elastic damping and Flexlink designs, in order to deal with torsional vibrations and high misalignments between engine and gearbox/shafting. 



An example of the Geislinger BC 110/25/106N/2/R + GFL S90T6A combination coupling fitted to the transmission lines of the new Algerian ferries built at IZAR's Sevilla yard.

NEW-GENERATION BULK CARRIERS

New Ultra Handymax and Japanamax bulkers from Oshima

THAT leading exponent of advanced bulk carrier design and construction, Oshima Shipbuilding Co, in Japan, has created yet another new standard model. This is the five-hold Ultra Handymax of 60,000dwt, which has almost achieved the deadweight of early Panamax designs while still remaining within the 190m length limitation of most Handymax types on a Panamax beam. Construction is based on Oshima's innovative Hy-Con hybrid concept (originally launched as the Newbulk) where the fore and aft holds (Nos 1 and 5) are of double-skin construction, with the remainder of single-skin type. The Newbulk concept - which aims to overcome the fact that the fore and aft holds are those most likely to suffer from stuck cargo and thus open to mechanical damage - was fully reported in *The Naval Architect* October 1998, page 7.

Oshima claims several technical benefits, including improved cargo loading and discharge, environment-friendliness, reduced fuel consumption, and enhanced safety. Deadweight is increased by some 1800tonnes when compared with the yard's current 52,500dwt Handymax design at the same draught. If required, 1.5 tiers of 15tonne hot coils can be loaded.

To aid efficient cargo handling, all five hatches are 18.60m wide and are served by four 30tonne (at 26m outreach) jib cranes, while

more effective propulsion should be ensured by the fitting of an Oshima WA-FIN (wake-acceleration fin). At the forward end, the new ship will have a so-called Seaworthy bow for improved speed performance in poor weather conditions, and better manoeuvrability and course-keeping is expected to result from the specification of an Oshima high-lift rudder system. This comprises a Schilling mariner-type rudder turned by rotary-vane steering gear; this package has been developed in association with Japan Hamworthy. At the time of writing, discussions were under way with various owners for orders.

New Panamax model - the Japanamax

At the same time, Oshima Shipbuilding has also launched a new Panamax-class bulk carrier, which has been carefully designed to carry a very high deadweight under a Panama Canal beam (32.26m) but still within a length overall of 225m; thus such a ship can reach all grain berths in Japan. This feature has given rise to the name of the new model: Japanamax.

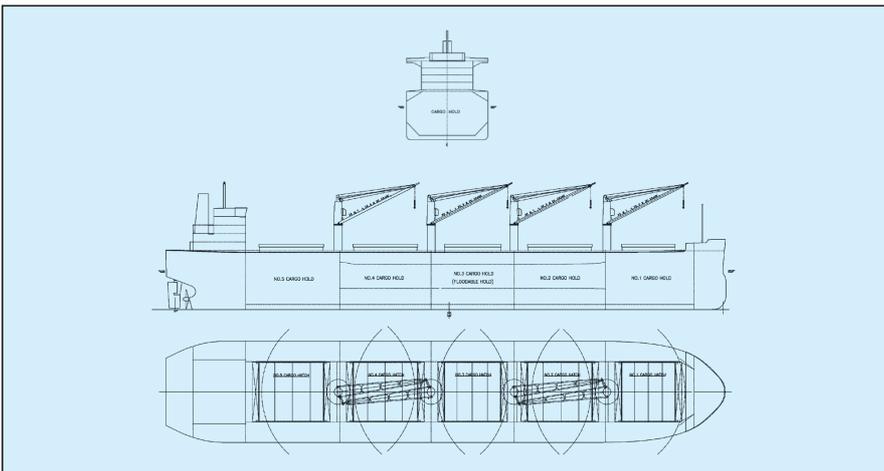
Along with the high deadweight of 82,000dwt and cubic capacity (96,000m³), new and special technical features include improved cargo loading and discharge, environmental protection, reduced fuel consumption, and safety (the same benefits as applied to the smaller Ultra Handymax discussed above). Deadweight is

