Separating Fact From Fiction:
Fuel Treatment For Shipboard Emissions Control

Numerous companies are making diverse claims for fuel savings and lower emissions these days, so Bunkerworld asked PRI's Ralph Lewis to sift through the evidence and to report on some actual benefits that might be gained from the use of additives.

With the implementation of MARPOL Annex VI, a wealth of technology is emerging from aspiring manufacturers to tap into the potentially lucrative marine emissions control market.

While some concepts are new, most are not. Selective Catalytic Reduction (SCR) for NOx reduction and oxidation catalysts for particulate reduction, for example, are well established.

Then there are fuel additives. Again, fuel treatments have been used for many years in onshore, oil-fired power plants, primarily for visible smoke reduction and vanadium control. Yet claims are now emerging from heavy fuel oil additive manufacturers for products that purportedly provide substantial reductions in nitrogen oxides (NOx), carbon monoxide (CO), carbon dioxide (CO_2), sulphur dioxide (SO_2), total unburned hydrocarbons (THC), and particulate matter (PM).

This begs more than a few questions. Have new 'miracle' chemistries been developed that can truly overcome the basic principles of combustion physics? Or is the little man behind the curtain simply bending the rules to dazzle potential clients?

This article answers these questions and reviews the various heavy fuel oil chemical treatment technologies presently offered to vessel owners, and also gives an analysis of emissions testing methodologies used to 'validate' sales claims.

The most rigorous of these methodologies is the emissions testing protocol established under MARPOL Annex VI - the marine industry's internationally accepted standard. Performing well in this test environment has been elusive for fuel additive manufacturers to date - with one promising exception.

Types of fuel treatments

Most HFO fuel treatments fall within three categories: dispersants, combustion catalysts, and vanadium control treatments.

Dispersants are often referred to as 'FOTs' (fuel oil treatments). All the major marine chemical suppliers offer them. Some are heavily diluted with a base mid-distillate, while others are very concentrated - accounting for the various dosage ratios.

The value of FOT is predicated on the fact that some sludge precipitation occurs when suppliers 'cut' residual fuel with a mid-distillate to achieve proper viscosity under ISO 8217 specifications.

Much waste sludge consists of usable organic fuel, accounting for as much as 1.0 to 1.5 percent of the total fuel bunkered. An effective FOT dispersant can inhibit organic sludge loss, recovering anywhere from 20-85 percent of the value lost. When an effective FOT is used on a consistent basis, fuel delivery systems also remain cleaner, and injectors are less likely to plug.

From an emissions standpoint, this is a good thing. A cleaner fuel delivery system can mean better injector spray patterns. The downside is that these chemistries provide no inherent chemical change in the combustion process itself. Even with the addition of a dispersant, a fuel of moderate to poor ignition quality will still have moderate to poor ignition quality.

Man B&W technicians monitor emissions testing of a fuel treatment developed by Power Research Inc.

More controversial are the myriad of 'combustion catalysts' - so-called because they purport to accelerate the rate of combustion. A chemical review of major brands reveals that most rely on ferrocene, an iron salt (cyclopentadienyl iron). Many studies confirm that ferrocene can be an effective ignition enhancer and soot reduction agent in gasoline and diesel engines respectively. Ferrocene is cheap, but it comes with hidden costs.

Simply, the ferrous oxide residue produced when ferrocene is combusted not only fouls spark plugs in gasoline engines, it has been shown to cause excessive wear in some diesel engines.

This residue can also plug certain particulate reduction devices - a reason why the California Air Resources Board has banned its use in diesel fuel. A 2005 study commissioned by the National Science Foundation also raised worrisome questions regarding the changing structure and potential toxicity of particulates generated from Ferrocene-laced diesel fuel.

Vanadium control agents typically rely on magnesium oxide to disrupt the complexing of vanadium with sodium and sulphur during combustion. Vanadium has a high melting point, but when combined with sodium and/or sulphur, the melting point of the compounds formed is lowered to a range where sticky slag is produced on internal engine components. Magnesium interferes with this process, blocking some of the formation of the low melting point material.

Getting a magnesium oxide, or MagOx, additive to work depends on delivering a sufficient amount of the metallic to the fuel. In land-based, oil-fired power plants, where MagOx is commonly applied, adequate space exists for tanks to accommodate additive sufficient for effective treatment. But in designing cost-effective, concentrated formulas for ships, chemists must curtail MagOx portions to avoid the falling out of the heavy material - even when it is blended to be oil soluble.

Resultantly, a magnesium-based formula that works well on some marine fuels can be grossly insufficient for others, giving marine magnesium additives a spotty record at best.

Extravagant claims

Marine engine manufacturers typically cast a jaundiced eye toward ash-bearing combustion catalysts and vanadium control additives. After all, they contain metallic components that can potentially cause excessive engine component wear. Wartsila, for example, states in their Fuel Additive Policy document, "if the additive contains ash (e.g. magnesium, iron etc.), we usually do not recommend customers to use it."

Perhaps this explains some reluctance by vessel owners to even try chemical fuel treatment. But more often than not, the failure of a product to live up to claims taints forever the whole concept of additive viability among prospective users who hope for the best, but suffer disappointment time after time.

Recently, for example, a manufacturer of a new additive product made the rounds among marine technical managers, making extravagant claims based on an 'emissions test' conducted by the manufacturer on a small ship. The data looked authentic enough, and one port engineer took the bait, only to discover that in long-term trials, the product failed to match claims. What went wrong?

