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Winter 2008-09

Environmental Protection

IN THE AIR

ON LAND

ON THE SURFACE

BENEATH THE WAVES

Forging Global Solutions to Environmental Challenges

PROCEEDINGS

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Vol. 65, Number 4

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On Land

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Special to This Issue

On Deck

Assistant Commandant's Perspective

By RADM Brian M. Salerno
U.S. Coast Guard Assistant Commandant for Marine Safety, Security and Stewardship

Our nation's prosperity relies upon the balanced and sustainable use of inland, coastal, and ocean waters and resources. The foundation for this prosperity—an efficient, resilient marine transportation system—must be maintained to facilitate maritime mobility and protect the nation's economy. At the same time, the marine environment must be protected against threats from pollution, environmental degradation, the spread of invasive species, and the illegal harvesting of marine resources.

The Coast Guard's multi-mission character positions us to conduct such distinct yet complementary functions in the maritime domain. For example, in coordination with other federal and state agencies, the Coast Guard enforces marine resource management and protection regimes that preserve healthy stocks of fish and other living marine resources. We work to keep the nation's waters free of invasive species. We also strive to protect our marine environment from contamination by oil, chemicals, and other sources of pollution.

Recently, much attention has been focused on ways to minimize air pollution from ships. For example, last July President Bush signed into law the Maritime Pollution Protection Act of 2008. This paves the way for the U.S. to become a party to MARPOL Annex VI, significantly enhancing the stature of the United States among the community of maritime nations.

Maritime safety, security, and stewardship are long-standing responsibilities assigned to the Coast Guard over more than two centuries of service. We have a proud tradition of successful service in all of these areas, but we are not content to rest on our laurels. We remain "always ready" to serve future needs. Sharing a common purpose with the world's maritime forces and a tradition of cooperation within international organizations will enable the Coast Guard to forge global solutions to these global environmental challenges.

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Champion's Point of View

By CAPT Michael Blair, *Chief*
U.S. Coast Guard Office of Operating and Environmental Standards

"Nature provides a free lunch, but only if we control our appetites."[1]

Environmental protection has been a key mission of the U.S. Coast Guard for many years, as we are diligent to eliminate environmental damage and the degradation of natural resources associated with maritime transportation, fishing, and recreational boating. Environmental protection has become increasingly important globally as the Earth's population has discovered the short- and long-term effects of our collective and individual environmental footprints. It has become more imperative than voluntary that we rise to meet the challenges of preserving and protecting our planet. Every organization must find ways to contribute to this effort if we expect to keep pace with our global demands for clean air, clean water, and other natural resources while balancing the need for prosperity in a globalized economy.

The U. S. Coast Guard is devoted to positively leveraging our governmental influence to protect U.S. waters, coasts, and natural resources for current and future generations. As part of the Standards Directorate, the Office of Operating and Environmental Standards has a diverse collection of responsibilities for developing and maintaining standards in the areas of maritime personnel, vessels and facilities, hazardous materials, and environmental protection through treaties, regulations, and policy. Staff members represent the U.S. at meetings of numerous national and international standards organizations, ensuring that U.S. initiatives and views are strongly supported in these arenas. The industry perspective is incorporated in standards development using input and advice from federal advisory committees. By using that input in the regulatory process, the needs of stakeholders are considered, while marine safety is enhanced and the marine environment is preserved and protected.

This issue of *Proceedings* will serve to update readers on recent innovations in policy, regulations, and technological advances in the air, on land, on the surface, and beneath the waves. My sincere thanks go to our Coast Guard and industry authors, who have taken the time to share their ideas and best practices. We hope that you will find this issue to be a valuable resource toward planning, evaluating, and maximizing the effectiveness of your own environmental goals.

Semper Paratus!

[1] William Ruckelshaus, first EPA administrator (1970-1973 and 1983-1985), Business Week, June 18, 1990.

Environmental Protection IN THE AIR

Using Wind Power

by Mr. Stephan Brabeck
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SkySails GmbH & Co. KG.

In today's environment, ship operating costs are skyrocketing, mainly due to rising oil prices and new international regulations for the reduction of ship emissions. In order to remain competitive, many shipping companies are looking for ways to minimize fuel consumption and emissions. One idea: Use wind power.

Two shipping companies, Beluga Shipping and Wessels Reederei GmbH & Co. KG, are testing one method using a large towing kite shaped like a paraglider to aid the propulsion of the vessel. The tethered, flying towing kites are designed to operate at altitudes between 100 and 300 meters, where stronger and more stable winds typically prevail. The Wessels vessel *Michael A* has been retrofitted with this system. MS *Beluga SkySails* hosts the first installation on a new build.

Taking advantage of the dynamic flight maneuvers this system is potentially capable of (such as figure-eights) could generate more power per square meter of sail area than conventional sails. It may be possible, then, to gain significant savings by using comparatively small sail areas.

System components are being long-term tested, and the results are continually used to improve and optimize the product. Research and development work will focus on advancing the technology and increasing its performance.

Early results indicate that while virtually all seagoing cargo vessels should be able to be retro- or outfitted with this propulsion, it is best suited for cargo ships with an average cruising speed of under 18 knots, as well as superyachts and fish trawlers of more than 24 meters.

About the author:
As the technical director of SkySails, Mr. Stephan Brabeck has had leadership oversight of research and development, manufacturing, and service since January 2005. He earned an engineering degree from RWTH Aachen University, Germany, where he majored in aerospace engineering.

Photo courtesy of SkySails GmbH & Co. KG.

Green Vessel Design

Environmental best practices.

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Environmental issues are increasingly at the forefront of public awareness. The short- and long-term implications of pollution, global warming, ozone depletion, and other environmental issues are becoming major influences in public policy, regulation, and enforcement. This is particularly relevant to the marine community when you consider that roughly 70 percent of the earth's surface is covered with water, about 50 percent of the world's population lived within approximately 60 miles of a coastline as of 2002, and the trend is on the rise.[1]

The marine industry is currently in a position to help shape policy and public opinion and has an opportunity to demonstrate its commitment to responsible stewardship. Generally, shipment by water is inherently energy efficient. There is no "greener" mode of transportation for significant quantities of goods. For example, the carrying capacity of one barge equals that of 16 rail cars or 70 truck and trailer combinations. This translates into 514 ton-miles of fuel for barges, 202 ton-miles for rail cars and 59 ton-miles for truck-trailers.[2]

Even when you consider the ships themselves (as compared to buildings on land) you will find that ships are inherently green in many respects. Ships are built primarily from steel, a readily recyclable material. Most plumbing fixtures are "low-flow" to minimize the amount of onboard water tankage and/or water-making capacity. Energy use is also minimized due to space constraints. Unfortunately, these same vessel "pros" can also result in environmentally unfriendly practices. Hulls may be coated with anti-fouling paints that can reduce ship speed and thereby increase fuel consumption. In addition, a ship is a small seagoing community with ongoing industrial processes, many of which may involve or produce hazardous materials.

As naval architects and marine engineers, we have the opportunity to improve upon design practices and benefit the environment. These practices can be summarized into a few guiding principles for environmentally responsible design:

- Minimize use of hazardous materials and environmental contaminates.
- Maximize use of recycled and recyclable material.
- Minimize waste and scrap.
- Maximize use of rapidly renewable and regional materials.
- Minimize air emissions.
- Minimize energy use.
- Minimize discharges to water.

These principles are interdependent and not mutually exclusive to economic performance. In many cases they are the natural progression of regulations that have been refined through use and enforcement in the field.

Minimize Use of Hazardous Materials and Environmental Contaminates

Any discussion of hazardous materials and environmental contaminates first requires some clarification of the terminology. The two most widely accepted indicators of environmental impact are "global warming potential" (GWP) and "ozone-depleting potential"

(ODP). GWP is the ratio of the warming caused by a substance to the warming caused by a similar mass of carbon dioxide. ODP is a number that refers to the amount of ozone depletion caused by a substance.

An ozone-depleting substance is a compound that contributes to stratospheric ozone depletion. Per the Montreal Protocol on Substances that Deplete the Ozone Layer, all CFCs and HCFCs (common refrigerants) are to be phased out by 2030. The Clean Air Act of 1990 has significant restrictions on the storage and handling of these refrigerants and other ozone-depleting substances, as well as strict requirements for the maintenance of equipment containing them, to limit the amount of leakage.

There are a number of programs that address the use and minimization of hazardous materials and containment. Per "Green Passport," an International Maritime Organization program, vessel owners are required to maintain accurate records of the potentially hazardous materials that went into the construction of their ships. The passport follows a ship through its lifespan and should accurately include any relevant modifications. This voluntary program is expected to become mandatory by 2010.[3]

IMO also addresses issues associated with ship and equipment recycling where it suggests identifying commonly used and potentially hazardous material (such as hydraulic fluid), and using less hazardous alternatives. The significant new alternatives policy is EPA's program to evaluate and regulate substitutes for ozone-depleting chemicals being phased out under the Clean Air Act. This program includes substitutes for refrigeration and air conditioning, cleaning solvents, fire suppression and explosion protection, adhesives, and coatings, all of which are critical to shipboard construction and operations.

Heating, ventilation, and air conditioning equipment offers an excellent area for improving a ship's environmental performance. Newer systems are available with a low refrigerant charge per ton of cooling capacity, as well as both low ODP and GWP. While some class society "clean" certifications permit an annual leakage rate of 10 percent, leakage of newer refrigeration systems can be as little as two percent, with a maximum of 10 percent released during final disposal and recycling of the refrigerant.

Minimizing use of volatile organic compounds (VOCs) is another key factor. VOCs are emitted as gases from certain solids or liquids and include a variety of chemicals, some of which may have short- and long-term adverse health effects. During ship construction and throughout a ship's life, use of low-VOC products can improve the air quality of the surrounding community, as well as the future occupants of the vessel. Today there are a number of low-VOC products on the market, such as paint and coatings, with many more in our future.

Maximize Use of Recycled and Recyclable Material

The environmental impact of a ship occurs in three distinct stages of its life: construction, operation, and disposal. There are many ways in which green considerations can be applied during vessel design, which will translate to improvements in both the construction and operation of a vessel throughout its lifecycle, and provide for a greener and more cost-effective recycling at the end of the ship's lifespan.

Using the maximum amount of recycled and recyclable materials possible is one approach to green design. Steel and aluminum used for ship construction are readily recyclable materials, but improvement in recycling is necessary for many other materials throughout the ship. A key consideration is the design and installation of systems that prevent non-recyclable and/or hazardous materials from contaminating recyclable material. This applies to insulating materials, as well as interior bulkhead systems and flooring systems.

Minimize Waste and Scrap

Much of the waste generated during construction can be reduced with careful production planning, weight control, and greater reliance upon detailed design and computer lofting of structure and piping systems. Frequently, the first step in vessel design is a study of hull size and form, propulsion/power configurations, and materials to determine the best approach to an owner's needs. Further design development involves optimizing structure, systems, and hull form for reduced energy use and production.

To accomplish this analytic approach, state-of-the-art tools such as finite element analysis and computational fluid dynamics are used. At the pre-production and production stages of design, computer lofting is extensively used to plan for almost all of the structure of the ship and increasingly in piping and wireways. When comprehensively applied, weight and waste will be minimized with the added benefit of reduced production labor.

Over the life cycle of a ship, reduction of waste generated during construction is a one-time event. However, the

waste built into the ship is detrimental throughout its operational life, with a cumulative effect on fuel efficiency.

Maximize Use of Rapidly Renewable and Regional Materials

Rapidly renewable materials are generally defined as having a natural replacement cycle of less than 10 years. Rapidly renewable products such as bamboo, linoleum, cork, poplar, and wool are less of a burden on our environment. Wool carpeting is already a standard for marine applications due to its inherent low-smoke characteristics. As another example, rapidly renewable wood products can directly replace hardwoods in almost every application, where feasible, with minimal or no cost increases.

Utilizing regional materials significantly reduces the energy required for their transport. This should include locally recycled material, regardless of its original production location.

Minimize Air Emissions

Diesel engines that power a majority of the world's fleet are responsible for carbon dioxide, sulfuric and nitrous oxides, smoke and particulate emissions, noise, and sensible heat leaving the stack. Positive change toward minimizing air emissions can lead to substantial environmental improvement. Areas for emission-minimizing opportunities include hull form optimization, speed considerations, diesel choices, and use of alternative fuels.

The conventional displacement hull, which makes up the majority of documented ships operating in the United States today, requires power that is exponentially proportional to speed, so reducing the resistance and power required can significantly lower both the size of the prime movers and the amount of fuel burned.

Figure 1 shows a typical speed-power curve for a modern 235-foot offshore support vessel. The horsepower is based on sea trial data with a service life and sea margin of 10 percent added. To upgrade a vessel from a top speed of 12.0 kt to 12.5 kt requires a power increase of 1550 hp, or 38 percent! If the 12.5-knot service speed were chosen, the next size larger engine would be required.

With this larger power plant comes an associated increase in fuel used, lubrication oil consumption, and harmful emissions. For a 500-nm run, the faster vessel would arrive only one hour and 40 minutes earlier. It is apparent that there must be an extremely strong case for high speeds to justify the inherent costs to the environment, the initial cost of the engines, and the fuel and operating costs.

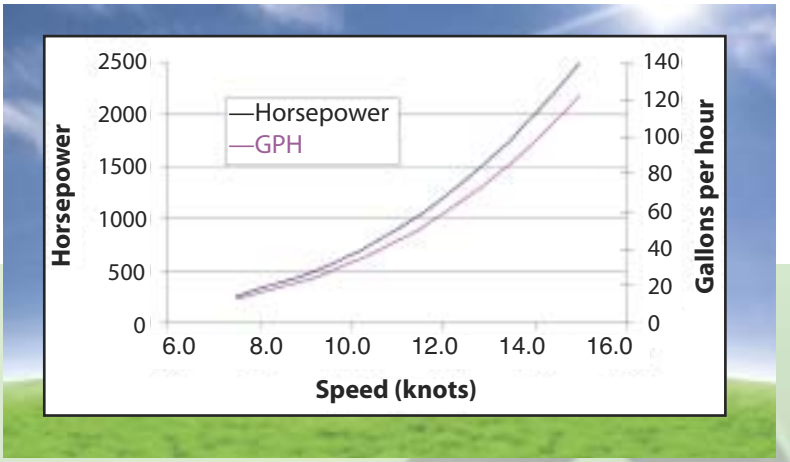

Figure 1: Powering penalty for increased speed. Graphic courtesy of Elliott Bay Design Group.

With an appropriate operating speed selected, optimizing the hull form for lowest resistance may mean spending an extra $20,000-$100,000 during the design stage. While this may seem a steep price to pay up front, in reality it can easily result in a life cycle cost savings of several orders of magnitude greater than the initial outlay, along with a tremendous decrease in harmful pollutants and greenhouse gases.

Designing diesel engines and ships to utilize dual fuel can also result in lower emissions. Converting engines to burn either standard diesel and fuel oils or liquefied natural gas (LNG) has been standard for large LNG carriers for some years now, but smaller-, medium-, and higher-speed marine diesels are now being modified to be dual fuel as well. In regions where there is an adequate gas supply, this is an attractive option. Natural gas also has fewer emissions compared to diesel.

This option can be designed from the beginning or reasonably retrofitted to existing vessels. LNG fuel systems do require 65 percent more storage volume, so this option may only be viable for ships with sufficient space for the additional fuel system. The barrier to wider use of LNG or compressed natural gas is not the engines or the design of the vessels to support the fuel systems, but rather the shoreside infrastructure to support distribution and refueling.

Simply using alternate fuels can greatly benefit the environment. The most obvious is the use of low sulfur fuel oils, although there is a price increase. While there is ongoing investigation to determine the impact of low sulfur diesel and ultra-low sulfur diesel (ULSD) on ma-

rine diesel engines, many operators are already beginning to use them to troubleshoot problems before the EPA requires ULSD use in 2015. Biodiesel offers a unique opportunity to eliminate sulfur dioxide emissions completely. Currently, most marine diesels are certified only for blends with up to 20 percent biodiesel, which is used in place of standard distillate.

All current and pending MARPOL and EPA regulations focus on the reduction of nitrogen oxides and other emissions and particulates. The regulations also have the unfortunate side effect of increasing CO_2 emissions, which is not currently recognized as an air pollutant by the EPA. The amount of CO_2 emissions for engines using diesel and fuel oils directly correlates with the amount of fuel they use. Beginning with the MARPOL Annex XI and each successive tier of EPA marine engine emissions regulations, engine fuel efficiency has decreased by one or more percentage points, thus proportionately increasing their carbon dioxide emissions. This trend of reduced fuel efficiency and increased CO_2 emissions will continue with the introduction of EPA Tier III and Tier IV. With Tier IV, CO_2 emissions will significantly increase due to the overall reduction of fuel efficiency caused by active regeneration required for the particulate filters, pumping requirements of selective catalytic reduction systems, and the added weight of the equipment, fuel, and urea[4] that the vessels must carry.

Figure 2: The harbor tug "ship docking module" design being adapted for hybrid drive. Photo courtesy of Elliott Bay Design Group.

Biodiesel can be substituted for fossil fuel and, in theory, can be carbon-neutral. That is, the release of carbon dioxide from the production and use of biodiesel would be no more than the release at the end of the plant's lifecycle. It is estimated that the use of biodiesel will produce 68 percent fewer greenhouse gas emissions than using regular diesel.[5] Biodiesel also offers the added benefit of moderately reducing dependence on foreign oil sources.

Current generation biodiesel is produced mostly from soy and canola crops and thus competes with the food uses of these crops. The crops devoted to the production of biodiesel compete for arable land that may be used for food production, and may contribute to deforestation. Next-generation biofuels to be developed from algae and other non-food crop resources will alleviate many of these concerns. Technical challenges remain with the large-scale production of biofuels from non-food resources, so they are not yet commercially available in significant quantities.

Hybrid drives use a combination of diesel-electric generator power and the stored energy from batteries to provide the electrical power required to drive propulsion motors (Figure 2). The use of hybrid drive technology has the potential to reduce the installed prime mover size and the resulting emissions. This is, however, dependent upon a suitable peak load operational profile. One example of a hybrid drive would be the use of a battery bank to provide the high-power, short-duration "pulse" required for bow thruster operation. The battery weight and volume, as well as the potential hazardous material created, must also be considered. Except in some very unique waterborne transportation applications, hybrid drives do not produce the levels of fuel efficiency gain seen in wheeled transportation.

More so than ever in the past, one thing is clear—ships must be designed to be adaptable to changing fuel types, and vessel systems will become increasingly complex to accommodate fuel storage and handling and emissions systems.

Minimize Energy Use

As noted, air emissions are highly dependent upon the energy efficiency of the vessel. An often-overlooked aspect of the design is the location and placement of the appendages, such as the rudder, bilge keels, keel coolers, etc. If not aligned to the water flow over the hull, they can increase the drag by a surprising amount.

Several modifications can be made to fleets in service to increase efficiency and decrease fuel consumption, such as a stern flap or wedge. These devices are essentially built-up plates that are fitted at the stern with a depth and angle determined by the flow characteristics at the most common operating speed for a given time/speed profile. A flexible but more expensive option is installing moveable trim tabs or vertical interceptors that serve the same purpose, but reduce motion as well. Powering savings between three and eight percent are not uncommon with this technology.[6]

Increased hull and compartment insulation is another significant energy saver.[7] HVAC requirements are typically the single largest electrical load on ships and are the primary driver for sizing service generators. With the current high costs of fuel, the payback for better insulation can be measured in months, not years.

Just as important as the selection of thermal insulating material is its installation. Inherent in traditional steel and aluminum ship construction is the potential for thermal short circuits—heat conduction through thermally conductive aluminum or steel from inside surfaces to outside surfaces. Thermal short circuits occur at joiner bulkhead-to-hull stiffener attachments, through windows and doors and their frames, through duct and piping penetrations, and generally through compressed or nonexistent insulation. A great deal of energy is lost, translating to increased fuel consumption and exhaust emissions.

To maintain interior air quality, 20 percent or more of conditioned ventilation air is typically exchanged with fresh air from the outside. While this improves interior air quality, it also represents lost energy used to heat or cool the air. Much of this energy can be regained by installing fresh air heat exchangers, which heat or cool the incoming fresh air using the waste conditioned air it is replacing. The installation of fresh air heat exchangers is now a common practice in land-side building construction but has yet to be adopted as a standard practice in ship design. A well-designed system, in combination with tight construction to reduce other leak paths, can improve the efficiency of a ship's HVAC system by as much as 10-15 percent.

On smaller ships, the installed generation capacity also can be reduced by utilizing parallel switchgear on systems not traditionally designed for parallel operation. Many operators of small ships shy away from parallel operation, thinking the system too complex for the small crew. Modern electronics, however, make parallel operation an extremely simple, reliable option, as well as a space, cost, and fuel saver. All marine regulations require that in the event of the loss of one generator, the remaining generator(s) are to be capable of supplying all critical loads and minimal habitability loads. Without parallel operation, this usually results in two generators, each of which must be capable of supplying the worst-case electrical load. Given that ships rarely see a worst-case condition, the operating generator set is usually operating at less than optimum load. Utilizing three smaller sets, sized such that any two would supply the worst-case load, would result in less total installed capacity and permit the on-line unit(s) to operate at a more fuel-efficient loading.

Much energy from fuel is lost as heat through the engine exhaust or for engine cooling. The typical heat balance of a vessel with high-speed diesel engines for propulsion is shown in figure 3.

The ship designer can recover some of this lost energy by utilizing jacket water heat recovery to produce fresh water or for accommodation heating. Exhaust heat can

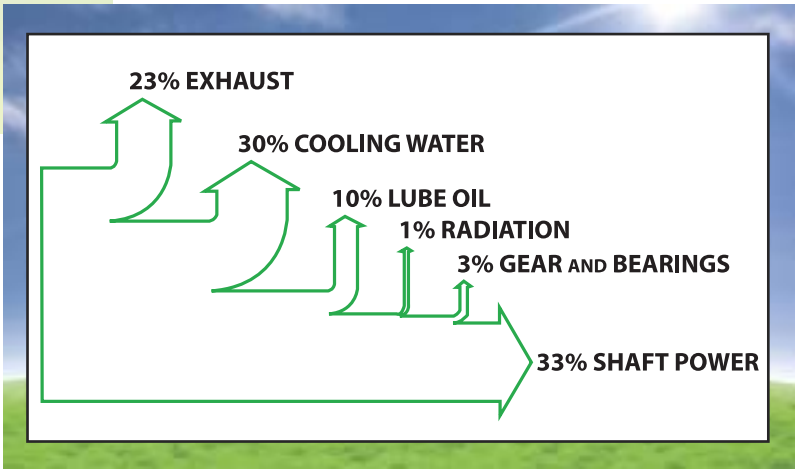

Figure 3: Typical heat balance of a vessel with high-speed diesel engines. Graphic courtesy of Elliott Bay Design Group.

be recovered and converted to steam through exhaust boilers for heating or for use in small steam turbo generators. In some ships, fuel efficiency gains can approach 10 percent.[8] Heat recovery is especially suited to ships that spend most of their time at transit speeds with the engines at or near their rated power. Opportunities for exhaust heat recovery will no longer be available when EPA Tier IV regulations are implemented; keeping the exhaust hot will be required for selective catalytic reduction and particulate filters.

Minimize Discharges to Water

Obviously, minimizing discharge into the water is a key guiding principle in environmental design. Ships such as large petroleum tankers and barges have been subject to the IMO, MARPOL, and OPA 90 double-hull regulations for some time, but smaller vessels have generally been exempted if they carry less than 500 cubic meters of fuel or have a damaged outflow less than a given criteria. Regardless of the size of the ship, placing oil tanks away from the side and bottom shell greatly reduces the probability of an oil spill in the event of grounding or collision.

An increasing number of ship owners are setting an ambitious and laudable goal of operating their ships to approach zero overboard discharge of waste. Achieving this goal requires a complex number of shipboard procedures and installed systems to either minimize the production of all types of waste and then process it for onboard reuse, or reduce and compact it for storage and shoreside recycling.

Past recent challenges have successfully addressed the elimination of oily waste discharge. The current challenge is the processing and total onboard recycling of black and gray water or treatment such that the overboard discharge is sterile water with no residual toxins. The future challenge will be treating ballast water to eliminate the transference of invasive species, again with no residual toxins. In each case, ship design and operation is evolving and adapting to suit these challenges.

Moving Forward

The greatest opportunity to achieve the greenest—as well as the most cost-effective—ship is in the early design phases of an acquisition program. Closely scrutinizing the ship's requirements and designing to them with a view to maximizing efficiencies is paramount to develop a vessel for best environmental practice. For ships already in operation, select design efficiencies and improvements can bring substantial benefit through greener technologies.

As designers, it is our goal to improve upon these practices and thereby benefit the environment and vessel owners and operators. It is very much the role of the designers—or, rather, their obligation—to our industry to introduce leading-edge best practices that will shape the future and health of our maritime environment.

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Endnotes:

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2. "Environmental Advantages of Inland Barge Transportation," U.S. Department of Transportation, Maritime Administration.
3. IMO Resolution 962, Ship Recycling.
4. Urea is essentially a liquid, non-hazardous form of ammonia that is injected into the exhaust gas stream as part of the selective catalytic reduction process for reduction of NOx emissions.
5. National Geographic, October 2007, Volume 212, number 4, page 54.
6a. Dominic Cusanelli and Christopher D. Barry, "Stern Flap Performance on 110 ft Patrol Boat *Staten Island*," Naval Surface Warfare Center.
6b. Dominic S. Cusanelli and Liam O'Connell, "U.S. Coast Guard Island Class 110 WPB: Stern Flap Evaluation and Selection," Naval Surface Warfare Center.
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Hybrid Propulsion

What is it, and when does it make sense for ships?

Environmental Protection IN THE AIR

by Mr. Chris B. McKesson, P.E.
Consultant

Mr. Thomas P. Risley
Alion Science & Technology Inc.

Hybrid vehicles are becoming increasingly common on the roadways. We see hybrid cars, buses, and even SUVs … but when will we see hybrid ships? By our experience, the answer is "soon." There is a rising tide of interest in marine hybrid drives and an increasing number of hybrid propulsion ship projects in existence.

What Do We Mean by "Hybrid?"
A "hybrid" drive means there is more than one power source that can turn the shaft, via an electrical interconnection. There might be a combination of batteries and diesel generators, all of which can feed their power into an electric propulsion motor. Additional power sources can include solar panels or even windmills. While the contributions from these sources may seem small, every drop of propulsion power collected from the sun and wind means one less drop of fuel purchased.

What Are the Advantages?
Fuel efficiency. In an ideal hybrid drive system, the system automatically determines the most efficient source of power for a given load demand. In the case of a large passenger vessel, the demands of the "hotel" load and "propulsion" load can be coupled together electrically and powered by a combination of power sources including generators, batteries, and alternative power sources. This permits operators to "tune" each operation into an extremely fuel-efficient mode that likely would have been impossible with traditional mechanically geared propulsion systems.

In hybrid operation, the engine in the system (e.g. a diesel generator) runs at a constant load. When this load suits the vessel's propulsion needs, this power is sent to the propellers (as electricity sent to a motor) and consumed in propulsion. But during those times when this power is not needed—during low-speed maneuvers, for example—the engine still produces the power, but it is "banked" in an accumulator array (usually batteries). Then, when required, the accumulator array is drawn upon and its power is added to the still-continuous output of the engine. Thus, the engine runs at a steady load even while the motor is throttled up and down. This steady load is optimal for best fuel consumption.

The stainless steel cases on the right-hand side house large battery banks on this hybrid vessel. All photos courtesy of RiverQuest, Pittsburgh, Pa.

Easy to upgrade. A hybrid drive is inherently modular. Consider a typical hybrid, having one or more diesel generators, a battery bank, and a propulsion motor. In a case like this, you can change out a major component of the system without disturbing the rest. This may be as sim-

Mythbuster

Traditional marine vessel propulsion plants require engines that are sized for the maximum output and speed that may be required. While there is an attempt to optimize fuel consumption across a wide range of power and RPM, even modern diesel designs with electronic injection systems have a reduced efficiency while operating at loads that vary from its design point. This necessarily involves compromises. Optimizing a hybrid drive for a single power point permits a tight optimization and the best fuel economy the engine is capable of.

Note that in this example the engine is sized for "average" power, and does not have the horsepower reserve required for peak power. Peak power is accomplished by drawing on the accumulator or battery system. This means that the diesel engine that is coupled to the generator is smaller than would be specified in a normal marine propulsion direct drive system.

But this reduction in engine size is not the key to reduced fuel consumption. The smaller engine will indeed have a smaller fuel consumption rate, but the total gallons per day needed may not be reduced, because a smaller engine must run longer hours. The "work"—the energy required to move the ship across X miles at Y knots—is the same for the smaller engine and its larger sister. If there is a reduction in fuel consumption it will not be because the engine is smaller, but rather because it operates at a more efficient point on its performance curves.

ple as removing one generator set and replacing it with another. Or let's imagine that NiMH batteries become affordable, an example of changing battery technology. In this case, you can change the battery bank without touching the motor or generator. For that matter, when other, more effective forms of energy storage are commercialized, the batteries can be replaced by them.

The engine room on a hybrid drive vessel showing the propulsion generator. The cabinet on the right holds propulsion control electronics.

A related advantage is that the individual components are generally smaller and lighter than their traditional counterparts. Thus, the manipulation of any one component is likely to be physically easier.

Additionally, modularity means that the components of the system need not come from a single vendor. One preference, for example, is to use a common power standard such as 120V AC, or 240V three-phase power. Using such a common standard is equivalent to using USB devices on your computer—everything is plug-and-play. The motor doesn't need to know what type of generator you have, the generator doesn't care what RPM the motor works at, etc.

Arrangeability. This modular or "component architecture" nature of a hybrid drive also brings some potentially important design flexibility: It is possible to put the components nearly anywhere on the boat. Thus, the generators can be placed in the bow or the stern, freeing the midships portion for mission-related functions.

Operational flexibility. In a hybrid drive there is no need for all the generators to be the same size. We might imagine a twin screw boat with two 400 hp electric propulsion motors and a 60kW ship service electric load, and equipped with one 400kW generator, one 200kW unit, and one 50kW unit.

With all generators online, full power can be delivered to the props (600kW is about equal to 800 hp). Running only the bigger generator attains an economical cruise at about 80 percent of max speed, while still providing the full ship service electrical capacity. Note that the propulsion power can still be evenly distributed to the two props, even though only one diesel is running. With just the 200kW generator running, the boat goes into a "quiet mode" at about 50 percent speed, say, for tourism. In fact, if there are batteries aboard, too, then both generators can be shut down for a super-quiet "stealth" mode, ideal for activities like whale-watching.

During all of these modes, both props are turning. It's a much more flexible mode than shutting down one conventional engine and limping along on one shaft only. Further, all of these generators could be based on the same engine while having different cylinder configurations, creating parts commonality galore. This system architecture gives the operator the opportunity to decide which power source to have online depend-

ing upon the immediate needs of the ship, instead of having a 400 hp engine putting out 100 hp for cruising.

What Are the Disadvantages of a Hybrid?
There Ain't No Such Thing as a Free Lunch. It's true that a hybrid drive can lower fuel consumption, be more flexible and arrangeable, and have other advantages over a conventional mechanical drive. Unfortunately, but unsurprisingly, those advantages also come at a cost. In some cases, this cost is financial, but some of the "costs" are measured in other units, such as complexity or weight.

In a conventional drive, the driveline is fairly simple: propeller, shaft, clutch, gearbox, engine. In a hybrid drive there are more pieces: propeller, shaft, motor (maybe no gearbox), cables, switchgear, batteries, generator. Further, let's look at the weight of some of these pieces. Imagine a 500-horsepower installation. The generator includes a diesel engine that may be slightly less than 500 hp—let's say 400 hp. The actual size will depend on the duty cycle questions mentioned above. Now we add the electrical part of that generator, which is a pretty big piece of copper that might weigh half as much as the diesel. Then we add a 500-hp electric motor, which is another very big piece of copper. The switchgear at this power level includes some pretty large cabinets of electronics, and finally we add batteries, which are made of lead. The result of all this is that, for equal total power, the hybrid drive system will be heavier than a mechanical drive system.

Of course, each of those "weighty" components must be purchased. Further, there is substantial cost involved in the installation, with wiring and other components necessary. The complexity of the system may also limit your choice of shipbuilders; not all boatyards are up to the challenge of installing a hybrid drive. So the cost of the hybrid drive is again likely to be higher than the cost of a mechanical drive.

Be Advised: Batteries Are Consumables. Of course batteries do not last forever. Battery choices include lead-acid, advanced glass mat, gel, nickel metal hydride, and lithium ion. For most operators, the lead-acid or advanced glass mat battery is still a very competitive battery candidate for a hybrid ship, but a lead-acid battery can only survive approximately 1,000 charge/discharge cycles. Eventually it reaches a point where it no longer holds a useful amount of energy. We have all experienced this with car batteries at times (usually whenever the weather is least pleasant).

Plugged In

In some applications, people speak of "plug hybrid" vehicles. These are vehicles wherein the power accumulator can be charged by plugging the vehicle into the electrical grid.

This may be thought of as a way of getting a "free tank of gas" by storing a full charge of energy without using the ship's engine. Of course, this is not free, but it is probably less expensive than producing the energy onboard.

It is also possible, depending on the route, that the morning charge could be large enough to permit a substantial reduction in the size of the onboard engine, with attendant weight and cost savings. At present, however, this technology is only suitable for very small vessels on very short runs.

As a result, while a hybrid drive may reduce fuel consumption, and this can benefit your bottom line, it will also lead to increased battery consumption. You should make the appropriate financial provisions for this in your operating budgets.

When Does a Hybrid Make Sense?
So what's the bottom line? Is the hybrid a good idea? Are all ships going to be hybrids in the next decade, or none of them? Well, as always, the answer is "it depends."

Hybrid drives are not suitable for all applications. A hybrid drive is a specialized means of optimizing a propulsion system, and, like any propulsion optimization effort, it depends upon the specifics of the vessel, the operation, the regional availability of resources (fuels), and myriad other concerns. An individual cost/benefit analysis is a must.

