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Maritime Administration
Office of Shipbuilding and Marine Technology

Energy Technologies

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Introduction

This issue introduces the new masthead "Energy Technologies" and highlights:

- the results of a study that developed a conceptual design of a GREEN ferry with diesel engines;
- the testing of emulsified diesel fuel;
- the European Union's maritime fuel cell research activities;
- a program addressing large ship energy and exhaust issues in the formulation stage; and
- a synopsis of EPA regulations for Category 1, 2, and 3 marine engines.

Our readership is approaching 1,000 for this issue, and we cordially invite informative articles from our readers. Your comments are always welcomed.

INSIDE THIS ISSUE:

The GREEN MACHINE: A Very Low Emissions High-Speed Ferry

This article was contributed by Richard Thorpe, Herbert Engineering Corporation.

The San Francisco Bay Water Transit Authority (WTA) is taking a leading position in planning an environmentally friendly high-speed passenger ferry boat system. In the spring of 2002, the WTA awarded a significant study contract to a special team lead by Glosten Associates and Herbert Engineering Corporation. Seaworthy Systems was invited to join them to prepare the concept design of a very low emissions high-speed ferry.

GREEN MACHINE

Since there will be a future demand for approximately ten high-speed ferries, it was decided to mitigate polluting emissions from the very start by choosing a hull system which measurably reduces the propulsion power at high speeds. This was effectively done using the air assisted catamaran hull configuration developed by Air Ride Craft, Inc. The WTA advanced design required less power at 35 knots than a conventional catamaran ferry of similar size, speed, and capacity.

Given the emissions reductions resulting from the lower power of an air assisted hull system, the next step was to evaluate the

(Continued on page 2)

EMISSION REDUCTION TECHNOLOGY DECISION FRAMEWORK

As more and more focus is placed on emissions from vessels, the marine industry is faced with important decisions in the selection of emission reduction technologies. MARAD has sponsored Dr. James Corbett with the University of Delaware to develop industry guidance to assist the industry in making these choices.

The choice of control strategies to reduce air pollution is complex and requires the consideration of many factors. These include cost, performance and compatibility with other ship systems. The report will outline the key decision factors that need to be considered when evaluating emission reduction alternatives and place these decision elements in an integrated evaluation framework. This framework will provide a method of evaluating choices about retrofit, modernization, and operational options to reduce air emissions for specific applications. The study is currently in progress and a report is expected to be available in the fall of 2003.

POC: robert.behr@marad.dot.gov

(Continued from page 1) GREEN MACHINE

emission reducing technologies expected to be available in the near term. Because the technologies are being developed at a rapid pace, the emission reduction systems selected can support a ferry delivered within three years of starting a project (design, equipment specification, and vessel construction). The following was selected:

- Wärtsilä 200 series engines employing electronic control of fuel injection and valve timing. This significantly reduces fuel consumption and, therefore, also reduces HC, CO, CO_2, PM, and SOx combustion byproducts.
- Direct Water Injection (DWI) reduces NOx by limiting temperature peaks during the combustion process.
- Diesel Exhaust Oxidation in a platinum or palladium coated catalytic converter transforms carbon monoxide and unburned hydrocarbons into CO_2 and water vapor.
- Selected Catalytic Reduction (SCR) further reduces NOx and is even more effective than DWI, reducing NOx by 85-95%, by converting it to nitrogen and water using a solution of urea and water.

The combination of all these technologies result in very low emissions and clean operation. Seaworthy Systems calls the ferry design the *GREEN MACHINE*. The following table compares the 2007 EPA requirements with the estimated emissions from the *GREEN MACHINE* in grams per kilowatt-hour.

The *GREEN MACHINE* has a length of 140 feet and a beam of 40 feet. Its full load displacement is 184 long tons. The seated capacity is 350 passengers. When wheelchairs and standees are added, the total certified capacity could be as high as 488 passengers. All passengers are accommodated on the main deck. With bow loading and unloading, the turn around time in the terminal is short. The upper deck is fitted with solar panels to produce about 8 kW of power on a sunny day. This, in combination with a large battery bank and shore power battery chargers, will power all navigation, communication, security alarm, and emergency lighting equipment, as well as engine, emission, and steering controls. The result is a zero emission vessel at dockside ready to fire up and go to work.

