

THE FOUR HORSEMEN OF THE FUEL APOCALYPSE

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When the IMO 0.5 percent sulfur mandate for marine fuel takes effect January 1, 2020, vessel owners have two basic choices.

First is to simply bunker these fuels. Second is to install a mitigating scrubber device which produces an equivalent level of stack emissions as that for the 0.5 percent fuel.

Most vessel owners are opting for the new fuel – but one beset with challenges. The IMO mandate simply requires that this fuel contains no greater than 0.5 percent sulfur content. That is all – no mention of what fuels to blend – light or heavy – or how to blend them. The devil is truly in the details.

Blending a heavy fuel with a lighter distillate to achieve viscosity requirements is hardly new. Marine fuel requirements under ISO 8217 have required suppliers to blend to meet standards for decades. Yet what has changed is the extent to which the new fuels must be blended – and the greatly expanded numbers of suppliers which now must blend them.

A first effort to blend to dilute sulfur content was when the USA Environmental Protection Agency (EPA) mandated the use of 1.0 percent sulfur fuels in oil fired power plants in October 1972. In short order, many changes in fuel consistency were observed, some very challenging. Early IMO requirements for ECA areas in 2000 mandated 1.5 percent sulfur fuel and 1.0 percent sulfur by 2010.

Many issues were observed with these fuels, including compatibility problems and in some cases, compromised ignition quality. Given the restricted local scope of fuel suppliers, the problems were typically limited to a handful of sources.

Fuel Sources

With the global mandate, many hundreds of suppliers will be in the mix. The base heavy fuel will have extreme variances. The blend or “cutter stock” – like today – will be from a wide variety of distillates – Light Cycle Oil (LCO) kerosene, MGO, naphtha, shale oil, and waste distillates coming from such

industrial sources as ethylene crackers and resin plants. Some will be laced with remnants of unsold biodiesel. Some refineries – through their own representatives – supply both the cutter stock and heavy residual fuel as a blend directly to vessels.

Quality control of the components is expected. Yet cutter stocks and heavy fuels are also supplied by a myriad of private brokers and suppliers, often through traders. In such cases, a given cutter stock may pass through several pipelines, tanks, and barges, suffering cross contamination with other fuels, picking up tank bottom residue along the way. This is where the problems begin, some annoying, some devastating.

Four challenges – the four horsemen of the fuel apocalypse – will dominate: fuel stratification, incompatibility, contamination, and compromised ignition quality.

Stratification

Stratification – or the formation of separate fuel layers in storage tanks – is largely the result of poor supplier blending practices. Surprisingly, as few as twenty percent of suppliers, according to some estimates, are even equipped with appropriate fuel blending equipment.

So-called “barge blending” for example, is not uncommon. At the refinery, the barge is first loaded with the heavier oil. A simple calculation then determines the amount of cutter stock necessary to dilute the final mixture to the desired sulfur content. This cutter stock is then pumped in on top of the heavier fuel in the tanks. The fuel mixes, the thinking goes, from the turbulence created from the rate of flow of the fuel being pumped.

Barge blending also relies on the same method in many cases. A dedicated tank is loaded with heavy fuel, then the cutter stock is then pumped in on top with hopes that the force of fuel flow will provide some semblance of mixing.

But unless these two fuels, with different densities and viscosities, are thoroughly mixed with commercial fuel blending equipment, they will always tend to separate and stratify. Stratification is hard on marine diesel engines, causing inconsistent operation, engine overheating and possible engine failure. The varying viscosities within the fuel simply play havoc with proper injection viscosity, at times overloading the engine – a chief engineer’s nightmare.

Incompatibility

The next great challenge, even if the fuels are properly blended, can result in a literal explosion of sludge precipitation from the effect known as incompatibility. The root causes are well understood. The chemical composition of heavy residual fuel is extraordinarily complex and highly variable – dependent on refining methods and crude source. All contain a wide range of hydrocarbon structures. In general, these can be classified as either paraffinic, aromatic or naphthenic.

High aromatic heavy fuel oils, for example, typically have a higher concentration of heavy asphaltene components, anywhere from 3-to-5 percent.

When these are blended with a low aromatic heavy fuel, or blended with a much lighter, low aromatic distillate cutter stock, usually those with high paraffinic content, the result can be disastrous.

Low-aromatic distillates act like a penetrating solvent, disrupting the sticky bond that keeps the maltene and asphaltene components tied together in suspension. BTU-packed asphaltenes drop out of solution, forming the sludge that mucks up fuel storage tank bottoms, fuel lines, and fuel heater components.

This process is further aggravated by a series of chemical chain reactions that occur when disparate fuels are commingled. On the plus side, these low aromatic distillate cutter stocks do have reasonably good ignition quality. But this comes at a cost. The sludge that precipitates contains high energy value, and this is value is lost. So is operational integrity – the sludge fouling the entire fuel delivery system, also risking high pressure fuel injector fouling.