The best place for a hybrid drive is in an application with a varied duty cycle, such as a vehicle that has many different levels of power demand during its day. Consider the following examples:

- A commuter ferry like those in Puget Sound or San Francisco Bay. In these cases the ferry runs are between 30 and 60 minutes long, and turnaround times are fairly short. There is not a lot of stop-and-go content to the service, as they operate only between two ports.

This type of operation is probably not suited to hybrid drive. We studied hybrid drive for the San Francisco Water Transit Authority and found that, for their nominal 45-minute runs, a hybrid drive would actually result in increased emissions, compared to a clean diesel installation. This is because the weight increases associated with hybrid drive resulted in reduced passenger

I have a hybrid electric drive on my recreational vessel. A few years ago, I "repowered" from one generator to another in one day by doing nothing more than lifting the old one off and placing the new one on and plugging it in. Had I performed a similar upgrade with a diesel it would have meant hours of fiddling with motor mounts, alignments, and other matters.

One of the more humorous results of using hybrid electric drive: I don't know where the fuel docks are in my area. When a transient boater asks me where to find fuel, I have to shrug and say something like, "I don't know. I don't use it, myself."

—Chris McKesson

capacity on the ferry, so that the fuel burned was moving fewer people, and the increases in fuel efficiency were not sufficient to compensate for this.

- A water taxi. This might be, in some ways, the opposite of the commuter case. Here, we envision a small-capacity boat making short hops between many closely spaced locales, with passengers hopping on and off frequently. Such services exist in New York, Fort Lauderdale, and Victoria, B.C., among other places.

The water taxi may, depending on the route, spend as much time idling at the dock as it does underway. In fact, the National Park Service's Arizona Memorial taxis in Pearl Harbor spend more time at idle than underway. These services are ideal for hybrid drive. A quite small generator can be used, which might have a power output as little as one-fourth of the propulsion motor power. As explained above, this little generator runs at full output the whole time, and the power is stored in batteries for use when the taxi "sprints" to its next destination.

Twin Seimens propulsion motors joined together in a combining gearbox. The propeller shaft emerges to the right.

- Escort tugs. These tugs use an extreme, newly emerging application of hybrid drive. In this application, there is a lot of horsepower that is rarely used. The tug spends much of its time merely being "available" to a ship, and then providing a significant push for a short time as part of harbor maneuvers. In such a case, it makes little sense to have a 5,000 hp engine running at idle just to lean on it for five minutes out of the hour. Instead, the hybrid tugs use a substantial battery bank and two small generators that feed the battery bank.

Another situation where a hybrid makes sense is where there is a substantial amount of shore power available. This could apply to a vessel that makes only one or two harbor cruises a day, or a vessel whose turnaround time is so long that it makes sense to plug in and charge up at each dock call.

In the most extreme case, this vessel could have no onboard engines, and be entirely battery-powered. Alternatively, we might want some onboard generating capacity, but this would be used primarily for ship service purposes or to power an electric galley, and the ability to cross-connect to feed the power into the propulsion plant would be only a backup or "casualty" mode, with the boat running on batteries 99 percent of the time.

Hopefully, we have painted the picture that a hybrid drive can have substantial attractions, but that it is also a complex system that needs to be well tailored to the particular application of the vessel.

Given the number of variables and areas for optimization presented by the hybrid concept, it is very important to approach it as an integrated, comprehensively engineered solution. It is too easy to collect a few good parts, but assemble them in a non-optimized or non-marinized system, and end up with a disappointment.

Of course, this is true of any of a ship's engineering systems, but the complexities and opportunities of hybrid drive make it all the more important in this case.

About the authors:

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Responding to Changing Marine Emissions Standards

What a hybrid tugboat means for our environment.

by Ms. Susan Hayman
Vice President, Health, Safety, Quality, and Environment
Foss Maritime Co.

Two of the United States' largest ports, Los Angeles and Long Beach, will soon have a new way to combat poor air quality—a hybrid tugboat. Together, these ports handle more than 40 percent of all containerized cargo coming into or leaving the United States.[1] Both ports have been under pressure to meet the goals of the San Pedro Bay Ports Clean Air Action Plan, which touches every facet of port operations, from reducing emissions on delivery trucks to ensuring that all cargo handling equipment is retrofitted or built to be as environmentally friendly as possible.

Part of the plan calls for all harbor craft based at San Pedro Bay ports (including Los Angeles and Long Beach) to meet Environmental Protection Agency (EPA) Tier II emissions requirements in the next two years.[2] The ports of Los Angeles and Long Beach contributed $1.39 million to make delivery in mid-2008 a reality. In exchange for this funding, Foss has agreed to homeport the new hybrid tug in Southern California for five years.

Matching Power to Need

The hybrid technology that will be incorporated into the propulsion system of the new tug minimizes fuel consumption by using a specialized power management system to match required power to the most efficient combination of batteries, generators, and main engines at whatever power level is needed.

For example, if a tug is simply idling or docked, a lower amount of power will be provided. For escorting or moving a ship, the full horsepower of a Dolphin-class tug will be available immediately. There are several different modes of operation for the tugs:

> **Tugboats are a good fit for the hybrid technologies because, while they have extremely high power requirements, it is only necessary for short durations. Existing hybrid technology, which has a flexible design allowing it to be adapted to a variety of power and duty requirements, will be modified for use in the tug.**

- minimal emissions, with a 0-5 percent load when idling or stopped;
- eco-cruise, with a 6-19 percent load during slow transit;
- mid-range, carrying a 20-65 percent load at faster speeds or while assisting ships;
- full power, carrying a 66 percent to full load at full-power ship assist speeds.

Based on the performance of the standard Foss Dolphin tugs operating in San Pedro Harbor, it is estimated that the hybrid will spend at least 75 percent of its operating hours in the lowest two modes of operation. In these modes there will be no main engine operating, only batteries and generators.

The Payoff: Reduced Emissions

Tugboats often spend time idling in a harbor or doing tasks less strenuous than full-powered ship assists. When that power is supplied only by diesel engines, resources are spent and unnecessary emissions are cre-

Part of the Clean Air Action Plan calls for all harbor craft based at San Pedro Bay ports to meet EPA Tier II emissions requirements in the next two years, which is where the planned hybrid tug comes into play. Photo courtesy of Foss Maritime.

ated. The hybrid tug will rely on battery power, supplemented by diesel generators and main engines.

Particulate matter and nitrogen oxides are expected to be reduced by 44 percent, as compared with the Dolphin tugs currently operating in San Pedro Harbor. Carbon and sulfur emissions—major contributors to greenhouse gases—are also expected to be reduced, as the hybrid tug is designed to burn less diesel fuel.

Though the first hybrid tug is a new build, other tugs could be retrofitted with the new hybrid technology, since the hybrid design has already been proven and is understood in other applications.

Specifications

The hybrid tug will look and perform like its 78-foot Dolphin-class sisters and will retain the Rolls-Royce azimuthing stern drives for propulsion. The engine room of the hybrid tug, however, will look quite different.

Two Cummins QSK50 Tier II main engines rated at 1,800 hp will be used instead of the two 2,540 hp engines carried by most of the Dolphin fleet. Supplementing the Cummins engine, the hybrid design will feature one 600 hp battery pack and two 1,200 hp motor generator sets.

The two auxiliary generators will increase in horsepower from 168 hp to 402 hp. The hybrid tug will also be able to recharge batteries from shoreside power, in addition to using the auxiliary generators.

Possible Benefits Beyond Reduced Emissions

We expect the hybrid tug will demonstrate benefits beyond using less fuel and having fewer emissions, such as fuel and lube savings, reduced life cycle costs, and the possibility of the hybrid tug acting as a mobile power generating station.

Also, by using battery power in standby mode and only bringing generators and main engines online when higher power is required, the hybrid tug will be generally quieter than traditional tugs.

About the author:
Ms. Susan Hayman, a graduate of the Merchant Marine Academy, holds an MBA from Harvard Business School. Responsible for driving the strategic and tactical work that ensures Foss's safety culture, Ms. Hayman oversees all company programs requiring that equipment and operating practices meet all applicable government and regulatory requirements.

Author's note:
In 2007, Foss joined the SmartWay Transport® Partnership, accepted into the program for its marine transportation services. The partnership is a voluntary collaboration between the U.S. Environmental Protection Agency and the freight industry, designed to increase energy efficiency while significantly reducing greenhouse gases and air pollution.

Foss is also certified under the American Waterway Operators Responsible Carrier Program, a set of safety, quality, and environmental standards for the U.S. tugboat, towboat, and barge industry. On May 28, 2008, Foss was awarded the EPA's Clean Air Technology Award for its development of the hybrid tug.

Endnotes:
This article first appeared in Port Technology International's Sept./Oct. 2007 edition.
1. See www.portoflosangeles.org.
2. The EPA Tier II requirements are part of a series of major initiatives that will reduce emissions from passenger vehicles, highway trucks, buses, and non-road diesel equipment, including harbor craft.

Onshore Power Supply for Ships

Reducing ship engine emissions.

by Mr. Thane Gilman, P.E.
U.S. Coast Guard Systems Engineering Division

Onshore power supply (or OPS, sometimes referred to as "cold ironing") is a system of procedures and equipment that provides ships with a source of electrical power as an alternative to the ship's service electrical power system. The primary benefit is that, since the ship no longer has main or auxiliary engines operating, the engine emissions are virtually eliminated in the port area.

Many ports around the world are located near large populations, and engine emissions from ships unfortunately contribute to unwanted levels of nitrogen oxides, sulphur oxides, particulate matter, and even the "greenhouse gas" carbon dioxide. Onshore power supply achieves a better emissions reduction result than ship-installed emissions equipment. On the other hand, there are difficulties associated with high voltage, varying frequencies, and infrastructure costs that must be addressed in order to justify an onshore power supply installation.

Cold Iron

Receipt of shore power, along with other utilities such as potable water and steam, is part of the process of placing the engineering plant in a status known as "cold iron."

The term originates from the steamship era, when ship boilers and engines would go relatively cold after being secured. To bring a steam plant back online, supplying its own power after a "cold iron" period, would involve a substantial light-off, warm-up, and transition period compared to modern, fully automated plants.

System Requirements

A typical OPS system (Figure 1) requires many components. At the very least, significant infrastructure is required for the cable handling system, switchgear, protective boxes, transformers, and power cables. Additionally, this equipment must not interfere with vessel cargo operations, cranes, or passenger transit, so proper location of the ship/shore interface is critical.

The design of many modern vessels with high voltage electrical distribution systems, such as those of 6,600 volts or 11,000 volts, enables more power to be transferred with less cable area than traditional 450V electrical systems. However, most of the vessels comprising the world's fleets are 440V to 480V systems. The in-port power requirements for different types of vessels—and even vessels of similar type but carrying different cargo—can vary substantially.

Generally, passenger ships with immense air condi-

tioning, cooking, and lighting loads have significantly higher electrical loads than, for instance, a container vessel where a shore-based crane offloads the containers and the number of refrigerated containers is low.

Benefits

The most notable benefit is, of course, the elimination of engine emissions in the port area. Once the infrastructure is set up, ships that make relatively frequent calls to particular ports can transition to onshore power supply as a matter of routine. This is already being successfully implemented in the ports of Juneau, Alaska; Gothenburg, Sweden; and Los Angeles, Calif.

A secondary benefit of a secured plant is that maintenance and repairs can be facilitated on equipment that is not in operation. Also, the interval for receiving engine bunker fuel may be increased slightly as less ship fuel is used, and the relative cost of the energy provided by the shore facility may be favorable compared to the operating cost of ship engine/generator combinations.

Concerns

There are a number of issues that make the overall setup and operation of shore power complicated, including:

Cost. The cost of infrastructure, including electrical equipment such as transformers, switchgear, power cables, cable handling equipment, and associated support structures on the piers is significant. Obviously, as the distance from the shore utility to the ships on the piers increases, the cost multiplies. Similarly, the cost increases as the number of onshore power supply locations on a particular pier increases.

Compatibility. The ship and shore frequencies must match within limits for OPS to even be considered. See figure 2 for frequencies of electrical worldwide electrical systems. It generally requires a frequency converter for a 50-Hertz supply (shore) to work with 60-Hertz loads (ship), or vice versa. Frequency converters at the power levels required are an expensive addition to an already significant infrastructure.

Safety and quality of power. Standards must be agreed upon between ship operators and shore personnel as to safety procedures at a particular installation. Additionally, the minimum quality of electrical power required needs to be defined by the ship, such that safe disconnection of shore power can be initiated if the power quality deteriorates to a level where ship equipment may be damaged.

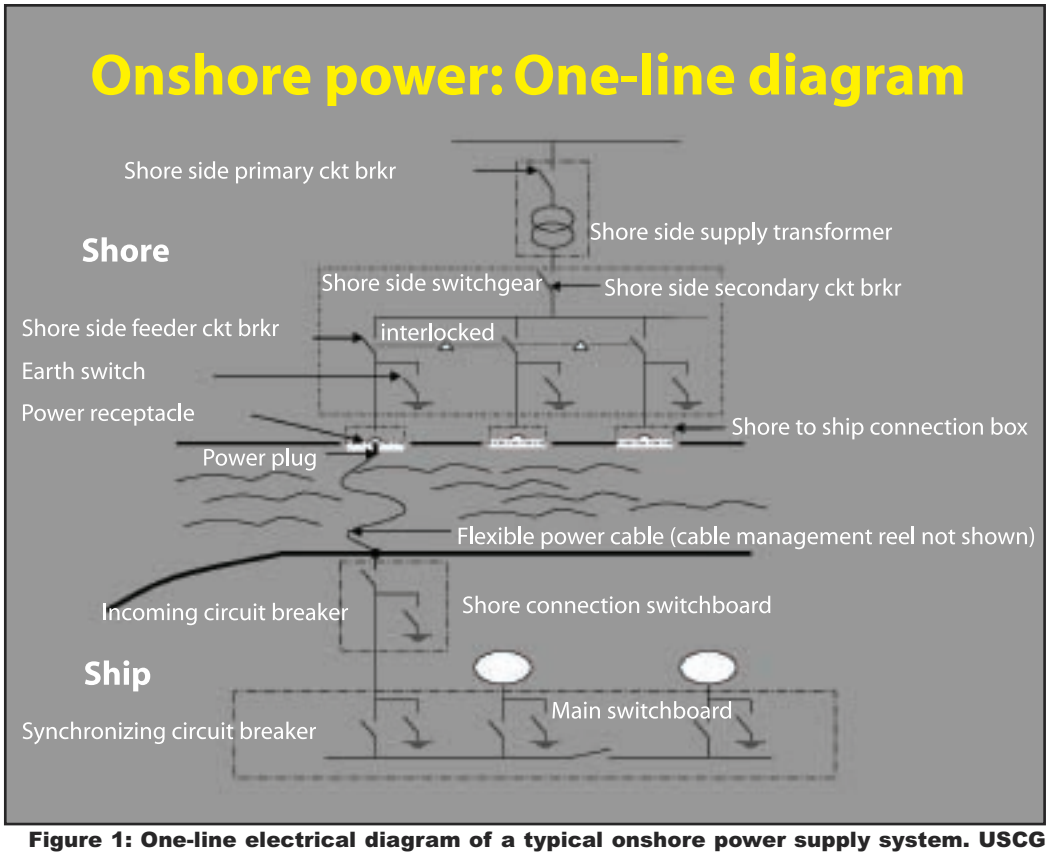

Figure 1: One-line electrical diagram of a typical onshore power supply system. USCG graphic.

Legalities. The number of stakeholders involved makes OPS incorporation into the law complicated. There are local, regional, state, national, and (potentially) international environmental and economic interests involved. Additionally, there are port authorities, vessel operators, and power companies with concerns. Many of the associated agencies have differing opinions with respect to the required strength of environmental laws. For instance, the laws of the state of California

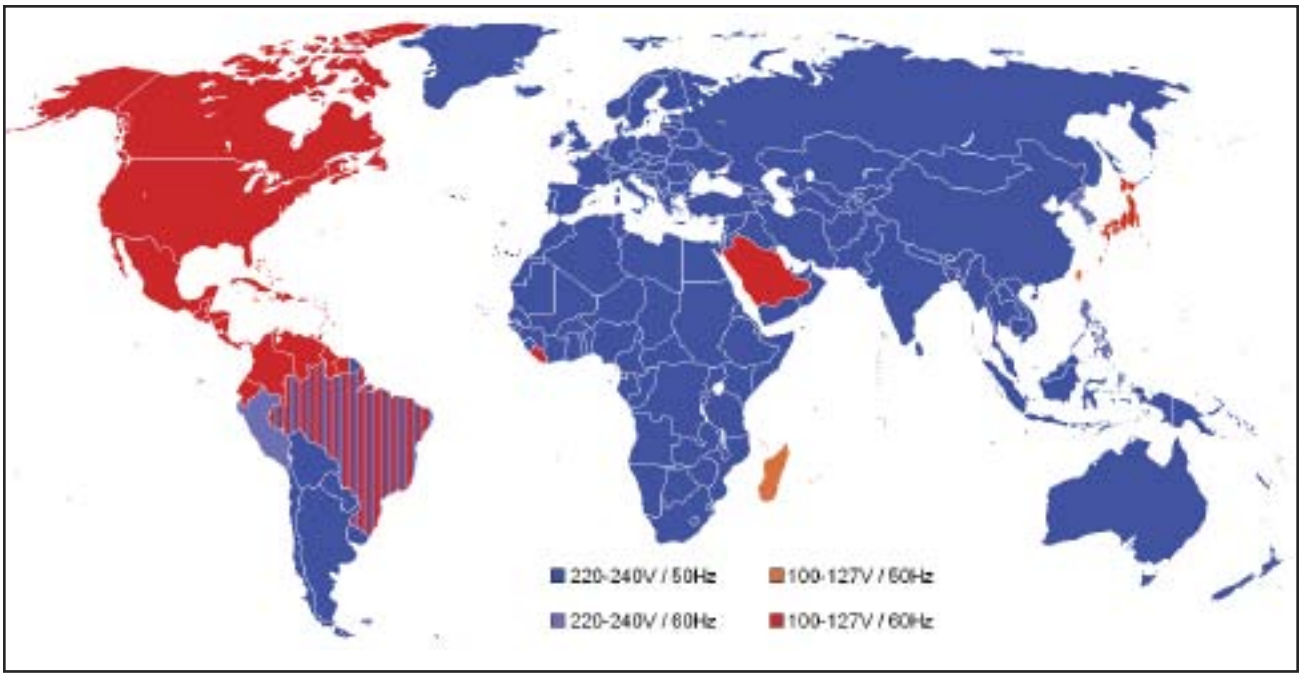

Figure 2: The frequencies of world electrical distribution systems.

may differ from those of the U.S. EPA, which may in turn not completely agree with the environmental standards set forth by the International Maritime Organization. What's encouraging regarding shore power is that, regardless of whether or not regulatory agencies agree on emissions levels, shore power provides a solution because it eliminates emissions.

Standardization. Efforts to formally develop an international standard for OPS installations have been underway within the International Organization for Standardization since 2006. The standardization work prioritizes onshore power supply issues such as:

- Safety requirements for the electrical system, including interlocks, grounding of faults, current-carrying capacity of components, and other protective features of switchgear and cable handling.
- Allowable variances in supplied electrical power when paralleling to ship's power and transferring loads.
- Documenting vessel-specific OPS issues. For example, the onshore power supply requirements for liquefied natural gas ships may be significantly different than for passenger vessels or container ships.
- Training and communications requirements during the OPS process. It is critical that personnel be trained in the operation of high-voltage power systems, and that both ship and shore areas designate persons in charge of onshore power supply procedures. Additionally, since there may be substantial distances between connections, equipment, and personnel, standards must be established for communications procedures and the sequence of steps in the OPS process.
- Definition of events that may trigger an emergency shutdown of onshore power supply, such as short-circuit faults or excessive movement of the ship relative to a pier.

About the author:
Mr. Gilman is an engineer for the U.S. Coast Guard at its headquarters in Washington, D.C. He serves as secretariat of the ISO TC 8/SC 3 Ships and Marine Technology/Piping and Machinery Subcommittee, overseeing 40 standards related to marine engineering and environmental protection. Mr. Gilman holds an M.S. degree, is a licensed professional mechanical engineer, and also maintains an active unlimited horsepower license as a marine engineer for both steam and motor vessels.

IMO Strengthens Air Pollution Regulations

New regulations include significant emissions restrictions.

by Mr. Wayne M. Lundy, P.E.
U.S. Coast Guard Office of Design and Engineering Standards

The Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO) has adopted amendments to the MARPOL Annex VI regulations to reduce harmful emissions from ships. Annex VI of MARPOL 73/78, which addresses the prevention of air pollution from ships, was originally adopted in September 1997 and entered into force in May 2005. Over the past several years, the IMO has been working to make meaningful strides that will result in minimizing harmful ship emissions.

In a nutshell, the new amendments include significant and progressive limits for sulphur oxides (SOx) and nitrogen oxides (NOx) and for the first time address emissions of particulate matter. Regarding NOx emissions, the amendments introduce the concept of emission control areas for stringent NOx reductions, similar to those for SOx emission control areas. Part of this effort to revise MARPOL Annex VI includes significant revisions to the NOx technical code, which includes the procedures for testing and certifying marine engines for compliance. Other amendments include a requirement for a ship-specific volatile organic compound management plan to help minimize these emissions from tankers while in transit.

The new amendments include significant and progressive limits for sulphur oxides and nitrogen oxides and for the first time address emissions of particulate matter.

The revised Annex VI will allow for an emission control area to be designated for sulphur oxide and particulate matter emissions, nitrogen oxide emissions, or all three types of emissions from ships. In addition to amendments to Annex VI, IMO is asking the International Standardization Organization to consider the development of a fuel oil specification addressing air quality, ship safety, engine performance, and crew health, with recommendations for future consideration by IMO.

SOx and Particulate Matter Emissions

The current regulation 14—sulphur oxides—is amended to achieve significant reductions of sulphur oxide and particulate matter emissions from ships. The new regulation 14 —sulphur oxides and particulate matter—includes a scheme for a progressive reduction in SOx emissions from ships.

It is generally recognized that SOx emissions are a function of the sulphur content of fuel. Reducing the sulphur content of fuel will also result in lower particulate matter emissions. Currently, there is a global "sulphur cap" of 4.5 percent on the sulphur content in fuel. Under the revised Annex VI, this cap would be reduced

TABLE 1

Global Sulphur Cap

Effective date	*Old sulphur limit*	*New sulphur limit*
January 1, 2012	4.5% S	3.5% S
January 1, 2020	3.5% S	0.5% S[3]

ECA Sulphur Cap

Effective date	*Old sulphur limit*	*New sulphur limit*
March 1, 2010	1.5% S	1% S
March 1, 2015	1% S	0.1% S

The new SOx limit requirements.

to 3.5 percent, effective January 1, 2012, and further reduced to 0.5 percent starting January 1, 2020 (subject to a feasibility review to be completed no later than 2018).

Regarding SOx emission control areas (now referred to by the generic name of emission control areas following the revisions to MARPOL Annex VI), the limits applicable in areas would be reduced starting on March 1, 2010, from the current level of 1.5 percent to one percent sulphur content of fuel consumed in those areas. The limit will be further reduced to 0.1 percent starting on January 1, 2015, subject to a review regarding the availability of fuel oil to comply with this fuel oil standard.[1]

NOx Regulations for New Engines

The Marine Environment Protection Committee also adopted amendments prescribing progressive reductions in nitrogen oxide emissions from marine engines. Allowing that the current levels for these emissions are known as Tier I and Tier II, limits were established for marine engines that represent roughly a 20 percent reduction in NOx that begins on January 1, 2011, followed by the most stringent controls on Tier III marine engines (those installed on ships constructed on or after January 1, 2016), operating in emission control areas where nitrogen oxide emissions are the focus. The Tier III limits represent roughly an 80 percent reduction from Tier II levels and would require the use of after-treatment systems.

The committee agreed on amendments confirming the proposed "three-tier" structure for new engines (which would set progressively tighter nitrogen oxide emission standards for new engines depending on the date of their installation). Tier I applies to a diesel engine that is installed on a ship constructed on or after January 1, 2000, and prior to January 1, 2011, and represents the 17 g/kW standard, as stipulated in the existing Annex VI.

For Tier II, NOx emission levels for a diesel engine installed on a ship constructed on or after January 1, 2011, would be reduced to 14.4 g/kWh.

For Tier III, NOx emission levels for a diesel engine installed on a ship constructed on or after January 1, 2016, would be reduced to 3.4 g/kWh, when the ship is operating in a designated emission control area. Outside a designated emission control area, Tier II limits apply.

NOx Standards for Existing Engines

Amendments were also adopted that established a NOx emission limit of 17 grams/kilowatt for a diesel engine with a power output of more than 5,000 kW and a displacement per cylinder at or above 90 liters installed on a ship constructed on or after January 1, 1990, but prior to January 1, 2000.[2]

TABLE 2

Tiers for NOx limits for new engine	*Effective date*
Tier I	January 1, 2000
Tier II	January 1, 2011
Tier III	January 1, 2016 (for use in ECAs)

New NOx limit requirements.

NOx Technical Code

The NOx technical code was revised, and includes a new chapter based on the agreed approach for NOx regulation of existing (pre-2000) engines established in the amended MARPOL Annex VI. The revised NOx code also includes provisions for direct measurement and monitoring methods, a certification procedure for existing engines, and test cycles to be applied to Tier II and Tier III engines.

Exhaust Gas Cleaning Systems

Guidelines for exhaust gas cleaning systems to remove SOx emissions from engine exhaust were adopted and issued as an MEPC resolution. The guidelines include a rigorous set of interim washwater discharge criteria, which are being forwarded to the joint group of experts on scientific aspects of marine environmental protection

for review and comment. These interim washwater discharge criteria will be revised in the future as more data becomes available on the contents of the discharged washwater and its potential effects on the marine environment.

Halons

A joint MSC-MEPC circular on decreasing availability of halons for marine uses was also adopted. The joint circular notes that the availability of halons is decreasing and recommends that ship owners, ship operators, shipping companies, and those other interested entities take appropriate action to reduce their reliance on halons. The joint circular also requests that IMO member governments collect data on halons from the maritime sector, in particular the number of ships equipped with halon systems (e.g., the total amount of halons installed for their merchant fleets), and to convey this information directly to the Ozone Secretariat of the United Nations Environment Program (Secretariat for the Vienna Convention and its Montreal Protocol).

Volatile Organic Compounds

IMO also adopted guidelines for developing a volatile organic compound (VOC) management plan. This management plan would be ship-specific and is intended to ensure that the operation of a tanker, to which regulation 15 of MARPOL Annex VI applies, prevents or minimizes VOC emissions to the extent possible. Regulation 15 addresses VOCs and requires a party that regulates tanker VOC emissions to submit a notification to IMO on the size of tankers to be controlled, on cargoes requiring vapor emission control systems, and the effective date of such control.

It is generally recognized that SOx emissions are a function of the sulphur content of fuel. Reducing the sulphur content of fuel will also result in lower particulate matter emissions.

About the author:
Mr. Wayne Lundy is a staff member of the CG-5213 Systems Engineering Division.

Endnotes:

1. If a decision is made that it is not possible for ships to comply, then the standard in that subparagraph shall become effective on and after January 1, 2025. Through this approach of tightening the sulphur content in fuel used in emission control areas, significant reductions in particulate matter will also be achieved where such reductions will contribute to significant improvements in air quality and respiratory health benefits in the adjacent land areas.
2. Such a retroactive requirement shall be applicable provided that an approved method for that engine has been certified by an administration of a party and notification of such certification has been submitted to IMO by the certifying administration. Certification of an approved method is to be in accordance with the NOx technical code. Further, it is to include verification by the designer of the base marine diesel engine to which the approved method applies that the calculated effect of the approved method will not decrease engine rating by more than one percent, increase fuel consumption by more than two percent, or adversely affect engine durability or reliability, and that the cost of the approved method is not excessive, as determined by a comparison of the amount of NOx reduced by the approved method and the cost of purchasing and installing such approved method.
3. The reduction of the global sulphur cap in 2020 would be subject to a review that would be completed no later than 2018 to determine the availability of fuel oil to comply with this fuel oil standard. The review would take into account the following elements: (i) the global market supply and demand for fuel oil to comply with the proposed standard that exists at the time that the review is conducted, (ii) an analysis of the trends in fuel oil markets, and (iii) any other relevant issue. This review would be conducted by a group of experts established by IMO, comprising of representatives with the appropriate expertise in the fuel oil market and appropriate maritime, environmental, scientific, and legal expertise. If a decision is made that it is not possible for ships to comply, then the standard in that subparagraph shall become effective on and after January 1, 2025.

   In addition, a fuel availability provision is introduced under regulation 18, "Fuel Oil Availability and Quality," that describes what actions are appropriate should a ship be unable to obtain the fuel necessary to comply with a given requirement under the above-mentioned regulation 14.

   IMO has also approved an MEPC.1 circular containing unified interpretations related to the verification of sulphur content in fuel oil. These should be applied until the 2008 amendments to MARPOL Annex VI enter into force. This circular also provides the fuel oil verification procedure for MARPOL Annex VI fuel samples.

Bibliography:

International Maritime Organization documents from the 58th session, MEPC 58/23, MEPC resolutions MEPC.176(58) - AMENDMENTS TO THE ANNEX OF THE PROTOCOL OF 1997 TO AMEND THE INTERNATIONAL CONVENTION FOR THE PREVENTION OF POLLUTION FROM SHIPS, 1973, AS MODIFIED BY THE PROTOCOL OF 1978 RELATING THERETO (REVISED MARPOL ANNEX VI) and MEPC.177(58) - AMENDMENTS TO THE TECHNICAL CODE ON CONTROL OF EMISSION OF NITROGEN OXIDES FROM MARINE DIESEL ENGINES (NOX TECHNICAL CODE 2008).

International Maritime Organization and Environmental Protection Agency Marine Emissions Regulations

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The IMO MARPOL 73/78 convention and the EPA marine regulations are a complicated set of requirements for engine manufacturers, packagers, builders, operators, and enforcement agencies. In this article I will attempt to highlight the more unfamiliar aspects of the regulations.

IMO Prevention of Pollution From Ships (MARPOL 73/78) 2000—Current

The International Convention for the Prevention of Pollution from Ships, commonly identified as MARPOL, was adapted in 1973 and modified in 1978 and 1997. The convention consists of six annexes dedicated to various aspects of environmental pollution.

- Annex I – prevention of pollution by oil
- Annex II – control of pollution by noxious liquid substances in bulk
- Annex III – prevention of pollution by harmful substances in packaged form
- Annex IV – prevention of pollution by sewage from ships
- Annex V – prevention of pollution by garbage from ships
- Annex VI – prevention of air pollution from ships

Before an annex can be put into force, it must be ratified by an agreed-upon number of countries representing an agreed-upon amount of worldwide shipping tonnage. The latest annex to be adopted was Annex VI in May 2004. This annex was put into force one year later (May 2005) and provided a three-year period for ships to obtain the necessary documents to certify that each vessel met the requirements.

As of September 2008, 52 countries—representing 80.4 percent of the world's shipping tonnage—have ratified Annex VI.[1] In October 2008, the United States ratified MARPOL Annex VI. The enter-into-force date is three months after the U.S. submits the documents to the IMO Secretary-General. The annex establishes:

- limits of exhaust emissions for sulfur oxide (SOx);
- prohibition of deliberate emission of ozone-depleting substances;
- prohibition of on-board incineration of certain products;
- limits for exhaust emissions for nitrogen oxides (NOx).

All the sections of Annex VI are important toward improving air quality, and the maritime industry needs to understand and follow the requirements.

NOx Requirements for Engine Manufacturers

The MARPOL Protocol 97 Annex VI was not ratified until May 2004 and did not go into effect until May 2005. However, the requirements outlined in the NOx technical code are retroactive back to January 1, 2000. Therefore, engine manufacturers started producing engines with power levels equal to or greater than 130 kW (175 hp) that previously met the requirements in January 2000. The NOx limits range from 9.8 to 17.0 g/kW-hr, depending on rated engine speed. The limits are based on specific test cycles defined by ISO 8178-4. These test cycles represent typical load cycles in various applications, and the installed engines need to meet the NOx limits for their particular applications. The test cycles are:

- C1 – variable-speed, variable-load applications (auxiliary applications);
- D2 – constant-speed, variable-load applications (auxiliary applications);
- E2 – constant-speed, variable-load marine applications (controllable pitch props);
- E3 – heavy-duty marine engines (propeller law);
- E5 – craft < 24 m (79 ft) in length (propeller law).

Engine manufacturers are required to submit the test data to a recognized agency to certify that an engine meets these requirements. In some cases, this requires the certifying agency to witness the engine test and emissions measurement. Depending on the ratifying country, the recognized agency may be different.

In the U.S., the recognized agency is the Environmental Protection Agency (EPA). In many other countries, it is a marine classification society such as ABS, DNV, Lloyd's Register, BV, etc. The NOx code allows engine manufacturers to certify a "family" of engines or ratings that meet the air emissions requirements. However, the statement of voluntary compliance or the engine international air pollution prevention certificate and technical file must be specific as to the engine serial number, and related to the appropriate test cycle that the engine is being used in.

The NOx code does not require engine manufacturers to provide an engine label stating that the engine meets these requirements, but some engine manufacturers have elected to label the engine. However, this is not sufficient to identify the engines as meeting the requirements. Only a statement of voluntary compliance or engine international air pollution prevention certificate with the technical file is sufficient to demonstrate engine compliance.

NOx Requirements for Vessel Owners

The vessel owner is responsible for ensuring that installed diesel engines meet the requirements of MARPOL Protocol 97 Annex VI with regard to NOx output and appropriate test cycle.

The technical code requires that the following types of engines meet the NOx output levels:

- installed on vessels with keels laid on or after January 1, 2000, with a displacement of 400 gross tons or more, engaged in international travels, or flagged by one of the ratifying countries;
- installed on vessels with keels laid on or after January 1, 2000, with a displacement of less than 400 gross tons, and the ratifying country has established it as the governing regulation for that country or particular application (i.e. a fishing vessel);
- operating on floating drill rigs and other platforms unless they are solely dedicated to the exploration, exploitation, and associated offshore processing of seabed mineral resources;
- subjected to a major modification, independent of the year the keel was laid. Major modifications are identified as:
  - new engine installed that was built after January 1, 2000;
  - power greater than 10 percent of the engine being replaced, rebuilt, or remanufactured;
  - "substantially modified" (fuel injection timing, fuel injection equipment, charge air system, combustion system).