TECHNICAL PARTICULARS OSHIMA ULTRA HANDYMAX BULKER

Length, oa.....	less than 190.00m
Length, bp.....	186.00m
Breadth.....	32.26m
Depth.....	18.55m
Draught, design.....	11.29m
Draught, scantling.....	13.40m
Deadweight, design.....	49,700dwt
Deadweight, scantling.....	60,000dwt
Gross.....	33,600gt
Cargo capacity.....	74,600m ³
Heavy fuel.....	1900m ³
Diesel oil.....	200m ³
Water ballast.....	31,800m ³
	(including No 3 hold)
Main engine.....	MAN B&W 6S50MC-C or Mitsubishi 6UEC50LSII
Output, MCR....	8379kW at 113.00rev/min
Speed, service, NCR rating, 15% sea margin, design draught.....	14.50knots
Auxiliary engines.....	3 x 440kW
Complement.....	25
Classification.....	Class NK NK, NS* (BC-A), (ESP), MNS*, Strengthened for Heavy Cargo Loading where Hold Nos 2 and 4 may be Empty (2004 Edition)

claimed as approximately 2700dwt extra at the same draught compared with an existing 77,000dwt vessel.

continued



TECHNICAL PARTICULARS JAPANAMAX BULK CARRIER	
Length, oa.....	225.00m
Length, bp.....	221.50m
Breadth.....	32.26m
Depth.....	19.99m
Draught.....	14.44m
Deadweight.....	82,000dwt
Gross.....	43,600gt
Cargo capacity.....	96,000m ³
Main engine.....	MAN B&W 5S60MC-C
Output, MCR.....	9371kW at 88rev/min
Speed, service.....	14.50knots
Complement.....	25
Classification.....	Class NK

Profile, plan view, and cross-section of Oshima's new Ultra Handymax bulk carrier, planned to be built to the yard's Hy-Con concept, where the fore and aft holds only are of double-skin construction.

Oshima has also adopted its Hy-Con hybrid philosophy for this new design; here, this means that the fore and aft holds only (Nos 1 and 7) have double side-skins. A smooth interior helps to reduce structural damage and

corrosion to otherwise exposed stiffeners. Holds 2-7 all have 15.88m wide hatch openings.

Light-coloured pure epoxy paint has been specified for the outer shell, weather deck, and

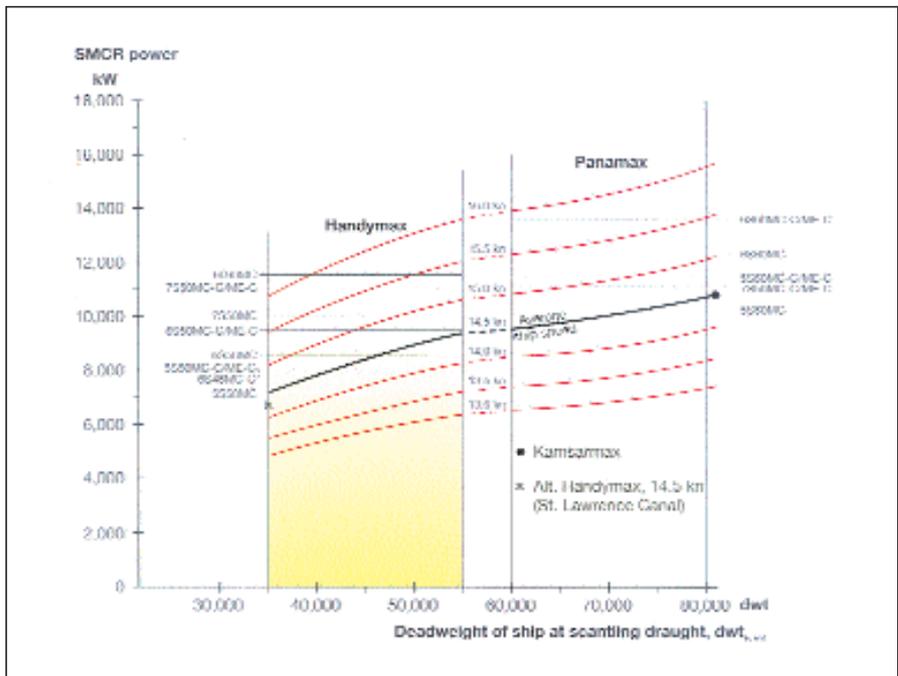
all cargo holds, with tar-free modified epoxy for water ballast tanks. An MAN B&W 5S60MC-C will give a service speed of 14.50knots, and like the smaller Ultra Handymax, this new Japanamax design will be fitted with Oshima's WA-FIN, Seaworthy bow, and high-lift Schilling rudder with rotary-vane turning gear. ⓘ

Slower propeller speeds for newest bulk carriers

A USEFUL new booklet published last September (free of charge) by MAN B&W Diesel, in Copenhagen, is an excellent aid to calculating the propulsion power for most types of bulk carrier. *Propulsion Trends in Bulk Carriers* is the last in a trilogy of short but attractively produced publications (the first two deal with tankers and container ships). In its 15 pages are many useful graphs and tables that would aid naval architects having to make decisions about power plants for the various common bulker sizes - Handysize, Handymax, Panamax, Capesize, and very large - and there is a special section on the additional power needed for ice-strengthened vessels. The various low-speed engine model options are included in the tables.

