

Customer Technical Service THE FUTURE OF SHIPPING

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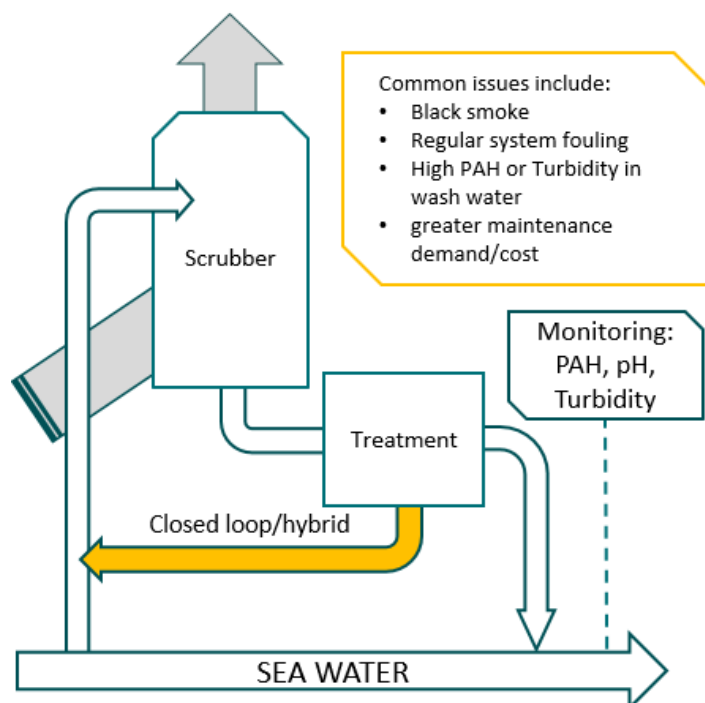
Innospec is a key partner in ensuring predictability when using marine fuel – and Octamar™ performance chemicals are the preferred choice for fuel reliability. We are proud to introduce Octamar™ Complete for vessels using HSFO in conjunction with scrubbers and other post combustion systems, so your fleet can continue to operate with minimum disruption and maximum performance.

This bulletin addresses the common issues faced by vessels using SOx scrubbers and other post combustion systems. Each section presents and explains how topics such as exhaust emissions, fuel economy and quality are vital to vessel performance, and how small changes today will impact our long term success.

The shipping industry has embraced the move towards a more sustainable future, adapting quickly to objectives set out by the IMO to reduce emissions hazardous to both human health and the environment as a whole. We are on the path to success thanks to the adoption of systems such as Exhaust Gas Cleaning Systems (EGCS/ Scrubbers), Selective Catalytic Reduction (SCR), Exhaust Gas Recirculation (EGR) and alternative fuels such as VLSFO (Very Low Sulphur Fuels 0.5%) or Biofuels.

While VLSFO and Biofuels have no shortage of issues, this bulletin will focus on the engineering solutions being implemented (visit our website for more information on VLSFO and distillate instability).

Reduced emissions from traditional fuels will ultimately need to come from better performance, reduced fuel consumption and reduced margins for error. This is where the unpredictable quality of residual marine fuels such as HSFO has proven to be problematic. Post combustion systems such as EGCS, EGR and SCR systems are sensitive to deposits caused by poor quality fuels or incomplete combustion, the same mechanisms that cause fouling, after-burn and black smoke in exhaust gases and/or high levels of PAH and turbidity in wash water systems.



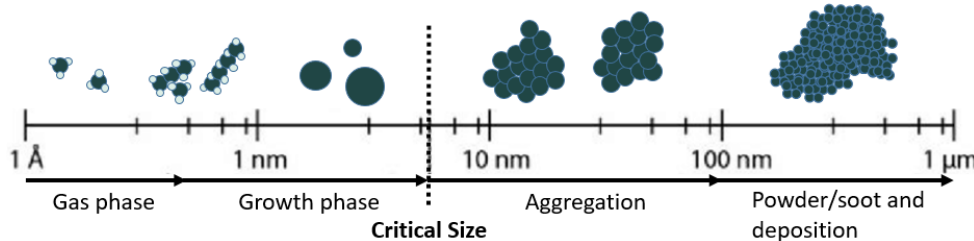
The shipping industry is using the latest technology to meet the challenges of the coming decades, however they do present a fresh host of issues that will need to be overcome.