Vessel owners need to request an inspection from a recognized agency to issue a vessel international air pollution prevention (IAPP) certificate. In the U.S., the agency is the Coast Guard, while other countries may use marine societies or other governmental agencies. In order for one of these agencies to issue the IAPP for the vessel, the owner must have a statement of voluntary compliance or engine international air pollution prevention certificate and a technical file aboard the vessel for each engine above 130 kW (175 hp).

Owners of U.S.-flagged vessels engaged in international travels need to be aware that other countries might not recognize EPA documents. Therefore, owners may need to obtain from the engine manufacturer a set of documents issued by an agency other than the EPA. Because independent agencies charge engine manufacturers to issue these documents, the engine manufacturers may, in turn, charge the owner, builder, or equipment manufacturer. The owner is also responsible for maintaining the engine service log of emissions-related components identified in the technical file, and must be prepared to present it during any vessel inspection.

Tier I Standards and Timing

Displacement (L/cyl)	Date Commercial and Recreational	Maximum Test Speed (RPM)	NOx (g/kW-hr)
≥ 2.5	2004	< 130	17.0
		130 ≤ N < 2000	$45*N^{-0.2}$
		≥ 2000	9.8

Tier II Standards and Timing

Category	Displacement (L/cyl)	Commercial Date	Recreational Date	NOx + HC (g/kW-hr)	CO (g/kW-hr)	PM (g/kW-hr)
1	D < 0.9 (P ≥ 37 kW)	2005	2007	7.5	5.0	0.40
	0.9 ≤ D < 1.2	2004	2006	7.2	5.0	0.30
	1.2 ≤ D < 2.5	2004	2006	7.2	5.0	0.20
	2.5 ≤ D < 5.0	2007	2009	7.2	5.0	0.20
2	5.0 ≤ D < 15.0	2007	N/A	7.8	5.0	0.27
	15.0 ≤ D < 20.0 (P < 3300 kW)	2007	N/A	8.7	5.0	0.50
	15.0 ≤ D < 20.0 (P ≥ 3300 kW)	2007	N/A	9.8	5.0	0.50
	20.0 ≤ D < 25.0	2007	N/A	9.8	5.0	0.50
	25.0 ≤ D < 30.0	2007	N/A	11.0	5.0	0.50

Enforcement and Penalties

Only countries that have ratified MARPOL Annex VI can enforce the regulation. This applies to vessels flagged by the ratifying country and vessels flagged by other countries but operating in the ratifying countries' territorial waters. Penalties for regulation violations are established by the ratifying countries and can be as severe as vessel detention.

EPA Requirements

The EPA began regulating emissions of diesel engines greater than 0.9 L/cyl and 37 kW used on U.S.-flagged vessels in January 2004.[2] The EPA took a tiered approach to the emission reductions, with each tier consisting of a "phasing in" of engine displacement, power density, and power ranges.

The marine industry includes a diverse mix of applications, and the EPA put marine engines into different categories and based its regulations accordingly:

- category 1 engines: displacement range of 0.9 L/cylinder to 5.0 L/cylinder;
- category 2 engines: displacement range of 5.0 L/cylinder to 30 L/cylinder;
- category 3 engines (not regulated by this rule): displacement of greater than 30 L/cylinder.

An engine's category will determine when it must become compliant with the appropriate tier requirements. Additionally, the type of vessel the engine will be used in also determines when the rule becomes effective. It is extremely important that all marine industry personnel understand how the EPA defines recreational and commercial vessels because this determines if a recreational or commercial engine can be used in the vessel.[3]

As the table indicates, all the engines need to meet the Tier II requirements today.

Requirements for Manufacturers, Dressers, Owners

Engine manufacturers are subjected to various testing, document controls, and labeling requirements. Once an engine is tested to the appropriate test cycle (same as defined in IMO MARPOL Protocol 97 Annex VI) and EPA approves the data submitted for certification, the engines can be produced. The engine manufacturer must permanently label the engine for the intended use.

For example, if engines are going into a yacht that meets the EPA definition of a recreational vessel, then the engines must have a label that states that it is for use in a recreational vessel. However, if the vessel is greater that 100 gross tons and a person will pay to be on the vessel (i.e. a charter), then that vessel becomes a commercial vessel and the engines must be labeled as commercial engines. All auxiliary engines are considered commercial engines.

Engine manufacturers cannot produce new engines for introduction into the U.S. commerce stream that do not meet the current emissions levels for the engine displacement per cylinder and power levels.

The marine emissions rules have different emissions levels than land-based engines, such as heavy-duty highway engines (40 CFR part 86), non-road diesel engines (40 CFR part 89), or locomotive engines (40 CFR part 92). However, the marine rule allows a marine dresser[4] to use these land-based engines in marine applications. This includes packagers for gen-sets or other auxiliary drives, such as a pump engine on a barge or an engine used in a Hovercraft.

The marine dresser must use an engine that meets the current standard under which it was certified and cannot change the engine in any way that will affect emissions. The dresser must use an engine certified to the appropriate test cycle for the application. For example, if a gen-set is packaged with a land-based engine to be installed on the deck of the barge, it must be certified to the D2 test cycle.

Another example of the barge application is the pump drive engine to pump the cargo off. Historically, this application has been a land-based engine that is a variable-speed engine, allowing the operators to set the RPM at the optimum speed to pump the cargo. Because different speeds are used and engine loading is dependent on the type of cargo, this would be a variable-speed, variable-load application requiring an engine certified to C1 test cycle. In addition to the above, the marine dresser must also add a permanent label (per section 94.907 of 40 CFR part 94) and report to the EPA the number of engines dressed annually.[5]

Manufacturers of new vessels or organizations that make major modifications to vessels are responsible for selecting the proper engine for their applications. According to the EPA, a new vessel is defined as:

- a vessel for which the purchaser has not received the equitable or legal title;
- a vessel that has been modified such that the value of the modifications exceeds 50 percent of the value of the modified vessel;
- an imported vessel that has already been placed into service but has engines manufactured after the date specified in this regulation.

In the case of the major modification, if the above criteria is met but the engines were not changed during the modification, engines that meet the current tier level at the date the modification was completed would have to be fitted.

The engines must be installed in a manner that meets the engine manufacturer's installation guidelines. The cooling system, exhaust system, and air inlet systems are critical to the installation. The guidelines established by the engine manufacturers are there to ensure the engines operate within the combustion system tolerance to ensure the exhaust emissions are within limits.

Owners of vessels are prohibited from tampering with the engine or the emissions controls. Owners are also responsible for ensuring that engines are rebuilt or replaced with engines such that they will meet the same emissions levels as the original engines. These regulations should be carefully reviewed when investigating used or reconditioned engines. Records on the replacement or rebuilt engines must be understandable and available to the enforcing agencies for two years after the work has been completed.

Enforcement and Penalties

The EPA Office of Enforcement and the USCG are authorized to enforce the requirements of this regulation. The rules have been established in an attempt to simplify the inspection of engines meeting these requirements. However, the rules make various allowances to accommodate the diversity of the marine industry.

This makes the task of inspection and confirmation difficult. Engine manufacturers, vessel manufacturers, retrofit organizations, and owners are all subject to fines and other penalties if violations are identified.

Recent Action

In May 2008, the EPA released the final rule for a new set of standards for exhaust emissions from marine diesel engines. Again, it has taken a tiered approach to emissions reductions, and each tier will consist of a "phasing in" of engine displacement and power ranges. In the new rule, the EPA has modified the category of engines.

- category 1 engines: displacement range of 0.9 L/cylinder to 7 L/cylinder
- category 2 engines: displacement range of 7 L/cylinder to 30 L/cylinder
- category 3 engines (the EPA has proposed a separate rule for engines of this size): displacement of greater than 30 L/cylinder

It's also important to understand which emissions would be regulated. Between 2009 and 2018, the proposed Tier III standard will reduce NOx plus hydrocarbon (HC) output by 20 percent and particulate

matter (PM) by 50 percent from current Tier II levels. Between 2014 and 2017, the proposed Tier IV standard will reduce NOx output by 80 percent and PM output by 90 percent from current Tier II levels.

An engine's category will determine when it has to become compliant with the appropriate tier requirements. However, the EPA breaks it down further within each category and spells out which horsepower ranges have to meet which emissions standards in each model year.

New Vessels and Repowers

The new rule will regulate any engine installed on a new vessel flagged or registered in the U.S. and applies to replacement engines and rebuilt engines.

The regulation defines a "new vessel" as:

- a vessel for which the purchaser has not received the equitable or legal title;
- a vessel that contains no category 3 engines and has been modified such that the value of the modifications exceeds 50 percent of the value of the modified vessel. The notice of proposed rulemaking provides the following equation to determine if the fractional value of the modification exceeds 50 percent:

  % of value = [(assessed value after modification)-(assessed value before modification)] / 100% (assessed value after modification).
- a vessel with category 3 engines that has undergone a modification that substantially alters the dimensions or carrying capacity of the vessel, changes the type of vessel, or substantially prolongs the vessel's life;
- an imported vessel that has already been placed into service but has engines manufactured after the date specified in this regulation.

Engines used for replacement, either as a repower or as a result of an engine failure, must meet the emissions levels in effect at the date of the replacement.

For example, let's imagine one of the engines fails in a twin-engine vessel and cannot be repaired. The owner is required to replace it with the current tier engine. It is possible to use an engine equal to the failed engine if it can be shown that no other engine on the market is available and that the vessel will not function properly with the higher-tier engine. The EPA must approve this substitution. There are a number of engine labeling requirements, and the engine manufacturer must take possession of the failed engine.

The new rule also includes a requirement for remanufactured engines. This requirement applies to commercial marine engines of more than 600 kW (805 hp) built between 1973 and when Tier II went into effect. The EPA is defining a remanufactured engine as an engine that has all cylinder liners replaced in a single maintenance event or over a five-year period. For this rule, "replaced" also includes removing, inspecting, and requalifying a liner. The rule requires an owner/operator who is remanufacturing the engine to use a certified system if one is available. The EPA will maintain a list of certified systems on its website. If no system is available for the engine, it is not required.

Category 1 Tier III Standards and Timing

Power Density and Application	Displacement (L/cyl)	Maximum Engine Power	Model Year	PM (g/kW-hr)	NOx + HC (g/kW-hr)
all	disp < 0.9	kW (hp) < 19 (25)	2009	0.4	7.5
		19 ≤ kW < 75	2009	0.30	7.5
		25 ≤ hp < 100	2014	0.30	4.7
Commercial engines with kW/L < 35 (hp/L < 47)	disp < 0.9	kW (hp) ≥ 75 (100)	2012	0.14	5.4
	0.9 ≤ disp < 1.2	all	2013	0.12	5.4
	1.2 ≤ disp < 2.5	kW (hp) < 600 (805)	2014	0.11	5.6
			2018	0.10	5.6
		600 ≤ kW < 3700 805 ≤ hp < 4962	2014	0.11	5.6
	2.5 ≤ disp < 3.5	kW (hp) < 600 (805)	2013	0.11	5.6
			2018	0.10	5.6
		600 ≤ kW < 3700 805 ≤ hp < 4962	2013	0.11	5.6
	3.5 ≤ disp < 7.0	kW (hp) < 600 (805)	2012	0.11	5.6
			2018	0.10	5.6
		600 ≤ kW < 3700 805 ≤ hp < 4962	2012	0.11	5.6
Commercial engines with kW/L > 35 (hp/L > 47) and all recreational engines	disp < 0.9	75 to <3700 kW 100 to <4962 hp	2012	0.15	5.8
	0.9 ≤ disp < 1.2		2013	0.14	5.8
	1.2 ≤ disp < 2.5		2014	0.12	5.8
	2.5 ≤ disp < 3.5		2013	0.12	5.8
	3.5 ≤ disp < 7.0		2012	0.11	5.8

Category 2 Tier III Standards and Timing

Power Density and Application	Displacement (L/cyl)	Maximum Engine Power	Model Year	PM (g/kW-hr)	NOx + HC (g/kW-hr)
Commercial engines	7.0 ≤ disp < 15.0	kW (hp) ≤ 3700 (4962)	2013	0.14	6.2
	15.0 ≤ disp < 20.0	kW (hp) ≤ 3300 (4425)	2014	0.34	7.0
		3300 < kW ≤ 3700 4425 < hp ≤ 4962	2014	0.27	7.0
	20.0 ≤ disp < 25.0	kW (hp) ≤ 3700 (4962)	2014	0.27	9.8
	25.0 ≤ disp < 30.0	kW (hp) ≤ 3700 (4962)	2014	0.27	11.0

Category 1 and 2 Tier IV Standards and Timing						
Power Density ıd Application	Displacement (L/cyl)	Maximum Engine Power	Model Year	PM (g/kW-hr)	NOx (g/kW-hr)	HC (g/kW-hr)
Commercial only	all	600 ≤ kW < 1400 805 ≤ hp < 1877	2017	0.04	1.8	0.19
	all	1400 ≤ kW < 2000 1877 ≤ hp < 2682	2016	0.04	1.8	0.19
	all	2000 ≤ kW < 3700 2682 ≤ hp < 4962	2016	0.04	1.8	0.19
	disp. < 15.0	kW (hp) ≥ 3700 (4962)	2014	0.12	1.8	0.19
	15.0 ≤ disp < 30.0		2014	0.25	1.8	0.19
	all		2016	0.06	1.8	0.19

Engine Installation Requirements

Engine manufacturers are required to provide emissions-specific installation requirements. Installers that fail to follow these instructions may be subject to fines and other penalties.

Engine manufacturers must label the engine with information about the emissions certification. If the engine is installed in a way that makes this label hard to read during normal maintenance, owners must request a duplicate label and place it in a visible location on the vessel.

Tier III Issues

It appears that a Tier III marine engine will not be much different than a Tier II marine engine. The Engine Manufacturers Association (EMA), whose members have worked with the EPA during the development of this rule, believes the Tier III emissions levels can be achieved through in-cylinder technologies. An engine at a given power level certified as a Tier II engine might have a larger displacement for the same power to meet Tier III levels. The EMA also believes that a Tier III engine will not require ultra-low sulfur diesel (ULSD) fuel.

Those who have to replace a non-certified Tier I or Tier II engine after Tier III becomes effective will face the biggest challenge. It may become more difficult to find an engine that will physically match the older engine at the same power level. This could be critical for multi-engine vessels.

Tier IV Issues

EMA members agreed that Tier IV will require after-treatment devices, which will require ULSD fuel. The regulations state that the engine and the vessel will be labeled as such. It will be considered a violation if ULSD fuel is not used, and owners may be subject to fines and other penalties.

If a vessel has an engine installed that uses a selective catalytic reduction system with urea[6] or other reductants, the owner or operator must report to the EPA within 30 days of any operation of the engine without the appropriate urea. Failure to do so may result in fines and other penalties.

The after-treatment devices are substantial in size. Tier IV requirements are only for commercial vessels and engines with power ratings greater than 600 kW (805 hp). The after-treatment devices will be required to reduce NOx and particulate matter. For NOx reduction, an SCR system using urea injection seems to be the best alternative at this time. For particulate matter reduction, an active diesel particular filter, combined with a diesel oxidation catalyst, seems to be the best alternative.

The new rule has identified that Tier IV engines are not required as a replacement engine. This is due to the potential for extensive vessel modification to fit the after treatment devices and the effect it could have on vessel performance and safety.

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Endnotes:

1. International Maritime Organization, "Status of Conventions by Country," May 2008.
2. The regulation is detailed in Federal Register 40 CFR.
3. Per 40 CFR Part 94.2, a recreational vessel "has the meaning given in 46 U.S.C. 2101 (25), but excludes 'passenger vessels' and 'small passenger vessels' as defined by 46 U.S.C. 2101 (22) and (35) and excludes vessels used solely for competition. In general, for this part, 'recreational vessel' means a vessel that is intended by the vessel manufacturer to be operated primarily for pleasure or leased, rented, or chartered to another for the latter's pleasure, excluding the following vessels:
   (1) Vessels of less than 100 gross tons that carry more than 6 passengers (as defined in this section).
   (2) Vessels of 100 gross tons or more that carry one or more passengers (as defined in this section).
   (3) Vessels used solely for competition."
   A commercial vessel is defined as "a vessel that is not a recreational vessel."
4. A dresser is any entity that modifies a land-based engine for use in a marine application.
5. The reader is advised to consult 40 CFR part 94 and the technical amendments associated with it for specific details on how to properly apply this marine dresser provision properly.
6. Urea is essentially a liquid, non-hazardous form of ammonia that is injected into the exhaust gas stream as part of the selective catalytic reduction process for reduction of NOx emissions.

Environmental Imperatives

Essential elements of a maritime environmental compliance plan.

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Much ink has been spilled, dozens of legal challenges have been filed, and scores of impassioned speeches have been given over the past decade protesting or seeking to forestall the investigation and criminal prosecution of environmental cases against vessel owners and operators. Despite these protests, the number of environmental criminal cases filed against maritime companies by the United States Department of Justice (DOJ) continues to escalate (a record 34 new cases filed in 2007 alone), and the level of criminal penalties imposed as a result of the convictions obtained are at an all-time high ($67 million dollars in 2007).[1]

The broader reality is that the environmental profile of commercial vessel operations has been raised dramatically in the United States and around the world in recent years. The areas of environmental interest reach well beyond the management of waste oil and now include ballast water exchange, garbage, gray and black water discharges, and air emissions. This trend shows no signs of abating.

As a consequence, many vessel owners and operators are searching for technical measures and management tools to help them more effectively address environmental responsibilities and avoid the escalating risks associated with noncompliance. More maritime companies are now considering, or have already implemented, some of the practices that have been employed for decades by major shore-based businesses in many sectors of the economy to manage environmental responsibilities. Two of these are:

- a comprehensive environmental compliance plan (ECP) to address the full scope of technical and operational details of environmental compliance,
- a compliance management system (CMS) to ensure that a company's environmental compliance policies are understood and adhered to by employees at all levels of the organization.

MARITIME ENVIRONMENTAL COMPLIANCE PLANS

Organizations employ corporate environmental compliance plans to demonstrate the company's commitment and to integrate verification procedures into operational and management systems to help ensure compliance with regulatory requirements, detect nonconformities, and correct identified deficiencies. Many businesses have implemented ECPs as a component of their overall business strategy.

Numerous ECP models targeting technical, operational, and managerial standards have been commercially developed and marketed to a wide range of business, industry, and government organizations. Many of these plans have focused on achieving compliance with environmental standards and the need for implementing comprehensive compliance management systems. What is key, however, is tailoring these plans to a particular company's operations and getting buy-in from all levels of company management and employees.

From a law enforcement perspective, the existence and adequacy of an ECP is viewed as a potentially mitigating factor in the exercise of prosecutorial discretion concerning the decision whether to file criminal charges against an organization. The guidelines for the federal prosecution of business organizations require a federal

prosecutor to evaluate the adequacy of any compliance plan and direct the prosecutor to make an informed decision as to whether the corporation has adopted and implemented a truly effective program that, when consistent with other federal law enforcement policies, may result in a decision to charge only the corporation's employees and agents.[2] Policy guidance issued by the DOJ's environment and natural resources division in 1991 similarly requires that prosecutors handling environmental criminal cases evaluate the existence and scope of any environmental compliance program in determining the appropriateness of criminal enforcement.[3] Finally, in the event criminal charges are filed against an organization and a criminal conviction is obtained, the United States sentencing guidelines for organizations advise the sentencing court to determine, as one mitigating factor, whether the company had an effective compliance program in place.[4]

Since the mid-1990s many of the criminal cases against maritime companies for environmental violations have required, as part of a plea agreement, the development and implementation of an ECP designed to prevent, detect, and remedy any environmental violations aboard the company's vessels. Performance under the environmental compliance plan is typically monitored by the court, the U.S. Coast Guard, and the DOJ throughout the period of probation. The scope and complexity of these ECPs have grown substantially over the years, and the role of the court in the design and oversight has likewise expanded.The commercially marketed ECPs, the evaluative criteria contained in the sentencing guidelines, and the ECPs associated with recent criminal prosecutions have a number of key elements in common. Although varying in format and complexity, each of these models typically includes various elements.

- **High-level management oversight.** One common feature is the designation of a shoreside environmental manager to serve as the company's overall coordinator for the environmental compliance plan. This person is charged with confirming that the elements of the ECP are being implemented as designed and ensuring that any deficiencies are identified and corrected in a timely manner. In addition, the shoreside manager is typically required to make periodic reports to the company's president and/or board of directors concerning performance under the plan.

  The management aspects of environmental compliance are often collected in a separate document, generally a compliance management system, and the requirements of that system must be thoroughly integrated into the overall ECP.

- **Defined shipboard responsibility.** The compliance management systems associated with most ECPs require the company to issue clear, comprehensive policy statements specifying how crewmembers are to meet environmental objectives. These policy statements often establish detailed monitoring responsibilities concerning environmental compliance for senior shipboard officers.

  In addition to the predictable set of responsibilities for the chief engineer regarding the management and disposal of oily wastes, many compliance policies require the master to be actively engaged in oversight and to verify that the training, operational, and documentation elements of the ECP are consistently fulfilled. The master is also typically designated as the primary point of contact with the shoreside environmental manager.

  Some companies have further strengthened their ECPs by creating a new officer position aboard their vessels—an environmental, compliance, or operational integrity officer—whose sole responsibility while the vessel is underway is to monitor compliance with safety and environmental standards and to ensure that any nonconformities are understood and promptly remedied.

- **Auditing processes.** The most critical component of an environmental compliance plan is the procedure for conducting comprehensive audits of the vessel's pollution control systems, equipment, and components, as well as assessing the knowledge, skills, and abilities of shipboard and shoreside personnel. There is, of course, a wide variety of auditing procedures and different requirements from company to company depending on the size and age of the fleet, the vessel classification, the age and technical capabilities of the pollution control equipment, the maintenance practices for that equipment, and the commitment of shoreside management to make the sustained investment required to reduce the risk of environmental noncompliance.

  Depending on the company's degree of environmental sophistication and its prior auditing practices, the initial audit process may have to establish a baseline of information regarding the quantity and characteristics of the waste streams generated aboard each vessel; the performance capabilities of the vessel's oily water separator, incinerator, sewage system, and ballast system, among others; the ability of the crew to handle the operational, maintenance, and repair

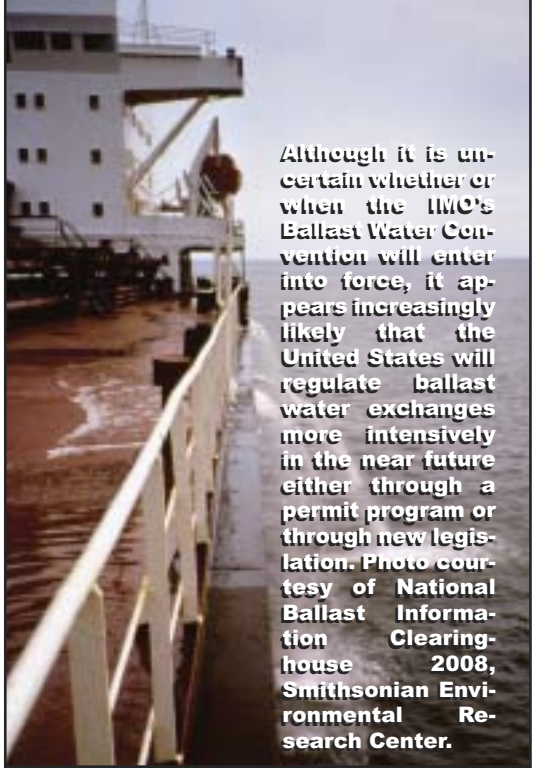
workloads of all pollution control systems and maintain the associated records; the adequacy of policies and practices regarding the storage and disposal of waste streams; the adequacy of environmental compliance training; and the adequacy of procedures and reporting systems (internal and external) for detecting, responding to, and remedying deficiencies.

More generally, some of the periodic audits should be conducted while the vessel is underway to permit a more realistic assessment of the systems and their capabilities. Many companies utilize an internal auditing group to handle auditing functions, but it is beneficial to incorporate a third-party audit and unannounced audits into the schedule to help ensure integrity and improve the credibility of the audit results.

Finally, audit reports and recommendations must be distributed in a timely manner to shoreside management and shipboard officers, and procedures must be in place to ensure that identified deficiencies are tracked and promptly corrected. It is critical that findings are shared among ships in the fleet to ensure that any identified deficiencies are corrected fleet-wide and not just on the ship that garnered the particular finding.

- **Technical requirements.** An ECP must also address the engineering features aboard the vessel that will facilitate compliance with environmental standards and help prevent intentional efforts to circumvent pollution prevention equipment. These can include the use of uniquely numbered seals on all crossover valves or flanges associated with overboard piping that could be used, for example, for the discharge of oily bilge water. Some environmental compliance plans incorporate the use of other protective or mechanical devices, such as "white boxes" or "enviologgers," which are designed to prevent unauthorized access to or tampering with the pollution control systems. But even these devices can be defeated, so the ECP must incorporate periodic operational testing of the pollution prevention equipment by engineering personnel not assigned to the vessel. Many companies are also requiring the use and certification of tank sounding logs by engine department personnel to provide an independent means of cross-checking and verifying entries in the machinery space oil record book.

- **Budget.** An adequate and flexible budget for environmental compliance and procedures for monitoring such expenditures is a critical component of any environmental compliance plan. In the past, companies have too often established unreasonably low operational budgets for environmental compliance and, to compound the problem, have sometimes tied bonuses for shipboard officers to meeting those budget targets. This arrangement has inadvertently incentivized chief engineers to restrict "discretionary" expenditures for environmental compliance.



Although it is uncertain whether or when the IMO's Ballast Water Convention will enter into force, it appears increasingly likely that the United States will regulate ballast water exchanges more intensively in the near future either through a permit program or through new legislation. Photo courtesy of National Ballast Information Clearinghouse 2008, Smithsonian Environmental Research Center.

One solution is to remove environmental management and maintenance budgeting from the operational budgets of individual vessels and to task the shoreside environmental manager with overseeing the environmental budget for the fleet. Regardless of whether changes are made in the budgeting process, the ECP must contain clear policy guidance, reinforced by training and managerial oversight, that the company views expenditures for environmental compliance as priority budget items and that shipboard personnel will be provided the technical, logistical, and financial support needed to comply fully with environmental standards.

- **Procedures to determine reason for nonconformity and ensure correction.** One additional feature found in many ECPs is the need to incorporate management review of the environmental compliance plan and the CMS on a periodic basis to assess the adequacy and effectiveness of the program. These management reviews must draw data from a broad range of sources and should actively evaluate the need for changes and improvements.

ELEMENTS TO ADDRESS IN ENVIRONMENTAL COMPLIANCE PLANS

Management of all major waste streams and systems, such as bilge, black and gray water, ballast, and agricultural, chemical, and universal wastes must be incorporated into the ECP. Other items that must be incorporated include federal, state, and local release reporting requirements. Many of these programs are well established and fairly static.

The United States Congress has passed legislation implementing MARPOL Annex VI governing air emissions from vessels, and other pending legislation would impose stringent new requirements for ballast water management.

However, vessel owners and operators must contend with an onslaught of new laws and regulations governing ship operations at the international, federal, and state levels. These new developments, on the environmental front, are predominantly related to ballast water exchange and air emissions from ships. The regulatory attention to the environmental effects of commercial vessel operations is very likely to intensify in the coming years. Thus, it is imperative that ship operators closely monitor and track these new developments to help ensure compliance.

By incorporating these developing requirements into the environmental compliance plan now, the vessel owner and operator can more efficiently manage environmental objectives and adjust the standards more smoothly as the regulatory programs develop.

Ballast Water Management

The management of ballast water discharges began with the enactment of the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA) as an effort to prevent the introduction of additional invasive species into the Great Lakes. Since then, NANPCA was amended by the National Invasive Species Act of 1996 and the issue has progressed over the intervening years to a much larger campaign to regulate all vessel discharges into U.S. waters. The issue is currently being played out before the courts and Congress and, as such, changes in the regulatory regime are imminent.

There are several key components of the ballast water management equation. The first is the International Maritime Organization's International Convention for the Control and Management of Ships' Ballast Water and Sediments (adopted February 2004), which enters into force 12 months after ratification by 30 states representing 35 percent of world tonnage. At present, it has been ratified by 13 states representing 3.62 percent of the tonnage. The convention requires ballast water exchange and has a staged transition to treatment, but likely will not go into effect for several years.

The second component has developed from a 2003 lawsuit Northwest Environmental Advocates (NEA) brought against the Environmental Protection Agency (EPA). In that lawsuit, NEA challenged the EPA's longstanding position that discharges incidental to normal vessel operations, including ballast water discharges, were exempt from National Pollution Discharge Elimination System permits under the Clean Water Act.

In September 2006, the District Court for the Northern District of California sided with the environmental groups and ordered the EPA to vacate this regulatory exemption, which included discharges of ballast water, gray water, bilge water, and deck runoff, among others, despite EPA's argument that Congress had acquiesced in EPA's interpretation of the law, which had been in place for over 30 years.[5] The court issued an order requiring EPA to develop a permitting program for incidental discharges from vessels by September 30, 2008. Although the case is on appeal, EPA has, in the meantime, begun a rulemaking to institute a permitting process for discharges of pollutants incidental to the normal operation of vessels. This program could cover more than 18 million vessels—more than all other point sources regulated by EPA.

The third key component is the plethora of pending legislative proposals regarding ballast water management. Companion bills (S. 2645 and H.R. 5594) introduced early in 2008 would render the ruling of the District Court in *NEA v. EPA* moot by removing from EPA the authority to regulate incidental discharges from vessels and giving separate authority to the U.S. Coast Guard to establish a new uniform national discharge standard in lieu of any permit program. Two other bills (Ballast Water Treatment Act of 2007, incorporated in Title V of H.R. 2830, the U.S. Coast Guard Authorization Act of 2007, and S. 1578) seek to strengthen NANPCA. Both bills track the Coast Guard's current ballast water management scheme, and address the critical issue of preemption, allowing state regulation of ballast water management provided the state regulation does not conflict with federal standards.

Finally, the administration, through the Coast Guard and EPA, has put forth a legislative proposal that would moot the District Court ruling and implement national uniform discharge standards for ballast water and other incidental discharges in lieu of a permitting regime. At this time, the legislative outlook is unclear. As a result,

barring a contrary ruling from the Ninth Circuit on appeal, EPA must proceed with a regulatory regime for permitting incidental vessel discharges by September 30, 2008. This will likely take the form of a general permit specifying standards and planning requirements with which the industry will have to comply.

Air Emissions From Ships

There are also efforts at the international, federal, and state levels to regulate air emissions from vessels, generally including the more traditional pollutants, such as nitrogen and sulfur oxides (NOx and SOx), particulate matter, and certain ozone depleting substances. On the international and federal front, in July 2008 the Senate passed and the president signed the Marine Pollution Prevention Act of 2008 into law to implement MARPOL Annex VI, which entered into force on May 19, 2005. Annex VI sets international standards for NOx and SOx emissions, among others.

In a related development, the EPA has issued regulations that would impose stringent exhaust emission standards for marine diesel engines on U.S. and foreign-flag ships, generally consistent with Annex VI. In addition, the IMO has approved and is expected to formally adopt a series of amendments to MARPOL Annex VI to achieve greater reductions in the emission of air pollution from ships. It appears that it is only a matter of time before the EPA and the international community adopt more stringent regulation of NOx and SOx emissions from ships. Thereafter, it appears likely that greenhouse gas emissions from ships will receive additional scrutiny.

The California Air Resources Board (CARB), impatient and dissatisfied with federal government actions to regulate vessel emissions, adopted its own regulations. On January 1, 2007, CARB began enforcing state regulations limiting emissions of particulate matter, NOx, and SOx from the auxiliary diesel engines of ocean-going vessels operating within 24 miles of California's coast. The regulations were challenged by the Pacific Merchant Shipping Association and, after much litigation and several appeals, the Ninth Circuit Court of Appeals held the regulations were pre-empted by the Clean Air Act.[6] Thus, while this on-again, off-again rule wound its way through the judicial system, shipowners were extraordinarily challenged with keeping track of compliance obligations. CARB has announced that it intends to redraft its regulations and to petition EPA and seek permission to develop its own standards.

These regulatory initiatives regarding ballast water management and air emissions from ships all require ship certification and detailed record-keeping—documentation that will certainly be scrutinized closely during port state control inspections. Thus, as these new regulatory requirements are finalized, they should be quickly incorporated into an ECP.

General Vessel Permits

The EPA issued a notice of proposed permit issuance for vessel general permits in June 2008 to cover a broad range of discharges incidental to the normal operation of vessels, such as ballast water, washdown, deck runoff, gray water, and bilge water.[7] If this EPA permitting regime is implemented, it will constitute a wholly new set of environmental compliance requirements. Vessel owners will be required to submit to EPA a notice of intent to be covered by the vessel general permit to maintain comprehensive records concerning permit compliance, and to routinely conduct the required inspections and monitoring.

STEPS TO CREATE OR REVISE AN ENVIRONMENTAL COMPLIANCE PLAN

A carefully crafted environmental compliance plan can reduce the risks associated with unlawful discharges from ships, including the risk of port-state control actions, criminal investigation, and prosecution. In addition, a properly fashioned plan can serve as a mechanism to enable a company to avail itself of the leniency provisions in the U.S. Coast Guard's voluntary disclosure policy (discussed below).

Many companies are under the impression that they already have an ECP in place, mistakenly believing that the safety management system meets these requirements or could with minor tweaks. It does not. The safety management system, however, is a fundamental building block to develop an ECP. It is imperative that a company invest the time and effort, including the advice of outside counsel, in developing its ECP to ensure it fits the company's operations and culture and meets all applicable regulatory requirements.

Review Current Policies, Procedures, and Practices

As an initial matter, a company should review and analyze relevant portions of its safety management system and other company guidance documents concerning environmental compliance. Second, the technical and operational parameters of pollution prevention equipment and monitoring systems should be reviewed with the assistance of a technical consultant. This should be followed by interviews of key personnel

with a significant role in environmental compliance practices at all levels of the company, including company officers, the ISM-designated person, and select chief engineers and port superintendents.