MAN B&W notes the buoyant bulk carrier market, particularly in relation to the Chinese economy, and particularly records that propeller speeds are steadily becoming slower, because the larger the propeller diameter that can be accommodated in a given hull, the slower the propeller speed and, for a directly coupled two-stroke engine, the lower the corresponding power requirement. This will make the cost/tonne of cargo transported lower. At the same time, average ship speed today, except for small and Handysize bulkers, is noted to be generally higher than, or equal to, 14.50knots.

Also recorded is the common length of 225m for Panamax-size ships, which is actually much shorter than Panama Canal lock dimensions, but is limited to this figure because a majority of ports are currently built to accommodate this length. There are, of course, exceptions, such as so-called Kamsarmax ships (229m length), able to enter the iron ore port of Kamsar in Equatorial



Propulsion power (SMCR) power demands for Handymax and Panamax bulk carriers to achieve various speeds, taken from the new MAN B&W booklet *Propulsion Trends in Bulk Carriers* and showing the various engine options possible.

Guinea, and the new Oshima Japanamax (225m length overall) design discussed elsewhere in this feature. In addition, there are some other special sizes, such as the Setouchmax ship - Capesize vessels of 205,000dwt but with a low design draught of 16.10m that allows them to enter ports in Japan's Inland (Seto) Sea.

For ships navigating in ice, the rules most often used are the Finnish/Swedish ones,

which have recently been updated. According to MAN B&W though, model tests have shown that the power found when using these new ice-class formulae is often in excess of the real power needed for propulsion. Furthermore, it has been concluded that the formulae can only be used within certain limitations of ship particulars, and therefore an Annex 1, listing restrictions to the validity of the formulae, has been added to the rules. ⓘ

First of new double-hull design delivered

CHINESE shipyard Chengxi recently delivered the first of a new Diamond 53 bulk carrier series, named *Spar Lyra*. This Carl Bro/Dwinger Marineconsult-designed vessel sees a double hull that has an additional water ballast capacity which totally removes the use of No 3 hold for heavy weather ballasting. However, this compartment is still designated for dual use if required in other circumstances.

This new design concept, specially created for UK owner Graig Shipping, was first discussed in *The Naval Architect* in November 2002, on page 7, and more details can be found in *Significant Ships of 2004*. The Diamond 53 design was tested at model basin SSPA in Sweden. Thirteen more of these vessels are currently on order, for various owners.

Other features of the Diamond 53 design include only limited use of high-tensile steel, and the development of an overall robust structural design with a maximum allowable hull girder bending moment 50% to 70% higher than class



The Chengxi-built *Spar Lyra* is the first of 14 newly designed double-hull bulk carriers to be delivered.

TECHNICAL PARTICULARS SPAR LYRA

Length, oa.....	190.00m
Length, bp.....	183.05m
Breadth, moulded.....	32.26m
Depth, moulded to upper deck....	17.50m
Design draught.....	11.10m
Gross.....	31,000gt
Displacement.....	65,000tonnes
Lightweight.....	11,600tonnes
Deadweight, design.....	44,800dwt
Speed, service.....	14.0knots
Main engine.....	1 x MAN B&W
Classification.....	Det Norske Veritas +1A1
	Bulk Carrier, ESP, NAUTICUS
	(Newbuilding), BC-A (Holds
	Nos 2, 4 or 3 empty), GRAIN-U,
	HA(+),DK(+), iB(+), EO, TMON

minimum. This feature enables cargo to be evenly distributed between holds Nos 1, 3, and 5, when loading to scantling draught with alternate holds (Nos 2 and 4) empty.