1. Greater system complexity: new skills for crew, increased backpressure, greater fouling risk
2. Increase in ongoing costs: more planned and unplanned maintenance, spare parts and upkeep
3. High performance machinery demands much more from fuels, poor or unpredictable fuel quality

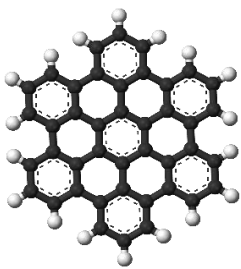
Emissions / Black Smoke

HSFOs are notorious for producing soot and black smoke as they contain high levels of residual aromatics such as asphaltenes (approximately 15 % m/m) which burn poorly if unstable i.e. grow into larger structures that settle out as sludge in tanks or contribute to poor combustion. If a fuel is kept stable, asphaltenes remain small enough to burn completely, releasing the large amount of chemical energy they contain during combustion without causing after-burn and excessive particulates. Otherwise if unstable, they will form excessive deposits, impinge on liner walls and remove Cylinder Lube Oil (CLO), damaging liners or creating harmful emissions and post combustion fouling.

Incomplete and poor combustion is the primary cause of black carbon, soot and PAH in exhaust gases. The process starts in the gas phase after combustion where unburnt fuel grows into larger structures that either foul turbochargers, economisers and scrubbers, or leave the stack as black smoke or PAH in scrubber wash water.



Unburnt fuel in the exhaust stream grows from the gas phase as temperatures and velocities reduce, eventually growing and depositing in exhaust systems to increase back pressure and reducing scrubbers, Exhaust Gas Boilers (EGB) and Exhaust Gas Recirculation (EGR) efficiency.



PAH and Scrubber Wash Water

Polycyclic Aromatic Hydrocarbons (PAH) are organic hydrocarbons that exist in large numbers within residual marine fuels. The primary source of PAH in the environment is incomplete combustion and unburnt fuel which normally would be expelled into the atmosphere, but are now captured by the wash water from SOx scrubbers. PAH levels are closely monitored in scrubber wash water due to the severe damage they cause to human health and the marine environment, and for this reason the IMO stipulates that the PAH content of wash water shall not exceed 50 µg/L, a level that is often difficult to meet due to the poor combustion and fouling characteristics of HSFO.

The introduction of a powerful combustion and soot catalyst like Octamar Complete has the potential to address PAH by improving combustion and reducing Particulate Matter (PM) and therefore PAH particulates by 60%.

Fouling, back pressure and fuel efficiency

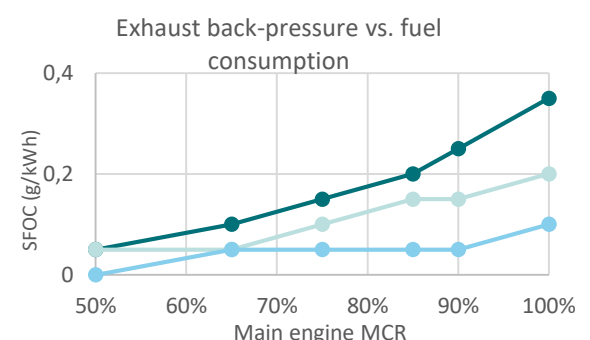
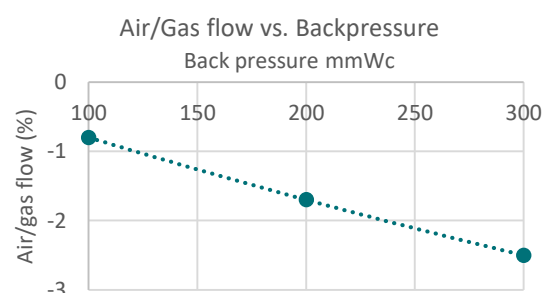
Even small changes in back pressure have been proven to increase fuel consumption and reduce gas flow (see graphs right), and is affected through two primary mechanisms:

1. Lower turbocharger efficiency (lower temperature drop across the turbine) and therefore lower scavenge pressure
2. Lower scavenge efficiency i.e. a reduction in the fresh air caused by reduced gas flow through the engine

The installation of additional equipment downstream is known to increase back pressure and without the proper precautions (by re-matching turbochargers or nozzle rings), has a significant negative effect on engine performance. That is why MAN B&W strongly recommends that a scrubber installation does not increase the back pressure of an engine by more than 305 mmWc (MAN B&W, MUN2017-06-21).