Often the emissions test 'data' will reveal clues that betray product validity. For example, if data shows a concurrent reduction in carbon monoxide, carbon dioxide and NOx, the red flag should be raised, and raised high. It is simply a matter of combustion physics. Improved combustion is indeed indicated by CO reduction. But there is a carbon trade-off. When CO is reduced, CO_2 must always go up.

The same holds true for NOx. As an engine experiences more efficient combustion, NOx will slightly elevate. Fact is, no additive can surmount the inviolable principles of combustion physics.

Much of this stems from a basic flaw in test methodology. More often than not, data is obtained with portable, hand-held emissions measuring instruments that measure in parts per million (ppm). But measuring ppm at a specific engine speed fails to account for power produced.

Therein lies the rub. Accurate emissions testing methodology relies on measuring emissions against power produced. This is why very stringent international protocols have been established for all automotive and marine engine testing.

MARPOL Annex VI designates the specific protocol for marine engines. And only a few facilities worldwide are capable of conducting such rigorous tests - most of them operated by marine engine manufacturers.

A new wrinkle is the development of a shipboard continuous emissions monitoring system by UK-based Martek Marine Ltd. The standard MariNOx® system - the only such shipboard system accredited under MARPOL Annex VI - measures both NOx and CO_2. Additional sensors can be fitted which measure CO, HC (unburned hydrocarbons), SOx (oxides of sulphur), oxygen, and PM.

"It will be interesting to see the results of additive testing with our system," said Simon Brown, Martek business development manager. "Many additive companies have approached us with emissions test reports - and so far I have seen mostly jumbled figures and poor methodology."

Numbers that make sense

But there is an exception. Recently, Brown reviewed the data from an emissions test of a fuel treatment conducted by Man B&W at the company's Holeby engine emissions certification facility.

"These numbers make sense - showing the proper relationships in emissions reductions based on improved combustion," Brown said.

The product tested was PRI-RS, a heavy fuel treatment developed by Power Research Inc. (PRI), a Houston, Texas based industrial additives manufacturer. PRI-RS chemistry relies on a principle long established in additives for automotive fuels.

These automotive additives are formulated to block the formation of unburnable, high carbon weight structures that form during the combustion process. In turn, this inhibits carbon formation on engine components while also reducing unburned hydrocarbon and particulate emissions.

This is why the U.S. 1977 Clean Air Act mandated refiners to develop and use these 'deposit modifier' additives in gasoline. After all, regulators thought, a cleaner automobile engine produces fewer emissions and operates more efficiently.

Recognizing that the specific chemistries used for gasoline were insufficient for heavier fuels, Power Research Inc. began developing effective additive technologies for mid-distillates and heavy fuels in the early 1980s.

"Originally we marketed PRI-RS as a deposit control technology for heavy fuel. We found it had an uncanny capability in improving ignition quality while greatly reducing engine component wear by inhibiting carbonaceous deposits on pistons, valves and turbochargers," said Blake Davidson, chief financial officer of PRI. "On these features alone, the product was a resounding success."

"But then in the late 1990s we began helping cruise ship operators in Alaska comply with the state's tough smoke opacity laws, and our additional niche as an effective emissions control additive was born," Davidson added.

In addition to marine vessel operators worldwide, PRI counts several oil-fired power plants as clients, where product capabilities to reduce particulate emissions and NOx (thanks to reduced excess air with more efficient combustion) have been amply demonstrated since 1996 with EPA mandated continuous emissions monitoring methodology.

Then in April 2007, PRI-RS faced the greatest challenge - emissions testing under MARPOL Annex VI protocol at Man B&W's engine emissions certification facility in Holeby, Denmark. Conducted at all load ranges on a four stroke Man B&W 5L21/31 engine, the test did not disappoint.

"We were impressed," said Michael Kryger, facilities manager. "The particulate reductions at low load operations were especially interesting."

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> **- Blake Davidson, PRI**

Overall, reductions in particulate emissions, carbon monoxide and unburned hydrocarbons were achieved with PRI-RS application to the fuel across all load ranges. Power Research Inc. returns to Holeby in Spring 2008 for more evaluation.

"We believe the ship emissions challenge will be accomplished with the blend of several technologies," said PRI's Blake Davidson. "A clear example is of a vessel operator using both PRI-RS and an exhaust particulate oxidation catalyst. Not only will PRI-RS help effect a greater particulate reduction - it will help reduce the workload of the catalyst and keep it in better operating condition long-term."

So even with the present skepticism and the understandable reluctance of many vessel operators to use them, fuel treatment seems here to stay. Power Research Inc. has garnered an impressive client base worldwide - built on a growing body of data from proper test protocols and satisfied clients. And company officials believe the future holds great promise.

"We're all about providing a value and service to our clients far greater than the investment they make in our product," Davidson explained. "They realize increased engine reliability, increased on-time schedules owing to less downtime, increased safety at sea, and an increase in profitability that stems from product capability to recover previously lost fuel value."

He also believes that one day soon, PRI fuel treatment technology may be mandated in some areas for bunker fuel application - mirroring the requirements proscribed under the US 1977 Clean Air Act for automotive additives.

"After all, cleaner engines are more efficient and less polluting, a fact not lost on US regulators when they passed that law more than 20 years ago," he concluded. "The same logic still applies." ■

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