After garnering a good understanding of current practices, strengths, weaknesses, and perceptions, visit representative ships. During this time, the pollution prevention equipment and systems should be analyzed, along with the associated logs and records. Document review should also include selected inspection reports,

An environmental compliance plan must incorporate detailed procedures to ensure the proper maintenance, repair, and operation of a ship's oily water separator, as well as adequate monitoring and underway testing to ensure that the company's compliance policies are being followed. Photograph courtesy of Marlins™ 2007.

audits, and port state control inspections and detentions, as well as documentation of corrective actions.

Drafting the Environmental Compliance Plan

After the company's policies, procedures, and practices are well understood, both on paper and in real-life operations, the next steps would be to:

- establish procedures to quantify and characterize wastes from ships;
- establish procedures to minimize waste generation;
- review existing pollution control technology and maintenance protocols and assess the adequacy of each;
- review shipboard recordkeeping procedures;
- review monitoring and auditing procedures;
- confer with shoreside management to review budgetary practices;
- consider designating a shipboard environmental/compliance officer;
- review personnel practices to ensure they reward environmental compliance and penalize noncompliance;
- review/update training procedures and materials;
- identify procedures to foster internal reporting of environmental violations;
- identify procedures for prompt and appropriate tracking and correction of environmental violations, including sharing findings fleet-wide;
- specify procedures for when to engage counsel to investigate alleged violations so a well-founded determination can be made regarding reporting the violation to the flag administration and/or the U.S. Coast Guard under its policy.

After there is a solid understanding of company practices and procedures, and a good handle on what gaps remain and what holes need to be plugged, shoreside management and a technical consultant should review the draft ECP.

Developing an ECP that works for the company will require an iterative process. As a result, those involved in its development will already have an in-depth understanding of the requirements. The company then must develop a strategy for effective communication of management's priorities regarding environmental compliance. This generally involves the communication of a message that there will be "zero tolerance" for noncompliance with regulatory requirements or the environmental compliance plan.

Implementation, Review, Assessment, and Revision

There should be a formal and widespread roll-out within the company, making clear the company's expectations and delineating responsibilities. After the initial roll-out, a concerted effort will be required from senior management regarding their commitment to the success of the program.

An ECP is a living document. At the outset, it is recommended that plan evaluations be performed at six- and 12-month intervals to ensure that those responsible are on the right track and that the plan is being properly implemented. This would largely involve meeting with the shoreside environmental manager, technical consultant, select port engineers, and shipboard personnel to review implementation of the ECP and identify any areas that may need revisions.

RELATIONSHIP TO U.S. COAST GUARD POLICY

In November 2007, the U.S. Coast Guard issued its voluntary disclosure policy for environmental crimes cases. In summary, the policy states that if a vessel owner/operator has previously implemented a compliance management system (CMS) to prevent, detect, and correct environmental violations and if, nonetheless, a new vio-

lation is detected and voluntarily reported, the U.S. Coast Guard will evaluate the disclosure to ensure that it meets the conditions of the policy.[8] If the conditions are satisfied, the U.S. Coast Guard will not refer the matter to the DOJ for criminal prosecution.

It is important to understand that the compliance management system discussed in the voluntary disclosure policy is not a substitute for (or an alternative term) to describe an ECP. Compliance management systems are derived from the general corporate governance responsibilities of corporate officers and directors. An environmental CMS focuses on management's ongoing obligation to clarify the requirements of and ensure compliance with applicable environmental standards. It is an important complement to the operational and technical elements of an environmental compliance plan.

The policy highlights six elements deemed critical for a CMS:

(1) compliance policies and procedures that specify how shipboard employees and agents are to meet environmental standards;
(2) assignment of overall responsibility for overseeing compliance with environmental policies and standards, including those aboard each vessel;
(3) mechanisms for systematically ensuring that compliance policies are carried out, including monitoring and auditing systems;
(4) communication of the company's standards and procedures to all employees and agents;
(5) appropriate positive incentives to perform in accordance with compliance policies and disciplinary mechanisms for failures to adhere to those policies;
(6) procedures to correct violations and to modify the CMS to prevent future violations.

It is also important to note that a CMS alone, even if it tracks each of the critical elements contained in the voluntary disclosure policy, will not be sufficient to satisfy the requirements of the policy or the broader goal of improving environmental compliance. The compliance management system must be integrated with a comprehensive ECP that addresses operational and technical elements required to establish, monitor, and improve environmental compliance.

Once these individualized systems are developed, the vessel owner/operator should confirm that the six critical elements summarized in the policy are adequately and visibly incorporated into the CMS and that the management system itself is effectively integrated with the operational and technical components of the ECP.

Finally, there is one additional factor that is not explicitly addressed in the voluntary disclosure policy, but that should be woven throughout a company's CMS and underlying ECP—the process used to oversee and document all aspects of the ECP. Documentation facilitates communication of key compliance policies to employees and confirms the company's commitment to environmental compliance. Thorough documentation creates a transparency in the environmental activities of the company that enables management to assess performance capabilities, detect instances of noncompliance, and implement and track corrective actions. Additionally, should the need arise, careful documentation of prior compliance efforts also enables a company to demonstrate to regulators or enforcement officials its prior good-faith efforts to ensure compliance with environmental requirements.

Thus, while the voluntary disclosure policy outlines several factors the U.S. Coast Guard will use to assess a company's due diligence, the policy is only a starting point for the development of a comprehensive CMS and ECP.

About the authors:
Mr. Gregory F. Linsin has more than 25 years of experience as a federal prosecutor and concentrates his practice on environment criminal litigation and compliance counseling. He is a frequent author and speaker on environmental criminal and compliance issues and is a member of the Maritime Law Association and the American Bar Association section of environment, energy, and resources.

Ms. Jeanne M. Grasso focuses her practice on maritime, environmental, and transportation law for domestic and international clients. She regularly writes and speaks on criminal enforcement of environmental laws, Coast Guard regulatory matters, and maritime security, and is a guest lecturer at Massachusetts Maritime Academy's OPA 90 qualified individual training program. She is on the board of governors of the Propeller Club of Washington, D.C., the advisory board of the Smithsonian Environmental Research Center, and is president of the Women's International Shipping and Trading Association of the USA.

Endnotes:
1. Statistics provided by Elizabeth Janes, paralegal, Environmental Crimes Section, United States Department of Justice.
2. Federal Prosecution of Business Organizations, United States Attorneys' Manual, Title 9, Criminal Resource Manual 162.
3. Factors in Decisions on Criminal Prosecutions for Environmental Violations in the Context of Significant Voluntary Compliance or Disclosure Efforts by the Violator, Environment and Natural Resources Division, July 1, 1991.
4. United States Sentencing Guidelines, §8A1.2(b)(2)(D).
5. Northwest Environment Advocates v. U.S. E.P.A., 340 F.3d 853 (9th Cir. 2003).
6. Pacific Merchant Shipping Ass'n v. Goldstein, 517 F.3d 1108 (9th Cir. 2008).
7. http://edocket.access.gpo.gov/2008/pdf/E8-13615.pdf
8. Environmental Crimes: Voluntary Disclosure Policy, November 2007.

Modernization and its Effect on Hazardous Material Management

Reducing environmental risks.

by Mrs. Shelley Diedrich
Deputy, U.S. Coast Guard Logistics Transformation Program

MK3 Smith begins a scheduled maintenance task. Step 1: Clean starter.

"Hmmm ... There are five possibilities in the locker. Clean with what? Is it hazardous? Do I need gloves? Eye protection? Additional personal protective equipment?

What do I do with it when I'm finished?"

A typical cutter storage shed. USCG photo by LT Andrew Joca.

You may have heard about one of the Commandant's modernization efforts—implementing a single standard logistics business model—and are now wondering, "What does this mean for me?" While I would enjoy detailing all aspects of this important modernization effort, this discourse will focus on managing hazardous material, or HAZMAT.

HAZMAT Management

Although HAZMAT management is not our concentration at this time, one key feature of this standard logistics business model is its primary emphasis on unit support designed to deliver operational capability while managing life cycle costs and regulatory compliance. A HAZMAT management program is designed to increase productivity through better tracking for procedures, procurements, inventory, usage, and disposal. The U.S. Coast Guard aviation program has successfully used this model for many years.

For hazardous material management, this standard business model (policy, processes, IT, and organizational construct) provides important inherent safeguards. The model's configuration-based, maintenance-driven design promotes systematic control of hazardous material through the approved chemical list (ACL). The ACL process requires first consideration be given to those chemicals already in the USCG's inventory. Only when supported by requirements are new items introduced to the approved chemical list.

This process offers several benefits and safeguards, including:

- a reduced hazardous material inventory footprint;
- centralized management of required chemicals;
- reduced probability of non-compliance;
- chemicals qualified as "appropriate" by material/industrial specialists;
- posture is known for hazardous materials.

Since the model is configuration-based and maintenance-driven, we can develop extremely detailed operations and maintenance procedures that identify the specific chemicals required to operate and maintain each asset. This means that we can ascertain the breadth and depth of all hazardous material use. Once the hazardous material (with its associated quantity) has been defined, a hazardous material management (HAZMART) program can be established to push support to units.

Hazardous materials remediation. USCG photo by PA2 Lisa Hennings.

A Coast Guard pollution investigator inspects an oil barrel. USCG photo by PAC Donnie Brzuska.

Units will no longer have to individually establish relationships with other organizations to provide hazardous materials, nor will they be left to their own devices to determine an appropriate chemical. Cautions and warnings associated with the chemicals identified will appear on each maintenance procedure card, reducing the probability of mishaps and/or equipment failures due to material/chemical incompatibility. For example, one over-the-counter "green" cleaner deteriorates aluminum, which eventually induces system failure.

How soon before operational units will have access to centralized hazardous material capability? Probably by 2011. Surface asset maintenance procedures for legacy assets are being reworked today (asset type by asset type) with an estimated completion of FY10's first quarter. An analysis of existing hazardous material management practices and footprint will be initiated in FY09. This will be a six-month effort, including developing a plan of action and milestones to initiate a USCG-wide HAZMART program.

About the author:
Mrs. Shelley Diedrich has been a member of the U.S. Coast Guard civilian workforce for seven years, with 20 years of experience in program and logistics management as a civil servant with the Department of the Navy. Mrs. Diedrich has served as logistics manager for the vessel logistics system; team leader for the Business and Processes Analysis Branch; and most currently as deputy of the Logistics Transformation Program. She is a recipient of the Commandant's Bronze Medal.

Acknowledgment:
Special thanks to Dr. Kenneth B. Malmberg, who develops policy for the Clean Air Act, environmental awards, recycling, and intern programs in the Office of Environmental Management at USCG headquarters.

Creating a Culture of Preparedness

The International Oil Spill Conference.

by LT Kristen Preble
U.S. Coast Guard Office of Incident Management and Preparedness

The U.S. Coast Guard is continually challenged to ensure that the oil spill response community is prepared to respond effectively to oil spills. To address this challenge, we seek ways to coordinate preparedness efforts. One such way we facilitate this is through our leadership role and active participation in the triannual International Oil Spill Conference (IOSC).

History

The IOSC is jointly sponsored by industry, government, and non-government organizations and is considered the Americas' premier oil spill preparedness, prevention, and response conference, reflecting 39 years of global environmental progress. Since its inception in 1969, a total of 20 International Oil Spill Conferences have been held. The inaugural conference was held in New York in 1969 and was followed by biannual conferences in various coastal locations throughout the United States and Canada until 2005. In 2005, the IOSC moved to a triennial conference cycle in concert with Interspill and Spillcon—comparable international oil spill conferences hosted in Europe and Australia, respectively. IOSC 2008 reflected the new triennial conference cycle.

The International Oil Spill Conference contributes to and enables preparedness within the oil spill response community, the broader field of incident management, and society as a whole. It provides a forum for professionals from the international community, the private sector, government, and non-governmental organizations to highlight and discuss innovations, lessons learned, and best practices that encompass prevention, preparedness, response, and restoration.

Furthermore, by providing conference scholarships it encourages participation from countries still working to develop their marine environmental response programs. Each IOSC also hosts a subcommittee to work on a project that is of interest to the international community. For example, the outcome of the IOSC 2008 workshop subcommittee was an international guide for oil spill response capabilities assessment.

IOSC 2008

The theme of IOSC 2008 was "creating a culture of preparedness." This theme served as a reminder to the response community that preparedness is a critical component of any oil spill response. More than 2,000 people from over 80 countries were in attendance for the technical sessions and viewed more than 250 exhibits. The conference began with a series of short courses that ranged in topic from the basics of oil spill response to oil spill response techniques in the Arctic and the use of dispersants. These courses were followed by an on-water demonstration of oil spill response equipment. Such equipment included helicopter deployment of a buoy/probe for oil pollution evidence in the environment, unmanned aerial vehicles, and some of the most state-of-the-art booming equipment available today.

The conference was officially convened by keynote speakers John Chatterton and Richie Kohler, co-hosts

of The History Channel's "Deep Sea Detectives" television show. They provided insight into the dangers involved in deep-sea diving and how crucial experience and training is to any operation, regardless of the profession. This session was followed by 40 technical sessions that included 186 presentations held over three days. The most widely attended sessions were the "hot topic" sessions that addressed:

- the ins and outs of today's liquefied natural gas policy and environmental issues,
- the *Hebei Spirit* incident that occurred in the Republic of Korea on December 7, 2007,[1]
- the *Pemex KAB-121* incident that occurred on October 23, 2007 in the Gulf of Mexico,[2]
- the IOSC workshop panel that provided an in-depth discussion regarding the suite of planning and readiness assessment tools the workshop subcommittee developed.

Finally, in his closing speech, U.S. Coast Guard Commandant ADM Thad Allen highlighted the 40th anniversary of the National Oil and Hazardous Substance Contingency Plan and the importance of cooperation among all levels of government, the private sector, and non-government organizations.

Future of IOSC

The next IOSC will be held in 2011 and will be going "green." IOSC 2011's convening dates and location will be announced in late summer 2008 and the general committee is specifically looking for venues that will reduce the conference's environmental impact. The committee will also be analyzing its processes and products to eliminate waste.

Those interested in participating in the 2011 conference as authors, abstract reviewers, paper peer reviewers, or session chairs should regularly check the IOSC website, www.iosc.org, to receive conference updates and find the appropriate points of contact.

About the author:
LT Kristen Preble is currently assigned to the Sector Hampton Roads Contingency Planning Division. She was previously assigned to the Office of Incident Management and Preparedness at U.S. Coast Guard headquarters and to Coast Guard Cutter Hamilton. *LT Preble graduated from the U.S. Coast Guard Academy in 2003 with a B.S. in marine and environmental science.*

Endnotes:

1. On December 7, 2007, the *Hebei Spirit*, a tanker vessel laden with 1.8 million barrels of crude oil, was struck by the crane barge *Samsung No. 1* five miles off the coast of the Republic of Korea after a towing line parted. As a result of the collision, three of the five tanks aboard the *Hebei Spirit* were punctured, causing 2.7 million gallons of crude oil to spill overboard. This was the largest oil spill that the Republic of Korea had experienced, to date, and resulted in devastating environmental and economic effects.

2. In October 2007, the Usumacinta drilling rig was contracted by Petróleos Mexicanos (PEMEX) to drill a third well alongside a natural gas well and oil well (KAB-121) at the KAB-101 platform in Campeche Sound in the Gulf of Mexico. On October 23, 2007, the Usumacinta collided with the KAB-101 platform and ruptured KAB-101's production tree, resulting in a leak of oil and gas. PEMEX personnel were not able to completely seal the valves during the initial response, which allowed the wells to continually leak oil and gas. Over the following eight weeks, PEMEX worked to gain full control over the wells, which was finally accomplished on December 17, 2007. This incident resulted in 21 reported deaths that occurred during the evacuation of the Usumacinta, 210,000 gallons of unrecovered oil spilled, and two major fires.

The IOSC is sponsored by the U.S. Coast Guard and some of its key maritime partners, including:

- **the International Maritime Organization,**
- **the National Oceanic and Atmospheric Administration,**
- **the American Petroleum Institute,**
- **the Minerals Management Service,**
- **the United States Environmental Protection Agency,**
- **the International Petroleum Industry Environmental Conservation Association.**

The U.S. Coast Guard provides critical leadership to the IOSC as co-chair of the general committee and chair of the program committee.

Electronics Stewardship

"Greening" the U.S. Coast Guard computer lifecycle.

by LCDR Amy Bloyd
Standard Workstation Asset Manager
U.S. Coast Guard Office of Information Systems and Infrastructure

Like any other federal agency, the U.S. Coast Guard relies on an extensive network of computers to support all of its missions. This network of more than 40,000 computers allows the Coast Guard to enhance maritime safety, maritime security, national defense, maritime mobility, and the preservation of natural resources. Managing these computers in an environmentally sound manner is an important goal of the U.S. Coast Guard's information technology (IT) community.

In order to ensure the most cost-effective and environmentally sound management of computer resources, we take steps to "green" the entire lifecycle of U.S. Coast Guard computer resources. This lifecycle includes the procurement, operation, and disposition of all computers.

Gakona Public School in Valdez, Alaska, was the recipient of 23 used computers courtesy of the local Coast Guard Marine Safety Office. USCG photo.

Environmentally Responsible IT Procurement

In procuring computer resources, the U.S. Coast Guard not only looks for the best value and performance in equipment; it also uses available federal resources to ensure its computers are environmentally friendly. An important tool used to procure computers is the electronic product environmental assessment tool™ (EPEAT). This tool was sponsored by the Environmental Protection Agency and developed by a team comprised of industry experts.

EPEAT is an evaluation tool that allows purchasers to compare electronic products based on environmental attributes, including reduction and elimination of environmentally sensitive materials, design for end of life, lifecycle extension, energy conservation, and packaging. All computers that are provided to the U.S. Coast Guard on its current computer contract are EPEAT-registered, and any future contracts will continue to require EPEAT-registered products.[1]

Environmentally Friendly Operations

Not only does the U.S. Coast Guard seek to minimize the environmental impact of its computer resources in procurement, but it also takes steps to operate its systems in a manner

that is safe for the environment. One important aspect of environmentally friendly computer operation is to conserve as much energy as practicable. The Coast Guard uses computers that are Energy Star®-qualified. Energy Star® establishes efficiency requirements for all modes of a computer's operation, which enhances energy savings. Qualifying computers include an internal power supply that is at least 80 percent energy-efficient.[2]

In addition to conserving energy during the operation of its computer resources, the U.S. Coast Guard also maximizes the lifetime of these resources. We currently purchase a five-year warranty with all Coast Guard standard workstations. A longer computer lifetime leads to decreased waste production and saves money by decreasing the demand for new hardware.

Environmentally Aware Disposal

After a computer has reached the end of its useful life, we take several important steps to ensure that all computers are disposed of in an environmentally friendly manner. One way is to transfer the equipment to other federal agencies that might be able to put the equipment to use.

Yet another option for computer disposal is to donate the computers to a learning program. Using this option, the U.S. Coast Guard can donate used computers to a variety of educational institutions throughout the country. Finally, if the systems are not suitable for donation to either schools or other federal offices, the U.S. Coast Guard transfers the equipment to local defense reutilization marketing offices, where the equipment is sold, donated, or disposed of in accordance with federal environmental regulations.

A Greener Lifecycle

By managing all elements of the computer lifecycle with an emphasis on environmental protection, the U.S. Coast Guard not only enhances its dedication to the environment, but also saves money by conserving energy and limiting turnover in its computer inventory. Because of this careful lifecycle management, the U.S. Coast Guard can take its environmental protection mission from the nation's coasts and waterways to its offices around the nation and the world.

Coast Guard watchstanders in the First District command center. All Coast Guard missions rely on computer support. USCG photo.

About the author:

LCDR Amy Bloyd has served in the U.S. Coast Guard for 11 years. A 1997 U.S. Coast Guard Academy graduate, she has served as a deck watch officer aboard a high-endurance cutter, a strategic intelligence analyst for the U.S. Coast Guard intelligence coordination center, and the deputy group commander of USCG Group Lower Mississippi River in Memphis, Tenn.

Endnotes:

1. Office of the Federal Environmental Executive, "Answers to Frequent Questions: EPEAT and the FEC."
2. Green Electronics Council, "EPEAT Ratchets Up."

Going Green Reaps Rewards

The Coast Guard recognizes industry's marine environmental protection efforts.

by LT Jarrod DeWitz
Vessel Response Plan Team
U.S. Coast Guard Headquarters Office of Vessel Activities

The William M. Benkert Award was created nearly 14 years ago, when our nation was still recovering from the environmental impact caused by the 1989 *Exxon Valdez* oil spill off the Alaskan coast. Following that devastating marine casualty, Congress enacted the Oil Pollution Act of 1990, which amended old and implemented many new requirements for the tanker community.

In addition to adhering to these obligatory regulations, the maritime industry independently made dramatic pollution prevention policy improvements in operations, maintenance, cargo handling, waste management, and training. As the primary regulating entity for the maritime community, the Coast Guard felt that it was necessary to recognize these outstanding efforts in marine environmental protection.

William M. Benkert

RADM William "Mike" Benkert was considered by many to be the father of the U.S. Coast Guard's marine safety program. While serving as the office chief of marine environmental systems, RADM Benkert initiated many of the programs we have in the prevention department today. He field-tested the then-new small passenger vessel regulations in 1960, which had a significant impact on small passenger community implementation and enforcement. In the late 1960s, when new legislation for fire safety standards went into effect, RADM Benkert expertly balanced the needs of public safety with industry push-back and ultimately satisfied both parties with patience and educational awareness.

Next, he moved on to work with the Federal Water Pollution Control Act, where he guided its major reorganization and expansion in 1972. As an avid U.S. Coast Guard voice on the international floor, he ensured that the 1974 Safety of Life at Sea convention was aligned with the needs of the U.S. Coast Guard. In a 1994 *Proceedings* article, the author wrote, "His ideals foreshadowed the environmental protection philosophy embodied in OPA 90."[1]

2008 Award Recipients

The 2008 Benkert Award presentations were held during the American Petroleum Institute (API) Tanker Conference.
This year's awards were presented by USCG Commandant Thad Allen.

Osprey
Dow Chemical, Freeport, Texas

Gold
Alaska Chadux, Anchorage, Ark.
Foss Maritime Company, Seattle, Wash.

Silver
U.S. Shipping Partners, Edison, N.J.
American Commercial Lines, Jeffersonville, Ind.
Marathon Petroleum Company LLC, Nashville, Tenn.

Bronze
APL Maritime, Ltd., Bethesda, Md. (Large Facility)
APL Maritime, Ltd., Oakland, Calif. (Large Vessel)
Marathon Petroleum, Ashland, Ky.

Honorable Mention
Todd Shipyard, Seattle, Wash.
SeaRiver Maritime Inc., Houston, Texas

RADM William M. Benkert Award

The Benkert Award is possibly the most sought-after environmental award in the maritime industry. This prestigious award recognizes outstanding achievements that extend far beyond mere compliance with industrial and regulatory standards. More than just a symbol of excellence, the award provides an avenue for creative exchanges of ideas and innovations that benefit both the industry and the public. This award also provides a system for measuring and assessing an organization's management strengths and weaknesses in environmental protection.

Ideally, participants will seek to institute additional procedures that will far exceed the minimum compliance standards of environmental laws. A platform is provided for applicants to discuss current policy where shared initiatives are to be expected. Above all, the U.S. Coast Guard hopes to increase industry and public awareness of the importance of protecting our marine environment and its delicate ecosystem.

Eligibility Details

Any marine transportation-related commercial organization owning, operating, or otherwise managing vessels, facilities, or fleeting areas; oil spill removal organizations; or other entities engaged in maritime operations are eligible to apply. There are six categories in which a company may submit an application. These categories are used to compare each company within its operation type during the initial application review. All applications will compete against each other during the second phase of the application review to select an overall winner. The categories are:

- **small business - vessel operations**
  less than 50 employees
  headquarters in the United States
- **small business - facility operations**
  less than 50 employees
  located in the United States
  regulated under 33 CFR 126.05 or 33 CFR 154.105
- **special small business**
  less than 25 employees
  located in the United States
  maritime transportation-related entity
- **large business - vessel operations**
  50 employees or greater
  headquarters in the United States
- **large business - facility operations**
  50 employees or greater
  located in the United States
  regulated under 33 CFR 126.05 or 33 CFR 154.105
- **foreign vessels**
  250 full-time employees or greater
  must have at least one foreign-flagged vessel over 1,600 gross tons and have conducted commerce at a U.S. port during the given award period

An application package should contain information on environmental achievements and activities that demonstrate the applicant's commitment and accomplishments for the two previous calendar years (or one award cycle). Organizations will be evaluated on:

- environmental policies, objectives, and targets;
- pollution prevention, preparedness, response, and safety management;
- environmental outreach;
- partnerships;
- performance measures and results.

Partnerships

The U.S. Coast Guard is proud to partner with the American Petroleum Institute (API) in this program. API has hosted the Benkert Award presentations during the last several award ceremonies and plans to continue its support of this award. API also provides senior event staff to assist with coordinating the Benkert Award presentations during its bi-annual tanker conference.

Although this event was originally geared toward the tanker community, it has expanded to include many important topics that cross all of the maritime industry.

The award program has three levels of recognition—gold, silver, and bronze. If an organization exceeds all review criteria expectations, then an "Osprey" is awarded as the top prize. The program is capable of recognizing multiple recipients at any or all of these levels.

The application submission deadline is February 1 every "even" year. The selection process concludes April 1, and the informal notification is expected in May of the award year. Award presentations are held in June. For more information, go to http://homeport.uscg.mil/benkert.

About the author:
LT Jarrod DeWitz is a marine inspector with five years of experience. He served one tour at Sector Miami, and he is currently on his second tour at Coast Guard headquarters in the Office of Domestic Vessel Compliance. Currently, he works in the Vessel Response Plan Program as the nontank vessel response plan specialist. He's also the program representative for the high-visibility nontank vessel response plan regulation implementation efforts.

Endnote:

[1] LTJG Pamela Zearfoss, "The legacy lives on … RADM 'Mike' Benkert," Proceedings of the Marine Safety Council, May-June 1994.

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Greener Oil Spill Response Operations

Ways to make less of a mess when cleaning one up.

by LT Kelly Dietrich
U.S. Coast Guard Office of Incident Management and Preparedness
Oil and Hazardous Substance Division

When marine oil spills occur, government and private sector response officials cooperate to minimize the environmental impact to the spill area. Typically the objectives for on-water operations include preventing oil or debris from migrating to the shore, removing oil from the water, and minimizing overall environmental intrusion.

Ironically, cleanup operations themselves can generate waste and environmental impact, such as:

- contaminated sorbents used in the containment/collection effort,
- contaminated personal protective equipment,
- floating trash that comes into contact with oil.

Waste Makes Waste

It is the responsibility of all responders to minimize environmental impact in the most cost-efficient manner possible. Objectives for minimizing net environmental impact should include reducing the amount of solid waste from boom and sorbents, reducing the amount of liquid waste from decontamination and on-water recovery, reusing cleanup equipment and resources, and recycling recovered oil.

Waste segregation. The "mixture" rule[1] states that any mixture of solid and hazardous waste must be considered hazardous waste, unless:

- the mixture doesn't have hazardous characteristics.
- discharge conforms to the Clean Water Act.

On-site example of excessive use of soft boom during a waterfront remediation project. Once discovered, the USCG assisted contractors toward creating a static hard boom containment procedure that required a minimal amount of soft boom to direct recovery operations. USCG photo by MST1 Joshua Doud.

- the mixture contains discarded commercial chemical products from de-minimis losses during manufacture.

Consciously keeping different waste types separated during a response can ensure that response actions minimize the amount of hazardous waste, and careful management of waste streams can increase the opportunity to recycle and/or reuse materials.

Example of the potentially excessive use of pads during a response to a hydraulic leak from a booming vessel during cruise ship bunkering operations. USCG photo by MK1 Joe Poma.

Decanting. The idea behind decanting is to separate oily water collected by skimming or other methods using the chemical properties of the oil. The oily water is left in a tank to separate. Water is then removed from the bottom until only the oil layer remains. This method greatly reduces the volume of liquid that requires treatment, which reduces the fuel needed to transport and incinerate it.

solid waste volume is reduced, this option can increase the liquid waste volume.

Personal protective equipment. Human health and safety is the number one priority during any spill response. Personal protective equipment (PPE)[2] may include one-time-use suits, gloves, booties, and eye protection, and can account for a majority of the waste at many oil spills. This is especially evident where shoreline cleanups take place.

Although health and safety specialists conduct hazard assessments to determine the appropriate level of PPE, many responders have a "more is better" mentality. When additional PPE is not actually necessary to provide protection, it may cause more environmental damage in the long run.

Beach clean-up. When oil hits the shoreline, all of the trash and organic material that comes into contact with it must be treated as hazardous waste. Picking up trash on beaches before the oil can migrate there reduces the total amount of hazardous waste. National Oceanic and Atmospheric Administration (NOAA) trajectories can help target which beaches to clean by providing an idea of which beaches have the highest potential to become "oiled."

How Clean Is Clean?

In the past, responders would squeeze oil from sorbent materials and reuse them until they fell apart. However, experience has shown that the amount of labor involved in transporting and squeezing the sorbents outweighs the benefits of reusing. This also increases responders' exposure and chances for injury. The trend lately has been to dispose of these materials by incineration.

Waste Generation During Oil Spill Response and Typical End Points

Activity	Waste Type	Waste Description	Product End Point
Decontaminating Containment Boom	Liquid	Oil/water mixture	Decantation and incineration
Skimming	Liquid	Waste water	Incineration
Using Sorbent Pads	Solid	Hazardous material	Incineration
Solidifiers	Solid	Solid	Landfill
Personal Protective Equipment	Solid	Gloves, protective suits, shoe covers	Landfill or incineration
Dispersant	Smaller oil particles	Unrecoverable oil particles	Water column / biodegradation
In-situ Burning	Smoke & Solid Residue	Combustion by-products (solid and fugitive particulates)	Atmosphere
Picking up Oiled Debris	Solid	Oiled vegetation and trash	Disposal as hazardous waste
Decontaminating Watercraft	Liquid	Contaminated water from washing oil from the hulls	Decantation and incineration
Cleaning Oiled Wildlife	Liquid	Soap/oil/water mixture	Collect and treat as hazardous waste

All generated wastes require follow-up treatment, storage, or disposal.

Reducing and reusing sorbents and booms. Sorbents and booms float at the surface and are made of material that attracts oil. These materials are very convenient and are almost certainly overused in the urgency of the moment. It takes discipline and understanding to decide how much sorbent to put in the water.

Another option is to use hard boom for collecting oil. This option does not work as quickly as sorbents but is still effective. Hard boom is designed for reuse but requires decontamination (with water). So although the

Reprocessing, incinerating, and recycling recovered oil. Liquid-recovered oil is not easy to reprocess, given the large amount of debris that is usually entrained in it. Some refineries can process recovered oil, provided they

Coast Guard Pacific and Atlantic Strike Team members watch as other responders apply oil-lifting chemicals to oiled rocks. Three areas were surrounded by containment boom and used to test two chemicals. This helps to determine the most effective, environmentally friendly method to supplement ongoing response efforts. USCG photograph by Petty Officer 2nd Class Andrew Kendrick.

have a way to remove debris, but usually only do so if the spill involves them or it occurs on their property. Even when this occurs, solid wastes must be incinerated or disposed of in a hazardous waste site. Recovered oil can also be incinerated, but the process must utilize a high BTU rate and the oil must contain no contaminants.

Another option is to send recovered oil to a waste recycling facility. This costs between 25 cents to a dollar a gallon, depending on how much contamination (solids, debris, water, etc.) the recovered product contains.

Dispersants, in-situ burning, bioremediation. Dispersants are chemicals applied directly to the spilled oil to remove it from the water surface. The idea is to break down the oil into small enough particles that they are diluted into the water column and are biodegraded easier. This method has been controversial because it involves adding chemicals into the environment. With in-situ burning, the tradeoff is that the contamination moves into the air in the form of particulates and smoke. Bioremediation uses micro-organisms to break down the oil through natural processes. This can take a very long time, and its effectiveness is still being studied.

Influencing Change

Over the past 20 years, the response community has not yet focused an effort to address decontamination and disposal options. However, some responders have made independent changes in technology and response methods which have had a small positive impact.

There are always new developments being researched for oil spill response operations in general. As pointed out in the incident specific preparedness review of a recent oil spill response in San Francisco, Calif., some programs require "best achievable technology" in response operations. Under this paradigm, success is measured by the ability to recover oil, not by waste control capability.

This leaves out the motivation for incorporating waste control. Putting a focus on all aspects of oil spill response technology and methods into established research and development programs may lead to greater influence on the net environmental impact.

Some ideas for specifically developing a way forward in waste control include:

- Programs can provide added motivation by providing monetary benefits. For example, one idea from industry was for every pound of waste recycled, a dollar is taken off the fine for spilling.
- Oil response contractors can share technology and methods for minimizing net environmental impact.
- Responsible parties and on-scene coordinators can emphasize waste reduction capabilities when choosing response options and objectives.
- Safety officers can ensure an appropriate level of protection in a way that minimizes waste.
- Determining "how clean is clean" can take into account the waste generated in balance with the recoverability of the remaining oil in the environment.

There's More Than One Way to Soak up Oil

There are other variations on sorbents that are designed to reduce environmental impact. One example was reported during a recent oil spill response.

Volunteer responders used more than 1,000 mats made from hair to pick up the oil that washed up on shore. These mats are designed so that after they are oiled, oyster mushrooms can be grown on them, turning the mats into nontoxic compost.

About the author:
LT Kelly Dietrich has served in the Coast Guard Reserves for eight years, with six on active duty supporting contingency planning and marine environmental response at four units prior to assignment at USCG headquarters. She is an industrial hygienist as a civilian and earned a master's in environment science from the Medical University of South Carolina.

Acknowledgments:
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1. See Resource Conservation and Recovery Act.
2. The Occupational Safety and Health Administration 29 CFR 1910.120(q) and applicable state laws require responders to wear PPE based on their expected exposure to hazardous substances.