POC: robert.behr@marad.dot.gov

Emission	2007 EPA Requirement	GREEN MACHINE	Percent: GREEN MACHINE to EPA
Nitrogen Oxides + Unburned Hydrocarbons (NOx + HC)	7.80 g/kW-hr	.34 g/kW-hr	4.4%
Carbon Monoxide (CO)	5.00 g//kW-hr	.33 g/kW-hr	6.6%
Particulate Matter (PM)	0.27 g/kW-hr	.10 g/kW-hr	37.0%

LUBRIZOL CORPORATION AND EMULSIFIED FUEL TESTING

PuriNOx™ by Lubrizol Corporation is a water/diesel fuel emulsion that reduces emissions from diesel engines. This technology is licensed to Lubrizol's fuel distributors who provide a finished diesel fuel product to their end-user customers. Distributors use a special blending unit developed by Lubrizol to produce a "water-in-diesel" fuel emulsion consisting of normal diesel fuel, purified water, and Lubrizol's proprietary PuriNOx™ additive. ChevronTexaco distributes the fuel as Proformix™ .

PuriNOx™ Technology is blended in both a warm and cold climate formulation. The registered warm-climate formulation contains 77% diesel fuel, 20% water, and 3% PuriNOx™ 1121A additive. The winter formulation consists of 74% diesel fuel, 16.8% water, 5.7% methanol, and 3.5% PuriNOx™ generation 2 additive. In each case, the water is encased in a chemical shell to prevent its contact with engine parts.

No engine modifications are required to burn PuriNOx™. As the emulsion is injected into the combustion chamber, the water droplets vaporize to improve the spray pattern. Combustion is more complete, reducing particulate matter formation by up to 50%. The water also reduces the combustion temperature, which reduces the formation of nitrogen oxides (NOx), typically by up to 20%. The California Air Resources Board (CARB) tests indicated that PuriNOx™ will reduce particulate matter by 63% and nitrogen oxides by 14%. See http://www.arb.ca.gov/fuels/diesel/altdiesel/altdiesel.htm for more information.

Since the water/fuel emulsion is an effective solvent, it tends to dissolve deposits within the fuel system which can result in the clogging of fuel filters during the initial use. Depending on the condition of the fuel system, it may be advisable to clean tanks and flush the system prior to changing fuels. The emulsified fuel is quite stable for storage periods up to 30 days. For longer storage periods, it is recommended that a small circulating pump be installed to move fuel from the bottom of the tank to the top. The pump should be sized to recycle the tank volume once a day.


Port Yard Tractor

Because the addition of water increases the total volume of liquid that must be injected into the cylinder for a specific power, the maximum power obtainable may be reduced based on the capacity of the fuel system. Often, this will not effect the operation of the equipment in question. The Port of Los Angeles is fueling about 400 pieces of terminal equipment (yard tractors, cranes, and forklifts) with PuriNOx™ with no significant operational impacts. The Port of Los Angeles' goal is to retrofit all standard diesel-powered marine terminal equipment to use emulsified fuel. The Port is also in the process of installing diesel oxidation catalysts (DOCs) to be used in conjunction with emulsified fuel to further reduce emissions.

The San Francisco Water Transit Authority (WTA) has partnered with the Golden Gate Bridge, Highway and Transit District, to test PuriNOx™ on the ferry *MV GOLDEN GATE*. The 28-year-old ferry is powered by two 671 BHP Caterpillar 3412C turbocharged and aftercooled diesel engines. Its fuel tanks were cleaned and for 11 weeks it ran on PuriNOx™ fuel instead of conventional diesel fuel. No filter fouling was observed. The fuel emulsion remained stable in the fuel

(Continued on page 8)

VESSEL EMISSIONS MEASUREMENT PROTOCOLS

Exhaust emissions measurement has become an increasingly important issue as the marine transportation community seeks to reduce air emissions from vessels. The uncertainty in currently available marine emissions data is a function of different vessel operating profiles, variability in measurement methods, and inconsistent reporting. MARAD has contracted with the University of Delaware to develop an emissions monitoring guide for in-service marine engines that will assist operators and policy makers in obtaining and reporting consistent emissions data for marine engines. Dr. James Corbett is the principal investigator.