However, the increase in post combustion complexities is also a cause of increased fouling as exhaust gases are slowed or forced to change direction with particulates in the exhaust gas dropping out to foul machinery surfaces.

Octamar™ Complete acts to prevent and remove the buildup of post combustion fouling, ensuring expensive exhaust systems work efficiently and vital machinery assets are protected.



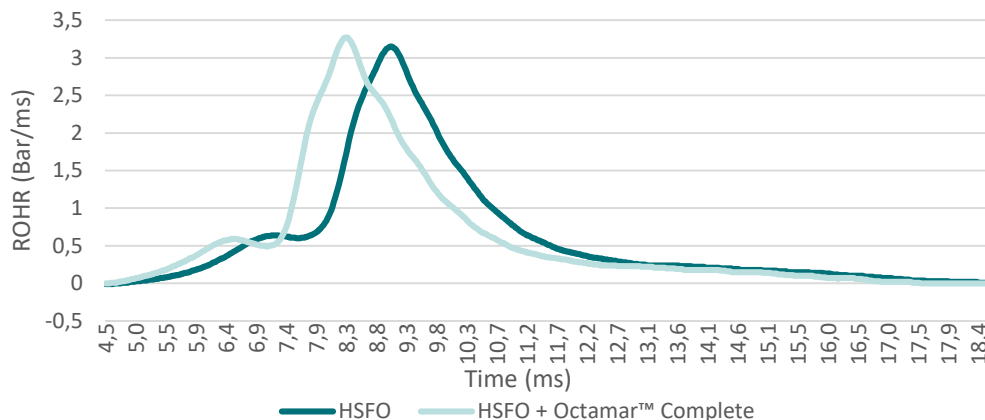
The effect of back pressure on gas flow rate and fuel consumption across different engine loads (J-Eng service letter WMS-F035/D).

Fuel Quality

The changing landscape

Octamar™ Complete contains Innospec's unique combustion catalyst that significantly improves the combustion of marine residuals, including all HSFO. Independently verified studies have proven how the combustion catalyst in Octamar™ Complete reliably reduces Ignition Delay (ID) and the end of Main Combustion Delay (MCD), while increasing the Estimated Cetane Number (ECN) to improve Specific Fuel Oil Consumption (SFOC) by as much as 2.2%.

Those using Octamar™ Complete enjoy all the benefits of a higher quality fuel for a fraction of the cost differential. Every Innospec product is designed to maximise the output and operability of fuel to ensure optimum performance. The table below demonstrates the results from our FIA (Fixed Ignition analysis) testing.



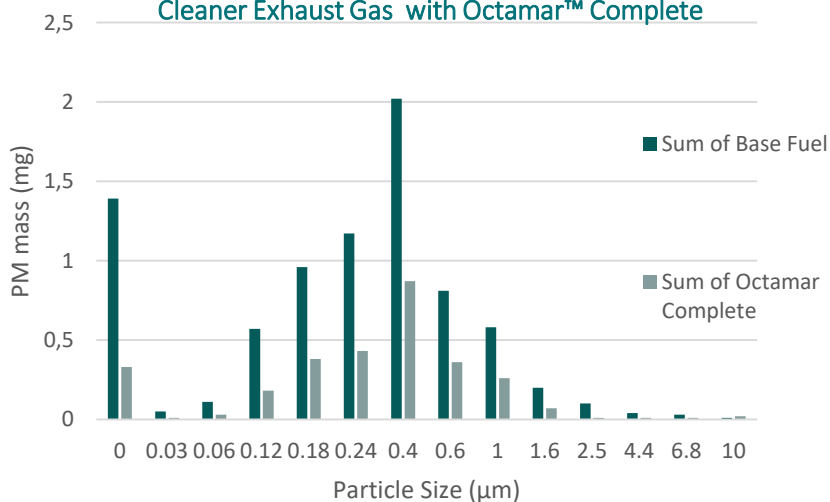
		Base Fuel	Base + Octamar™ Complete	Quality Improvement
ECN	Estimates Cetane Number	22.8	24.5	7.5%
MCD	Main Combustion Delay	6.66	6.4	3.9%
ID	Ignition delay	5.3	5.12	3.4%
EMC	End of Main combustion	12.01	11.54	3.9%

Fuel Consumption

This remarkable breakthrough verified by third parties including Shell, proves that by adding only 166 ppm of Octamar™ Complete to HSFO will measurably reduce SFOC, a remarkable testament to the power of chemically unlocking the potential of fuel. This is technology that can be added to existing fleets today, boosting the fuel efficiency and performance of existing tonnage with no upfront investment!