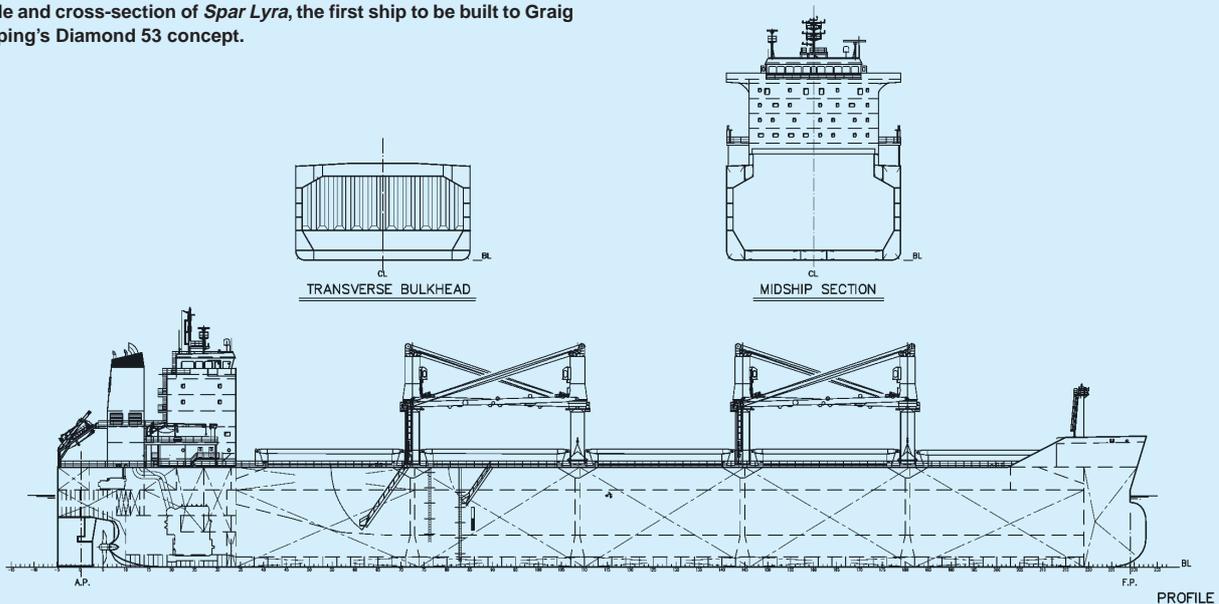
Usually, single-skin Handymax bulkers are required to load more cargo in No 3 hold in this condition. Uniform tanktop loading in all holds is 25tonnes/m² and the vessel can carry a full deadweight comprising two tiers of steel coils, weighing 25tonnes each, supported on timber dunnage, as well as the whole range of bulk cargoes.

The design has been configured to a Panamax beam of 32.26m with five holds and hatches, the latter providing virtually open access into the cargo spaces. A forecastle and forward breakwater afford protection for deck cargo and hatches. The double-hull arrangement incorporates top and bottom wing tanks, common with the side spaces and extended athwartships at the hatch ends as voids.

All piping and valves, plus electric cables, together with fore and aft crew accesses, are run in wing and double bottom pipe ducts, to improve maintenance and safety. The hatchways are closed by end-folding, high-stowing, hydraulically operated covers having a timber loading of 2.5tonnes/m², with cargo handling utilising four 36tonne electro-hydraulic Tsuji deck cranes mounted on the centreline and working to a 28m radius.

The Diamond 53 design has been developed to operate with either a Sulzer 6RTA48T-B, or MAN B&W 6S50MC-C main engine, with the owner of *Spar Lyra*, Spar Shipping A/S, of Norway, opting for the latter, a 9480kW/127rev/min unit which, when running at 82% MCR (7750kW) at scantling draught, and allowing a 15% sea margin, produces a service speed of 14knots. Electrical requirements are satisfied by three Daihatsu/Nishishiba 680kWe diesel-alternators.

Profile and cross-section of *Spar Lyra*, the first ship to be built to Graig Shipping's Diamond 53 concept.