Emissions Measurement Team on Hampton Roads Transit Ferry

The MARAD/ University of Delaware report will provide a summary of acceptable test procedures, key emissions measurement performance requirements, and consistent reporting methods and formats. The report will reference accepted national or international standards, interpret important aspects of these standards as they relate to measuring vessel emissions, generally describe technologies and methodologies that meet these standards and define consistent reporting requirements. The emissions monitoring protocol will enable operators to successfully measure and report emissions from both controlled and uncontrolled engine systems in a manner that will allow meaningful comparisons between alternative power systems and emission control technologies.

The first draft of the protocol is complete and is currently under review. The final document is scheduled to be complete in July 2003 and will be made available on the MARAD website.

POC: robert.behr@marad.dot.gov

MEETS PAPER

The Society of Naval Architects and Marine Engineers (SNAME) and the American Society of Naval Engineers (ASNE) will co-sponsor the Marine Environmental Engineering Technical Symposium (MEETS) to be held August 21-22, 2003, at the Sheraton National Hotel in Arlington, Virginia.

The Maritime Administration (MARAD), Naval Sea Systems Command (NAVSEA), John J. McMullen Associates, West Virginia University, and University of Delaware will present a paper on the need for consistent onboard marine air emissions measurement protocols. Measuring emissions onboard vessels presents unique challenges. The paper will address these issues and discuss possible resolutions. A number of organizations are currently preparing or contemplating measurement protocols. The paper will set forth arguments for the development of common or consistent requirements. We encourage participation in this important symposium. For the latest information, check SNAME's website at http://www.sname.org/events_information.pl.

POC: robert.behr@marad.dot.gov

EUROPEAN UNION SHARED-COST RTD PROJECT: FUEL CELL TECHNOLOGY FOR SHIPS

This article was contributed by: Morten Bøhlerengen, Norwegian Shipowners' Association; and Kjell Olav Skjølsvik, Marintek.

Significant efforts have been made in the last ten years addressing the development of Fuel Cell (FC) technology. Most of these efforts have been aimed at basic technology, land transport, and land based applications. Direct application of FC in waterborne transport has not been addressed to any large detail and will never be unless the problem areas specific to waterborne transport are properly dealt with.

Thus, the European Commission in 2002 decided to support a R&D project proposal on application of the fuel cell technology in ships as a part of the Competitive and Sustainable Growth Program. The proposal was in response to the Commission's invitation for development of critical technologies towards efficient, safe, and environmentally friendly ships.

The project "Fuel Cell Technology for SHIPs" (FCSHIP) aims to enable European Union (EU) fuel cell technology providers to be more competitive in the prospective future market for maritime applications, enable EU shipowners to utilize this new technology whose application to ships is expected to generate a lasting competitive advantage for shipowners, and to assist the EU in meeting sustainable development, energy saving, and air pollution reduction objectives.

In order to put the problem areas into perspective, the technical and scientific objectives considered are:

- Trade-off experience from other industrial fields to the waterborne transport through the inventory and synthesis of fuel cell research and demonstration actions relevant for waterborne applications;
- Development of safety and operational requirements for fuel cell application in commercial ships;
- Development of shipowners' specifications and functional requirements;
- Develop FC ship conceptual designs;
- Comprehensive assessment, through Life Cycle Analysis (LCA) techniques, of logistic, supply, and consequences with regard to cost-effectiveness and environmental impact aspects; and
- Develop plans for future R&D aiming at filling the gaps towards application of FC in waterborne transportation (both inland and sea navigation).

The short and medium term objectives of the work are to:

- Define the end users' demands for the application of fuel cells on board ships for both main propulsion and auxiliary applications;
- Evaluate safety and operational demands for ships equipped with fuel cells; and
- Assess both economically and environmentally, the potentials for fuel cell applications in waterborne transport.

After having evaluated these three parts, the FCSHIP project will draw a roadmap for further R&D on FC application on ships taking into account safety, environment, operation, infrastructure, and market aspects.