SFOC Improvement @ 100 % Load	1.1	%
SFOC Improvement @ 50 % Load	2.2	%
Base fuel SFOC	239.42	g/kWh
Octamar™ Complete SFOC	235.67	g/kWh

Cleaner Exhaust Gas with Octamar™ Complete



As you can see from the graph on the left, small changes in ECN, MCD and EMC provided by Octamar™ Complete give huge benefits to both reducing emissions and post combustion fouling, which is the primary failure mode for more post combustion systems.

A 3.9 % reduction in EMC has shown to reduce particulate mass in emissions by more than 60 %! Smaller particles (less than 0.03 µm) from incomplete combustion, which is responsible for PAH in exhaust gas and therefore scrubber wash water, are reduced by 73 %.

A cleaner combustion means cleaner exhaust gases, producing less PM, PAH and black smoke to protect your post combustion assets – so you can meet the challenges of tomorrow.

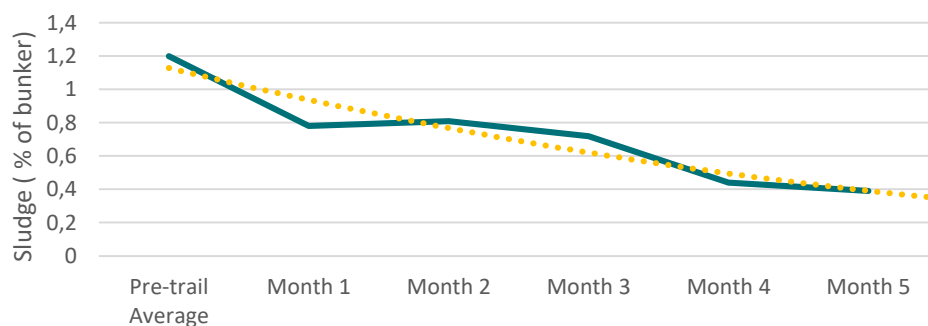
Fleet Performance

Fuel efficiency starts in the storage tank

Almost 2 % of all HSFO bunkered globally is lost as sludge due to fuel instability, this represents a significant loss of energy and contributes towards the cost of shipping as a whole, this goes without mentioning the associated costs related to handling and treating unstable fuels. This is why we believe fleet efficiency starts in the storage tank, a principle that has driven us to continually develop the best technology to ensure that fuel remains stable, so that more of it makes it to the combustion chamber, creating less problems on the way and burning more cleanly when there, resulting in increased fleet performance and reduced costs.

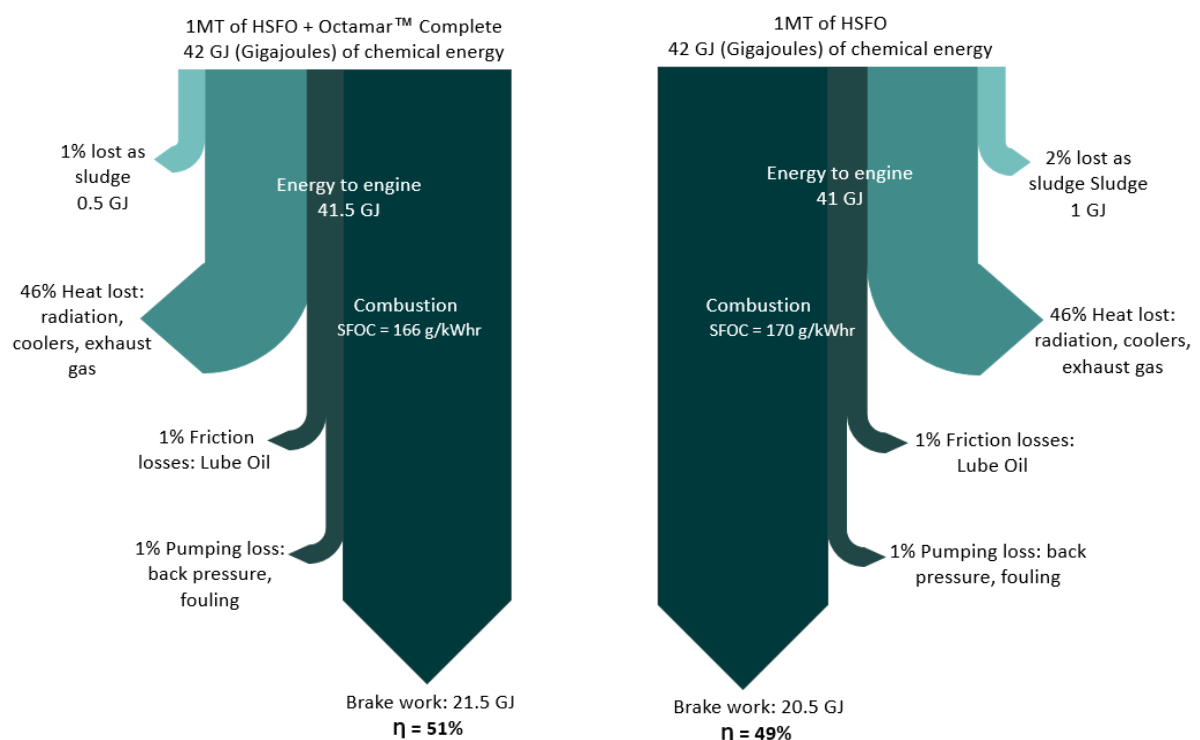
Octamar™ Complete has been used in millions of tonnes of bunkers globally to improve the quality of HSFO and mitigate the risks of using residual fuels. We take an evidence based approach to our work, and the trial below (one of many) demonstrates how selective chemical treatment gives real world benefits, reducing sludge on-board of over 60 %, a fact that saves not only money, but makes life easier on board for our hard working sea farers.