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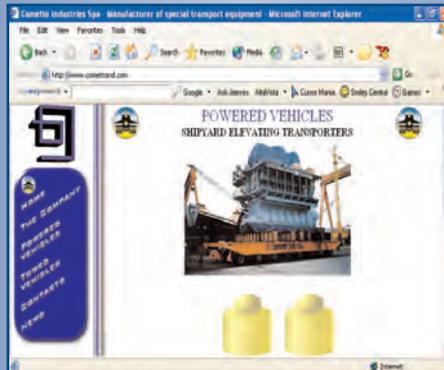
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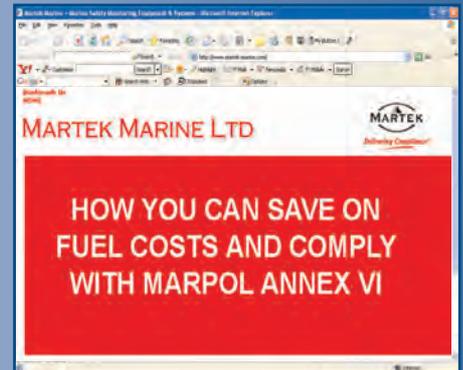
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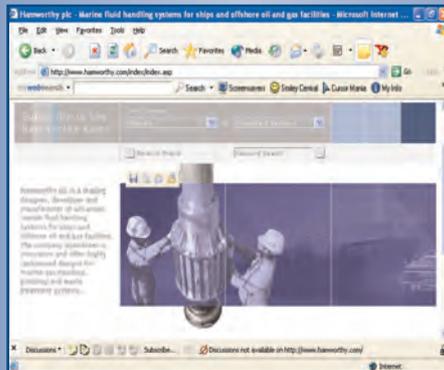
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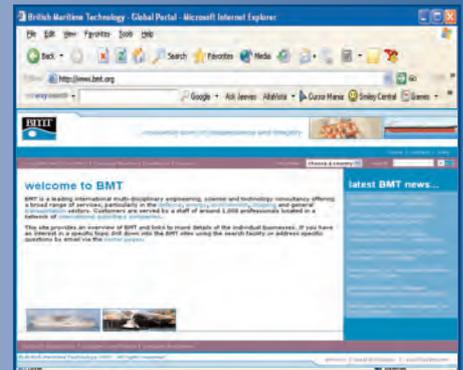
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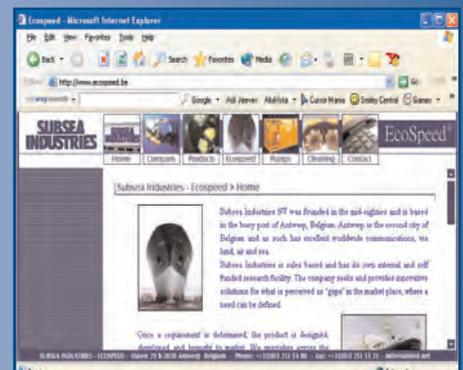
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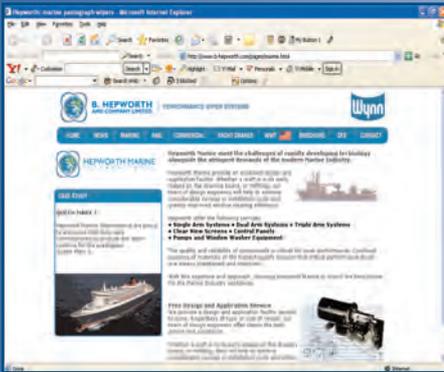
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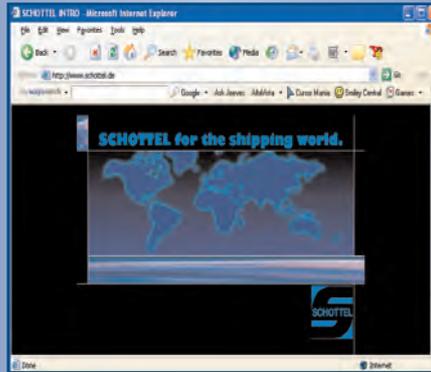
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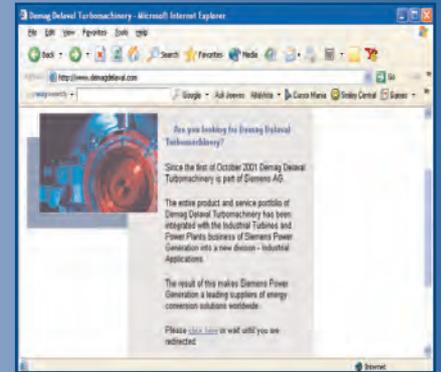