Introduction of new technology must be based on a proven design, which has been verified and approved by an independent verification body. In an early phase, this will require interaction between safety requirements set by such bodies and development of new designs. For fuel cell application in ships, no such basic requirements currently exist. Such basic requirements are vital for future implementation of the new technology, and an important element in the FCSHIP project work.

(Continued on page 8)

ALLIANCE WITH DEPARTMENT OF TRANSPORTATION CENTER FOR CLIMATE CHANGE

The Maritime Administration has joined forces with the Department of Transportation Center for Climate Change and Environmental Forecasting (CCCEF) to accomplish three marine related projects described below. The CCCEF was established in May of 1999 and is dedicated to fostering awareness on the potential links between transportation and global climate change. Through strategic research, policy analysis, partnerships and outreach, the Center creates comprehensive and multi-modal approaches to reduce transportation-related greenhouse gases and to mitigate the effects of global climate change on the transportation network. For the marine projects, climate change concerns are combined with related issues of power plant efficiency and criteria pollutants.

Large Vessel Emission Reduction Project – Containership owner, MATSON Navigation, Inc., has signed a **Phase I** Cooperative Research Agreement to examine off-the-shelf control technologies that can reduce specific exhaust gases from one of its vessels equipped with an approximate 40,000 hp, two stroke, diesel propulsion engine. Concurrently, several California based regulatory agencies, including the Santa Barbara Air Pollution Control District, California Air Resources Board, South Coast Air Quality Management District, Bay Area Air Quality Management District, and Region 9 of the Environmental Protection Agency are performing a similar technology review for large vessels.

These simultaneous research efforts are planned to be combined into a **Phase II** shipboard demonstration project. This second phase will measure the performance of operator selected control technologies aboard active commercial vessels. Two major southern California ports may also join the group for the technology demonstrations. The involved parties are also investigating methods of formulating an incentive program to encourage other operators to install similar emission mitigation systems.

Waterborne Fleet Engines, Emissions, and Fuel Consumption – Related inventories have been conducted by several organizations. Resulting data has varied widely, estimating that the commercial maritime industry consumes anywhere from 2-15% of fossil fuels globally. The goal of the project will be to organize information from the various previous inventories in a useful and accessible format, understand the causes of data conflicts, and to determine where knowledge gaps still exist.

Highway Ferry Integration Study – The CCCEF has released the findings of its sponsored study entitled, *Passenger Ferries, Air Quality, and Green House Gases: Can System Expansion Result in Fewer Emissions in the San Francisco Bay Area*. The study examined the potential for changes in green house gas and criteria pollutant generation if hypothetical percentages of daily commuters switched from

(Continued on page 8)

Control of Air Polluting Emissions from New Marine Diesel Engines (40 CFR Parts 9 and 94)

On February 28, 2003 (68 FR 9745-9789), the U.S. Environmental Protection Agency (EPA) published a final rule establishing near-term Tier 1 emission standards for new marine diesel engines installed on vessels flagged or registered in the United States with a displacement at or above 30 liter per cylinder. These standards are equivalent to the standards promulgated by the International Maritime Organization (IMO) for oxides of nitrogen and will be enforceable under U.S. law for new engines built on or after January 1, 2004.

The certification and compliance program for these standards is similar to the international program but contains additional provisions that reflect the requirements of the Clean Air Act. These standards will apply until EPA adopts a second tier of standards in a future rulemaking.

In developing the future rulemaking, which will be completed no later than March 16, 2007, EPA will consider the state of technology that may permit deeper emission reductions and the status of international action at the IMO for more stringent standards. At that time, EPA will also consider the application of such a second tier of standards to engines on foreign vessels that enter U.S. ports.

A new set of international marine diesel engine standards would apply to engines on all vessels, regardless of where they are flagged. Adoption of appropriate international standards has the clear potential to maximize the level of emission reductions from domestic and international vessels.