Ignition Quality

Conversely, if the heavier fuel is cut with a lighter distillate with a high aromatic content, like light cycle oil (LCO) or petroleum naphtha, incompatibility problems are rarely experienced. But there is a potentially disastrous flip side.

These types of cutter stocks typically have very poor ignition quality, often so degraded that some engines simply refuse to start on LSFO fuels blended with LCO. A major contributing factor is the poor thermal stability of LCO. With degraded thermal stability and poor ignition quality, these fuels produce a great amount of dense, unburnable petroleum coke in the second combustion stage. Most of this material consists of very high carbon weight molecular structures – difficult at best to fully combust.

On any given day, the light cutter stocks on hand will vary – sometimes high aromatic – sometimes low. Same for the heavy fuel. Whatever is available at the time gets blended, regardless of chemical composition. In the bunker supply business, “time is of the essence”, after all.

Complicating the issue is that fuel compatibility issues are almost always progressive.

A fuel taken from a bunker manifold drip sampling system at time of bunkering is tested for Total Sediment Potential (TSP) within a few days of receipt by the testing laboratory. The result is often within specification. Yet two weeks later the vessel suffers extreme sludging and purifier overload. A re-test of the fuel will reveal a much higher TSP result – sometimes even unfilterable. The same is true for “spot” compatibility tests. Although beneficial to detect an immediate issue, these tests have little predictive value.

Houston – We Have a Problem

In April 2018 in the U.S. Gulf, numerous vessels began reporting fuels issues which were seriously disabling fuel pumps and injection systems, leaving many dead in the water. The culprit? A sticky, crystalline resin known as 4-cumyl-phenol. Analysis by means of the Gas Chromatography Mass Spectrometry (GCMS) method revealed concentrations ranging from 300-to-1000 ppm in these fuels. The problem abated in Houston over the next several months yet apparently some remnants of the culprit fuel escaped to Panama and as far away as Singapore and Korea.

The source of the cutter stock from which the problem originated remains unknown. Yet it is almost a guarantee that as suppliers seek new cutter stock sources in year ahead to meet the 2020 demand – a few bad apples will be tossed into the mix.

Even today, some cutter stock components emanate from many industrial sources – containing residues from synthetic resin production – including phenolic compounds, terpenes and naphthalene.

Blends with shale oil are increasingly common, with more phenols and trace levels of arsenic. In Asia, coal tar residue fuels play havoc with purifiers and are a source of more phenolic compounds. Then there are residues of unsold biodiesel fuels turning up occasionally, which, when decomposing, create carboxylate acid and fatty acid methyl esters (FAME).

Residue from plastics manufacturing created widespread problems a decade ago and some of these yet appear on occasion, including methyl styrene and polypropylene. The only dictate under ISO 8217 is Clause Five which deems any contaminant completely unacceptable. Test standards under ISO 8217 do not yet include the methodology to determine such contamination. Fortunately, most fuel analysis laboratories are equipped with GCMS instruments capable of identifying the nature and quantity of these intruders.

The simplest remedy to avoid a contaminant crisis is to debunker and remove the threat altogether. Yet in mid-ocean, a vessel has no choice but to seek other remedies. A practical option is to heavily dilute the concentration of contaminants by blending the affected fuel with a fuel oil or gasoil known to be contaminate free.

In the recent crisis, one vessel blended 80 percent “clean” fuel with the contaminate laced fuel oil – then treated the mixture with a strong amine-dispersant additive manufactured by Newport Fuel Solutions. It worked, and the vessel made it safely to port.

Other vessels using the same treatment, in some cases blending, in others not, have avoided serious damages, Later GCMS analysis revealed that on these vessels, the 4-cumylphenol concentrations were as much as half that of the lowest concentrations of the Houston affected vessels. Yet the fuel treatment, NP-HFO, has chemical characteristics that tend to mitigate some of the issues associated with chemical contaminates.

Better Sailing Through Chemistry

Modern marine fuel treatments are an interesting assortment of so-called “combustion improvers”, dispersants and lubricity additives. They differ substantially from refinery additives in that they are typically blends of small amounts of “active” ingredients with substantial amounts of various, non- functional diluents, everything from diesel fuel, to kerosene and naphtha.

Low cost diluents are very inexpensive, greatly enhancing the profitability of such products for their makers. Yet given the very small concentration of active ingredients, dosage rates must be greatly increased to tackle a problem for which the treatment was intended – a very expensive solution. It is easy to determine the extent to which a fuel treatment maker has diluted a product. A quick look at a Safety Data Sheet (SDS) will reveal the percentage range and constituency of the components.

Engine makers understand the value of dispersants and lubricity additives but cast a jaundiced eye toward combustion improvers for quite valid reasons. Many contain ash bearing organo metallics, like ferrocene or magnesium which, when burned, deposit ash in engine spaces.

Others are blended with a substance far more volatile like camphor oil – an old trick of automotive hobbyists – but risky for industrial diesel engines.