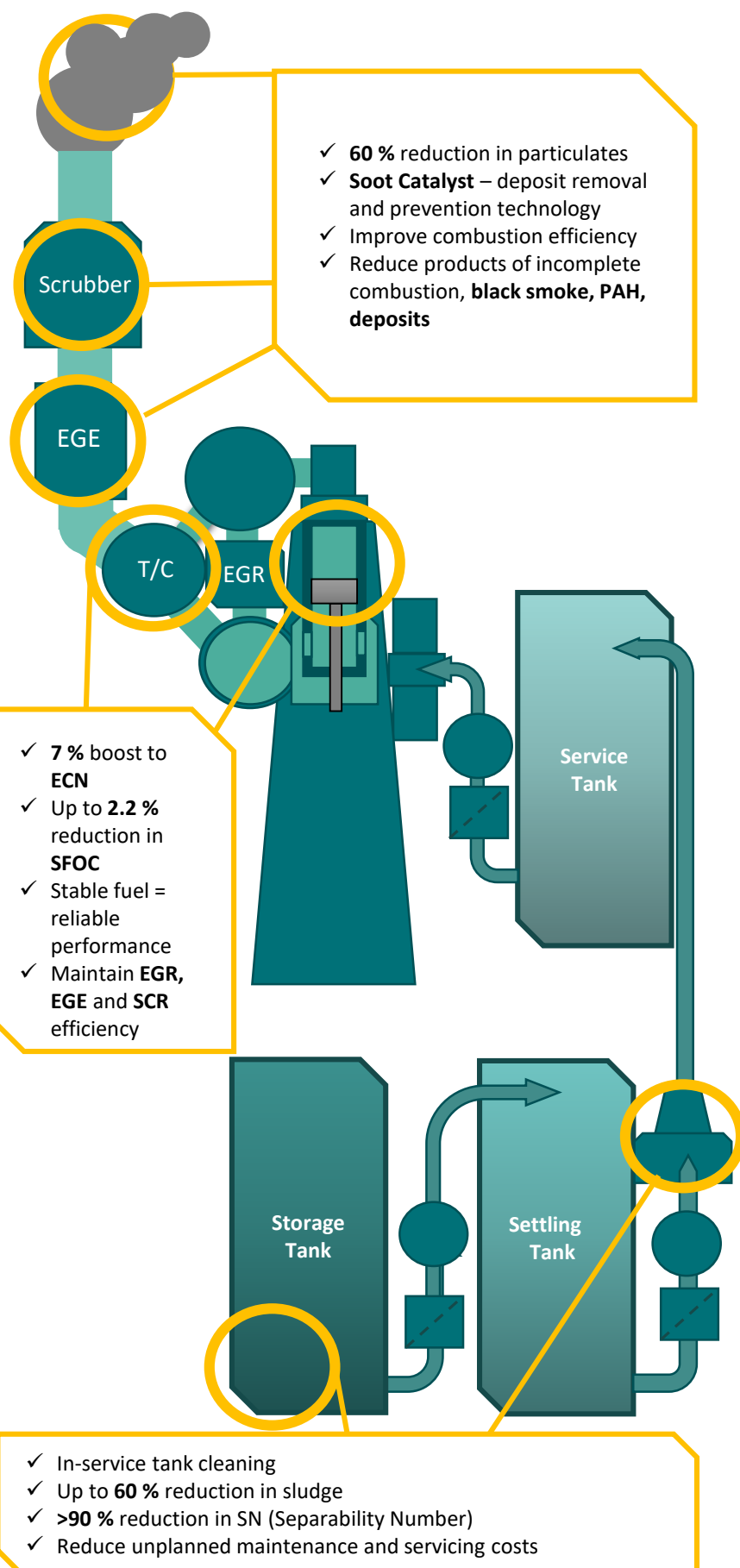
Octamar™ Complete Sludge Trial



Energy efficiency

By stepping back and thinking about fuel in terms of energy, it becomes clear that any improvement to fuel reliability and quality translates to overall fleet performance. Octamar™ Complete offers a targeted chemistry that improves fuel quality from storage to stack. Reducing the volume of fuel wasted as sludge, keeping asphaltene small and able to burn more completely, boosting the ECN of a fuel to reduce SFOC, and preventing deposits post combustion, so high performance machinery runs more smoothly and efficiently. Ultimately you gain all the benefits of a higher quality fuel, for a fraction of the investment.





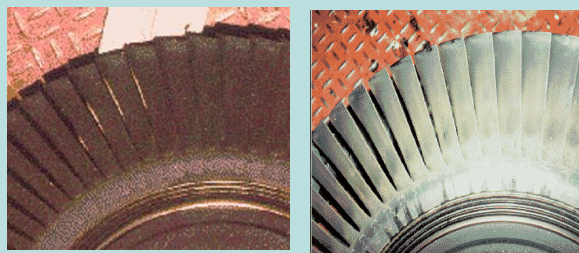
Fuel Quality

From storage to stack

Octamar™ Complete is used by vessels globally as part of their fuel and emissions strategy to improve fleet performance, protect marine assets and to mitigate the risk of using low quality residual marine fuels.



Octamar™ Complete's soot catalysts prevent and remove post combustion fouling for low impact protection of high performance machinery such as Exhaust Gas Recirculation (EGR), Exhaust Gas Economiser (EGE), SOx scrubber and Selective Catalytic Reduction (SCR) components.



A unique combustion catalyst that truly improves fuel combustion quality to improve Estimated Cetane Number (ECN) by 7 % and thereby reduces products of incomplete combustion by over 70 %, thus stopping the cause of engine fouling and wear at the source.



Octamar™ Complete improves fuel stability and reduces Separability Number (SN) by over 90 % on average. This means less sludge, less unplanned maintenance, less workload for the ship's crew, and more fuel to the engine.