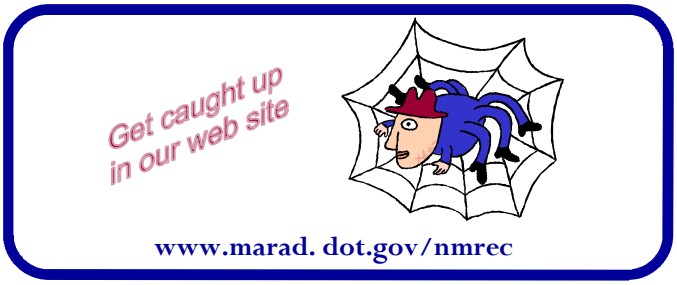
In this rulemaking, EPA also adopted additional standards for new engines on U.S.-flag vessels with displacement at or above 2.5 liters per cylinder but less than 30 liters per cylinder. These standards, which are currently voluntary, are also equivalent to the international standards for oxides of nitrogen. These standards will apply through 2006.

Beginning in 2007, the more stringent Tier 2 standards, which were finalized for these Category 1 and 2 engines in 1999, will go into effect (64 FR 73299-73373; December 29, 1999; 40 CFR part 94). The Tier 2 standards for the new Category 1 and 2 marine diesel engines address nitrogen oxide (NOx), particulate matter (PM), carbon monoxide (CO), and hydrocarbon (HC) emissions.

The international standards are contained in Annex VI (regulation 13) of the International Convention for the Prevention of Pollution from Ships, as modified by the Protocol of 1978 (MARPOL Annex VI). The MARPOL Annex VI emission limits for NOx range between 9.8-17.0 grams per kilowatt-hour (g/kW-hr) depending on engine speeds ranging between less than 130 to greater than 2000 revolutions per minute (rpm). Slower speed engines are permitted the higher emission limits. (It is highly likely that the Tier 2 emission standards for the Category 3 marine diesel engines will be significantly more stringent than the Tier 1 near-term standards.)

EPA has not set standards for the fuel used by marine diesel engines in this Tier 1 final rule. To obtain the benefits of lower sulfur fuel, EPA plans to investigate designation of one or more areas in the United States as sulfur oxide (SOx) emission control areas pursuant to the international process for this purpose (MARPOL Annex VI, regulation 14).

POC: daniel.leubecker@marad.dot.gov



U.S. Department of Transportation
Maritime Administration
Office of Shipbuilding and
Marine Technology

400 Seventh Street, SW
Washington, DC 20590
1-800-986-9678
X61924

Telephone: (202) 366-1924
Fax: (202) 366-7197

Newsletter comments and distribution inquiries
point of contact
regina.farr@marad.dot.gov

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FYI

CNG — compressed natural gas
CO — carbon monoxide
CO_2 — carbon dioxide
HC— hydrocarbons
NOx — nitrogen oxides
O_2 — oxygen
PM — particulate matter
SOx — sulfur oxides
THC — total hydrocarbon

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serves as a forum to convey timely articles of interest. You can find this and additional information on our web site at www.marad.dot.gov/nmrec

(Continued from page 3) Emulsified Fuel Testing

tanks. Because emissions testing was conducted during periods of passenger service, test points were limited to full cruising power, idle in-gear and idle in-neutral. PM was reduced by approximately 60% at high power but increased somewhat at idle. NOx was only slightly reduced at high power. There were no operational implication resulting from lower maximum power.

The Port of Houston Authority (POHA) has also tested PuriNOx™ Technology and NOx reductions of 20% and average PM reductions of 38% were measured. Five yard tractors and two gantry cranes currently use PuriNOx™ at the port.

Experience on marine platforms and in other industries seem to indicate that fuel/water emulsions should be considered a viable, relatively low cost, simple method that can provide modest emissions reductions.

Thanks to Greg Hoeth of Lubrizol Corporation for input to this article.

POC: robert.behr@marad.dot.gov

(Continued from page 5) FCSHIP

The FCSHIP project has a two-year duration commencing in July 2002.

The project consortium consists of 21 partners headed by the Norwegian Shipowners' Association. The consortium represents the major stakeholders in the European shipping industry, including shipowners, shipyards, classification societies, universities, and research institutes.

More information can be found at www.fcship.com.

(Continued from page 6) CCCEF

their normal mode of travel to riding three types of ferries.

The principle investigator for the study was the non-profit California based transportation consortia known as CALSTART. The Department of Energy Brookhaven National Laboratory and the Gas Technology Institute were co-sponsors. A copy of the report should soon be available on the CCCEF website at http://www.climate.volpe.dot.gov.

POC: daniel.gore@marad.dot.gov