Newport Fuel Solutions Inc. (NFS) takes an entirely different approach. All NFS products are manufactured under ISO 9001 as refinery concentrates – permitting highly effective dose rates at a very low treat cost per metric ton of fuel. The formulas are designed with careful consideration of functionality for all issues regarding fuel oil behavior.

For example, the company's NP-HFO chemistry, highly concentrated at a one liter per 20 mt dose rate, is purposefully formulated with a high pH value of 10.7. The idea is to offset and reduce the Total Acid Number (TAN) of some fuel oils – high TAN known for influencing fuel pump and injector deterioration.

In the recent contamination case, it is known that 4-cumylphenol contaminant has acidity which can attack fuel pump integrity, as do many other acid contaminants. As a crystalline structure, this phenol also has a low melting point – evidenced by the sticky gel found in purifiers and components of the damaged vessels.

Fortunately, the high base of NP-HFO helps neutralize contaminant acidity. Yet another purposefully formulated functionality is helpful in offsetting the accumulation of sticky residue on fuel pumps and injectors from a variety of sources which produce such substances.

Simply, NP-HFO is formulated with a strong “peptizing” dispersant to inhibit sludge precipitation – a powerful chemistry used for many years to disperse extremely heavy sludge in crude oil at refineries.

This chemistry slips in between the sticky molecular structures of asphaltenes, gums, resins and paraffin to suspend them evenly throughout the fuel blend in a colloidal solution – the result a reduction in sludge precipitation of 35-to-55 percent.

The extent to which NP-HFO disperses phenols – preventing molecular affinity and damaging, concentrated bonds, is unknown. The amine chemistries of NP-HFO are known to have reactivity with certain phenol groups – altering their states. Yet well understood is dispersion, which in combination with blending with an untainted fuel, can do nothing but help a disabled vessel make it into port.

Based on three decades of research and development, intense study of fuel reactions and long-term field experience, the Newport Fuel Solutions staff targeted expected issues with 0.5 percent sulfur blended fuels when formulating NP-HFO. NP-HFO is effective in all residual fuel grades under ISO 8217, it is especially designed mitigate the issues of contamination, stratification, incompatibility, and ignition quality. The result is an exceptionally strong thermal stability and dispersant additive with unmatched “peptizing” properties which separate the asphaltenes, gums, resins, and paraffinic components into a “colloidal” state – where these components are evenly dispersed and suspended throughout the fuel blend.

If the fuel is treated at time of bunkering with Newport - HFO – fuel stratification and incompatibility are altogether avoided. Should the fuel be blended with a poor ignition quality cutter stock, Newport-HFO compensates with improved ignition quality in a range of 5-to-8 percent, elevating peak firing pressure as much as five bars.

This is accomplished without any traditional “combustion improver” like organo-metallics, camphor or 2-ethyl-hexylnitrate – all of which can pose a potential threat by elevating combustion temperature. Rather, the effect relies in a well-known principle discovered decades ago by petroleum chemists.

Simply, fuels with better thermal stability perform better than those with poor thermal stability. The principle is based on an effect common to all petroleum fuels. During the combustion process, all fuels produce a measure of high carbon weight structures that fail to physically combust.

Technically, this is due to a process known as polymerization, where “unsaturated” hydrocarbon structures – those that have two or three pairs of shared electrons – tend to link with one another – forming very high, unburnable carbon weight structures.

The innovative chemistry of Newport-HFO blocks these interactions – providing a barrier that permits more complete combustion.

Peak firing pressure is elevated. Particulates are reduced as much as 50 percent. Formation of hard carbon deposits on critical engine surfaces is inhibited. Exhaust gas economizers remain clean, and back pressure maintained. For vessel operators installing scrubbers to continue to operate on conventional heavy fuels, this is exceptionally good news.

Modern scrubber designs, especially “open-loop”, are not expected to have any major effect on back pressure in the short term, or so some makers claim. Yet just as in a conventional vessel exhaust arrangement, the exhaust side will continue to be subjected to fouling as the result of unburned hydrocarbons, largely manifested as particulate agglomerations in the form of soot. As in normal vessel operations, back pressure builds in time.

The question remains. To what extent will the rate of back pressure increase build with the restrictions imposed by scrubber installation? And to what extent will any scrubber be affected by a progressive accumulation of soot in the exhaust stream?

This will largely depend on scrubber design. But regardless, the application of Newport-HFO thermal stability treatment will greatly inhibit soot accumulation, providing extended economizer and scrubber cleaning and maintenance intervals. Doubtless the endless unregulated fuel blend formulations, often deeply flawed blending practices, and the continued likelihood of fuel contamination will not make 2020 an easy transition for vessel operators. Yet no reason for despair. As these issues have had a deep history and are well understood by our highly experienced R&D staff, we are ready with solutions that will ensure heightened vessel reliability and operational integrity.

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