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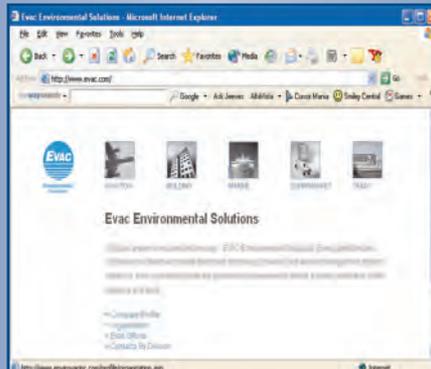
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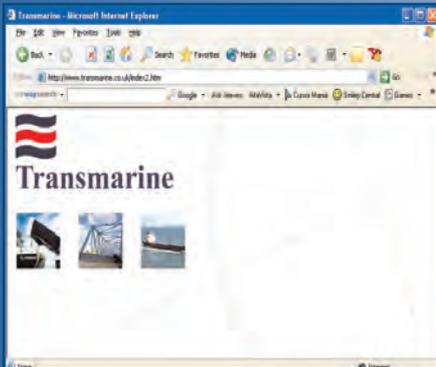
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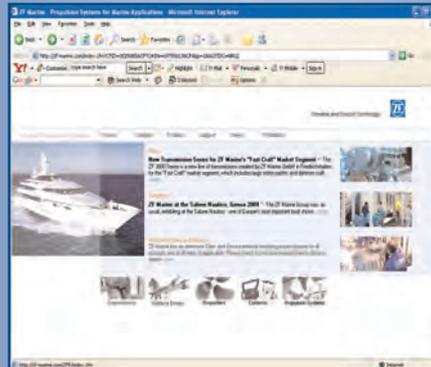
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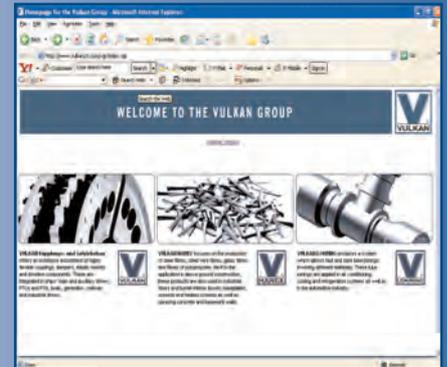
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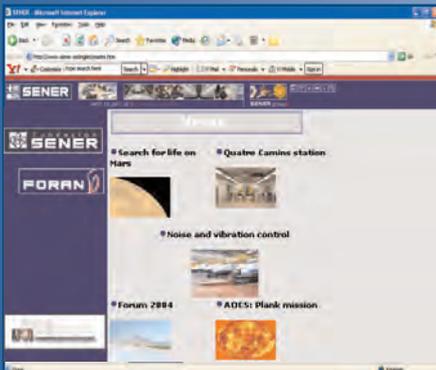
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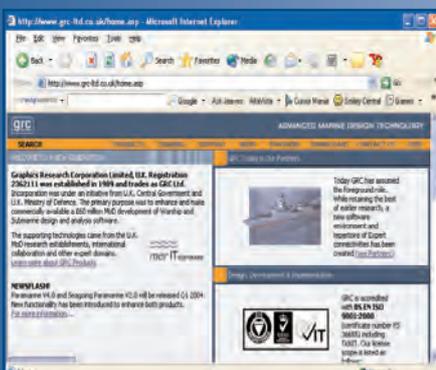
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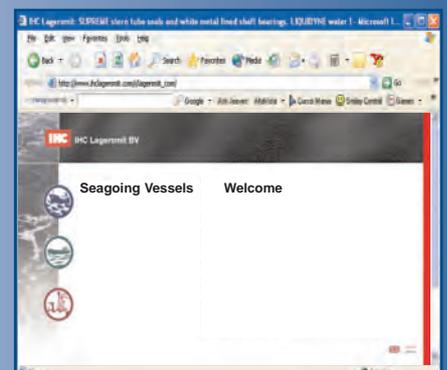
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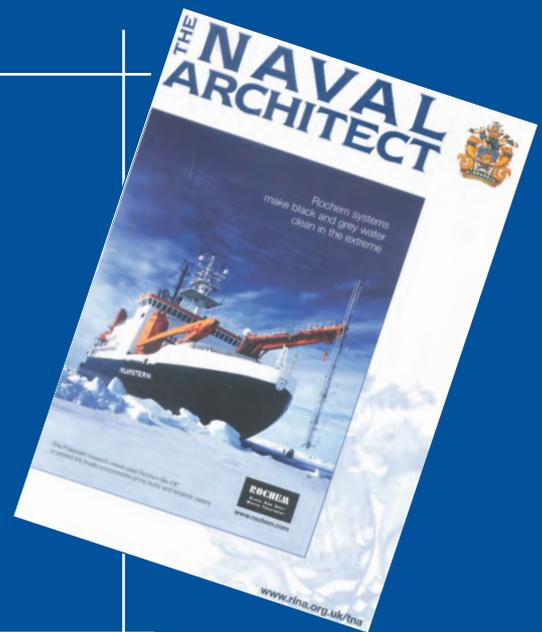
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