Octamar™ Complete: the most comprehensive fuel treatment chemistry currently available for vessels using HSFO and scrubbers.
Improve your fleet's performance today.

Octamar™ Complete

Octamar™ Complete provides a complete solution for HSFO and keeps your fleet moving by improving fuel stability and combustion quality while reducing soot formation and harmful emissions to face the future.

Achieve the levels of reliability and performance seen when using high quality fuels at a fraction of the cost with Innospec's targeted performance chemistry.

- Improve fuel quality to reduce operability issues, up to 60 % reduction in sludge produced
- 60 % reduction in exhaust particulates, for a cleaner post combustion system
- 7 % boost in ECN (Estimated Cetane Number), giving a 2.2 % reduction in SFOC and a cleaner combustion to reduce products of combustion
- Achieve the levels of reliability and performance seen when using high quality fuels, at a fraction of the cost
- The smartest way to improve Fuel Quality and mitigate the problems associated with Residual Marine Fuels



Summary

Innospec is at the forefront of developing fuel additive technology for a changing world. Our focus is on supporting the fuel industry as it adapts to major environmental challenges, new legislation and the more demanding performance targets set by OEMs. While we operate at the novel and cutting edge of technology, our goal as market leader is always to create reliable and highly functional products. We build global supply chain solutions by understanding the important differences within regional and national markets. Our worldwide network spans 23 countries. **We can work with you to create the next generation of fuels, today.**



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