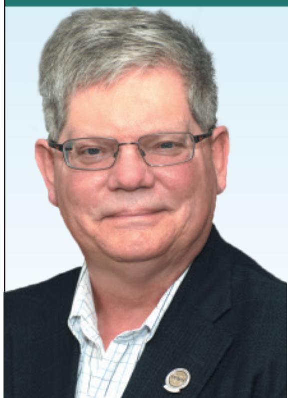

Bring It On

Engineers face challenging innovations to equip shipowners with low-carbon fuel options

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In the first part of this article, published in the spring edition of Great Lakes/Seaway Review (Vol. 49, No. 3), we explored—at a high level—the multitude of available alternative fuel options; some that are ready for the marketplace and some that are not quite ready.

There are certain fuels, like biodiesel, where the transition from marine gas oil to biodiesel is, practically speaking, relatively easy for both the operator and the engine maker. But alternative fossil fuels, like LNG or LPG, require significant changes to the ship, the engine(s) and the operating engineer to be fully effective. But even if you manage to work your way through the technical changes needed, you must still recognize that you do not yet have a permanent fix, but merely a temporary improvement.

While these fuels do a great job with NO_X and SO_X reductions, their impact on greenhouse gas emissions reduction is minimal, even as the requirement to do just that approaches. International Maritime Organization (IMO) delegates in 2018 agreed to instituting limits that require a reduction in shipboard greenhouse gas emissions of 50% from 2008 levels, by 2050! So, to make real and long-term environmental progress, a substantially different approach other than hydrocarbon-based fuels will be required.

One such approach getting a lot of attention from scientists, environmentalists, shipowners and engine makers is ammonia (NH_3). Although gaining what seems like new interest in the past decade or so, ammonia has been used in internal combustion engines since the early 1940s. Diesel fuel shortages during World War II, especially in Europe, prompted engineers to find a way to burn ammonia in engines.

At the time, while it was effective, it was not deemed to be very efficient, and the practice was abandoned as soon as adequate supplies of diesel were restored. But fast forward to 2021, and several major engine makers are knee-deep in engineering designs and testing programs to use their existing engines and burn ammonia directly.

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Benefits

There is a lot to like about ammonia. It does not emit carbon dioxide when it is burned, is quite abundant and is widely available, with a century of infrastructure already in place in North America.

- Ammonia can be manufactured using renewable energy sources, making it even more environmentally sustainable.
- It does not require high pressure storage tanks, nor is it stored at expensive cryogenic-level temperatures; and while it is only 50% of the energy density of diesel fuel, ammonia has 10 times the energy density of a lithium-ion battery.
- It is three times more energy dense than compressed hydrogen.

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Ammonia has one other feature that is exciting the scientific community. While the initial push to look at ammonia as a marine fuel stemmed from its carbon neutral, zero emission capabilities when burned directly in an internal combustion engine, ammonia has a unique chemical formula, in that it is comprised of one part nitrogen, to three parts hydrogen. So, ammonia can be used in a fuel cell, where the hydrogen can be easily stripped off from the nitrogen. The storage and movement of large amounts of readily available hydrogen has been one of the key issues keeping hydrogen from becoming the perfect alternative marine fuel.

Ammonia may be the best solution available at the present time.

However, as I wrote in my first installment of this article, there is no silver bullet when it comes to alternative fuels. No single alternative fuel checks all the boxes, and ammonia is no different. While it is widely considered to be the lowest cost, zero emission fuel available today, its energy density is only 50% of that of diesel fuel, meaning that a shipowner requires twice as much fuel by volume than if using diesel fuel; and this might mean that the shipowner would have to give up precious cargo space to accommodate the extra fuel, which is never a popular choice.

Because petroleum-based fuels have a higher energy density and are less expensive to produce, there has been very little incentive to explore the use of ammonia before now. But with such a high focus on carbon-neutral fuels, the old economics may be poised to undergo a dramatic change.

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Risks

Like most fuels by their nature, ammonia has its share of risks. Ammonia is toxic, and when spilled, it exposes people who breathe its strong smelling but colorless vapors to chest pains, eye irritation, severe headaches and even death. Installations that use ammonia as a marine fuel will require special ventilation and gas-absorption systems. To help mitigate the risk of leaks, piping systems will likely need to be double-walled and enclosed spaces will require additional gas monitoring and mechanical ventilation to mitigate risk in the event of leaks.

A number of other technical challenges exist when considering the use of ammonia as a marine fuel.

Ammonia can be corrosive to certain alloys that contain copper and nickel, as well as some plastics. Interestingly, the fuel is difficult to ignite and does not sustain combustion well, similar to LNG. So, a pilot fuel is needed, and while it might be tempting to use readily available diesel fuel, since the real intention is to reduce the carbon footprint, the use of hydrogen is perhaps a much better choice. Where can I get the hydrogen? Oh yeah, it's in the ammonia!

Costs

One of the major downsides to most, if not all of the alternative fuel options is that they are not economical to produce. At the moment, ammonia is, pardon the pun, in the same boat.

Currently, there are two different ways of producing ammonia. "Green" ammonia is produced with hydrogen that comes from water electrolysis that can be powered by renewable energy. "Gray" or conventional ammonia is produced by converting natural gas into gaseous hydrogen which is then combined with nitrogen.

Green ammonia costs three-to-four times more than gray or conventional ammonia. Conventional ammonia production is much less expensive but very carbon intensive since the reaction uses natural gas and extreme heat fired by carbon-based fuels. The key in reducing the production cost of green ammonia is reducing the costs of the renewable energy used in the process. This may take a while and will be dependent on the availability of wind, solar and hydro-electric resources.

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We are driven by the economics. The use of carbon-based fuels is likely to remain a shipowner's preferred alternative for the near-term. But worldwide, legislation will slowly and inexorably drive ship designers, shipowners and regulators to develop the technology that will bring the economics in line.

Forecasts are that by the year 2050, alternative fuels of all types will out-pace the carbon-based fuels of today. Possibly, the largest single segment of alternative fuels could be ammonia.

This is an exciting time for marine engineering companies in general.

Alternative fuels represent just one of the many challenges facing engineering companies and shipowners.

This is an exciting time for marine engineering companies in general. In a way that we have not seen in many years, there is an ever-increasing drive to find innovative ways to do the same old thing: carry the most cargo on the smallest platform possible, do it better, faster and in more environmentally friendly ways—all for the lowest possible cost. These are all great challenges, something every true engineer thrives on.

Bring it on! ■