Marine Debris

Solutions to a persistent problem.

by Mr. David Major
U.S. Coast Guard Environmental Standards Division

In 2007, the *Cosco Busan* oil spill in San Francisco Bay soiled a vast area and killed thousands of animals.[1] Public concern and significant media attention galvanized the recovery efforts of federal, state, and local agencies; nonprofit organizations; and Bay Area fishermen. In the wake of the spill, policy makers are looking to the lessons learned and developing strategies to better serve the marine environment.

Beyond spills, oil plays another significant role in marine pollution: oil is the raw material used to construct plastics, the major persistent debris problem in the ocean environment. Like oil spills, marine debris is known to harm marine animals and degrade the quality of American beaches.

Unlike oil spills, marine debris is usually not connected with a single, tangible event, and the lack of a unifying focal point for this form of environmental degradation may be the reason for the lack of media attention in the past decades.

As a compliance and enforcement agency, the U.S. Coast Guard regulates items that may become marine debris. Beyond this regulatory role, the U.S. Coast Guard provides support and leadership for a variety of anti-marine debris activities.

Persistent Materials

Depending on context, the term "marine debris" may encompass a wide variety of man-made items that persist in the marine environment. While shipwrecks and other artifacts indicate that man-made items are already present in the marine environment, the social and technical changes of modern times have added a new dimension to the marine debris problem.

A seal is entangled in marine debris. Photo courtesy of the National Oceanic and Atmospheric Administration.

Replacing natural fibers with synthetic fibers has exacerbated the marine debris problem. Fishing nets, for example, used to be made with natural materials such as cotton, hemp, or flax. Modern nets are typically made of synthetic materials and have numerous advantages: They are stronger and more durable than their predecessors, since they are impervious to photo-, mechanical, and biodegradation. In addition to resisting decay, modern nets are more likely than their natural counterparts to maintain positive buoyancy.

Coast Guard Seaman Bryan Grebe works to offload a mountain of fishnet from the Coast Guard Cutter *Walnut*. The *Walnut* and NOAA vessel *Townsend Cromwell* joined efforts to remove marine debris from Lisianski Island, Pearl and Hermes Reefs, and Midway Atoll in the Northwest Hawaiian Islands. USCG photo by PA3 Jacquelyn Zettles.

Increased use of persistent materials on land, such as product packaging, has the power to severely impact the marine environment. Since the 1960s widespread consumer use of persistent, single-use beverage containers, such as aluminum cans and plastic bottles, took hold in the U.S. Today, the "individual retail package" is a common sight on the shores of many American beaches.

In the case of consumer plastics, the advances in durability of synthetic fibers combined with a lifestyle based on throwaway goods can also create a significant threat to the marine environment. In fact, plastic straws, beverage bottles, and bags are the most commonly found marine debris items in the national marine debris monitoring program study.[2]

Plastic is also a key part of products many consumers would not associate with the persistent material—cigarette butts, for example. Given the widespread use of plastic products in the economy, it is unsurprising that the resin pellets, the raw units of plastic production, also find their way into the marine environment. From their first reported appearance on U.S. shores in the 1970s, the plastics industry's pellets had become one of the most commonly found items in American harbors by 1993, according to the EPA.[3]

Transportation of Marine Debris

Marine debris can enter the marine environment through a variety of vectors. Land-based debris may enter the marine environment as a result of:

- urban runoff,
- sewer overflow,
- inadequate garbage management,
- industrial activities,
- terrestrial dumping and littering activities.

Sea-based vectors include cruise ships, cargo ships, recreational boats, fishing vessels, and platforms.

One unique problem with marine debris prevention stems from the ocean's ability to move and circulate the debris. The combination of ocean currents and atmospheric winds can transport debris across great distances. It can also retain and concentrate items for later deposition.

Nets and other fishing gear may come from fisheries far from the marine ecosystem that suffers the impact; more than 80 percent of the northwest Hawaiian Islands' recovered derelict gear comes from seine or trawl fisheries operating hundreds or even thousands of miles away from the islands.[4] Furthermore, derelict fishing gear may circulate for years in areas like the North Pacific.

The Environmental Toll

Persistent items play a significant role in the degradation of the marine environment. As the result of human introduction, these items can injure and kill marine species. The negative effect is suffered not only by animals, but also by humans who interact with these coastal resources.

Marine debris is known to cause mortality among marine species. Even after being lost or discarded, fishing gear can continue to kill fish in a process known as "ghost fishing." In some cases, catch rates achieved by ghost nets can approach active gear rates.[5] Ghost nets can also entrap and kill species that were never intended to be netted. In 2003, the endangered Hawaiian monk seal had one of the highest entanglement rates of any seal worldwide.[6]

Items that were never intended to enter the marine environment have the potential to harm marine species when ingested. Seabirds may mistake fragments of plastic such as styrofoam products and bottle caps for

food. This may cause intestinal blockages or reduction in the absorption of nutrients. Small plastic pellets, including those from disintegration of plastic as well as those derived from industrial loss, may be mistaken for planktonic organisms and consumed.[7]

The large ratio of small plastic pieces to plankton in the environment is not just a risk to birds; filter-feeding organisms may be unable to distinguish between debris and plankton. Once ingested by these smaller marine animals, plastic accumulates within the marine food chain.[8]

Marine debris degrades all types of marine habitats. Derelict nets can become entangled with coral reefs and, as a result of natural wave movement, break off coral heads. Medical waste on beaches may make shorelines unusable; beaches were closed in New Jersey during the late 1980s due to the presence of potentially hazardous debris items.[9]

Coast Guard Activities to Prevent Marine Debris

The U.S. Coast Guard combats marine pollution by regulating the at-sea discharge of vessel-generated waste under the authority of the Act to Prevent Pollution from Ships. The discharge of plastic is prohibited and minimum discharge distances from land have been established for other types of garbage. For areas designated as "special areas" even greater restrictions exist.[10]

On larger vessels, Coast Guard regulations require records covering:

- the type of discharge operation,
- the date and time of the operation,
- the location of the discharge,
- the amount of garbage involved and when discharging at sea,
- the type of material discharged.

Certain vessels over 40 feet must maintain a written document that provides for compliance with Annex V of MARPOL 73/78 and U.S. law, including a description of procedures for collecting, processing, storing, and discharging garbage. Placarding is required for the smallest class of vessels.[11]

To ensure that garbage does not enter the marine environment at the port, the Coast Guard regulates reception facilities. Ports and terminals must comply with MARPOL Annex V under the criteria established for reception facilities for garbage in 33 C.F.R. Subpart D. For the larger ports and terminals, operation is conditioned upon meeting the requirements of a Coast Guard-issued certificate of adequacy.

Members of the Coast Guard cutter *Walnut* offload marine debris at Coast Guard Integrated Support Command, Honolulu. The debris was collected from the Papahanāumokuākea Marine National Monument during a multi-agency removal effort. USCG photo by Petty Officer 3rd Class Michael De Nyse.

The Coast Guard also ensures compliance with U.S. regulations related to marine environmental protection through inspections and boardings. In fulfillment of MARPOL Annex V obligations, the U.S. Coast Guard inspects U.S. commercial vessels annually and examines foreign vessels through the port state control program. For recreational and commercial fishing vessels that are not required by law to be inspected, boardings (such as domestic fisheries protection, marine sanctuaries protection, and random "at-sea" boardings) allow the Coast Guard to ensure environmental compliance.

Annual facility inspections and harbor patrol spot checks ensure compliance among reception facilities. When a vessel is found to have violated regulations, we may issue written warnings, impose monetary civil penalties, and, for the most serious instances, refer the case to the Department of Justice for criminal prosecution or civil ju-

dicial enforcement action. Many pollution violation penalties are imposed through the U.S. Coast Guard's notice of violation process, which in essence allows the U.S. Coast Guard to write tickets for violations.

As the head of the United States delegation to the International Maritime Organization (IMO), the Coast Guard plays an important role in maintaining high international standards on marine pollution. The IMO is the lead international organization that develops the regulatory framework for the shipping industry. Its multi-national decisions form the basis of member-state marine pollution enforcement regimes, including port state inspections, self-reporting, and recordkeeping.

Beyond Regulation: Finding Solutions to a Persistent Problem

During discussions at a Coast Guard-sponsored meeting in Irvine, Calif., marine industry members highlighted the strides they have taken to minimize waste. Some cruise ships have voluntarily developed advanced programs for waste minimization and waste stream management. One practical example is using beverage containers without plastic rings.

Concerned civic organizations in Southern California recently banded together to promote a "Day Without a Bag." Stores donated reusable bags and offered discounts and rebates to reusable bag users. Twenty-two local governments designated December 20, 2007 as a "Day Without a Bag." These efforts spread awareness of the link between consumer activity and marine debris.

Shippers are developing and promoting a "code of best practice" to prevent the loss of containers. For example, Maersk and Germanischer Lloyd have combined forces to investigate the potential causes of container loss.[12] Through the International Standards Organization, the U.S. Coast Guard works with its industry counterparts to develop an industry-initiated shipboard garbage standard.

Through the "Sea Partners" campaign, U.S. Coast Guard and Coast Guard Auxiliary personnel educate the maritime industry and boating public on pollution issues via public education classes, vessel safety checks, voluntary commercial vessel exams, public marine events, and annual pollution prevention conferences. Through school visits and educational materials, the

The Plastic Bag

The marine debris story may best be told by the ubiquitous plastic bag. This synthetic item has proliferated both in the marketplace and the marine environment. Beyond its fragmentation into smaller, yet still dangerous pieces, plastic bags persist in the ocean and perpetrate pervasive environmental damage.

Although only introduced in the last 25 years, plastic bags have captured at least 80 percent of the grocery and convenience store market. Its ascendancy is attributable to key design features as well as cost—a plastic bag is 25 percent the price of a paper bag. The low cost of plastic bags allows for their large-scale production and use, resulting in the worldwide use of at least 500 billion bags a year.[1]

These plastic bags may enter the marine environment by a multitude of vectors. In many instances, consumer plastic items enter the marine environment from land-based areas (urban runoff). Plastic bags can also enter the marine environment from a marine source. In the case of *United States v. Cook*, the Department of Justice successfully prosecuted a mariner for the dumping of asbestos–filled plastic bags.

Plastic bags can be found in the marine environment from Spitsbergen 78° North [latitude] to Falklands 51° South [latitude].[2] Due to lower temperatures and the ocean's shielding from UVB radiation, plastic bags will degrade at an even slower rate than on land; it is likely that even "biodegradable" plastic bags will persist in the marine environment.[3]

In the marine environment, plastic bags have a particularly insidious effect due to their resemblance to jellyfish and squid. Marine vertebrates may ingest these items, which they have mistaken for prey. In 1995, it was discovered that bags were the most common plastic item ingested by green, loggerhead, leatherback, hawksbill, and Kemp's Ridley sea turtles.[4] This can obstruct the esophagus or perforate the bowels of a turtle. Intake of plastic is one of the main non-natural causes of death for sea turtles.[5]

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"Officer Snook" program communicates Sea Partners' marine pollution mission to children.

Looking Forward

Within this persistent problem, the Coast Guard has authority over a mere fragment of items that might be considered marine debris. However, it is fitting that the solution to a problem composed of small persistent fragments is found in the aggregate effect of small contributions to marine debris prevention and reduction.

Through its traditional regulatory authorities, the U.S. Coast Guard can continue to limit the amount of persistent items entering the environment from sea-based sources. As a partnering organization, it can cooperate with international counterparts to prevent the deposition of debris beyond U.S. jurisdiction; work with government agencies to develop a policy that will reduce marine debris; remove items that pose significant harm to the environment; and assist industry to develop strategies that exceed legal obligations, especially in regard to garbage handling and source reduction.

Most importantly, the U.S. Coast Guard can educate a concerned public about the dangers of marine pollution and their ability, as individuals, to ensure that marine debris will become less pervasive.

Picking up the Trash

Beyond the scope of traditional missions, the U.S. Coast Guard uses its assets to reduce the amount of debris in the marine environment. One of the nation's most significant marine debris removal projects is the northwest Hawaiian Island partnership in the Papahānaumokuākea Marine National Monument.

To aid the partnership, the U.S. Coast Guard provides platforms and personnel on an "as-available" basis to support marine debris removal operations. Over the course of the partnership's history, Coast Guard buoy tenders and NOAA (National Oceanic and Atmospheric Administration) vessels have recovered more than 563 tons of marine debris.

In 2008, CGC *Walnut* assisted in the recovery of over 28 tons of debris. On various occasions, Coast Guard aviation has provided aircraft to transport Coast Guard, NOAA, and other agency personnel to conduct land-based marine debris removal.

In the aftermath of Hurricane Katrina, the Coast Guard worked to remove debris from the waterways of Louisiana, Mississippi, and Alabama.

About the author:

Mr. David Major currently serves as an environmental advisor in the U.S. Coast Guard Environmental Standards Division; his work includes representing the Coast Guard at the Interagency Marine Debris Coordinating Committee. He is a member of the California Bar and a former Coast Guard Reserve port state control officer.

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Lounging on the Deep Green Sea

Cruise line efforts in environmental stewardship.

by Mr. Steve Collins
Director of Environmental and Health Programs
Cruise Lines International Association, Inc.

Cruise ship life is a wonder unto itself, with waiters walking among poolside lounge chairs, delivering passengers frozen drinks with names like "Coco Loco" and "Bahama Breeze" on a warm Caribbean afternoon. The nearly all-day buffet overflows with goodies prepared by famous chefs, surrounded by carved fruit and ice sculptures. The sumptuous meals, the spotless cabins, and the world-class entertainment—all at sea while the vessel steams to the next port on the itinerary—are hallmarks of the cruise vacation.


The *Norwegian Dawn* sails past the Statue of Liberty. Photo courtesy of Norwegian Cruise Line.

What most people suspect, but don't really get a chance to see (employee spaces are off-limits to guests), is that the vessel is also world-class below decks. Cruise ships have adopted efficient environmental technology and best management practices to prevent water and air pollution.

Environmental Efforts

Cruise ships were some of the first in the industry to work with municipalities in Alaska and California to develop shore power connections at berth, allowing a vessel to shut down its engines and eliminate air emissions from the vessel. Other vessels are test platforms for ballast water treatment systems, more efficient lighting, and plasma arc gasification (a waste incineration process).

Cruise lines also work with equipment manufacturers to reduce emissions of nitrogen oxides, sulfur oxides, and particulate matter through in-engine technology and exhaust gas scrubbers. Many vessels are equipped with advanced waste water treatment systems to treat black (sewage) and gray water and turn it into clear, clean, effluent water.

Waste Management

As one might expect, cruise ships generate large amounts of waste, but it is not volume that constitutes or prevents pollution, it is the strength or failure of waste management practices and procedures. A cruise ship is, after all, a ship, and waste from engineering spaces has been managed ever since the addition of engines. But a cruise ship is also a resort, and the hotel and restaurant waste, black water, gray water, incinerator ash, paper and plastic, food waste, glass and cans, and special waste (including hazardous waste) must also be properly managed.

A barge takes on recycling materials from a cruise ship in Vancouver, B.C., Canada. Photo courtesy of Mr. Steve Collins, CLIA.

Cruise Lines International Association, Inc. (CLIA) cruise lines meet not only U.S. and international MARPOL Annex V standards for discharge of solid waste, but also have enacted proactive strategies such as waste minimization, source reduction, incineration, and recycling to reduce solid waste. CLIA members outperform Annex V requirements in that they do not discharge any bulk packaging materials, cardboard, paper, etc. Crushed cans are recycled, as is the majority of glass. Managing these wastes includes several options:

- landing them ashore to an approved disposal facility (much like you handle household waste),
- grinding and screening them for disposal to the sea (mostly food waste),
- sorting and combusting them in an incinerator,
- reusing them,
- sorting and compacting them for recycling.

Reduce

Cruise ships continually analyze where waste is generated and work with vendors to reduce the amount of waste coming aboard using a process called waste minimization. This process has been used to reduce waste from flower deliveries to salon products and continues to be one of the more effective means to reduce waste aboard.

The process has also been used to reduce toxicity of chemical products. One company removed 99 products[1] from its inventory, replacing them with more environmentally (and crew-) friendly products. Also, buying bulk concentrates and using dispensing stations reduces the number and volume of bottles of prepared products coming aboard. Reusing spray bottles and refilling them at the dispensing stations saves even more.

Reuse, Recycle

Today's port facilities can recycle aluminum cans, tin, glass, cardboard, white paper, photo copier cartridges, plastics, photo waste, cooking oil, carpet, paints and thinners, batteries, and even electronics. The list of recycling options grows as technological advances make recovery of the raw materials within these items possible.

One challenge for a vessel with a finite amount of storage space is deciding where to put items awaiting recycling. For example, cooking oil and glass from beer and wine bottles are stored in cold rooms to keep them from attracting pests. Most other recyclables will take up enormous amounts of space, but ships typically compact them into palette-sized bundles that can be stacked and easily landed ashore.

Ships are also unique in that they can land some wastes to the dock and others to a barge, opening recycling opportunities to both land- and sea-based companies. Some ships have taken storage one step further and designed special totes and bags, allowing them to manage large volumes while recovering the container, combining both recycling and reuse.

Other examples of waste management practices aboard cruise ships:

- Plastic pails from items such as laundry soap are cleaned and landed or reused aboard for things such as tote buckets for tools or to collect spent batteries for recycling.
- Dining room food wastes are separated by the wait staff and other crewmembers in the galley. Paper and plastics are channeled to different receptacles and wet food is transferred to pulpers (systems similar to residential garbage disposals) that grind up the waste, allowing for more efficient removal of water. The excess water is recycled through the food slurry line and is ultimately discharged as gray water. The "dried" food waste is often burned in the incinerator.
- Virtually all stateroom, bar, retail store, or venue trash is hand-sorted by housekeeping or other staff, separating all recyclable materials (from camera batteries to luggage tags) into labeled containers, with the remainder landed ashore or incinerated. Discarded items are separated and (if still in usable or repairable condition) are often cleaned and repaired and set aside for charities.

We're All in This Together

After waste minimization, recycling and reuse are excellent options for many items that would normally become waste. Reuse often takes more thought (and, admittedly, more work) but there are opportunities for those willing to champion the cause. Recycling reduces the demand for raw materials, which also reduces the need for energy in processing and transportation.

Cruise line organizations often work with environmental organizations to identify waste management opportunities, particularly when developing new cruise destinations, to ensure the cruise vessel leaves the smallest possible environmental footprint while maximizing the opportunity for best practices and protection of biodiversity and fragile ecosystems.

So when you hear the words "Coco Loco" at the pool, you can rest assured that your vacation will be like no other, remaining one of the most environmentally friendly means to enjoy a number of destination ports.

An Innovative Solution

We are all familiar with aluminum six-pack soda cans available at the grocery store that come on a cardboard box, wrapped in more plastic. Deliveries to cruise ships used to be similar, but also included yards of plastic shrink wrap to hold about four dozen cases on a pallet. It used to take workers hours to restock a vending machine because they needed to remove each soda can from the plastic wrap, cardboard flat, and plastic ring one at a time. Once removed, the vessel had a colossal amount of waste to manage.

One waste minimization process focused on the wrap, the plastic six-pack holders, and cardboard and asked how these could be reduced. It turned out that the soda manufacturers were also asking how they could reduce their costs, so the obvious net benefit to both was to eliminate the plastic six-pack holders. Replacing the cardboard was a much more difficult process, since the manufacturer needed to develop a reusable flat and also needed to develop a reverse distribution system, so that the flat could be returned and refilled at the factory.

Today, many vessels receive deliveries of aluminum drink cans on returnable flats (some that fold flat for easier storage) without disposable plastics, thus eliminating three wastes and making it possible for vending staff to restock a vending machine in half the time, with no residual waste.

About the author:
Mr. Steve Collins, certified hazardous material manager and former U.S. Coast Guard lieutenant, combines his Coast Guard, U.C. Berkeley, Yellowstone National Park, and Royal Caribbean Cruises Ltd. experience to provide CLIA member lines with perspective and strategic approaches to cruise industry environmental and medical issues.

Endnote:

1. Royal Caribbean Cruises Ltd. "Environmental Report 2000," Id, 2000, p. 22.

Environmental officer Malcolm Barry, right, prepares waste for landing ashore. Photo courtesy of Mr. Steve Collins, CLIA.

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Sustainability—the Good, the Bad, and the Green

by Mr. Dan Yates
President
Portland Spirit Dinner Cruises

Portland Spirit Dinner Cruises operates five vessels and conducts more than 2,000 cruises annually. In our operations, we try to maintain procedures and practices that reinforce the "green" thinking of the Northwest. In early 2007, TravelPortland, our local convention and tourism association, informed its membership that business referrals would be made only to those members who met their specific environmental standards. All local companies were given until the end of 2007 to comply. Since we receive a substantial amount of business from TravelPortland referrals, we made it a priority to meet their sustainability goal.

What is sustainability? Sustainability has to do with reducing your impact on the planet by recycling, using alternative energy, being "carbon neutral," composting, using recycled products, buying local products, using mass transit, and not shaving (OK, I made that one up).

While some elements of sustainability are common sense, there are also some that are controversial. I will attempt to give you an "on the ground view" of these issues as they relate to our dinner boat company. Some of my conclusions are unconventional; each individual needs to determine his or her own company or personal involvement in the sustainability concept.

THE "GOOD" OF SUSTAINABILITY

After an extensive review of all qualified certification programs that TravelPortland recognized, we felt most were impractical for us due to the bias toward land-based operations like hotels and restaurants. We eventually selected the RecycleWorks Program, which is administrated by the city of Portland's Office of Sustainability, as it had requirements that were general enough to include vessel operations in its criteria.

We then set up a "green team" comprised of volunteers from every department in the company. The team was assisted by a city of Portland employee from the Office of Sustainability, who was invaluable in providing advice. We developed a list of green practices/actions, and a budget to meet those needs.

A Bump in the Road

During this process, we discovered—to our dismay—that our existing paper recycling containers were actually being dumped into the general trash, even though we separated it in our office. There was apparent confusion with our trash collector; he had not provided us the correct containers for paper waste when we moved locations eight years prior. We generate a lot of paper in our business and it was disturbing to find out that we were not doing one of the "basics" of sustainability!

With paper recycling corrected, and feeling reinvigorated, we looked for more ways to reduce paper usage and get more products into the recycling waste stream. For example, our main photocopier/printer generates about 500,000 copies per year, so we worked to use the double-sided function and have changed the habit of

"I need a hard copy as a backup to the computer back up." This has reduced paper usage by about 20 percent.

Back on Course

Annually, we print about 200,000 brochures and 800,000 maps. This year we switched to recycled paper. There is a cost increase, but it seems the right thing to do. We opted to go for the FSC (Forest Service Council) grade of recycled paper. The FSC logo certifies that the paper comes from well-managed forests, controlled sources, and recycled wood or fiber. The increase was about 2.5 percent of total print costs, for a total of $3,000 additional cost.

In our office break room we would use about 10 rolls of paper towels per month. One of our green team members volunteered to bring in 50 cloth/cotton napkins and to take them home to be washed if we eliminated the paper towels. We made the switch, and it was so successful that we have instituted a rotation in the office for washing the napkins.

Every computer location companywide has a paper recycling bin next to it, and we keep them full. The savings from using less paper has allowed us to absorb the nominally increased cost of using FSC paper in our daily products, which was formerly not a budgetary consideration.

Another simple project was to acquire and replace, as needed, light bulbs with extra-long-life power savers. We are only installing the bulbs as the old style burn out, and only in areas where the light is not turned on and off more than a couple of times per day. This is a slow process, but we decided that it would be wasteful to replace all the old-style bulbs while they were still useful. We also have an aggressive "turn out the light" program in place to reduce power usage. Another easy project was collecting scrap metal for recycling. In the past year, we have sold this scrap metal for about $2,000.

Food Waste

We have always recycled cardboard, glass, and engine oil, but were missing a huge opportunity with waste food products. About fifty percent of a conventional restaurant waste stream is food product. On a daily basis, we were filling our garbage containers with food scraps.

We were wary of composting onsite due to rodent control and odor issues. Initially, we explored using some locally created composting technology that our state government was promoting. Their proposal was a custom-made box with a series of trays housing about 200,000 hungry exotic earthworms. It appeared promising, but our investigation revealed that we would need approximately 10 boxes, and that the worms would need to be replaced when the temperature drops below 40 degrees. The area required to handle our volume of waste was too great for us to dedicate, and the expense of replacing worms was excessive.

Our solution was to get a dedicated four-yard dumpster dedicated to food waste. We initially thought we would purchase special compost plastic bags to transfer the waste from the boats to the compost dumpster. Unfortunately, the bags in question are quite expensive. Part of any sustainability program is to look for a simple solution, and we selected five-gallon buckets over the bags. Food scraps are loaded directly into the buckets and then hauled by electric cart to the compost dumpster. The buckets are then washed out and returned to service for the next cruise. We did have several days of over-85-degree temperatures, and we avoided the odor issue by placing the dumpster downwind.

Changing our buying habits for chemicals, cleaning products, and solvents was a bit more difficult. We researched and found many products that work efficiently and are cost-effective. The challenge was to continue purchasing the acceptable products while identifying more acceptable options. We now purchase

The *Crystal Dolphin* burns conventional diesel instead of ethanol-based biodiesel, waiting for a more sustainable version to make it to the market. Photo courtesy of Portland Spirit Dinner Cruises.

cleaning products by the 42-gallon barrel and refill cleaning containers, instead of disposing hand-held containers after their first use.

Carbon Offsets

We began offering "carbon offsets" for our customers. The way carbon offset works is pretty simple in principle, but more difficult to put into action: A person decides he wants to spend money (self-taxing) on programs that will compensate for the carbon impact he is creating with his onboard event. Carbon offsets are not difficult to calculate for your engines, but it is a process that can be overwhelming if you are too detail-oriented. If you want to calculate the carbon impact for all the food, linen, labor, transportation to and from the vessel, your share of the construction of the vessel, and water for an event you can get overwhelmed.

We wanted to provide our clients an average carbon impact for their ride on our boat. Our dilemma was to determine the carbon impact, on average, when we offer 10 different cruises that run from two hours to 10 hours in length, with some offering food and others sightseeing only. We also had to make the system easy to use and ensure that the money was specifically directed to carbon offsets.

The cost we eventually arrived at was $ .25 per operating hour and $ .50 per person in the group. For public cruises it was a flat $1 per person. Once you figure out your carbon footprint and its associated cost, then you need to know where to direct the money. We did a great deal of research to find an organization that collected the money and actually directed it toward carbon reducing activities. We went to our local congressman for advice and were directed to an organization that had a solid track record of investing in wind power with carbon offsets. The only problem? The organization was in Europe and I wanted the money to stay in the United States. After more research, we found an organization in Oregon, and we now direct our clients to forward their carbon offset purchases to ClimateTrust.org.

Sustainable Menu

In a similar vein to carbon offsets we have created organic, sustainable menus. A sustainable menu means that the food was grown locally and created the least carbon impact on the earth due to reduced transportation costs. Organic means it was grown without chemical fertilizer, pesticides, or growth hormones, and was not genetically modified. Organic for fish means it was not farm-raised and was caught in the wild.

There are some considerations with these types of menus. The cost of organic and wild food is much higher, and can often be of lesser quality. By quality, I mean more fruit is bruised and vegetables are spotted. Americans have come to expect their food to be perfect in appearance and are willing to sacrifice flavor for visual perfection. The lack of pesticides affect production, and the products sent to markets don't look as good. Additionally, smaller yields per acre, coupled with a higher spoilage rate and shorter shelf life, adds up to a higher product cost.

Another issue with a sustainable food supply is that it is much more seasonal. Americans are accustomed to their food wants being satisfied year-round, which requires us to source food from around the world. The additional cost for producing this type of product can be absorbed by individual families, but when an organization needs to feed 300 people and the organic menu is $10 more per person, the incremental cost becomes significant enough to move people to conventionally grown food. To date, we have never had a group purchase an organic and/or sustainable menu.

On the Boats

The ideas above can be executed in almost any restaurant or office environment. We also evaluated what we could do from the marine side of our business. Over the last three years we began replacing all our diesel engines with the latest technology. We started this program when one vessel needed new engines. The newest engines come with electronic control systems that provide the necessary information to allow a captain the option to reduce RPMs and determine the reduction of fuel usage. The fuel savings between a 20-year-old engine and new technology motivated us to speed up our engine modernization programs. We have completely replaced the propulsion systems in four of our five boats. The last boat to modernize is about 10 years from justifying new engines. On our jet boat, the new diesel saved us so much fuel we were able to eliminate the fueling stop at the midway point on its 10-hour cruise. This saves us a $45 service charge daily and about $1 per gallon since we no longer have to fuel in a remote location.

Several years ago we started to experiment with lube oil purifiers. At first, we were careful to send the lube oil for testing at every 150-200 hour mark, as required by the manufacturer. In the past we would change out gallons of lube oil every 150-200 hours. But after a couple of years of testing we have found that the purifiers work great, and instead we are getting about 1,000

hours between change-outs. This has saved thousands of dollars in lube oil and labor. We now have lube oil purifiers installed on every diesel in our fleet.

We have always recycled our lube oil and recently we started to recycle our lube oil filters, as well. A new service now offered is recycling fuel oil filters. The cost of recycling all our filters is about $200 per year. This is a small price to pay to keep them out of landfills.

We have been frustrated with fogging windows in our flagship the M/V *Portland Spirit*, a 600-passenger dinner vessel. The windows were 1988 single-pane windows with lightweight aluminum frames. We have been concerned that vessel movement would break double-paned window seals. After a few unsuccessful experiments with local glass vendors, we were directed to a company that specialized in skyscraper windows. After a six-month experiment, we were pleased with the new window technology and have installed more than 80 windows at $1,000 each. The fogging issue is gone, and the added bonus is that we also get substantial energy savings on both air conditioning and heating. The windows are so efficient that we have instituted a replacement program on the other three dinner boats.

When we had all the requirements in place for certification for the RecycleWorks program, we had to be audited by the city's Department of Sustainable Development. It was a painless yet professional review of our processes for maintaining our current program standards. In August of 2007 we were issued our membership into RecycleWorks.

THE "BAD" OF SUSTAINABILITY

This is not a discussion of the validity of global warming or global climate change. I believe one can work toward many sustainability goals without taking a position on global issues. There are elements of conventional sustainability that we have not adopted and our opposition should be explained.

In my opinion, using corn-based ethanol is a mistake that should not be supported. There are three main concerns with corn-based ethanol. First, we cannot plant enough corn to replace our dependence on oil. One acre of land planted with corn may produce about 20 gallons of fuel per year. The U.S. uses over 400 million gallons of oil daily.[1] The math is simple: We cannot plant our way out of this problem.

Secondly, land planted with corn sheds tons of nitrogen into surrounding waterways. The nitrogen kills off sea life. The nitrogen plume around the mouth of Mississippi was slowly growing, and now that we have ramped up corn production, the plume of dead seawater is growing by miles each year.[2]

The last issue is that food prices have exploded worldwide with the increase in energy cost, and diverting any part of the agricultural farming away from food has contributed to increased costs in food.

Solar power was made very popular in Oregon due to the creation of a large tax credit by our local government and the generous federal credit. Combining all the tax credits, about 90 percent of the total cost of the project would be available for tax credit. We just researched installing solar power for our office building. A $500,000 investment would reduce our electric bill by about 30 percent. Since our electric bill is about $1,000 per month, at $300 per month savings, we would have a more than 30-year payback when maintenance and repairs costs are figured in. At present, we have opted out of pursuing solar power until the cost becomes more competitive.

THE "GREEN" OF SUSTAINABILITY

All our hard work turning the company green was recognized in April of 2008, when the *Portland Spirit* was awarded the first-ever Governor of Oregon Tourism Sustainability Award. Oregon prides itself in being a state on the cutting edge of developing sustainable practices and this mantra has infected all local government activities.

Our move into a leadership position on sustainability was not planned, but it did not just happen by accident, either. In May 2008, we won a large charter from a Fortune 500 company that chose us over our competitors because of our aggressive green program. Two years ago, the *Portland Spirit* organization did not worry about sustainability and didn't understand how it figured into our company's mission. Two years ago, we didn't even know what sustainability was supposed to be or mean. Despite our relative newness to the game, it is our hope to continue to be a leader in the green movement within our industry.

About the author:
Dan Yates has been the president of Portland Spirit Dinner Cruises and its five vessels since its start-up in 1994. Under his leadership the business won the first Governor of Oregon Sustainability Award in 2008. Mr. Yates has an MBA from the University of Virginia and was a U.S. Navy officer for nine years.

Endnotes:
1. http://journeytoforever.org/biodiesel_yield
2. http://www.ens.newswire.com/ens/jul-2008/2008-07-15.asp

The Care and Handling of Liquefied Natural Gas

Back by popular demand: ***Chemical of the Quarter.***

In response to reader requests, we're reviving this feature, with a new focus—you. We'll be taking a look at chemicals from the mariner's perspective, answering the questions:

• What is it? • Why should I care? • What's the Coast Guard doing about it?

Let us know what you think: www.uscg.mil/proceedings; click on "Your opinion."

by Dr. Alan Schneider
U.S. Coast Guard Office of Operating and Environmental Standards

What is it?

Natural gas is a flammable gas that we use to heat our homes, cook our food, and make electricity. It may, in the future, also power our cars. It is made up of over 90 percent methane. The United States no longer produces enough natural gas to meet our needs, so we import it as liquefied natural gas (LNG) in tank ships from countries thousands of miles away.

How is it shipped?

LNG's main component, methane, is the lightest of the hydrocarbons. It has only one carbon. LPG (liquefied petroleum gas), or "bottled gas," is a heavier gas that can be liquefied under pressure or by refrigeration. Gasoline is heavier still, containing between 5-12 carbons, and is a liquid at room temperature.

Natural gas must be converted into a liquid before you can put it on a ship. If you didn't, you'd need 600 ships to carry the same amount as a gas!

By its nature, natural gas cannot be liquefied by compressing it—no matter how much you compress it. It must be cooled to below its boiling point (-258°F) before it can be placed in ships' cargo holds as liquefied natural gas.

Why should I care?

➤ *Shipping concerns*

Engineers design LNG tank ships with special metals and materials placed where LNG makes contact with parts of the ship (cargo tanks, pumps, piping). They do this because LNG is so cold that it will immediately crack ordinary steels—like the ship's deck—so precautions to prevent spills onto the ship's deck need to be followed. For example, whenever you make or break a line you need to put a drip pan made of a material that is not brittle at LNG temperatures underneath. Aluminum makes a great drip pan.

➤ *Health concerns*

As noted, LNG is extremely cold, and will freeze and kill skin (in other words, give you frostbite) if you get even a small amount on you. Additionally, LNG is an asphyxiation concern in unventilated areas; as it vaporizes, it pushes air out of the space. Great care needs to be taken when entering an area containing LNG that does not receive air exchanges on a timely basis.

➤ *Fire or explosion concerns*

LNG is very flammable. If spilled on water, it will quickly boil off and form a potentially flammable vapor cloud. If it catches fire (on land or water), it will rapidly burn with a tall, hot flame.

Does that mean that an LNG ship is a "floating bomb"? No. LNG won't burn unless it is a vapor, and only then if it is diluted to between five and 15 percent LNG vapor in air. LNG does not explode, even if it catches fire.

What's the Coast Guard doing about it?

LNG's safety record is excellent, due to the high safety standards that have been implemented throughout the industry. The Coast Guard normally escorts LNG carriers in and around ports and also routinely creates a restricted area around moving LNG tank ships and shoreside terminals.

About the author:
Dr. Schneider is a chemical engineer who has worked in hazardous materials and fire protection in the Coast Guard for the past 35 years. He currently works in such diverse areas as developing domestic and foreign bulk cargo classification, chemical compatibility, chemical databases such as the chemical hazards response information systems, weapons of mass destruction, liquefied natural gas, and hazardous spill response.

Chemical of the Quarter

Greenwater

The future of sewage regulations, equipment design, and testing.

by LT Rob Griffiths
U.S. Coast Guard Office of Design and Engineering Standards

Mr. Matthew D. MacGregor
Executive Director
TEi-Testing Services

Commander Stephen P. Markle, USN (Ret.), P.E.
Engineering Director
Navalis Environmental Systems

Recent changes to international regulations that govern discharge of ships' sewage into the sea have left many people wondering if the United States will formally adopt the new standards and, if it does, how such action might impact the industry at large. Vessel owners and operators, shipyards, and boat builders; manufacturers of marine sanitation devices and sewage treatment plants; and the independent laboratories that test such equipment are all concerned about the status of MARPOL Annex IV in the United States.

While it may be too soon to predict when or even if the United States will ratify the sewage annex, everyone involved can agree that a clear understanding of both U.S. and international sewage regulations is necessary to avoid running afoul of the enforcement authorities both here and abroad.

Sewage regulations can easily be broken down into three discrete categories covering vessels, equipment, and testing facilities. These regulations can then be placed into one of three different scenarios:

- a U.S.-flagged vessel on an international voyage,
- a U.S.-flagged vessel on a U.S. voyage,
- a non-U.S.-flagged vessel on a U.S. voyage.

These regulations affect nearly all types of vessels, from the larger inspected vessels that carry passengers and cargo, to the smaller uninspected vessels that tow ships and barges, to even private vessels such as yachts and recreational vessels. In essence, any vessel with an installed toilet may be subject to these requirements.

Aerobic digestion of sewage waste by biological device. Courtesy TEi-Testing Services.

U.S. Sewage Regulations and Related Policies

For a U.S.-flagged vessel on a U.S. voyage, existing sewage regulations covering the vessel, its equipment, and related testing requirements can be found in 33 CFR Part 159. These regulations have not changed much since they were first introduced in 1975, with the exception of those for the cruise ship industry operating in certain Alaskan waters.[1]

Inspected vessels with an installed marine sanitation device (MSD) are examined by the U.S. Coast Guard during annual and five-year certificate of inspection renewals. Uninspected vessels (which include recreational vessels) with an installed MSD are checked periodically to ensure the device is in operable condi-

tion to the satisfaction of a Coast Guard boarding officer. Equipment is subject to design approval to verify it meets the requirements of 33 CFR Part 159 (or an equivalency) and then undergoes testing, evaluation, and inspection by an independent laboratory under simulated operating conditions. Equipment manufactured in the United States meeting both U.S. and international requirements may be eligible for a certificate of type approval. Finally, testing facilities that meet the requirements of independent laboratory testing standards in 46 CFR 159.010-3 are issued a U.S. Coast Guard letter of acceptance.

Oxidation/Reduction MSD. Courtesy Navalis Environmental Systems.

For a U.S.-flagged vessel on an international voyage, sewage regulations covering the vessel, its equipment, and related testing requirements can also be found in 33 CFR Part 159 with a concomitant equivalency made to MARPOL Annex IV by MOC policy letter 03-03. In this case, the U.S. Coast Guard issues a certificate of equivalency to a U.S.-flagged vessel on an international voyage having an installed and operational MSD. Uninspected vessels over 400 gross tons are issued a certificate every five years, endorsed annually during the IOPP (international oil pollution prevention) survey, or can receive a statement of voluntary compliance from their classification society. Inspected vessels over 400 gross tons and those of less than 400 gross tons carrying 15 or more passengers may be issued a certificate every five years, endorsed annually. This is true for all but small passenger vessels (i.e., 46 CFR Subchapter T and K), which receive an endorsement on their certificate of inspection every five years, endorsed annually. Equipment and testing requirements are similar to those detailed above for a U.S. vessel on a U.S. voyage.

For a non-U.S. vessel on a U.S. voyage, sewage regulations can be found in the prior MARPOL Annex IV with an equivalency made to 33 CFR Part 159 by Navigation and Vessel Inspection Circular No. 9-82, Change 1. In this case, the U.S. Coast Guard verifies the vessel's certificate of type test during a port state control examination.

Revised International Sewage Regulations

In 2004, the Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO) adopted and reissued the revised MARPOL Annex IV in resolution MEPC.115(51), resulting in several key changes to the international sewage regulations:

- Inspection criteria were enhanced to include onboard surveys of installed sewage systems prior to being placed into service and periodically throughout the life of the vessel.
- Standards for discharging treated sewage (i.e., effluent) into the water were enhanced and made more stringent.
- Equipment testing procedures were standardized.
- Discharge rates for untreated sewage were established.

The IMO adopted MEPC.115(51) on April 1, 2004, and is applicable to new ships on international voyages with a keel laid date on or after September 27, 2003, or delivered on or after September 27, 2006, and existing ships after September 27, 2008, that are 400 gross tons and above or that are certified to carry more than 15 persons. The term "person" is defined here to include both passengers and crew. Annex IV requires ships that engage in international voyages to be equipped with one of the following: a sewage treatment plant; a sewage comminuting and disinfecting system with holding tank, or a sewage holding tank.

Under Annex IV, the discharge of sewage into the sea is prohibited except when:

Mobile testing laboratory for compliance testing. Courtesy TEi-Testing Services.

ment plants for new ships with a keel laid date on or after January 1, 2010, and for existing ships having plants installed or delivered on or after January 1, 2010. Existing ships having sewage treatment plants installed or delivered prior to that date may continue to use either the 1976 international effluent standards contained in MEPC.2(VI) or other applicable national specifications (e.g., 33 CFR Part 159).

Finally, on October 13, 2006, resolution MEPC.157(55) adopted a standard for the maximum rate of discharge of untreated sewage in holding tanks at a distance equal to or greater than 12 nautical miles from the nearest land.

- The ship has in operation an approved sewage treatment plant.
- The ship is discharging comminuted and disinfected sewage using an approved system at a distance of more than three nautical miles from the nearest land.
- The ship is discharging sewage that is not comminuted or disinfected (untreated) at a distance of more than 12 nautical miles from the nearest land.

The term "sewage" includes drainage and other wastes from toilets and urinals; drainage from medical spaces including wash basins, wash tubs, and scuppers located in such spaces; drainage from spaces containing live animals; and other waste water, when mixed with any of these drainages.

Additionally, on October 13, 2006, resolution MEPC.159(55) adopted the revised effluent standards and performance tests that are applicable to new installations of sewage treat-

Prior Equivalency

Considering the recent changes to MARPOL Annex IV, it may well be that the prior equivalency afforded U.S.-flagged vessels on international voyages has been all but

COMPARISON OF SEWAGE REGULATIONS

Table 1. U.S. Vessel on U.S. Voyage

	U.S. Regulations & Policy	MARPOL Annex IV
Vessel	Inspected vessel MSD examined during annual and 5-year renewals of COI, and checked for compliance with 46 CFR Subchapter F & J. Uninspected vessel MSD must be in operable condition to the satisfaction of the USCG boarding officer.	N/A
Equipment	**MSD Design Approval:** USCG approves MSD design that meets requirements or equivalency in 33 CFR Part 159. **MSD Certification:** USCG issues *Certification Number* to manufacturer following evaluation/testing at *Recognized Facility* under simulated operating conditions in 33CFR159 for MSD to either *all vessels* or *uninspected vessels*. Label required.[1] USCG adds MSD to *Approved Equipment List*. **Foreign MSD Manufacturer:** USCG issues *Letter of Certification* to foreign manufacturer that meets above MSD criteria. **Sewage Treatment Plant:** USCG issues *Certificate of Type Approval* to U.S. manufacturers that comply with both MARPOL Annex IV and above MSD criteria.	N/A
Facility	**Recognized Facility:** USCG issues *Letter of Acceptance* to *Recognized Facility* that meets requirements of *Independent Laboratory* testing standards in 46CFR159.010-3. **Classification Society** may apply for and be accepted by USCG as *Recognized Facility* that meets requirements of *Independent Laboratory* testing standards in 46CFR159.010-3.	N/A

[1] Type III MSD used for storage of sewage/flushwater at ambient air pressure/temperature has no certification number/label under 33CFR159.12a; inspected vessels comply with 46CFR Subchapters F & J.

COMPARISON OF SEWAGE REGULATIONS

Table 2. U.S. Vessel on International Voyage

	U.S. Regulations & Policy	MARPOL Annex IV
Vessel	USCG issues *Certificate of Equivalency* to U.S. vessel with installed/operational MSD on international voyage: • **Uninspected Vessel** >400GT every 5 years, endorsed annually at IOPP survey; or *Statement of Voluntary Compliance* issued by class; ≤400GT no program in place. • **Inspected Vessel** >400GT and <400GT carrying 15 or more passengers, every 5 years, endorsed annually, except **Small Passenger Vessel** (Subchapters T & K) receive endorsement on COI, every 5 years, endorsed annually as per MOC Policy Ltr 03-03.	*International Sewage Pollution Prevention Certificate* issued/renewed by Administration (or authorized entity) after onboard Survey described in MEPC.115(51) at: • Initial installation; • Renewal every 5 years; • Repair to all vessels on international voyages: • ≥400GT • <400GT w/ >15 *persons* (i.e., passengers & crew) that are applicable to: • **New Vessels**: Keel laid on/after 27Sept2003 or Delivered on/after 27Sept2006; • **Existing Vessels**: on/after 27Sept2008. Vessels <400GT w/ ≤15 persons shall establish *appropriate measures* per Administration.
Equipment	**MSD Design Approval**: USCG approves MSD design that meets requirements *or equivalency* in 33 CFR Part 159. **MSD Certification**: USCG issues *Certification Number* to manufacturer following evaluation/testing at *Recognized Facility* under simulated operating conditions in 33CFR159 for MSD on either *all vessels* or *uninspected vessels*. Label required.[1] USCG adds MSD to *Approved Equipment List*. **Foreign MSD Manufacturer**: USCG issues *Letter of Certification* to foreign manufacturer that meets above MSD criteria. **Sewage Treatment Plant**: USCG issues *Certificate of Type Approval* to U.S. manufacturers that comply with both MARPOL Annex IV and above MSD criteria.	**9.1.1 Sewage Treatment Plant**: *Certificate of Type Approval* issued by Administration to manufacturer following full-scale testing using actual operating conditions of effluent & performance standards in MEPC.159(55) and environmental standards in MEPC.107(49); applicable to equipment installed or delivered on or after 01Jan2010. **Existing Vessels**: *Acceptable* to use *national specifications* in lieu of effluent/performance standards in MEPC.159(55). **9.1.2 Commissioning & Disinfecting System** and **9.1.3 Holding Tank** are not issued *Certificate of Type Approval* but may be issued *International Sewage Pollution Prevention Certificate* if they meet MARPOL Annex IV.
Facility	**Recognized Facility**: USCG issues *Letter of Acceptance* to *Recognized Facility* that meets requirements of *Independent Laboratory* testing standards in 46CFR159.010-3. **Classification Society** may apply for and be accepted by USCG as *Recognized Facility* that meets requirements of *Independent Laboratory* testing standards in 46CFR159.010-3.	**Qualified Testing Facility**: Testing facility is *Qualified* by Administration to assure uniformity among various testing facilities; effective for all vessels 01Jan2010. **Sewage Reception Facility**: Government provides adequate facilities at port and terminals for reception of sewage from holding tank used by Commissioning & Disinfection System 9.1.2 or holding tank 9.1.3.

[1] Type III MSD used for storage of sewage/flushwater at ambient air pressure/temperature has no certification number/label under 33CFR159.12a; inspected vessels comply with 46CFR Subchapters F & J.

COMPARISON OF SEWAGE REGULATIONS

Table 3. Non-U.S. Vessel on U.S. Voyage

	U.S. Regulations & Policy	MARPOL Annex IV
Vessel	USCG verifies *Certificate of Type Test* issued to foreign flagged vessels by their Administration during Port State Control boardings, accepted by policy in NVIC 9-82 Ch-1.	*International Sewage Pollution Prevention Certificate* issued/renewed by Administration (or authorized entity) after onboard Survey described in MEPC.115(51) at: • Initial installation; • Renewal every 5 years; • Repair to all vessels on international voyages: • ≥400GT • <400GT w/ >15 *persons* (i.e., passengers & crew) that are applicable to: • **New Vessels**: Keel laid on/after 27Sept2003 or Delivered on/after 27Sept2006; • **Existing Vessels**: on/after 27Sept2008. Vessels <400GT w/ ≤15 persons shall establish *appropriate measures* per Administration.
Equipment	N/A	**9.1.1 Sewage Treatment Plant**: *Certificate of Type Approval* issued by Administration to manufacturer following full-scale testing using actual operating conditions of effluent & performance standards in MEPC.159(55) and environmental standards in MEPC.107(49); applicable to equipment installed or delivered on or after 01Jan2010. **Existing Vessels**: *Acceptable* to use *national specifications* in lieu of effluent/performance standards in MEPC.159(55). **9.1.2 Commissioning & Disinfecting System** and **9.1.3 Holding Tank** are not issued *Certificate of Type Approval* but may be issued *International Sewage Pollution Prevention Certificate* if they meet MARPOL Annex IV.
Facility	N/A	**Qualified Testing Facility**: Testing facility is *Qualified* by Administration to assure uniformity among various testing facilities; effective for all vessels 01Jan2010. **Sewage Reception Facility**: Government provides adequate facilities at port and terminals for reception of sewage from holding tank used by Commissioning & Disinfection System 9.1.2 and holding tank 9.1.3.

eliminated. The effluent standards alone in MPEC.2(VI), when compared to MEPC.159(55), are not only numerically different but also appear to be substantially different. See the comparison between the current sewage regulations and the revised international regulations in Tables 1, 2, and 3.

Equipment Design and Manufacturing

The design of a wastewater treatment system is fundamentally the same for both land- and marine-based systems. Most successful designs follow a rule of thumb by first removing that which settles and that which floats, and then treat the remaining 95 percent of liquid, referred to as "mixed liquor." At this point, roughly 90 percent of the treatment challenge has already been accomplished, leaving the dissolved and suspended material for subsequent processing. It is therefore useful to break down the regulatory requirements into functional system requirements in order to meet the discharge standards. These requirements exist as six discrete functions, as depicted in Figure 1.

While land-based sewage treatment systems have incorporated these steps in a variety of ways, only recently has regulatory action required the manufacturers of marine systems to consider such functional requirements. For example, sludge or bioresidue is the byproduct of those systems that produce the highest-quality effluent. Management has typically been to dump it at sea where permitted, bring it ashore, or with limited success, incinerate it onboard. However, for those systems that treat to a less stringent standard, the effluent is typically discharged overboard either as part of the process or where legally permitted to do so.

Making the transition from functional requirements to engineering specifications requires a firm understanding of process chemistry as well as material standards. U.S. regulations offer several sections with robust design guidance. Similarly, ASTM standard F 2363-06, specification for United States Coast Guard type II, or IMO MARPOL 73/78 Annex IV marine sanitation devices (flow-through treatment) offers specific materials and testing requirements for these types of systems.

Today, most marine systems employ biologic activities that remove dissolved organic material. These systems employ bio-reactors that are exceptionally sensitive to influent loading from hydraulics and pollutants. Hydraulic loading is handled through equalization tanks and onboard flow management to ensure the system receives a fairly constant rate of influent. The more successful biological systems are coupled with chemical equalization to maintain constant nutrient loading. What is difficult to plan for are upsets caused by the introduction of cleaning and disinfecting products commonly used throughout the ship that harm the bacteria in the bio-reactor.

Modern biological systems can be grouped into one of three categories:

- systems that remove solids using dissolved air flotation and remove suspended solids by flocculation and mechanical means;
- systems having high concentrations of solids as measured by mixed liquor suspended solids using membrane technology to filter the water;
- systems that operate primarily on the principle of gravity-driven clarification, where gravity causes suspended matter to fall out, resulting in clarified material passing over a wall or weir and onto the next step, which is typically disinfection.

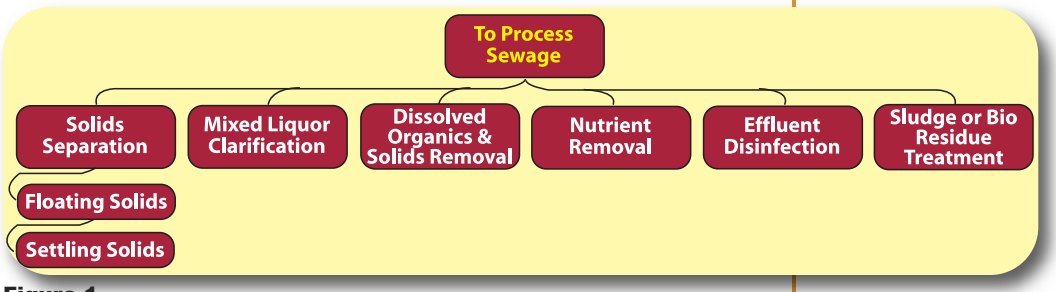

Figure 1.

When operated within strict guidelines, these systems generally produce excellent effluent, but are susceptible to periodic upset and require not only large quantities of air to maintain the bio-reactor but also large tanks. While most systems still employ chlorination disinfection, some have recently switched to ultraviolet (UV) light-based systems for this function. Although UV systems are very effective at disinfecting highly clarified water, biological treatment systems often produce effluent with color or turbidity that diminish the effectiveness of this technology.

Another marine system commonly used today is the physical/chemical type. These systems macerate incoming wastewater, then mix it with high concentrations of chlorine-containing compounds that are typically generated from seawater. These systems rely on chlorine to oxidize a fraction of the organic material and to disinfect. Many of these systems also introduce, as process water, the seawater that was used to generate the chlorine compounds. Some systems use 10 times the amount of process water compared to the amount of wastewater being treated and are typically found on smaller vessels where available space is at a premium. Increased effluent quality standards coming into force over the next several years will create serious challenges for smaller systems of this type, especially for residual chlorine content and removal of solids and nutrient material.

A third type of system has recently entered both the large and small ship markets, receiving USCG certification as a Type II MSD in January of 2008. This system is based on advanced oxidation to remove dissolved pollutants in wastewater. The trick here is to remove the particulate organic and inorganic material to offer the oxidizer an easier target. Solids are first screened, flocculated, filtered, and then ultra-filtered to produce a permeate with turbidity approaching one NTU (nephelometric turbidity unit). The permeate is then brought into contact with dissolved ozone gas in a stirring device where oxidation of dissolved material occurs. The ozonated water is then introduced into a high-power UV system that converts the residual ozone gas to a highly reactive oxygen species that further polishes the effluent. This process not only removes residual organic material, but is also highly

effective at disinfecting the effluent. Typical effluent values are below detection for suspended solids and fecal coliform, and average five-day biochemical oxygen demand is below five milligrams per liter.[2]

Subsequent system development has led to an ozone-based sludge management system that reduces the volume of organic solids through oxidation but increases the settleability of solids, thus allowing a higher-content sludge that is partially disinfected and mineralized. These systems are now being adapted to marine use, having already proven themselves in land-based sewage treatment systems as well as graywater reuse applications.

The future of reusing water aboard ships looks promising. In the previously mentioned system, blackwater consisting of sewage and galley water can be treated in a system separate from graywater. By separating out the water in laundry and hotel accommodations, treatment becomes greatly simplified and produces an effluent that is suitable for reuse aboard the ship as technical water. Treated water[3] can be readily used in a ship's laundry, for engineroom technical water, as a source for fuel oil emulsification for engine oxides of nitrogen reduction, or for deck washdown and the like. With the ability to treat upwards of 80 percent of shipboard domestic wastewater, future systems may eventually lead to reduced fuel consumption from water generation, storage, and transport. Perhaps we can have smaller ship sizes, given reduced requirements for tankage, and even reduced operational costs through lower maintenance of water management technology.

Compliance Testing

Initial qualification testing evaluates mechanical and electrical performance as well as effluent processing. The mechanical and electrical performance requirements are based on a device's ability to withstand the rigors of the marine environment such as corrosion, vibration, and incidental impacts. The new international requirements for such testing are not much different from current requirements and therefore will not be presented here.

There is, however, a substantial difference in effluent processing performance during the initial qualification testing. First, the device manufacturer should consider where the device will be placed into service (coastal, intercoastal, etc.). Second, consideration should be given to the type of device. For example, if you have a comminuting/disinfecting system that simply transforms the sewage into an effluent reduced in size, which then disinfects to prevent the spread of harmful pathogens but keeps its original nutrient value, this produces an effluent that must be discharged beyond three nautical miles from shore. That is different from a treatment device that first reduces the sewage bio-limiting nutrients through biological digestion or oxidation and then disinfects the effluent to prevent propagation of harmful pathogens, which would produce an effluent that can be discharged within three nautical miles from shore. Another type of device might be a totally "green" device with an environmentally compatible effluent that not only addresses bio-limiting nutrients using an alternate disinfection method, but also is capable of reducing both graywater and blackwater effluents to a zero ecological effect on the aquatic system, thus producing an effluent that can be discharged virtually anywhere, including in designated no discharge zones. To decide which system is best for a given application, a background in processing testing may be helpful.

Processing testing is based on the ability of a given device to affect the basic composition of sewage that has physical, chemical, and biological elements. Testing for these elements is done using three types of analysis—physical, chemical, and biological challenges.

Physical testing determines the amount of matter discharged in the effluent which is made up of the solid residues found in sewage such as fibrous, cellular, and foreign material. Testing looks for the amount of total solids untreated by the MSD that are subsequently passed into the environment.

Chemical testing determines the amount of natural and introduced chemicals found in the influent. These chemicals constitute what is known as bio-limiting nutrients and hazardous materials. Bio-limiting nutrients are naturally occurring in human waste and, if untreated, promote unwanted growth in an aquatic system. These bio-limiting nutrients are determined by testing for chemical oxygen demand, nitrogen, phosphorus, and total organic carbons.

Hazardous chemicals include those used to treat waste such as disinfectants or chemicals found in graywater that are introduced into the MSD. Testing for residues indicates the presence of hazardous chemicals, which drastically affects the acidity, alkalinity, chlorides, pH, semi-volatiles, volatiles, and other analytical methodology. The type and amount of analysis done is based

on the extent of purity desired for the effluent. For example, you would not test for chemicals not listed in the regulation unless you wanted to demonstrate the purity of the effluent for possible use of a MSD in a "no discharge" zone.

Biological testing determines the amount of natural pathogens found in human waste. These pathogens constitute harmful microorganisms that promote illness and use available oxygen, thus limiting or destroying the growth within the natural aquatic system. These microorganisms are determined by testing for biological oxygen demand and thermotolerant coliforms.

Another factor in MSD design involves dilution. The U.S. Environmental Protection Agency strictly prohibits the use of dilution to reduce effluent to meet discharge requirements. Although dilution is not applicable to comminuting/disinfecting devices, the amount of processing water used by an MSD indicates whether it is a dilution device. If the ratio of process water to influent water is greater than 5:1 when cycled, an investigation should be made as to whether the MSD is using dilution to meet the discharge requirements.

It is important to realize that design approval and certification indicates a device is capable of meeting discharge regulations, but does not necessarily guarantee that a given device will always meet the discharge requirements. The condition, maintenance, and operation of the MSD all affect the quality of the effluent. When properly maintained and operated, most MSDs will remain compliant with the discharge criteria, but should be tested periodically to verify compliance.

The future of testing will be based on using analytical methods that will evaluate the MSD effluent to ensure minimum effect on the aquatic system to the extent that all physical, chemical, and biological elements of shipboard graywater and blackwater have been removed or otherwise neutralized. Only then will the most sensitive of aquatic systems be unaffected by the passage of a ship, thus creating a more earth-friendly environment.

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Mr. Matthew D. MacGregor is the executive director of TEi-Testing Services, LLC. Mr. MacGregor has over 25 years experience in testing and is a technical expert for marine sanitation devices, bilge separators, and oil content monitors and has served as a professional services advisor for the U.S. State Department and the U.S. Coast Guard at United Nations IMO proceedings. Mr. MacGregor holds both a bachelor's and master's degree. Mr. MacGregor is also a LTC in the U.S. Army Reserves and has completed the U.S. Army command and general staff college. LTC MacGregor is a master aviator and has over 2,500 hours flying military aircraft. His current qualification is in the AH-64A "Apache" helicopter.

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Endnotes:

1. In 2001, a new Subpart E was added to 33 CFR Part 159 to implement "Title XIV—Certain Alaskan Cruise Ship Operations" governing the discharges of sewage and graywater from cruise vessels, requiring sampling and testing of sewage and graywater discharges, and establishing reporting and recordkeeping requirements. This subpart applies to each cruise vessel authorized to carry 500 or more passengers operating in the waters of the Alexander Archipelago and the navigable waters of the United States within the State of Alaska and within the Kachemak Bay National Estuarine Research Reserve.
2. Development of this system is further described in *"Design and Prototype Development of Advanced Oxidation Black and Gray Water Treatment Systems,"* presented at the American Society of Naval Engineers (ASNE) Marine Environmental Engineering Symposium in January 2006 and published in Naval Engineers Journal, Volume 118, Number 3, 2006, pp. 51-64(14).
3. E.g., "California Code of Regulations Title 22" water reuse criteria.

MARPOL Annex I

USCG inspectors and industry working together for a cleaner, greener environment.

by LCDR Ryan Allain
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U.S. Coast Guard Office of Vessel Activities, Foreign & Offshore Vessels Division

The International Convention for the Prevention of Pollution from Ships

The International Convention for the Prevention of Pollution from Ships, commonly known as the MARPOL 73/78 convention, was created primarily in reaction to a major oil spill resulting from the 1967 grounding of the tanker *Torrey Canyon* in the English Channel. Although international conventions to reduce pollution already existed prior to the *Torrey Canyon* grounding, these conventions were aimed at routine shipboard operations, but did little to address accidental pollution discharges. To remedy this, many operational requirements of the existing conventions were left in place, and ship design standards were added during the development of MARPOL 73/78 to reduce accidental discharges. One significant requirement limited the size of cargo tanks on tankers so the effects of single-tank damage would be limited.

By 1983, after much deliberation, the MARPOL 73/78 convention entered into force. MARPOL currently contains six annexes, each of which is concerned with preventing pollution from various shipboard operations. MARPOL Annex I specifies requirements that specifically prevent pollution from oil. As such, Annex I sets forth a comprehensive list of requirements that include control of the vessel's cargo handling operations, the design and construction of the vessel, and equipment specifications to reduce the occurrence of oil discharge.

In the United States, the pollution prevention requirements contained in MARPOL Annex I are verified and enforced on foreign vessels during a Coast Guard port state control (PSC) exam. Coast Guard policy to enforce MARPOL Annex I is contained in G-PCV Policy Letter 06-01 and also in Navigation and Inspection Circular 06-03, Change 2.[1]

Promulgated in January 2006, G-PCV Policy Letter 06-01 outlines MARPOL Annex I examination procedures for Coast Guard port state control officers (PSCO). The MARPOL Annex I exam begins with a review of required documentation, including the international oil pollution prevention (IOPP) certificate, the oil record book, and the shipboard oil pollution emergency prevention plan (SOPEP).

Vessels required to comply with MARPOL Annex I are issued an international oil pollution prevention certificate. The certificate details the ship's arrangement and equipment for meeting Annex I requirements. During a port state control exam, the port state control officer examines the certificate for validity and verifies the vessel's name and registry. Exemptions and equivalencies are carefully noted. The officer then verifies that the vessel's arrangement matches what is listed on the IOPP certificate.

The PSCO also reviews the engineer's oil record book. This book must document all shipboard oil transfer and discharge operations. It must also contain documentation for machinery space operations as well as entries documenting the ballasting and cleaning of oil fuel tanks, disposal of oily residues, and discharge overboard or disposal of bilge water that accumulated in machinery spaces. Additionally, on oil tankers, the oil record book must also contain entries recording cargo and ballast operations, loading and unloading of cargo oil, cleaning of cargo oil tanks, and dis-

Figure 1: This overboard discharge valve should be examined for loose bolts, splattered oil on the valve stem, and evidence of recent work, like greasy handprints and chipped paint. USCG photo.

posal of cargo tank residues.

During a PSC exam, the PSCO checks for irregularities. Common irregularities found in the oil record book include dates out of order, missing pages, repetitive entries, and significant differences in tank levels than were recorded in earlier entries. Oil tankers 150 gross tons and above are required to carry cargo monitors that provide continuous recordings of oil discharges from slop tanks. If the discharge monitor is equipped with an automatic recording device, the port state control officer reviews the dates, times, and concentration of discharges recorded in the oil record book and compares that to the recording from the oil discharge monitor. The port state control officer vigilantly searches for entries that may indicate tampering with the automatic recording devices.

Finally, the PSCO reviews the shipboard oil pollution emergency plan to ensure it is approved by the vessel's flag state. The officer will then verify that pollution response equipment listed in the SOPEP is aboard the vessel and in serviceable condition.

Examination of Required Equipment

Once a thorough review of the required documentation is completed, the port state control officer proceeds to the engine room and machinery spaces to verify the condition of the required equipment. Upon entry to the machinery spaces, a PSCO will form a general impression of the cleanliness of the engine room and all equipment contained within it. Leaking fuel oil lines, excessive oily water in the bilge, and disassembled equipment will often indicate problems with the vessel's oil pollution prevention equipment.

One of the most important pieces of pollution prevention equipment required by MARPOL Annex I is the oily water separator (OWS). All vessels greater than 400 gross tons and oil tankers greater than 150 gross tons are required to have an oily water separator. This is used to make clean water from oil-contaminated bilge and ballast water. The oily water separator can use several methods to clean the contaminated water. Regardless of the method, in order for the OWS to be approved in accordance with MARPOL standards, it must reduce the oil content in the discharged water to no more than 15 parts per million.

During a port state control exam, the PSCO will ask the vessel's crew to perform an operational test of the oily water separator. If the crew has trouble demonstrating the proper operation of the equipment, this could indicate infrequent use. If conditions aboard the vessel indicate that more frequent use of the OWS equipment is required, the PSCO looks for indications of improper disposal of oil-contaminated bilge water (Figure 1). A typical operational test of the oily water separator lasts no longer than 15-20 minutes and should follow the written test procedures indicated by the manufacturer. During the operational test, the port state control officer ensures that the fluid entering the oily water separator is coming directly from the bilge holding tank or rose box[2] and that it is not diluted by an open sea or fresh water connection prior to entering the OWS. The PSCO also makes an effort to verify that the discharge processed by the OWS is visibly clean and that no surface oil is visible.

Ships of 10,000 gross tons or more are required to have an oil content meter, or OCM (Figure 2). This is an electronic sensing device that measures the content of oil in the discharge processed through the oily water separator. Port state control officers witness an operational test of this meter, usually at the same time as the oily water separator test. The PSCO closely examines the oil content meter for signs of tampering such as simple electrical modifications or bypasses. The officer then ensures that the sample analyzed by the OCM is actually oily water separator output by tracing the sample line. An operational test of the oil content meter will never involve tripping of the sensor with sticks, coffee, or tea. Only the equipment manufacturer's specified test procedure or the vessel's written procedure is used to verify the condition of the oil content meter.

A check of the vessel's sludge tank is then conducted to ensure that the level of sludge corresponds to entries made in the oil record book. The sludge tank stores oil residue, sludge, or waste oil that is typically left over from processing oily water through the OWS and from other sources like the fuel oil and lube oil purifiers.

Investigating Violations of MARPOL Annex I

When a port state control officer discovers possible violations of the MARPOL Annex I requirements, there are several options to take depending on the gravity of the violation. Minor deficiencies might include discrepancies on the IOPP certificate or missing signatures

in the oil record book. These discrepancies can often be corrected on the spot or forwarded to the vessel's flag state administration for correction. More serious violations, such as a crew's failure to demonstrate proper operation of the oily water separator, can result in detention of the vessel. In cases where the vessel is detained, it is not allowed to leave port until it rectifies the deficiency. In most situations, vessel operators do not like to have their ship detained, since this can result in significant unexpected delays and financial cost.

In the most egregious of MARPOL Annex I violations—those types that are willful violations of the requirements—criminal charges are pursued (see *Proceedings*, Winter 2004-2005, Vol. 61, No. 4, "The Trail of Environmental Crimes," at www.uscg.mil/proceedings).

In recent years, criminal cases have been pursued against unscrupulous vessel operators and crew who have willfully bypassed the oily water separator and pumped unfiltered oily bilge water directly into the sea. In almost all these cases, fraudulent entries were made in the vessel's oil record book indicating the oily bilge water was processed through the OWS. The fraudulent entries in the official record (the oil record book) represent a false statement when it is presented to a port state control officer. Criminal investigations into willful MARPOL Annex I violations often require a coordinated investigation conducted by the local Coast Guard sector, the Coast Guard Investigative Service, and the Department of Justice.

Measures to Improve MARPOL Annex I Compliance

Commercial vessel owners and operators are using several methods to improve shipboard compliance with MARPOL Annex I. One method involves creating an environmental compliance program (ECP), which includes a comprehensive system to verify MARPOL Annex I compliance. A typical environmental management system (EMS) documents incorporate policies and procedures, establishes the use of outside consultants to access performance, and implements the use of non-regulatory practices.

In most cases, the use of an ECP/EMS is mandated as the result of a conviction in a criminal prosecution for an environmental crime. However, many progressive and environmentally conscious ship owners and operators have proactively implemented an ECP/EMS to improve and ensure compliance with MARPOL Annex I. A successful ECP/EMS contains many elements and usually includes non-regulatory practices. Examples of non-regulatory practices include:

- the use of a numbered seal program to track and record the opening and closing of valves related to the bilge, oil waste, and sludge management system;
- installation of piping modifications that allow full operational testing of the oily water separator and oil content meter without risk of an oil discharge;
- consultation with vessel engineers to determine bilge loads, sludge accumulations, storage capabilities, and the performance of pollution prevention equipment.

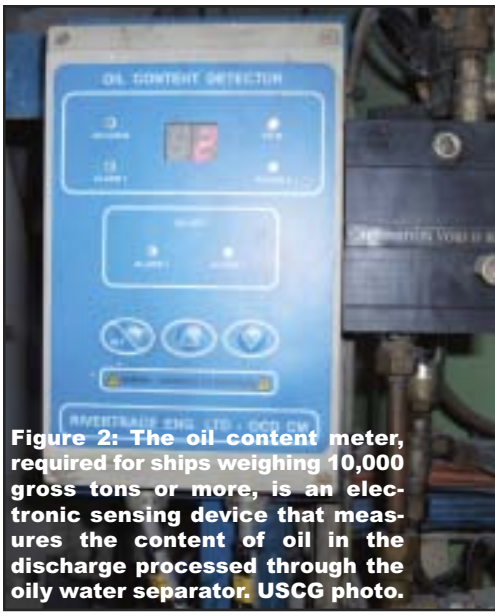


Figure 2: The oil content meter, required for ships weighing 10,000 gross tons or more, is an electronic sensing device that measures the content of oil in the discharge processed through the oily water separator. USCG photo.

If a vessel operator encounters a facility that has inadequate MARPOL reception facilities, the operator should make a timely and detailed report to the local Coast Guard captain of the port (COTP). Per 33 CFR 158.167, any person may report inadequate reception facilities to the local Coast Guard COTP. Reports may be made orally, in writing, or by telephone. Reports may also be anonymous and after the fact. However, the more timely and detailed the report, the better the chance for the Coast Guard to correct the reported inadequacy.

Strict compliance with the requirements contained in MARPOL Annex I is crucial for commercial vessel owners and operators to protect the vast natural resources contained in our world's oceans and seas. Coast Guard port state control officers are trained to conduct thorough examinations of MARPOL Annex I requirements during every port state control exam. When vessels are found to be in non-compliance with the requirements, Coast Guard PSCOs will hold the vessel personnel accountable for infractions and ensure that discrepancies are corrected. Vessel owners and operators are strongly encouraged to ensure their vessels are in compliance with MARPOL Annex I prior to entering the waters of the United States.

About the author:
LCDR Allain has over 16 years of experience in the Coast Guard, with more than 10 years working in the marine safety and security field. His previous tours include Marine Safety Office Tampa, Fla., and supervisor of Marine Safety Detachment Ft. Myers, Fla.

Endnotes:

1. CG-3PCV policy letters can be found at http://homeport.uscg.mil. NVICs are at http://www.uscg.mil/hq/g-m/nvic/.
2. A perforated metal box used as a strainer.

Natural Gas Regasification Technologies

Efficient, environmentally friendly LNG vaporization methods.

by LT Hannah Kawamoto
U.S. Coast Guard Office of Operating and Environmental Standards
Deepwater Ports Standards Division

Natural gas is odorless, colorless, nontoxic, and noncorrosive, and, when supercooled to minus 260 degrees Fahrenheit, turns into liquefied natural gas (LNG). Liquefying natural gas reduces its volume by more than 600 times, which makes it more efficient and practical to store and transport.

At present, three percent of the United States' natural gas needs are imported from foreign sources in special-purpose LNG tankers.[1] When the LNG cargo reaches its destination, the liquefied natural gas is revaporized back into a gas, which is then linked to pipelines that transport the gas for use. This revaporization (or regasification) activity is significant in terms of operating costs and possible impact on the environment.

Offshore facilities, also known as deepwater ports, face unique challenges in structural design and siting. However, the opportunity to build deepwater ports for LNG importation has also opened doors for new and unique methods to bring natural gas into the United States. Newer technologies utilize engine cooling technology and waste heat recovery from generators, boilers, or a combination of heat sources to warm the LNG, thus improving the efficiency of regasifying and reducing impact on the environment.

Best Available Commercial Technologies

The three sources of thermal energy typically used to warm LNG from a liquid to a gaseous state are ambient air, natural gas (heat from combustion), and seawater. The basic types of vaporization systems that utilize these sources of thermal energy include:

- intermediate fluid vaporizers,
- ambient air vaporizers,
- open rack vaporizers,
- shell and tube vaporizers,
- submerged combustion vaporizers.

VAPORIZATION SYSTEMS AS THEY RELATE TO THERMAL ENERGY

VAPORIZATION SYSTEM	DIRECT OR INDIRECT HEAT	THERMAL ENERGY SOURCE: Ambient Air	Natural Gas (Combustion)	Seawater
Intermediate Fluid Vaporizer (IFV) propane or refrigerant	indirect heat[a]	x		x
Intermediate Fluid Vaporizer (IFV) water/glycol	indirect heat	x	x	x
Ambient Air Vaporizer (AAV) or indirect heat	direct heat[b]	x		
Open Rack Vaporizer (ORV)	direct heat			x
Shell and Tube Vaporizer (STV)	direct heat			x
Submerged Combustion Vaporizer (SCV)	indirect heat		x	

a. Indirect heat is defined as when the thermal energy source (ambient air, natural gas, or seawater) is used to warm a secondary heating medium that re-vaporizes the LNG.
b. Direct heat is defined as when the thermal energy source (ambient air, natural gas, or seawater) directly warms and re-vaporizes the LNG.

Each system uses a vaporization process that passes the liquefied natural gas through pipes that are surrounded by a heating medium to transfer heat into the LNG. "Direct" heat is when the heating medium directly warms the LNG. "Indirect" heat is when the heating medium is used to warm an intermediate (or secondary) medium that transfers the heat to the LNG.

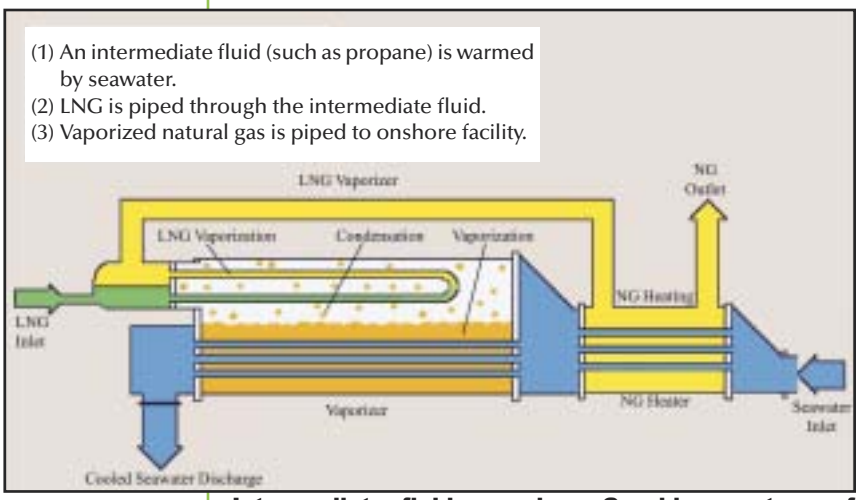
Lastly, each vaporization system can be set up as an "open-loop" or "closed-loop" system. Using seawater to heat the LNG is referred to as open-loop vaporization, while using natural gas combustion is closed-loop vaporization.

Intermediate Fluid Vaporizers

An intermediate fluid vaporizer (IFV) uses an intermediate heat transfer fluid to revaporize LNG. IFV technology can be configured to operate in a closed-loop, open-loop, or combination system. The most common intermediate fluid vaporizers use propane, refrigerant, or a water/glycol mixture as an intermediate fluid. Although propane and refrigerant have low flash points that are ideal for heat transfer, the operational risks are much higher when handling these types of fluids, and these fluids are very costly. The water/glycol mixture has a high flash point, requiring a larger heat transfer area, which results in a larger system than the propane or refrigerant systems. However, the water/glycol fluid system is more cost effective and the associated operational risks are relatively low.

An IFV typically uses a "shell and tube" heat exchanger (more about this system later), where LNG flows through the tubes with the intermediate heating medium circulating inside the shell and around the tubes. There are two stages to heating the LNG with an intermediate fluid vaporizer. First the liquefied natural gas is heated by an intermediate fluid in a heat exchanger, in which the LNG becomes a gas. The intermediate fluid flows through tubes in separate heating equipment (such as a propulsion boiler) to absorb heat. Then the vaporized natural gas is circulated through a second shell and tube heat exchanger, with seawater as the heating medium used to bring the gas to the temperature required to send it out through pipelines for use.[2]

The open-loop IFV technology requires seawater intake. Therefore, environmental issues include adverse effects (and assumed mortality) to marine life from entrainment in the intake, as well as exposure to seawater discharged back into the ocean at a temperature lower than the surrounding water. If an intermediate fluid vaporizer system operates with propane or refrigerant as the intermediate fluid, then these fluids add a potentially hazardous material to the facility operations. An IFV system that uses the water/glycol mixture is considered a safer way to operate. Lastly, depending on the combustion process used to heat the intermediate fluid,



Intermediate fluid vaporizer. Graphic courtesy of KOGAS LNG Technology Research Center.

air emissions are also an environmental concern, unless the system uses waste heat recovery.

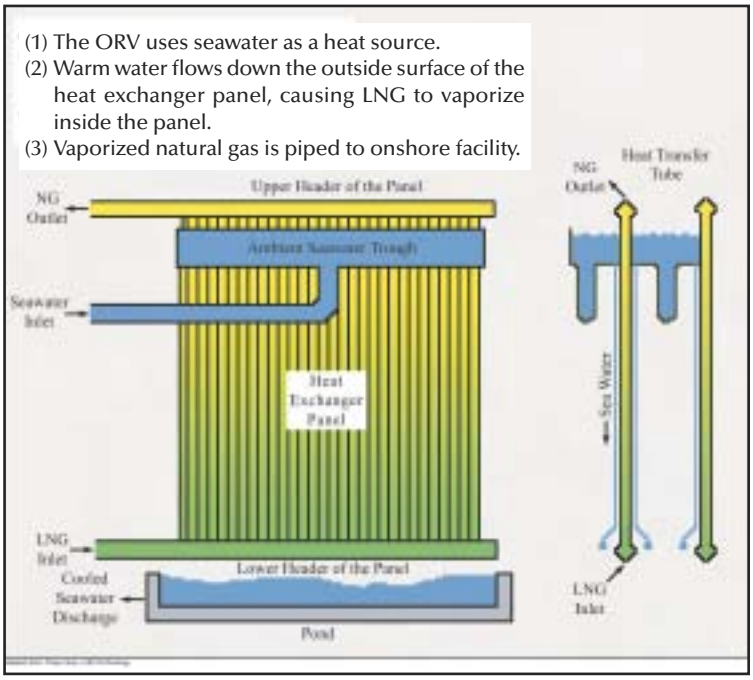
Ambient Air Vaporizers

Ambient air vaporization (AAV) technology uses ambient air as the thermal energy source to vaporize the liquefied natural gas. The LNG is distributed through a series of surface heat exchangers where the air travels down and out the bottom of the vaporizer. The air flow is controlled on the outside of the exchanger through natural buoyancy of the cooled, dense air, or by installing forced-draft air fans.

This process can be set up as either a direct heat or indirect heat system. AAV technology is best suited for areas with warmer ambient temperatures. In cooler climates, a supplemental heat system would be necessary to maintain effective use during colder weather conditions. Frost forming on the vaporizer is an issue because the LNG is vaporized directly against the air (direct heat system) and the water vapor in the air condenses and freezes. Frost build-up reduces performance and heat transfer. To maintain continual operation,

additional units are typically installed to provide the required throughput. The ambient air vaporization system requires a significant amount of space to prevent ambient air recirculation and to maintain the vaporizer capacity.

There is no seawater intake associated with this system. However, cooling ambient, moist air (which condenses into fresh water) necessitates treatment to prevent biofouling in the freshwater discharge piping. Discharging the treated freshwater back into the ocean could potentially have an adverse impact on the sea water. Also, depending on geographical locations (such as areas with high dew points) cooling the ambient air can generate a "fog bank." This is essentially benign, but you must consider siting issues.[3] Since the AAV technology typically burns natural gas only for supplemental heating during colder months, air emissions overall are relatively low compared to the other vaporization technologies.



Open rack vaporizer. Graphic courtesy of Tokyo Gas.

Open Rack Vaporizers

Open rack vaporizers (ORV) use seawater as the thermal energy source in a direct heat system to vaporize the LNG. To control algae growth within the system, sodium hypochlorite (chlorine) is injected on the intake side of the system. The treated seawater is then pumped to the top of the water box and travels down along the outer surface of the tube heat exchanger panels, while LNG flows upward through these tubes and is vaporized.[4] The cooled seawater collects in a basin under the open rack vaporizer and is discharged through the water outfall, while the vaporized natural gas is removed from the top header of the system. Because this technology relies on seawater as the primary heat source, it is only effective where seawater temperatures exceed approximately 63 degrees Fahrenheit.

The ORV technology does not require combustion and this process poses no new ignition sources. There are several environmental issues, including seawater intake, seawater outfall, and air emissions. Open rack vaporizer technology requires large volumes of water, which could adversely affect marine life. Further, the cooled and treated seawater that is returned to the ocean could potentially affect marine life and water quality. Although the ORVs do not directly produce air pollution emissions, powering the seawater pumps does.

Shell and Tube Vaporizers

Shell and tube vaporizers (STV) also use seawater as the thermal energy source. In an open-loop STV system, LNG enters the bottom of the STV, which is mounted vertically to optimize vaporization efficiency. The liquefied natural gas passes through multiple tubes while seawater enters a shell surrounding the tubes.

A closed-loop system uses an intermediate fluid (such as propane or a water/glycol mixture) to transfer heat. The intermediate fluid flows through tubes in separate heating equipment (such as a propulsion boiler) to absorb heat, then the fluid passes through the STV unit to re-gasify the LNG. Since there are two heat exchangers, this requires a large amount of space.

The open-loop technology reduces air emissions, since there is no combustion. Further, these STVs are generally small. Conversely, since the open-loop system uses seawater as the thermal energy source, there are environmental issues similar to the ORV system.[5]

Submerged Combustion Vaporizers

Submerged combustion vaporizers (SCV) do not use seawater for LNG vaporization. Instead, the LNG is warmed by flowing through tube bundles that are submerged in a water bath, which is heated by natural gas combustion. The submerged combustion burner emits hot exhaust gas that directly heats the water bath by bubbling through the water to an exhaust stack.

Since the thermal capacity of the water bath is high, it is possible to maintain a stable operation even for sudden start-ups/shutdowns and rapid load fluctuations.[6]

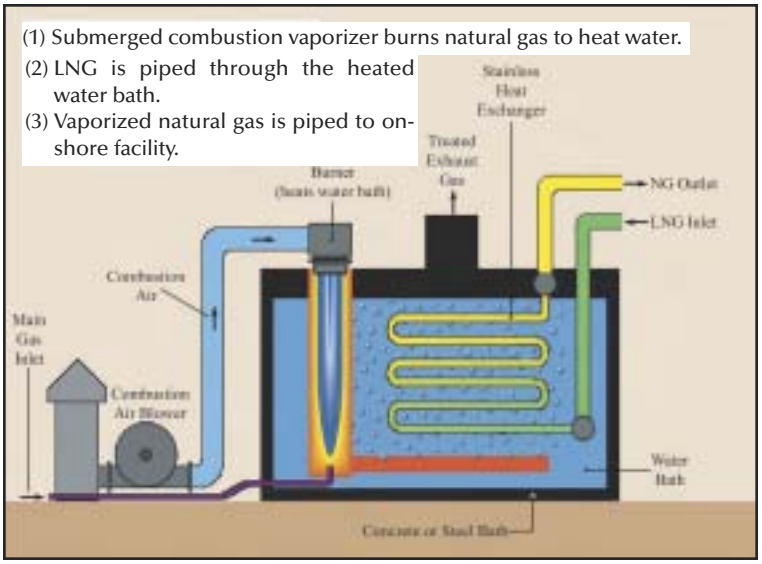
Thus, they provide great flexibility to quickly respond to changing demand requirements.[7] Since the SCV has such a huge reserve heat bank, even when the combustion process fails, surges can be mitigated with the heat just from the water bath.

During operation, SCVs consume anywhere from 1.5 to 2.0 percent of the LNG cargo to fuel the combustion burner, which is a significant operating cost.[8] In addition, the bathwater becomes acidic as the combustion products are absorbed during the heating process. It's necessary to add chemicals to the water bath, which results in excess combustion water that must be neutralized before being discharged. Lastly, the submerged combustion vaporizer system produces large quantities of air emissions from the flue gas. This can be reduced through exhaust gas control technology, but adds significant operating costs to the SCV system.

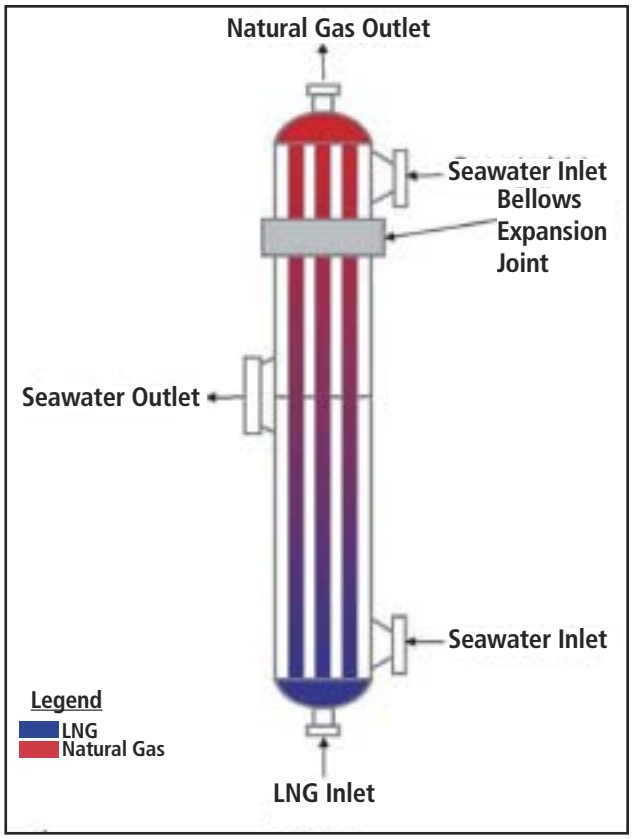
Waste Heat Recovery and Engine Cooling Technology

Deepwater ports can use regasification vessels (which are equipped with revaporization systems onboard) to vaporize the LNG to natural gas. Waste heat recovery and engine cooling technologies have been incorporated as part of the revaporization system to improve the efficiency (and reduce the emissions) of these regasification vessels.

Additionally, using engine cooling technology reduces the amount of seawater intake because, instead of cooling the engines solely with seawater, cooled water from the LNG vaporization process is used to cool the engines. Additionally, any cooling systems can be tied into the intermediate fluid, such as the heating, ventilating, and air conditioning systems.



Submerged combustion vaporizer. Graphic courtesy of Sumitomo Precision Products.



Shell and tube vaporizer.

About the author:

LT Hannah Kawamoto has served in the U.S. Coast Guard for five years and became a qualified marine inspector at Sector San Francisco prior to transferring to Coast Guard headquarters. LT Kawamoto is a graduate of the U.S. Merchant Marine Academy, with a B.S. in marine transportation and a third mate unlimited tonnage deck officer license.

Endnotes:

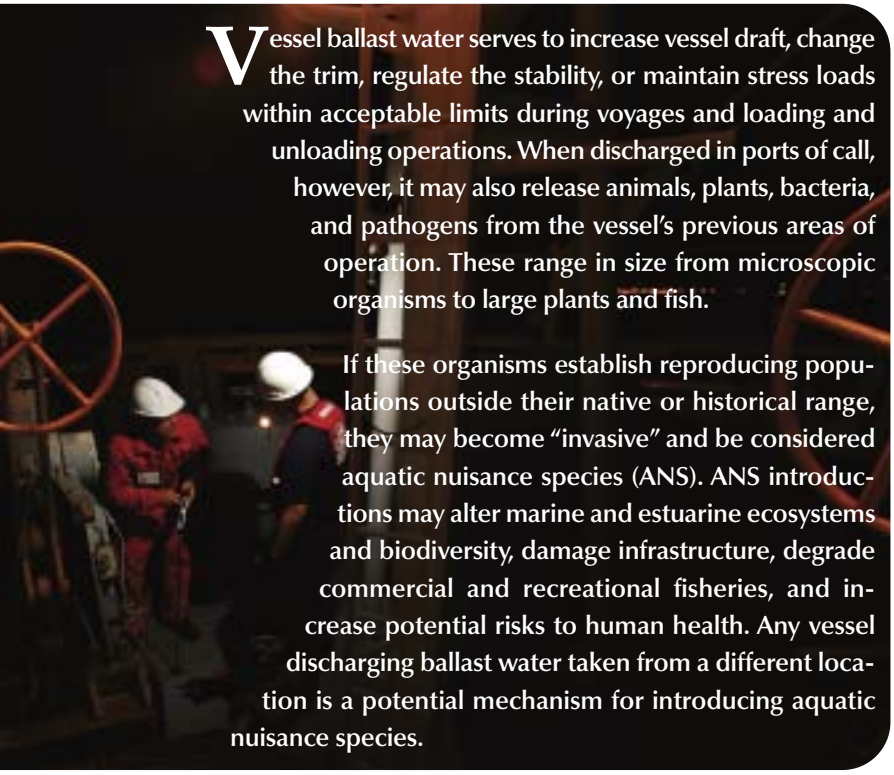
1. National Petroleum Council statistic.
2. U.S. Coast Guard (USCG) and Maritime Administration (MARAD). Draft Environmental Impact Statement for the TORP Bienville Offshore Energy Terminal Deepwater Port License Application (Docket No. USCG-2006-24644), July 6, 2007.
3. M. J. Rosetta, B. C. Price, and L. Himmelberger, "Optimize Energy Consumption for LNG Vaporization: New Methods Maximize Heat Transfer to Re-gasify Natural Gas with Minimum Environmental Impacts," Black & Veatch—Reports & Studies, 2006.
4. Ibid.
5. U.S. Coast Guard (USCG) and Maritime Administration (MARAD). Draft Environmental Impact Statement for the TORP Bienville Offshore Energy Terminal Deepwater Port License Application (Docket No. USCG-2006-24644), July 6, 2007.
6. U.S. Coast Guard (USCG) and Maritime Administration (MARAD). Final Environmental Impact Statement / Final Environmental Impact Report for the Cabrillo Port Liquefied Natural Gas Deepwater Port License Application (Docket No. USCG-2004-16877), March 16, 2007.
7. C. C. Yang and Z. Huang, "Lower Emission LNG Vaporization," LNG Journal, 2004.
8. U.S. Coast Guard (USCG) and Maritime Administration (MARAD). Final Environmental Impact Statement/ Final Environmental Impact Report for the Northeast Gateway Deepwater Port License Application (Docket No. USCG-2005-22219), October 27, 2006.

Environmental Protection

Setting a Course for Ballast Water Management

Reducing the global spread of aquatic nuisance species.

by Mr. John Morris
Environmental Protection Specialist
U.S. Coast Guard Office of Operating and Environmental Standards



Vessel ballast water serves to increase vessel draft, change the trim, regulate the stability, or maintain stress loads within acceptable limits during voyages and loading and unloading operations. When discharged in ports of call, however, it may also release animals, plants, bacteria, and pathogens from the vessel's previous areas of operation. These range in size from microscopic organisms to large plants and fish.

If these organisms establish reproducing populations outside their native or historical range, they may become "invasive" and be considered aquatic nuisance species (ANS). ANS introductions may alter marine and estuarine ecosystems and biodiversity, damage infrastructure, degrade commercial and recreational fisheries, and increase potential risks to human health. Any vessel discharging ballast water taken from a different location is a potential mechanism for introducing aquatic nuisance species.

In our Great Lakes, more than 160 non-native species have been introduced since the 1800s—one-third of which have appeared in the past 30 years. The zebra mussel alone is estimated to have cost $750 million to $1 billion in damages or control measures between 1989 and 2000.[1] The Chesapeake and San Francisco Bays, Puget Sound, and other waters of the U.S. have been similarly affected by aquatic nuisance species.

Their spread is a threat to the global marine environment, not just to U.S. waters. The North American comb jellyfish has decimated Black Sea anchovy fisheries, Chinese mitten crabs burrow into German riverbanks, and "red tides" caused by Japanese toxic dinoflagellates impact Australian shellfish beds.

U.S. Efforts

In response to concerns regarding aquatic nuisance species in the Great Lakes in the mid-1980s, the federal government enacted the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA). It was reauthorized and expanded to cover all U.S. waters with the National Invasive Species Act of 1996 (NISA).

NANPCA/NISA directed the Coast Guard, in association with the Smithsonian Institution, to establish the National Ballast Information Clearinghouse (NBIC). The Smithsonian Environmental Research Center in Edgewater, Md., created and maintains the NBIC's electronic database to track and analyze changes in patterns of ballast water discharge and management in U.S. waters. More than 100,000 ballast water management reports are entered annually, the majority of which are now submitted by vessels as e-mail attachments or via direct web-based entries.[2]

The statute also established the ANS Task Force as an intergovernmental organization to implement the NANPCA/NISA mandates. The task force is comprised of 10 federal agency representatives and 12 ex-officio members, and is co-chaired by the Fish and Wildlife Service and National Oceanic and Atmospheric Administration.

The Coast Guard has promulgated several regulations under 33 CFR 151 Parts C and D, and continues to develop regulations to address this issue. Under NANPCA, the Coast Guard developed mandatory ballast water management (BWM) regulations for vessels in the Great Lakes in 1993, and extended them to the Hudson River north of the George Washington Bridge in 1994.

In 1996, NISA established a national ballast water management program for all U.S. waters. The Coast Guard issued voluntary guidelines in 1999 and mandatory regulations in 2004. These regulations require each vessel to maintain a BWM plan and assign responsibility to the master or appropriate official to understand and execute the ballast water management strategy. All vessels arriving in U.S. ports or places must submit BWM reports to the National Ballast Information Clearinghouse and follow a suite of management requirements.

All vessels inbound from outside the exclusive economic zone must conduct mid-ocean exchange, retain ballast water, or use a Coast Guard-approved alternative method. Vessels unable to exchange are not allowed to discharge ballast water while in the Great Lakes. Mid-ocean exchange or retention will remain the only available options until the Coast Guard develops a ballast water management system type approval process.

The Coast Guard has also developed the Navigation and Vessel Inspection Circular 07-04, Change-1, "Ballast Water Management for the Control of Aquatic Nuisance Species in the Waters of the United States." This provides guidance for Coast Guard personnel, vessel owners and operators, masters, shipping agents, and persons-in-charge. concerning compliance with and enforcement of the BWM program.

The Coast Guard and the NBIC have initiated the equivalent reporting program, a simplified reporting program for vessels that operate exclusively in the U.S. exclusive economic zone or the Canadian equivalent. This program offers an alternative to allow submission of required BWM reports in a single batch once a month, instead of on a port-to-port, pre-arrival schedule. The program is not available to vessels the Coast Guard has listed on a "lookout list" for failing to submit a BWM report or that have been found to have submitted incomplete or inaccurate reports.

In 2005 the Coast Guard established a policy on best management practices for vessels declaring "no ballast on board," or NOBOB. These NOBOB vessels may carry unpumpable ballast water and/or sediments in their ballast tanks. The policy encourages NOBOB vessels to conduct mid-ocean exchange on all ballast-laden voyages or, if unable to do so, conduct saltwater flushing of their "empty" ballast tanks prior to entering the Great Lakes.

International Efforts

The international community is developing BWM agreements and guidelines to reduce the economic, ecological, and health threats from aquatic nuisance species in ballast water. The International Maritime Organization (IMO) adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments in 2004. However, it will not enter into force until it has been ratified by at least 30 countries representing 35 percent of world merchant shipping tonnage. Only 16 countries representing 14.24 percent have ratified the convention to date.[3]

The Coast Guard coordinates the U.S. government's participation on the IMO's Marine Environment Protection Committee (MEPC). The MEPC serves as the IMO's coordinating body on marine pollution issues, and develops agreements and technical and administrative guidelines necessary for effective implementation of conventions.

The MEPC has adopted the original 15 guidelines needed to implement the convention's objectives. However, concern over the availability of type-approved ballast water management systems is a major obstacle that must be resolved before enough member states agree to ratify the convention. Member states and industry organizations have questioned whether it will be feasible to maintain the first implementation date of the convention's ballast water performance standard in 2009, since only a limited number of ballast water management system technologies have received final IMO type approval and will be available for ship owners.

The 25th IMO assembly adopted a resolution in response to these concerns, specifically that ships constructed in 2009 with a ballast water capacity of less than 5,000 cubic meters will not be required to comply with the convention's ballast water performance standard until its second annual survey, but no later than December 31, 2011.

The Coast Guard works with other federal agencies, including the Environmental Protection Agency, Fish and Wildlife Service, Maritime Administration, Navy Department, National Oceanic and Atmospheric Administration, and State Department, to coordinate U.S.

government positions and analyses on technical and administrative issues for IMO MEPC meetings. These agencies will ultimately make recommendations to the president and Senate on U.S. ratification of the BWM convention.

At a regional level, the United States, Canada, the U.S. St. Lawrence Seaway Development Corporation, and the Canadian St. Lawrence Seaway Management Corporation cooperate to inspect ocean-going vessels entering the Great Lakes. The Coast Guard and Transport Canada signed an agreement in 2004 to share resources and track results.

In response to concerns regarding the differences between the Coast Guard's no ballast on board policy and Transport Canada's mandatory ballast water regulations, the four jurisdictions created the Great Lakes ballast water working group in 2006. This group developed the joint BWM exam program for targeting and inspecting foreign vessels entering the Great Lakes.

Petty Officer 3rd Class Travis Kelly, Marine Safety Detachment Massena, looks through a refractometer at a sample of ballast water from a motor vessel in Montreal. USCG photo by Petty Officer 3rd Class William B. Mitchell.

This program has reduced duplication of inspections for mariners and provided broader program oversight. The working group recorded a 96 percent compliance rate for ballast tanks tested during the 2007 Great Lakes shipping season, with 100 percent of the water in non-compliant tanks either retained onboard or treated with salt or brine to raise salinity prior to discharge.[4]

Ballast Water Management Systems

The use of ballast water exchange as an option is intended to be an interim step toward the goal of managing ballast water to prevent the introduction and spread of ANS. Companies are exploring various ballast water management system technologies to overcome the challenges of developing large-capacity water treatment systems for shipboard use. The Coast Guard is developing a program for type approval of BWMS, and coordinating with the EPA regarding ballast water management systems that use active substances. These technologies may include:

- mechanical means of removal such as filtration or separation;
- physical means of killing or disabling organisms such as ultraviolet light, de-oxygenation, ultrasound, or cavitation;
- chemical biocides added to ballast water or generated onboard, such as ozone or hypochlorite generators.[5]

The Coast Guard initiated the Shipboard Technology Evaluation Program (STEP) to provide incentive for ship owners and operators to participate in the experimental testing of prototype BWMS. Ships with installed experimental ballast water management systems accepted to participate in STEP may receive a designation of equivalency to future ballast water discharge standard regulations. This may last throughout the life of the vessel or the system, so long as the prototype system operates satisfactorily. (For more information on this program, see the following article by LCDR Brian Moore.)

The Way Forward

Because the effectiveness of ballast water exchange varies from vessel to vessel, the Coast Guard believes that setting a performance standard will be the most effective way to approve methods that are environmentally protective and scientifically sound.

The Coast Guard is preparing the way for fundamental changes in how the U.S. and its partners will regulate ballast water discharges. The results of STEP prototype evaluations, the ballast water discharge standard rulemaking, and the various proposals for legislation to manage vessel discharges are milestones that the shipping industry should monitor. Together, these initiatives will provide the maritime community with powerful tools to enhance its ability to protect the global marine environment.

About the author:

Mr. John Morris is an environmental protection specialist at Coast Guard headquarters. His previous positions include a director at the American Chemistry Council trade association and an environmental protection specialist for the U.S. Department of Energy. Mr. Morris has a master's in environmental policy and management from the University of Denver.

Endnotes:

1. U.S. Government Accountability Office, "Progress and Challenges in Preventing Introduction into U.S. Waters via the Ballast Water in Ships."
2. National Ballast Information Clearinghouse (NBIC), Smithsonian Environmental Research Center.
3. International Maritime Organization (IMO), http://www.imo.org.
4. USCG Ninth District, http://www.piersystem.com/go/doc/443/204139/.
5. Chemical biocides intended for use in BWMS may require registration by EPA under the Federal Insecticide, Fungicide, and Rodenticide Act. Developers considering the use of chemicals to treat ballast water should contact the EPA Office of Pesticide Programs for a determination at http://www.epa.gov/pesticides/.

Survey available online: www.uscg.mil/proceedings

Your Opinion, Please

What You're Saying

"Why is celestial navigation still a test subject for merchant marine officers and are there are any plans to discontinue it?

Why is the TWIC not required for public vessels sailors (Navy/Coast Guard)? CG places this on commercial mariners, but is it required for mariners who sail on public vessels?

I would like articles on public vessel mariner credentials.

I would like to see an article addressing how the CG tracks medical conditions of non-licensed personnel.

Recommend seeking more comments and articles about the CG from the professional mariner standpoint.

I would like to see reaction letters to subjects brought up by mariners in mariners' speak.

While I don't always agree with your (USCG's) stand on an issue (e.g., TWIC cards), by reading *Proceedings*, I at least understand your position/point of view.

I would like to see an update on the Towing Safety Advisory Committee. What has been accomplished? What is the path forward? Are there going to be third-party inspectors? How would an organization become approved to be an inspector or auditor?

Your analysis and follow-up of the *STAR PRINCESS* and *STELLAMARE* casualties was VERY informative and useful.

Why is smoking still permitted on the inside of towing vessels? Over 75% of the towing industry smokes. I think this the only place left in this country where you can smoke in the workplace. This is unfair and unsafe for the non-smoking mariner. Any relief in sight?

Discussion of how public vessel mariner credentials are tracked and who verifies them.

More discussion on the increasing EPA presence in the maritime industry. EPA regulation of discharge permits illustrates another administrative burden being placed on commercial mariners."

What We're Hearing

You have questions and you want authoritative answers from someone who speaks your language.

Stay tuned for answers and for information on ways to share your opinions and interact with the Coast Guard.

The Shipboard Technology Evaluation Program

A U.S. Coast Guard aquatic invasive species reduction incentive.

by LCDR Brian Moore
U.S. Coast Guard Office of Environmental Standards

The accelerating problem of invasive species in U.S. marine ecosystems is driven largely by changes in shipping practices and increases in traffic volume over the last few decades. In the past, most species' translocation occurred when people purposely introduced organisms they wished to establish in a new location, or when the occasional "hitchhiker" species clung to the hull of a ship to make its way to a new location. Shipworms (Teredo navalis) are an example of this.

Stowaways

More recently, single-purpose ships such as crude oil carriers now routinely sail to one port with cargo and return to the loading port in ballast, carrying millions of gallons of water each ballast voyage and repeatedly inoculating the waters in the loading port with water from the cargo offloading port. This can reinforce small foothold colonies of species that may have been deposited on previous voyages. Where existing environmental conditions may not have been accommodating enough for a new species to get successfully established under a less systematic presentation, the repeat depositing of millions of gallons of aquatic organism-carrying water is the perfect design for establishing viable colonies of nonindigenous species in new locations.

Whether called "nonindigenous species," "aquatic nuisance species," or "invasive exotics," no one can dispute the impact of these intruders. In some areas of the world they have been devastating:

- When the European zebra mussel (Dreissena polymorpha) was introduced in the Great Lakes between Canada and the United States, it drastically changed the ecosystem, threatening fisheries and resulting in billions of dollars in costs to clean fouled underwater structures and water intake pipes.
- When the American comb jelly (Mnemiopsis leidyi) was transported to the Black and Azov Seas, it caused the near extinction of the anchovy and sprat, drastically reducing those existing fisheries.

As shipping practices evolve and trade increases, such ship-mediated invasions put additional areas at risk for similar ecological and economic impact.

What's Being Done?

International, national, state, and local efforts have been initiated to address the problem of ballast water-facilitated species translocation. Currently, through the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (as amended by the National Invasive Species Act of 1996), Congress has directed the Coast Guard to develop a national ballast water management program.[1] Under these laws, ships have the option to conduct mid-ocean ballast water exchanges (discharging ballast water taken near shore and replacing it with deep ocean water). Other options include retaining all ballast water aboard while in U.S. waters or using a

continued on page 86

SOME NOTABLE INVASIVE SPECIES

NAME:	*NATIVE TO:*	*INTRODUCED TO:*	*IMPACT:*
Cholera **Vibrio cholerae**	Various strains with broad ranges	South America, Gulf of Mexico, and other areas	Some cholera epidemics appear to be directly associated with ballast water.
Cladoceran Water Flea **Cercopagis pengoi**	Black and Caspian Seas	Baltic Sea	Reproduces to form very large populations that dominate the zooplankton community and clog fishing nets and trawls, with associated economic impact.
Mitten Crab **Eiocheir sinensis**	Northern Asia	Western Europe, Baltic Sea, and West Coast of North America	Undergoes mass migrations for reproductive purposes. Burrows into river banks and dikes, causing erosion and siltation. Preys on native fish and invertebrate species, causing local extinctions during population outbreaks. Interferes with fishing activities.
Toxic Algae **(Red/Brown/Green Tides)** **(various species)**	Various species with broad ranges	Several species have been transferred to new areas in ships' ballast water.	May form harmful "algae blooms." Depending on the species, can cause massive kills of marine life through oxygen depletion and release of toxins and/or mucus. Can foul beaches and impact tourism and recreation. Some species may contaminate filter-feeding shellfish and close fisheries. Human consumption of contaminated shellfish may cause severe illness or death.
Round Goby **Neogobius melanostomus**	Black, Asov, and Caspian Seas	Baltic Sea and North America	Highly adaptable and invasive. Increases in numbers and spreads quickly. Competes for food and habitat with native fishes, including commercially important species, and preys on their eggs and young. Spawns multiple times per season and survives in poor water quality.
North Pacific Seastar **Asterias amurensis**	Northern Pacific	Southern Australia	Reproduces in large numbers, reaching plague-like proportions rapidly. Feeds on shellfish, including commercially valuable scallop, oyster, and clam species.
Asian Kelp **Undaria pinnatifida**	Northern Asia	Southern Australia, New Zealand, West Coast of the United States, Europe, and Argentina	Grows and spreads rapidly, both vegetatively and through spore dispersal. Displaces native algae and marine life. Alters habitat, ecosystem, and food web. May affect commercial shellfish stocks through space competition and alteration of habitat.
European Green Crab **Carcinus maenus**	European Atlantic Coast	Southern Australia, South Africa, the United States, and Japan	Highly adaptable and invasive. Resistant to predation due to hard shell. Competes with and displaces native crabs and becomes a dominant species in invaded areas. Consumes and depletes wide range of prey species. Alters intertidal rocky shore ecosystem.

Coast Guard-approved alternative ballast water management method.

Ballast water exchange has some functional limitations. For example, ships transiting less than 200 miles from shore are not required to deviate from their course to reach sufficiently deep waters to conduct an exchange and are exempted from ballast water management requirements. Even when conducted, ballast water exchange is considered to be only 95 percent effective (at best) at removing near-coastal organisms from ships' ballast, thus leaving some threat of successful species translocation.

More information on STEP can be found at: http://www.uscg.mil/hq/cg5/cg522/cg5224/step.asp

To facilitate the invention of new systems to address organisms in ships' ballast water, the U.S. Coast Guard developed the shipboard technology evaluation program (STEP) to provide an incentive for ship owners to participate in experimental evaluations of promising technologies on operational cargo vessels.

The STEP Process

Under STEP, successful applicants receive an "equivalency," whereby the Coast Guard deems that use of the experimental system satisfies ballast water management requirements. Enrollment includes a rigorous evaluation of the prototype's likelihood of success based on a thorough review of the science and engineering behind the technology.

Following this efficacy review, the applicant's study plan is peer-reviewed for scientific rigor and validity. Finally, the Coast Guard completes a thorough evaluation of the potential environmental impact associated with the use of the system in the specific marine areas the ship operates in. This includes review under the Endangered Species Act, National Marine Sanctuaries Act, Marine Mammal Protection Act, and National Environmental Policy Act. Only upon completion of these screening measures are systems accepted and allowed to begin in U.S. waters.

Currently, four ships have applied to participate in the program. The ships are widely varied in route and service, including:

- a North Atlantic container freight,
- Caribbean and Pacific Ocean passenger cruising,
- a Pacific Ocean bulk dry cargo integrated tug and barge,
- a Gulf of Mexico bulk liquid tank ship.

Having this breadth of routes and service types is crucial to getting a comprehensive data set. However, each enrolled vessel will only represent one data set for the particular impacted waters and service type. Therefore, the U.S. Coast Guard is very interested in exploring the possibility of enrolling additional vessels and their associated technologies in new locations. This will allow for a geographically broader view of a particular technology's capability, and review it on different types of ships within overlapping service areas to determine if there are potential volume or flow rate capacity limits.

Such expansion is necessary to more fully characterize these new state-of-the-art ballast water management technologies. Once such detail is obtained, we can make realistic conclusions about how robust treatment levels need to be to meet the desired results.

Technologies Under Evaluation

Current applicants have proposed mechanical filtration systems that further expose remaining organisms to ultraviolet energy, use of in situ-generated chlorine ions, and dosing ballast water with chlorine dioxide for sterilization.

Additional technologies that are being advanced include using ultrasonic energy to disrupt cellular structures, heat to sterilize the water, various chemicals as biocides, and de-oxygenation to suffocate any organisms.

As these ballast water treatment efforts mature, a future focus will include dealing with organisms that attach themselves to ships' hulls, shafts, and anchors, a process that also transports species outside their native range.

About the author:
LCDR Brian Moore is a marine safety officer with experience in the offshore oil and gas exploration and development fields (port facilities and liquefied natural gas, petroleum, and chemical shipping). Prior to joining the U.S. Coast Guard he was a chemistry teacher and an Army National Guard air cavalry aeroscout. He has master's degrees in quality systems management and environmental earth sciences and environmental policy.

Endnote:

1. 33 CFR 151 Subparts C&D.

Natural-born Killers

Anti-fouling coating systems and their mixed effects on the marine environment.

by Mr. Charles (Bud) Darr
U.S. Coast Guard Office of Maritime and International Law

Like so many issues related to environmental protection, balancing the benefits of a particular protective measure against the potential harm is a prime consideration. For example, anti-fouling hull coating systems can provide substantial environmental benefits, but an effective coating system can also have an unfortunate negative impact on the marine environment. There are very good reasons to keep a ship's hull free from bio-fouling, but the methods employed may cause severe damage to the environment. In other words, what happens when the natural-born killers are too good at killing?

At present, there are regional, national, and international regimes in place to control the detrimental effects of anti-fouling coating systems. This is because there is a compelling need to minimize the environmental harm caused by the biocides employed. In particular, the harm caused by organotins, or more specifically Tributyltin (also known as TBT), is well documented.[1]

Positive Effects of Anti-fouling Coating Systems

As a ship's hull becomes fouled with biological matter, the resulting surface friction causes a significant increase in the power required to maintain a desired speed.

The additional power output results in increased fuel consumption, which adds cost. As power output increases, the air pollution emissions from a shipboard propulsion system also increase. Components of this air pollution include nitrogen oxides, sulphur oxides, particulate matter, and greenhouse gases. Therefore, using anti-fouling coating systems can increase fuel efficiency, decrease air pollution emissions, increase operating speeds, and minimize the spread of aquatic invasive species.

Possible Environmental Harm

Among the environmental harm caused by TBT/organotin anti-fouling coating systems are documented mutations in invertebrate species, long-term heavy metal deposition, effects on marine mammals, and dangers to human health and welfare.[2]

SLIP

A fouled hull results in a reduction in vessel speed for any fixed power output. The increased hull friction will cause a diminished speed through the water for a fixed number of turns, which can be quantified by a metric known as "slip."

Slip is typically measured on a daily basis by comparing the theoretical distance a ship should have traveled—based upon a total number of turns made over a 24-hour period—against the actual distance traveled through the water during that same period.

There are well-documented concentrations of organotin biocides in areas such as Puget Sound, San Diego Harbor, and Hampton Roads.[3] The concentrations of these substances tend to be highest where ships remain stationary for extended periods of time.

There is some evidence that organotin has detrimental effects upon marine mammals. Some studies have found elevated concentrations of these biocides in the livers of stranded mammals.[4] Although more research remains to be done, there is a growing belief that the top of the food chain, including these mammal vertebrate species, is substantially affected by exposure to organotin biocides.

There is also a well-founded concern among the scientific community that human health and welfare is at risk due to organotin and other biocides. This is largely due to exposure related to the application and removal of anti-fouling coating systems, as well as human consumption of species where the biocides are concentrated.

At present, the principal substitutes for TBT are copper-based coating systems. Copper is far from a perfect solution because it is also associated with negative environmental effects, though not believed to be as serious as those related to TBT. Until a viable alternative can be identified for copper-based coating systems, it seems unlikely that there will be a move to ban (or largely limit) them.

Although there are some less toxic alternative biocides under consideration, some of the most promising alternatives may be those that approach the problem by inhibiting adherence of the species to the hull rather than killing the species directly.

Regulations

The key regulations in place include the U.S. Organotin Antifouling Paint Control Act of 1988 (OAPCA), the IMO anti-fouling system (AFS) convention, and the European Union regulation EC/782/2003.

In 1988, the United States acted unilaterally through the OAPCA of 1988. This legislation imposed controls on the supply chain and focused on banning use of organotin on recreational vessels. Whereas the existing unilateral regime focused on the domestic supply chain and recreational vessels, the AFS convention sought to regulate the entire supply chain and applications upon all types of vessels.

In 2003, the IMO adopted the AFS convention. Having met the minimum thresholds following ratification by Panama in 2007, the convention entered into force on September 17, 2008. At present, the annex to the convention only controls organotin, but it will likely be amended at some point in the future to include other biocides.

Although framed as regional or national measures, the practical effect of the EU regulation is to implement the IMO AFS convention in its entirety. This regulation supplemented a prior EU directive (2002/62), promulgated in 2002, which was primarily focused on cutting off the supply chain of organotin compounds within the community.

Ongoing Initiatives

The United States is presently signatory to the AFS convention, pending ratification. In early 2008, the president transmitted the convention to the Senate for advice and consent, together with proposed implementing legislation. The administration's proposed implementing legislation takes the form of amendments to the OAPCA of 1988. It principally provides for the U.S. Coast Guard to have primary responsibility for shipboard enforcement and for the EPA to have primary responsibility for shoreside enforcement. Congress has yet to act on the president's proposal.

The IMO Marine Environment Protection committee is addressing measures to minimize the translocation of invasive aquatic species through the bio-fouling of ships. At present, a correspondence group has begun work on the topic, under the leadership of New Zealand.

Domestically, the U.S. Coast Guard already has authority and a congressional mandate to prevent the introduction and spread of aquatic invasive species via means that include hull fouling. This authority is granted by the NANPCA of 1996, which amended the National Invasive Species Act of 1990. The U.S. Coast Guard has exercised this authority by requiring the regular cleaning of vessel hulls, via promulgation of regulations at 33 CFR 151.2035.

At the present time Congress is considering a variety of legislative proposals that may alter the U.S. Coast Guard's authority to regulate invasive species. The administration has expressed its concern that the U.S. Coast Guard's authority to regulate hull fouling as a vector for the introduction and spread of aquatic invasive species should not be compromised by legislative action. This vector is frequently overshadowed by the threat posed via ships' ballast water effluent, but is nonetheless quite important.

About the author:
Mr. Darr is a civilian Coast Guard attorney who advises the marine safety, security, and environmental stewardship programs. He has served on a wide range of IMO delegations at the assembly, committee, subcommittee, and working group levels. He graduated from the U.S. Merchant Marine Academy in 1993, cum laude, and from The George Washington University Law School in 2001, with high honors. He is a retired Coast Guard marine inspector, investigating officer, and law specialist.

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4. "Organohalogen and organotin compounds in killer whales mass-stranded in the Shiretoko Peninsula, Hokkaido, Japan," Natsuko Kajiwara, Tatsuya Kunisue, Satoko Kamikawa, Yoko Ochi, Shinichi Yano, and Shinsuke Tanabe, (2006), Marine Pollution Bulletin Vol. 52, Issue 9, 1066-1076.

The Successful Use of the Auxiliary in the Sector

by Mr. Michael LaRue, AUX, S.T.M., M.S.
Planning Assistant, U.S. Coast Guard Sector Delaware Bay

On September 13, 2006, the Commandant of the Coast Guard, Admiral Thad Allen, issued a new auxiliary policy statement that included the following directive:

"Every commander, commanding officer, officer-in-charge, and program manager shall work closely with their Auxiliary counterparts to fully leverage the resources, skills, qualifications, and profound dedication that reside within the Coast Guard Auxiliary. Such focused collaboration is essential to our unwavering commitment to mission excellence in serving and protecting the public trust."

We at Sector Delaware Bay have been working to implement this directive, with varying degrees of success, and offer this overview in the hope that other commands may be able to copy and improve upon our successes, avoid our mistakes, and work together to overcome obstacles to effectively implement this directive.

Coast Guard Auxiliarist Bill Hougar works with the Grant County Sheriff during a holiday weekend patrol at Wanapum Lake, Wash. USCG photo by Petty Officer Eric J. Chandler.

Auxiliarists at Sector Delaware Bay

In the last few years, Sector Delaware Bay has experienced significant success in attracting a small but devoted and professional group of volunteers to forward our mission. We started with four or five volunteers who persisted despite some obstacles, with the assistance of people in the command who were convinced that the auxiliary was both useful and underutilized. These volunteers were able to make a difference, and to convince more people in the command of the auxiliary's usefulness, such that now we have a dedicated group that provides thousands of hours annually to support the sector.

We are now successfully employing auxiliarists on the aids to navigation team, as our interim educational services officer, in the command center and command suite, on the quarterdeck as watchstanders, and (the largest number) in planning. Auxiliarists not only provide administrative support, but also have also successfully headed up projects of their own. An auxiliarist serves on the sector's history committee. One of our auxiliarists has even turned into something of a physical fitness buff in the last year, and is now active as a unit health promotion coordinator and on the wellness committee.

The Care and Feeding of Auxiliarists

Some key factors played into this success. Our auxiliarists have always been professional and dependable. In addition, our auxiliarists are comfortable working in a military environment, and able to work in a military culture. It helped a great deal that two of our volunteers are retired senior military officers.

Another factor is that we have been selective about the auxiliarists to whom we have given orders. Not every auxiliarist is going to be a good fit at such a command. It is hard to say no to volunteers, but sometimes you have to. It also takes time and patience to build up trust in the command.

Additionally, our auxiliarists have been willing to put up with a lot, go out of the way to be responsible and make a good impression, be quick to admit and correct mistakes, and even to seek out correction. Not everyone has this level of patience or humility.

We also found it useful to look for self-starters—people who can be given projects and then run with them. Active duty personnel and civilian employees often simply do not have time to baby-sit volunteers, so having someone who can take charge and do a good job is most helpful. Conversely, having auxiliarists who are cheerful about doing grunt work is also a great help.

Having a good auxiliary sector coordinator (ASC) is key to the success of our program. Our present ASC clearly demonstrates the important traits necessary—being diplomatic and having good people skills and good judgment. If one is looking for auxiliary help, it is first useful to identify shortfalls and then look at what auxiliary billet might fill that shortfall, including the hours and skill sets desired. The ASC may then be able to find people who can fill those needs. We are just beginning to get a formalized process in place to facilitate this.

Exploring Areas for Improvement

Many obstacles—cultural, personal, and institutional—prevent the successful use of the auxiliary, as we have discovered. Some aspects of the problems facing the auxiliary are ongoing and unlikely to change. The spirit of volunteerism is unlikely ever again to return to the level it was in the 1950s.

However, there are still untapped or underutilized sources of talent. That being the case, we should consider how best to attract the kinds of volunteers we need into the auxiliary. The most attractive things about the auxiliary are its traditions (which embrace those of the Coast Guard), its mission set, and the opportunity for fellowship with others of similar interest.

As with the Coast Guard in general, custom and tradition are very important in maintaining professionalism and dedication among personnel. Sociologically, learning about its history and engaging folks in the customs and traditions of an organization reinforce their sense of belonging and their commitment to being responsible members of that organization.

At our sector we have seen the benefits of having a brief on sector history. It raises our people's awareness of the past accomplishments of the Coast Guard in this region, makes them proud of being members of the sector, and sets good examples for them to follow. In addition, anything we can do to make our people aware of the auxiliary and its past achievements, and to encourage pride in our auxiliarists, will further our goal of having a good working relationship with auxiliarists.

Get Them on the Water

Probably the most attractive mission that the auxiliary has is its involvement in search and rescue. Getting people involved in on-the-water activities is a powerful recruiting tool, and often leads to willingness to perform other kinds of missions. Working directly with the active duty personnel in any kind of operational activity is also a powerful motivator.

Further, people recruited into these kinds of activities will tend to be younger and more physically fit, and thus better in the long term as volunteers. It thus seems prudent that we should better explore opportunities for expanding operational use of the auxiliary and how to recruit on this basis.

Who Salutes Whom?

There is probably nothing about the auxiliary that causes more confusion (and no small amount of resentment) than auxiliary office devices. First, as set forth in the auxiliary manual, auxiliarists are to exchange uniform courtesies with officers.

This is entirely appropriate, given that they are in uniform. However, the fact that they are supposed to do this is not widely appreciated, even within the auxiliary. Further, given that auxiliary officer devices do not represent rank, there is much confusion about who is to initiate a salute.

A simple solution, and one envisioned by the auxiliary manual, is to have one's auxiliarists not wear auxiliary officer devices. Some auxiliarists will not like this at all. There is also the question of how to deal with, say, an auxiliarist who is also a retired Navy captain, someone certainly deserving of the title and recognition his retired military rank deserves.

There is probably no single solution short of entirely reworking the auxiliary officer devices, but in dealing with the auxiliary at sectors or other commands it is important to know that these are problems, so that one can mitigate the difficulties as best as one can.

Physical fitness is necessary at any age, and just about anyone can participate in activities to improve health. It has already been mentioned that we have an auxiliarist as our unit health promotion coordinator. Anything that commands can do to get auxiliarists involved in physical fitness is likely to have payback in terms of a better member who will work and look like a credit to the command. Further, the benefits to one's health provided by participation in Coast Guard wellness activities can be a powerful additional incentive for an auxiliarist.

This Does Not Compute

Unfortunately, at the same time that the auxiliary began to function more independently from the rest of the Coast Guard, computer information systems began to come into use. This means that separate information systems, separate databases, separate credentialing (including separate systems for ID cards), and separate business procedures came into use, which in turn made it very difficult to do certain things with auxiliarists. I would suggest this is one of the major obstacles to using them.

Our most recent problem in this respect had to do with travel claims. Further significant problems have had to do with getting some kinds of training recorded, with procuring necessary uniform items when the source of supply was a Navy exchange, and even with getting auxiliarists' phone extensions in the sector directory.

Unfortunately, here at Sector Delaware Bay we have wasted hours on sometimes fruitless attempts to get things done with a bureaucracy to whom auxiliarists are invisible, and it can be fatally discouraging for the career of some volunteers. Until those with more authority find solutions to integrate the auxiliary better with the rest of the Coast Guard, it is important for anyone using auxiliarists at the sector to identify these problems, to work together to find ways to work around them, and to do everything we can to ensure that our auxiliarists do not have to shoulder an insupportable and alienating bureaucratic burden in order to be of service. Support from one's Coast Guard supervisor and willingness to intercede with the bureaucracy on behalf of one's auxiliarists can make a decisive difference.

Acknowledgment

The only pay that auxiliarists receive is the sense of belonging to an important team accomplishing an important mission, and the thank-you of their superiors and team members when they have done a good job.

At Sector Delaware Bay, we have a small annual event for auxiliarists. The command has also been good about ensuring that auxiliarists receive awards when deserving. However, even a habit of saying "thank you" has great benefit and is a powerful motivator. Remember, these people are not doing it for money, and showing gratitude is a very inexpensive way of paying for the hours of service they provide.

The Coast Guard needs all the help it can get, and we should be grateful for the foresight of those in the Coast Guard in the 1930s who saw the need for such a force of volunteers. We can and should take full advantage of the means that they and others who have gone before them have provided to better and more fully accomplish our mission.

About the author:

Mr. LaRue has been a member of the U.S. Coast Guard Auxiliary for nine years, and has served on the planning staff of Sector Delaware Bay for two and half years. He is also a rare materials cataloguer and researcher with expertise in naval, military, and maritime history, and is active in humanitarian work through the Order of Malta. In the fall of 2006 he received the Auxiliary Achievement medal for his work on improving force readiness and information management at the sector level.

Course Correction

It has proven important, when difficulties or issues have arisen with auxiliarists who were not meeting the basic standards expected of them (for example, not wearing the uniform properly or behaving inappropriately), to take quick remedial action.

Positive peer pressure is very useful in this, and can prevent a superior from having to take action. Often we have found that just taking the auxiliarists aside and quietly informing them of the problem will solve it.

Sometimes one has to be persistent. The auxiliarist will usually either correct his or her behavior or stop volunteering. On the other hand, trying to sidestep or ignore a problem in order not to offend the auxiliarist has been shown time and again to have negative results—on all sides.

Auxiliarist Larry Owens, right, and SN David Jacobson exit the water after a rescue demonstration. USCG photo.

Nautical Engineering Queries

Questions

Prepared by NMC Engineering Examination Team

1. A loud buzzing noise at the contacts of a magnetic controller could indicate _____.

A. weak contact spring pressure
B. misalignment of the magnet faces
C. excessive line current
D. mechanical binding

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2. The sum of the sensible heat and the latent heat of any substance is known as _____.

A. total heat
B. residual heat
C. specific heat
D. superheat

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3. Where will you find procedures for the reporting of oil discharge into the water?

A. the vessel's certificate of inspection
B. the vessel's oil record book
C. the vessel's oil transfer procedures
D. the vessel's international oil pollution certificate

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4. The main lube oil sump of a main propulsion engine should be constructed of _____.

A. coated steel plating to reduce corrosion
B. nonferrous metal plating to prevent corrosion
C. clean steel plating
D. pinchback plating

Nautical Deck Queries

Questions

Prepared by NMC Deck Examination Team

1. Which area is designated a special area by Annex V to MARPOL 73/78?

A. the Gulf of St. Lawrence
B. the Sargasso Sea
C. the Red Sea
D. the Great Lakes

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2. A source of an air mass labeled mTw is _____.

A. the equator
B. the Gulf of Mexico
C. Alaska
D. Canada

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3. You are ordering ship's stores. Which statement is TRUE?

A. Aerosol cans of engine starting fluid must be stowed in either the paint locker or portable magazine after receipt.
B. Drugs and medicines must be stowed in accordance with the directives of the Food and Drug Administration.
C. Flammable ship's stores must be certified for use on inspected vessels by Underwriter's Laboratories.
D. Properly labeled consumer commodities need not be labeled in accordance with Title 46 CFR.

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4. What is NOT required as special safety equipment on a tank ship carrying hazardous cargoes in bulk?

A. a shower and eyewash fountain
B. equipment to lift an injured person from a pumproom
C. two portable vapor detectors suitable for the cargoes carried
D. a safety locker adjacent to the emergency shutdown station

Engineering Answers

1. A. weak contact spring pressure — Incorrect Answer: Excessive burning of the contacts is an indication of weak contact spring pressure, excessive load current, oxidized contacts, or a poorly bolted connection.

B. misalignment of the magnet faces — Correct Answer: A loud buzzing noise, or contact buzz, could indicate misalignment of the controller's magnetic faces, broken shading coil, low voltage, or dirt on the magnet faces.

C. excessive line current — Incorrect Answer: Welded or excessively burnt contacts would indicate excessive line current.

D. mechanical binding — Incorrect Answer: Failure of the contactor to pick up could indicate mechanical binding, low voltage, or an open coil.

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2. A. total heat — Correct Answer: Sensible heat is the heat absorbed or released when a substance undergoes a change in temperature. Latent heat is the heat that causes a change in state (phase) of a substance with no change in temperature. The sum of the sensible and latent heat of a substance is referred to as the total heat.

B. residual heat — Incorrect Answer: Residual heat is defined as the heat remaining in a substance after it has done its work.

C. specific heat — Incorrect Answer: Specific heat is the amount of heat required to raise the temperature of the unit mass of that substance one degree. The specific heat of water is one calorie/gram °C = 4.186 joule/gram°C, which is higher than any other common substance.

D. superheat — Incorrect Answer: Superheat is the number of degrees a condensable gas is above its boiling temperature at a given pressure. At atmospheric pressure, 212˚F steam has no superheat; 213˚F steam has one degree superheat, etc.

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3. A. the vessel's certificate of inspection — Incorrect Answer: The vessel's certificate of inspection describes the route(s) that it may travel, the minimum manning requirements, the survival and rescue craft carried, the minimum fire extinguishing equipment and lifejackets required to be carried, the maximum number of passengers that may be carried, and the name of the owner and managing operator.

B. the vessel's oil record book — Incorrect Answer: 33 CFR 151.25(g) states "In the event of an emergency, accidental or other exceptional discharge of oil or oily mixture, a statement shall be made in the oil record book of the circumstances of, and the reasons for, the discharge."

C. the vessel's oil transfer procedures — Correct Answer: 33 CFR 155.750(a) states "The transfer procedures required by 155.720 must contain, either in the order listed or by use of a cross-reference index page: (9) Procedures for reporting discharges of oil or hazardous material into the water."

D. the vessel's international oil pollution certificate — Incorrect Answer: 33 CFR 151.19 (a) states "Each U.S. oil tanker of 150 gross tons and above, and each other U.S. ship of 400 gross tons and above; that engages in voyages to ports or off-shore terminals under the jurisdiction of other parties to MARPOL 73/78 must have on board a valid international oil pollution prevention (IOPP) certificate." Before an IOPP certificate is issued, a survey that includes a complete examination of the ship's structure, equipment, systems, fittings, arrangements, and material must be conducted in accordance with the provisions of 33 CFR 151.17. The IOPP certificate is valid for a maximum period of five years from the date of issue.

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4. A. coated steel plating to reduce corrosion — Incorrect Answer: The damage possible due to coating failure has resulted in manufacturer recommendation that coatings not be used.

B. nonferrous metal plating to prevent corrosion — Incorrect Answer: Nonferrous metals have a catalytic effect on the oil, which will tend to promote oxidation.

C. clean steel plating — Correct Answer: Lube oil tanks are generally constructed of clean carbon steel plates with welded joints. All lube oil tanks should be fabricated in accordance with the general requirements of National Fire Protection Association (NFPA) 30, Flammable and Combustible Liquids Code (1996), for flammable liquid storage.

D. pinchback plating — Incorrect Answer: "Pinchback" plating is not a type of metal plating.

1. *Note: Special areas, according to the MARPOL 73/78 Convention, are areas that, due to their special ecological conditions, are considered to be so vulnerable to pollution that especially far-reaching and mandatory regulations are needed to limit discharges of pollutants.*

A. the Gulf of St. Lawrence — Incorrect Answer: This is not a special area identified by Annex V to MARPOL 73/78.

B. the Sargasso Sea — Incorrect Answer: This is not a special area identified by Annex V to MARPOL 73/78.

C. the Red Sea — Correct Answer: 33 CFR 151.06 (a) (4) mirrors MARPOL 73/78, stating that the Red Sea area, including the Gulfs of Suez and Aqaba, is considered a special area under Annex V. Annex V comprises regulations to prevent pollution by discharges of household waste and other solid waste. The annex defines the different types of waste that are to be regarded as garbage, the distance from land where they are allowed to be discharged, and in what ways.

D. the Great Lakes — Incorrect Answer: This is not a special area identified by Annex V to MARPOL 73/78.

2. *Note: Air masses are classified into a number of categories: (A) for Arctic, (E) for equatorial, (P) for polar, and (T) for tropical. For polar and tropical categories, the air mass is symbolized with a "c" when it originates over land (cP, cT) and an "m" when it originates over the water (mP, mT). Additionally, following the symbol would be "w" or "k" indicating whether the air is warmer (w) or colder (k) than the surface over which the air mass is passing.*

A. the equator — Incorrect Answer: This air mass known as equatorial (E) originates in equatorial and tropical sea areas, producing high temperature and humidity.

B. the Gulf of Mexico — Correct Answer: This is an air mass source within a subtropical, high pressure area "T" originating over water "m," producing moderate high temperatures and high relative humidity. A "w" when added to the symbol would represent the air mass being warmer than the surface over which it passes.

C. Alaska — Incorrect Answer: This is an air mass source within a subpolar continental area "cP," producing low temperatures and low constant humidity.

D. Canada — Incorrect Answer: This is an air mass source within a subpolar continental area "cP," producing low temperatures and low constant humidity.

3. A. Aerosol cans of engine starting fluid must be stowed in either the paint locker or portable magazine after receipt. — Incorrect Answer: Engine starting fluid (ether) is classified as a flammable gas and is required to be stored in a paint locker in large quantities and allowable smaller quantities in approved portable containers outside of work spaces. A magazine is a storage area for ammunition (which is classified as an explosive) and is not meant for the storage of flammable material.

B. Drugs and medicines must be stowed in accordance with the directives of the Food and Drug Administration. — Incorrect Answer: Drugs and medicines are to be stowed and dispensed in accordance with the Department of Health and Human Services (DHHS) publication *The Ship's Medicine Chest and Medical Aid At Sea.*

C. Flammable ship's stores must be certified for use on inspected vessels by Underwriter's Laboratories. — Incorrect Answer: Any flammable ship's stores may be brought aboard as long as they are labeled in accordance with 46 CFR 147.30 and meet all other requirements of Part 147, *Hazardous Ship's Stores.* Underwriter's Laboratories certify stowage containers.

D. Properly labeled consumer commodities need not be labeled in accordance with Title 46 CFR. — Correct Answer: Hazardous ship's stores that are consumer commodities (i.e. Lysol) and labeled in accordance with the Federal Hazardous Substances Act regulations in CFR Title 16 need not be labeled as specified in 46 CFR 147.30, *Labeling.*

4. *Note: 46 CFR Subchapter O—Certain Bulk Dangerous Cargoes, Part 153, provides regulations for ships carrying bulk liquid, liquefied gas, or compressed gas hazardous materials.*

A. a shower and eyewash fountain at all times. — Incorrect Answer: Part 153.216 states that each self-propelled ship must have a shower and eyewash fountain that operates

B. equipment to lift an injured person from a pumproom — Incorrect Answer: Part 153.214 states that each self-propelled ship must have two wire stretchers or wire baskets with equipment for lifting an injured person from a pumproom or a cargo tank.

C. two portable vapor detectors suitable for the cargoes carried — Correct Answer: Part 153.465 states that each tankship that carries flammable cargo must have two vapor detectors, where only ONE of the vapor detectors needs to be portable.

D. a safety locker adjacent to the emergency shutdown station — Incorrect Answer: Part 153.215 states that each self-propelled ship must have at least two safety lockers, where one safety locker must be adjacent to the emergency shutdown station.

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